DESIGN AND SIMULATION OF ADVANCED EMERGENCY BRAKE SYSTEM FOR COMMERCIAL TRUCK VEHICLES (ISUZU TRUCK)

By

Biniyam Leta Beshah

A Thesis Submitted to

The Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Masters in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

September, 2021

Adama, Ethiopia

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Advisor: Mekonnen Liben (Asst.prof.)
Co-Advisor: Dr. Ramesh Babu

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DECLARATION

I hereby declare that this Master Thesis entitled **“Design and simulation of advanced emergency brake system for commercial truck vehicles (Isuzu truck)”** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Biniyam Leta Beshah		
Name of the student	Signature	Date

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled **"Design and simulation of advanced emergency brake system for commercial truck vehicles (Isuzu truck)"** prepared under our guidance by Biniyam Leta Beshah submitted in partial fulfillment of the requirements for Master of Science in automotive engineering. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Mekonnen Liben (Assistant professor)	______________	______________
Major Advisor	Signature	Date
Dr. Ramesh Babu	______________	______________
Co-Advisor	Signature	Date

APPROVAL PAGE

We, the advisors of the thesis entitled "**Design and simulation of advanced emergency brake system for commercial truck vehicles (Isuzu truck)"** and developed by Biniyam Leta Beshah, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date
Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Biniyam Leta Beshah have read and evaluated the thesis entitled **Design and simulation of advanced emergency brake system for commercial truck vehicles (Isuzu truck)"**and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Automotive engineering.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate studies, Dean	Signature	Date

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ACRONYMS

ECU	Engine control unit
UNO	One (Italy)
LCD	Liquid-crystal display
BAS PLUS	Brake Assist System PLUS
BAS	Brake Assist System
EBS	Embedded brake system
PCS	Pre-Crash Safety
IR	Infrared ray
RF	Radio frequency
ASV	Advanced Safety Vehicle
ARM	Advanced RISC Machines
BMW	Bayerische Motoren Werke
DC	Direct current
LED	Light Emitted diode
EMB	Electromagnet brake system
AWE	Automatic wind deflector
AEBS	Advanced emergency brake system

ABSTRACT

Researches on the national high way traffic safety administration determined that nowadays car accidents are mostly caused by a delay of the driver to apply the brake at desired time. This thesis was aimed to design an automatically controlled brake system and auxiliary brake by using a different programming and modeling software, as well as develop a prototype that enables collision avoidance of a commercial vehicle such as ISUZU truck. This thesis work was majorly focused on design and simulation of an advanced emergency braking system for head-on collision avoidance with the help of electro mechanical control system and newly designed auxiliary brake systems. The main advantage of this thesis work is to avoid occurrence of accident or collision at emergency time by reducing stopping distance and increasing braking force and efficiency of the truck. Reduction of the reaction distance of the truck by integrating sensing, controlling and actuating unit were done with the use of electro mechanical control system so that the brake is applied automatically. Detection of the existence of an obstacle and measurement of the speed of the truck were done with the use of ultrasonic sensors and infrared sensors to detect the existence of an obstacle and to measure speed of the truck; then measured data was sent to the controller unit. The data from the sensors were received by the application of the Arduino Uno device which was used as controller unit. This enabled control of all activities of braking at emergency time by giving desired command to the actuators based on detection pulse information and preprogrammed data. Conversion of electrical signal of controller to physical actuation were done by employing different types of actuators such as relay switch, pneumatic solenoid valve, pneumatic cylinder, LCD display, LED, and alert horn. To increase braking force and braking efficiency of truck at emergency time two auxiliary brake systems (i.e. electromagnetic brake system and automatic wind deflector) were used in this study. Generation of the magnetic force and retardation force against rotating propeller shaft were possible with the activation of electromagnetic brake system which is one of the auxiliary brake systems. Reduction of the effect of Aerodynamic drag force on a truck by giving aerodynamic effective shape and its use as brake at emergency time were possible with the application of automatic wind deflector. The reduction was achieved by changing the angle of inclination from 30^0 *to* 90^0 *to increase frontal area of the truck so that drag force was used as brake force through automatically actuated pneumatic cylinder; As a result it was found that applying this newly designed brake system the stopping distance of the truck was reduced from 112 m to 66 m and braking force and braking efficiency of truck increased from 75,460 N to 95,710 N and 68.6 % to 88.8% respectively. In conclusion inclusion of these newly designed components to the case vehicle ISUZU truck will be of paramount importance for reduction of car collision avoidance remarkably.*

***Key word**:-pneumatic solenoid valve, electromagnet brake, automatic wind deflector, Arduino*

CHAPTER ONE

1. INTRODUCTION

This chapter presented that the introductory part of the thesis and it include background of study, objective of the thesis, statement of problem, scope and limitation of the thesis. And also in this chapter cause and effect of accident in world and in Ethiopia are discussed.

1.1 Back ground of the study

Driving is a compulsory activity for most people. People use their cars to move from one place to another place. The number of vehicles is increasing day by day. Nowadays, accidents are increasing and are uncertain. According to research conducted by WHO in 2019 An accident will occur every time and everywhere and cause the worst damage, serious injury, and even death and accident statistics reveal that driving at an in appropriate speed and delay of the driver to apply the brake at emergency time are the primary causes of most accidents. Other accident sources are incorrect use of the road, failure to maintain the safety margin to the preceding vehicle, errors concerning right-of-way and traffic priority, errors occurring when making turns, and driving under the influence of alcohol.

1.1.1 Effect of accident in the world and in Ethiopia

Every year around the world nearly 1.3 million people lose their lives on the road and as many as 50 million others are injured (Sleet D. et.al 2011). Globally 17 road fatalities per 100,000 population per annum are reported when it converted per day; every day, more than 3000 people die from road traffic injury. The Low-income and middle-income countries account for about 85% of the deaths and for 90% of the annual disability because of road traffic injury. Projections show that, between 2000 and 2020, road traffic deaths will decline by about 30% in high-income countries but increase substantially in low-income and middle-income countries (Dawit. O, 2016).

Road traffic accidents not only adversely affect the livelihood of individuals but also their family members, as it can lead households into poverty via the enduring effects of the episodes: the costs of medical care, treatment and loss of family’s income generators. Road traffic accidents have also a gigantic impact on national economy by consuming the already inadequate resources, damaging invaluable property, and killing and disabling the productive age group of the community (Persson 2008).

According to the transport authority, the number of people killed and the rate of accidents occurred registered major increases during the period the number of people killed increased from 4,500 to 5,118 while a record number of close to 41,000 traffic accidents were registered during the 2017/18 fiscal year. Another 7,754 people had also sustained serious physical injuries from traffic accidents across the country, while some 7,775 others had light injuries, according to the report of the Ethiopian Federal Transport Authority. The authority also indicated that Ethiopia's rate of traffic incidents during the just concluded fiscal year has registered a 6-percent increase as compared with the previous year (Abegaz T and Gebremedhin S (2019).

According to the latest WHO data published in 2018 Road Traffic Accidents Deaths in Ethiopia reached 29,386 or 4.81% of total deaths. The age adjusted Death Rate is 36.78 per 100,000 of population ranks Ethiopia is 24th of Road Traffic Accidents Deaths registered country in the world.

Figure 1.1: Accident in Ethiopia (source: federal police commision, 2021)

As Figure 1.1 shown that the accident occurred in Ethiopia on different truck on the same day because of driver delay to apply the brake at desired distance and condition. According to the federal police commission report, pedestrians and passenger are the highly likely victims of fatality accidents compared with drivers, motor cyclist and cyclist as shown in Figure 1.2 below. Most accidents occur because drivers do not give priority to pedestrians and driver response delay to apply the brake at desired time. Hence, major work needs to be done by concerned Organizations to safeguard the safety of passengers and pedestrians and save lives.

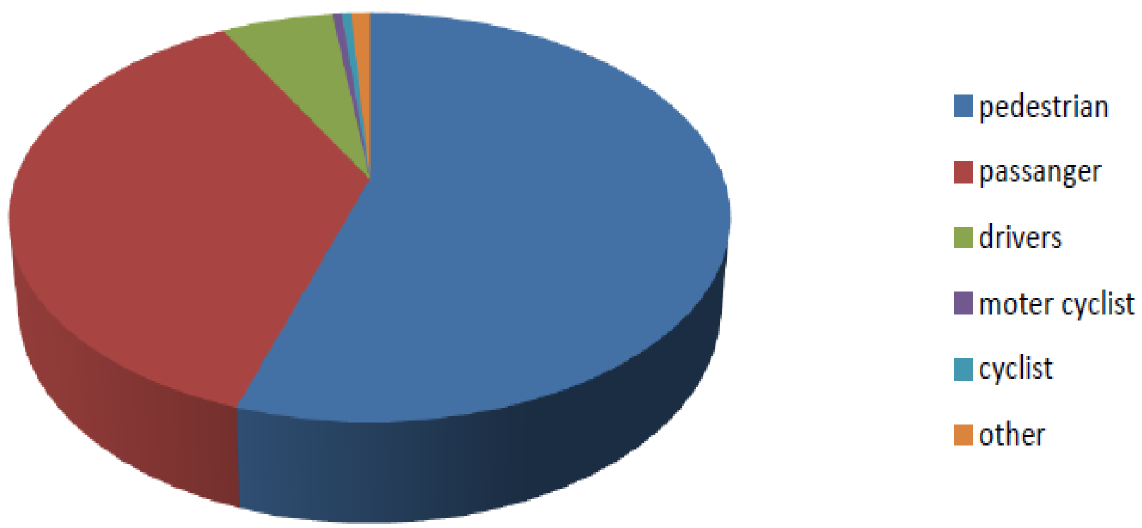


Figure 1.2: Traffic accident death by road user category (source: Federal police commission annual report (2018)

1.1.2. Requirement of Brake system

The braking system on a vehicle has various requirement. It consist the following here main Requirement (Julian 2001).

- It must decelerate a vehicle in a controlled and repeatable fashion and when appropriate cause the vehicle to stop.
- It should permit the vehicle to maintain a constant speed when travelling downhill.
- It must hold the vehicle stationary when on a flat or on a gradient.

The common braking of ISUZU truck is not sufficient for the avoidance of accidents when a driver is not active. Further improvement has to be done in the braking system of commercial vehicles in order to stop a vehicle when a driver is not able to apply a brake at the emergency time therefore, it may need an automatic braking system. This Thesis is designed to develop a new system that can solve this problem where drivers may not brake manually but the vehicles can stop automatically due to obstacles. The automatic braking system allows the vehicle to brake without the support of the driver. The work presents on advanced emergency braking system for forward collision avoidance of ISUZU truck is with the help of a electro mechanical control system(sensing unit, controlling unit and an actuating unit) and auxiliary brakes (electromagnet brake system and automatic wind deflector) which actuates brake automatically and increase total brake force of the truck at emergency time.

1.2. Statement of the Problem

Most good and products are transported from city to city by using commercial trucks and they are readily subjected on accident or collision because mostly they drive at night and use high speed driving to deliver good or products as afresh. Accidents involving commercial truck vehicles rarely occur due to brake failures but occur frequently due to brake defects and driver delay to hit the brake at emergency time. Statistics indicate that truck tractors pulling semi-trailers accounted for 63% of the trucks involved in fatal crashes and about 47% of the trucks involved in non-fatal crashes. About 25% of the crashes involving trucks are due to brake deficiency, 60% are because of the delay of the driver to apply the brake at exact stopping distance and time and the remaining 15% is because of road condition (Tilahun et al. 2015).

The convectional pneumatic brakes system used on truck have the following chief problems.

1. Common braking is not sufficient for the avoidance of accidents when a driver is not active.
2. The vehicle's safety is extremely dependent on the driver's state
3. The appropriate stopping distance for the vehicle may not be maintained at the time of the emergency braking.

And also the existing emergency brake system and auxiliary brake system design to assist the driver have the following problem

1. The automatic brake system they designed was worked only by considering the distance between the vehicle and obstacle, they don’t consider the speed of the vehicle.
2. The electromagnetic brake system designed by previous researchers was operated manually

Hence this thesis aims to provide the safety measures for driver and passenger eliminating the above-mentioned problems by integrating the elector-mechanical system to detect the existence of the obstacle, measure the distance between vehicle and obstacle, and speed of the vehicle, give alert for the driver and if the driver neglect to apply the brake at the predetermined stopping distance the system will apply wheel brake, electromagnet brake system, and automatic wind deflector before collision happen. If this thesis finishes and works practically the accident occurs by delaying the driver to apply the brake at the emergency time will decrease 80% from the total accident that occurs by a delay of the driver to apply the brake at exact stopping distance and time.

1.3. Objectives of the study

1.3.1. General objective

- The general objective of this thesis is to design and simulation an advanced emergency brake system for commercial truck vehicle especially for ISUZU truck.

1.3.2. Specific objective

Specific objectives are to:

- Design modified brake system
- Design emergency brake system closed-loop configuration
- Write the controller program
- Develop the circuit diagram
- Simulate the developed circuit diagram
- Design automatic wind deflector and electromagnet brake system
- Develop the final prototype to show the working principle of the system

1.4. Significance of the study

This thesis work is done for the vehicles that are operating with conventional pneumatic braking systems such as heavy-duty vehicles, commercial truck vehicle and commercial passenger vehicle specially for ISUZU truck to make automatic actuation of the brakes during the time of emergency braking and support the wheel brake by using automatically operated wind deflector as aerodynamic brake and electro magnet brake system for retardation of propeller shaft during unexpected obstacle and vehicle is occur in front of moving vehicle. The general contribution of this thesis is to create vehicle accident free environment and safe driving condition for all.

Specifically when this thesis is finished, it will play a great role for

- The reduction of vehicle accidents and loss of lives
- The reduction of economic loss due to vehicle accident
- The reduction of infrastructures damage due to collision
- The reduction of the intensity of the collision
- The application of appropriate stopping distance in heavy-duty vehicles is maintaned
- The reduction of drivers stress for the safety consideration

1.5. Scope and Delimitation of the study

The scope of this thesis is to design and develop an advanced emergency brake system with mechanical, electrical, and pneumatic parts operating in an integrated manner. And prepare complete documentation on basis of sciences and working efforts have to be considered to develop an advanced emergency brake system for ISUZU truck by electromechanical system. This thesis also shows how electro mechanical control system control all activity of brake at emergency time and auxiliary brake systems (electro magnet brake system and automatic wind deflector) support the previous main brake system to develop a usable advanced emergency braking system for ISUZU truck as a prototype. But this thesis not cover and give detail about the science behind electro mechanical control systems method of data transferring, coding and material configuration of some of the electrical device which used for sensing and controlling of the system, because the main objective of this thesis is to design and develop advanced emergency brake system for ISUZU truck by selecting the appropriate sensing, controlling and actuating device and designing the auxiliary brake systems based on the general-purpose to integrate with the conventional pneumatic brake system and apply the brake at emergency time

1.6. Limitation of the study

There are limitations on the thesis, mainly on time and finance restriction to construct prototype and to collect actual data like traffic accident, cause of traffic accidents, number of accident that occur by driver mistake , traffic flow (volume) and format / availability of data required for the research work. Therefore, to implement the study one have to verify all the collected data and refine the assumptions taken. Assumptions adapted on this thesis are the state; road parameters and drivers behavior remains constant. Another limitation on this study is unavailability of high performance computer and some electro mechanical control system devices and problems of getting accurate numerical analysis result of CFD fluent analysis and constructing prototype for demonstration of the study respectively.

1.7. Organization of the study

This thesis is organized into seven chapters. Chapter one is an Introduction which comprises background of the study, statement of the problem, objectives, and scopes, significant of the study, limitation, and organization of the thesis. Chapter two presents a review of literatures related with the study that emphasize on study of emergency brake system and auxiliary brake systems. Chapter three describes the Materials and Methods used to complete this work. Also, describes some of the basic material that used on this study. The fourth chapter focus on design of advanced emergency brake system of the study. It include design of electro mechanical control system, design of auxiliary brake system (electromagnet brake system design and automatic wind deflector design), and describes CFD analysis of aerodynamic performance of the truck that show effect of new designed automatic wind deflector. The fifth chapter discuss the brake force and stopping distance calculation for existing truck brake system (truck without new designed advanced emergency brake system) and truck with new designed advanced emergency brake system and show effect of each auxiliary brake system on brake force and stopping distance of the truck at emergency braking. Chapter six present result and discussion of new designed advanced emergency brake system and effect of new designed advanced emergency brake system on brake force and stopping distance of the truck. The seventh and the last chapter present the conclusion, recommendation and future work of the system respectively.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

Many research and development in various brake systems have been done in the past year to improve the performance and efficiency of such system as well as to reduce the occurrence of accident or collision because of brake system failure and limitations. There have been several innovation in the design of brake system for different type of vehicles through years of research, and still lot of researchers try to improve efficiency of brake system by using different mechanism and electro mechanical control systems. In this chapter effect of braking on stopping distance to reduce accident, factors affecting stopping distance, different researcher work on improvement of brake system, auxiliary brake system development were reviewed. Finally, the summery of all literature and its gap also included.

2.2. Braking system

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system it is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction. The main function of the brake system is to decelerate or decrease the speed of a vehicle. By stepping on the brake pedal, the brake pads compress against the rotor attached to the wheel, which then forces the vehicle to slow down due to friction. The principle of braking in road vehicles involves the conversion of kinetic energy into thermal energy (heat).When stepping on the brakes, the driver commands a stopping force several times as powerful as the force that puts the car in motion and dissipates the associated kinetic energy as heat. Brakes must be able to arrest the speed of a vehicle in short periods of time regardless how fast the speed is. As a result, the brakes are required to have the ability to generating high torque and absorbing energy at extremely high rates for short periods of time (TAPSA, 2014).

Braking systems are indispensable for the roadworthiness and safe operation of a motor vehicle in road traffic conditions. They are therefore subject to strict legal requirements. The increasing effectiveness and sophistication demanded of braking systems over the course of time has meant that the mechanical systems have been continually improved. With the advent of microelectronics, the braking system has become a complex electronic system (Post W., 2014).

2.2.1. Air Brake System

Air brakes are used in trucks, buses, trailers, and semi-trailers. George Westinghouse first developed air brakes for use in railway service. He patented a safer air brake on March 5, 1872. Originally designed and built for use on railroad train application, air brakes remain the exclusive systems in widespread use (Bennett Sean, 2010).

Air brakes systems are very powerful as compared to the ordinary mechanical or hydraulic brakes. Hence, manufacturers widely use them in heavy vehicles. Air brake systems use a much greater force to apply the brakes. An air brake system includes a compressor to generate more compressed air as needed .This greater force created due to air compressor is needed to cope with the heavy loads of commercial vehicles. Air brake systems are carefully designed with valves, tubing, or hoses, etc., selected to result in balanced vehicle braking performance where all the brakes apply as close to simultaneously as possible and with the desired amount of force and it tolerant to small leaks, the smallest leak in a hydraulic system could result in brake failure.

2.2.1.1. Component of Conventional Air brake system

A compressed air brake system is divided into a supply system and a control system. The supply system compresses, stores and supplies high-pressure air to the control system. Typical the supply system of Air brakes systems consist of a compressor, a reservoir, a brake valve, and diaphragm units. The function of the air compressor is to compress the air and send it to the air reservoir for storage. The air reservoir stores the compressed air in it for later usage. The function of the unloader valve is to release the excessive air pressure to the atmosphere. And the control system of air brake consist brake valve as a control valve and directs the pressurized air to the respective diaphragm to expand it. The function of the diaphragm is to expand due to the compressed air pressure and operate the “S” cam shoes and thereby the brakes. The main component on Conventional Air brake system that used on most truck and high duty vehicles are shown in the Figure 2.1.

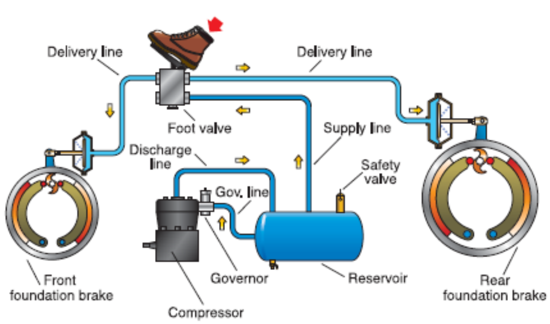


Figure 2.1: Component of Conventional Air brake system (Commercial vehicle air brake)

2.3. Stopping distance

The stopping distance is the distance the vehicle travels before it comes to rest or the stopping distance is the distance travelled between the time when the driver decides to stop a moving vehicle and the time when the vehicle stops completely (James, 2009).

Total stopping distance includes.

Perception Distance: How far the vehicle travels when the need to brake occurs and the driver recognizes that need.

- Reaction Distance: How far the vehicle travels as the driver reacts and applies the brake
- Brake Lag Distance: How far the vehicle travels from the time the brakes are applied and the vehicle begins to slow down.
- Braking Distance: How far the vehicle travels from the brakes starting to slow the vehicle and the vehicle coming to a complete stop

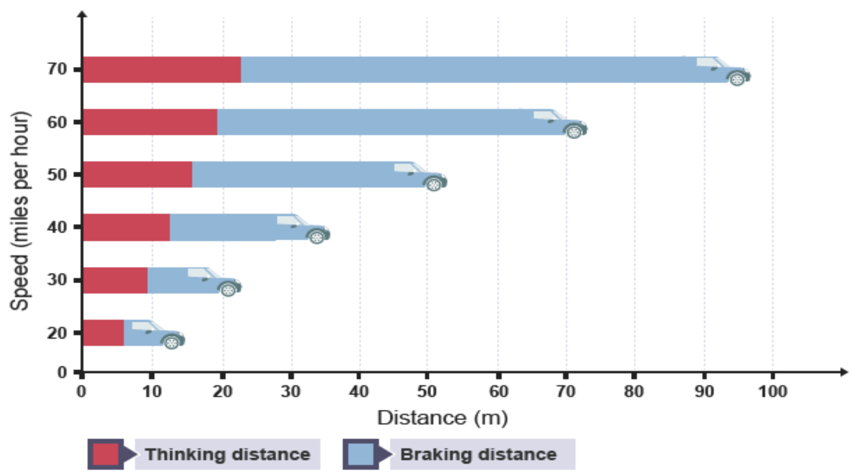


Figure 2.2: stopping distance of vehicle at normal condition (source: https://www.bbc.co.uk/bitesize)

Stopping distance is an important design parameter which influences e.g. geometric design, road safety, construction cost. The stopping distance consists of the reaction distance and the braking distance and stopping distance of the vehicle at normal condition is as shown in Figure 2.2.

2.3.1. Thinking (reaction) distance

Thinking distance is the distance a vehicle travels during the time it takes for the driver to perceive a hazard, recognize that action needs to be taken and decide what the necessary action is, before applying pressure to the brakes. Thinking distance varies from driver to driver, and can be influenced by a number of factors, including driver fatigue, distraction and visual impairment (James, 2009).It is important to note that the thinking distance is proportional to the starting speed. This is because the reaction time is taken as a constant,

$$S = V \times t_r \qquad \text{......(2.1)}$$

Where S = thinking (reaction) Distance

V = speed,m/s

t_r = reaction time ,s

Brake Reaction Time:-The brake reaction time is the amount of time that elapses between the recognition of an object or hazard in the roadway and the application of the brakes. The length of the brake reaction time varies widely between individual drivers (Kate H.Z et.al, (2003).

An alert driver may react in less than 1 second, while other drivers may require up to 2.5 seconds. Extensive research has shown that 90% of the driving population can react in 2.5 seconds or less (AASHTO, 2018).The brake reaction time depends on an extensive list of variables, including:

- Driver characteristics such as attitude, level of fatigue, and experience.
- environmental conditions such as the clarity of the atmosphere and the time of day
- The properties of the hazard or object itself, such as size, color and movement.

2.3.2. Braking distance

Braking distance is the distance that the car travels from the moment that the brakes are applied to the moment that the car stops (Reif, 2014). Figure 2.3 shown that different factors which affect braking distance of the vehicle. The braking distance is dependent on a number of factors including

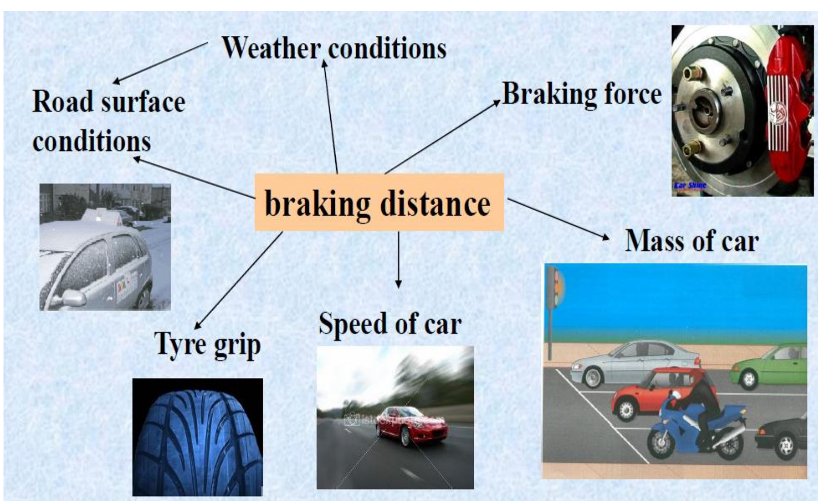


Figure 2.3: factors that affect braking distance of the vehicle (Modern Automotive technology text book)

2.3.3. Effect of speed and stopping distance vehicle accident or collision

According to NHTSA reducing the stopping distance of the vehicle is one of the major measure to reduce the accident and collision of vehicles. The distance being traveled each second during the stop is always greater at the beginning of the stop. To keep stopping distance as short as possible, it is important that the brakes become fully effective when the pedal is depressed by the driver. Any time lost between the instant the brake pedal is depressed and the instant actual deceleration begins is important because the vehicle continues to travel at close to its initial speed. According to an overview of recent studies (Rósen et al., 2011) at a collision speed of 20 km/h nearly all pedestrians survive a crash with a passenger car; about 90% survive at a collision speed of 40 km/h, at a collision speed of 80 km/h the number of survivors is less than 50%, and at a collision speed of 100 km/h only 10% of the pedestrians survive.

2.4.Literature review on different types of emergency brake systems

Abubakar R Golandaj (2014) suggested a pneumatic braking system with an automated sensor. This braking system, he says, is made up of an IR transmitter and receiver circuit, a control unit, and a pneumatic braking system. The obstacle is detected using the infrared sensor. When an obstacle is detected in the route, the IR sensor detects it and sends a control signal to the braking system. The solenoid valve is activated by the control circuit. The piston rod is moved by compressed air, which activates the pneumatic cylinder. The braking system is engaged as the piston goes forward. The wheel is moved by an ac motor and a pulley with a belt drive system. Because of the piston movement, the braking arrangement is used to brake the wheel gradually or suddenly. The “flow control valve” is used to vary the braking speed by changing the valve.

Babu et al. (2017) designed and developed a control system based on an intelligent electronically controlled automotive braking system is called “automatic reverse braking system”. An IR transmitter and receiver circuit, a control unit, and a pneumatic braking system are included in this braking system. When an impediment is detected in the path, the IR sensor detects it and sends a control signal to the braking system. The controller sends a signal to the pneumatic brake system, which is used to break the system. At a speed of 50 kilometers per hour, the "pneumatic braking circuit" may bring the car to a stop in 2 to 3 seconds. The reverse braking system is a completely automated project that provides a safe living environment.

Bhumkar et.al (2018) presented a system of accident avoidance & detection on highways. This project is about advanced technologies in cars to make it more intelligent and interactive for avoiding accidents on roads. This technique is about using modern technology in automobiles to make them more intelligent and interactive in order to prevent road accidents. The aim of such a model is to advance a system to detect fatigue symptoms in drivers and control the speed of car to avoid accidents. ARM is using this method to create more efficient, reliable & effective. This system has the advantage of preventing accidents. The major component of this system consists of a variety of real-time sensors such as gas, eye blink, alcohol, and gasoline impact sensor, as well as software that interfaces with GPS and Google maps APIs to determine position. They presented an intelligent car system for preventing accidents as a result of their study.

Chetanraj Patil et.al (2018) presented Design and Analysis of Intelligent Braking System. The goal of this research is to create and build an “intelligent braking system,” which is a control system based on intelligent electronically controlled automobile brakes. The IR transmitter and receiver circuit, the Control Unit, and the pneumatic breaking system make up the Sensor Operated Pneumatic Brake. The obstacle is detected using the infrared sensor. When an obstacle is detected in the route, the IR sensor detects it and sends a control signal to the braking system. The pneumatic breaking mechanism is then used to brake the system in response to the controller's input signal. So, in this case, the vehicle brakes on its own by calculating the distance from the object.

Dhanya (2012) proposed a sensor fusion-based technology for an advanced automated braking system. They do this by combining the capabilities of capacitive and ultrasonic sensors to detect the presence of an obstruction and calculate the distance between the vehicle and the obstacle, which is then utilized to control automatic braking systems for safety. To control the process, they utilize a 32-bit microcontroller with an ARM processor (LPC2138) as the brain of the system. The technology also includes automated retarding and automatic horn disabling in restricted areas, which is accomplished via RF signal communication. The value of the limiting speed in km/hr and a signal corresponding to disabling the horn are transmitted via an RF transmitter mounted in the traffic signal, which automatically reduces speed to a certain rate and disables the horn in that region.

Divya K.S et.al. (2015) presented a CAN-based Vehicle Speed Control System. With onboard sensors and a microprocessor, this paper proposes an idea to develop a collision avoidance system. A communication system based on the CAN-bus is being developed for an accident avoidance system.

Furthermore, the ARM 7 processor used in this system provides excellent efficiency, fast operation, low power, cheap cost, and improved performance. It also makes use of radar installed in front of the car. It is an object detecting system that scans the front environment using radio waves to identify the range, altitude, direction, and speed of things and trigger a signal to the main controller. When an obstacle is detected, the servo motor will control the vehicle's speed. If the distance is less than a certain value, the vehicle's speed is decreased using a servo motor.

Ezoe et al. (2006) proposed a study on a collision mitigation braking system for trucks. A millimeter wave radar sensor, yaw rate sensor, and steering wheel angle sensor are included in the system, and their outputs are analyzed to predict the chance of a collision. According to this study, if the chance of a rear-end collision with an object ahead is determined as probable, the driver will get auditory and visual warnings to alert him, and also an automated braking impulse will be triggered. When the driver fails to respond to the warnings and the risk of a collision is determined to be high, the system uses full autonomous braking to lower the impact speed via the vehicle EBS.

Gopal et.al (2014), proposed Speed Control and Automatic Braking System. The major goal of this paper is to design a vehicle speed control and automated braking system. They claim that electronic circuits such as sensor, relay, control system, microcontroller, signal transmitter and signal receiver, and Peripheral Interface Circuit (PIC) would be used in the speed control and automated braking system. In this project, they strive to apply their electronic circuit design skills and expertise to a speed control and automated braking system. They used an ultrasonic sensor to identify the obstruction and an infrared sensor for the automated braking system in this project. The system will be designed to keep the driver and passenger’s safe inside the car.

LS saloon and Lexus (2007) have presented additional features to the Pre-Crash Safety (PCS) system. The device combines data from millimeter-wave radar operating at 25GHz with a twin-lens infrared stereo camera to detect the presence of obstacles. The camera detects near-infrared radiation generated by specialized units installed into the car's headlamp high-beam projectors and reflected by objects up to 25 meters away. Based on the position, speed, and trajectory of an object ahead, the PCS system determines the chance of a collision. If the likelihood of a collision is determined to be high, a warning buzzer and ‘brake' alert are shown on the dashboard display are activated. If the driver fails to brake within a specific amount of time and, the system may automatically apply the brakes and lower speed to assist the driver in lessening the impact and, in certain circumstances, avoiding the accident.

Matsumoto et al (2001) conducted a research on accident avoidance technologies on the Nissan Advanced Safety Vehicle (ASV). When the driver is slow to brake or does not brake adequately in proportion to an impediment ahead, automatic braking brings the car to a halt or decreases the collision speed as much as feasible. When there is a higher chance of colliding with an object in front of the host car such as a stopped car, due to human error caused by the driver's inattention or misjudgment, audio and visual alerts inform the driver to the possible hazard. Automatic braking is used to lessen the collision speed when the driver fails to steer around the barrier. In this situation, if the driver brakes to slow down, the driver's action takes priority. If the driver's action does not adequately slow the car to achieve maximum accident avoidance, the system continues to control the brakes.

McCarthy et al. (2004) conducted research that resulted in the development of a proof-of-concept sensor system that could detect pedestrians in front of a vehicle. This study discovered that such a system could be used to stop the car and/or install active secondary safety measures like a pop-up bonnet, and that it could provide significant advantages in pedestrian accidents. To identify pedestrians on the road, the prototype system combines a high-resolution 24 GHz short-range radar with a passive infrared sensor. The radar was used to precisely determine the distance and relative velocity of a pedestrian, while the infrared sensor was utilized to determine whether or not the object identified by the radar was a pedestrian. This system allows the driver to take actions based on detected signals, such as reducing vehicle speed or stopping at a predetermined stopping distance.

Muqaddas Bin Tahir (2012) proposed a new distance measurement technique (Hurdle Detection) for a safe environment in the car using ultrasonic rays to decrease vehicle collisions or accident. Eight ultrasonic sensors are utilized in this system to detect the various types of objects that may be present on the vehicle ahead. However, in this system, the ultrasonic sensor is only used to detect the presence of an object (hurdle); no action is taken. The car and sensor will be allowed to run normally until the sensor identifies a possible risk by applying a possible enhancement in the safety system in the vehicle. The sensor does not produce or send a signal until the automobile is within 75 feet of an object, at which point the timer transmits the hurdle information to the driver. The sensor only detects the existence of an object; the user or driver must overcome the obstacle.

Nitsche and Schulz (2004) presented the ALASCA laser scanner's potential automotive applications, with a particular reference to warning and emergency braking systems. They claim that the

ALASCA laser scanner, when combined with proper analytic algorithms, is capable of identifying and classifying the following types of road users: Pedestrians, Trucks, Bicycles/Motorcycles and Cars, in order to provide warning before an accident occurs. The report distinguishes pedestrian detection and protection capabilities from automated emergency braking functions, which are characterized as the activation of devices such as deployable bonnets that protect pedestrians during an accident. The study does not specify specifically whether pedestrians can be detected in time for the automatic emergency braking system to be successful or not, but it does state that the sensors can identify pedestrians earlier than is required for the activation of deployable devices, indicating that it is possible.

Niveditha.P (2014) presented an Ultrasonic Collision Warning System and an Automatic Braking System. Using Stereo Multi-Purpose Cameras, Automated Emergency Braking Systems, and Ultrasonic Sensors, this system develops electromechanical systems to avoid vehicle accidents. The stereo multi-purpose camera has a spatial intelligence range of up to 50 meters in front of the vehicle, as well as a 500-meter environment recognition range. When the sensor detects obstacles or any other hindrance, the car using this technology can automatically brake. The braking circuit's purpose is to automatically brake the vehicle after getting a signal from the sensors. Three concepts underpin these integrated safety systems. Collision avoidance, collision mitigation braking systems, and forward collision warning are the three technologies.

Pankaj Jat (2015) proposed an Advanced Brake Assistance System. The objective of the project is to build a system that will assist the driver in crucial braking situations. This system is equipped with the necessary algorithm for detecting and distinguishing between emergency and non-emergency situations. In emergency situations, the advanced brake assistance system interprets a fast pushing of the brake pedal. The speed at which the brake pedal is applied is detected using a proximity sensor. In emergency situations, proximity sensor readings are supplied as input to the unit processor, which can enhance the braking force by pressing the piston by motor. In an emergency situation, it needs high breaking force. So, the motor pulls the hand brake wire for a few seconds, which helps to stop the car while also creating a strong braking force.

Rajyalakshmi.M et.al (2018) presented Design and Fabrication of Intelligent Mechatronic Braking System. In this study, ultrasonic sensors are proposed for use in safety systems for controlling vehicle speed. An intelligent mechatronic system contains an ultrasonic wave emitter and receiver mounted on the front section of a vehicle emitting and receiving ultrasonic waves frontward at a specified distance. Then, based on the detecting pulse information, a microcontroller is utilized to regulate the vehicle's speed and to push the brake pedal and apply the brake on the vehicle stupendously for safety reasons. By implementing advanced control of braking system operation, the electronic control's extremely fast response time may be employed to significantly decrease the braking distance.

S-Max and Galaxy (2007) have presented Volvo S80 with a Collision Warning with Brake Support system, which uses a radar sensor to continuously monitor the area in front of the vehicle. When a driver fails to react when approaching a car in front of them, an audible signal and a warning light is activated. If the driver fails to stop hard enough, the brake linings are automatically prepared so that they are only in touch with the discs, and the system boosts the braking force while flashing the brake lights to alert vehicles behind. If the driver does not respond to these warnings or begin braking, the chance of colliding with the vehicle in front of him or her increases, and effective brakes is done automatically.

Tushar Kavatkar et al. (2012) presented a collision avoidance system based on ultrasonic control. Using embedded system design, a braking system was created and implemented on an automobile to make the driving process safer. The majority of accidents occur because the driver takes too long to press the brakes. In this project, a braking system is created that, when activated, may apply brakes based on the object sensed by the ultrasonic sensor to stop the car in an emergency without the need for a driver instruction. Ultrasonic sensors are used. The vehicle's brakes is controlled by a microcontroller based on the detecting pulse. Vehicles are now often designed with active safety technologies to decrease the risk of accidents, which are common in metropolitan areas.

Vidyadhar (2014) proposes a system that can improve vehicle safety. This system can aid the driver by warning the driver of oncoming obstacles and approaching vehicles that may cause a collision. They are also introducing an auto retarding system to help avoid accidents during emergency situations. Ultrasonic sensor, motor driver, and LCD are used in this system. Furthermore, they have incorporated an automated wiper speed control system that regulates the wiper speed depending on the severity of rainfall. The IR sensor in the wiper speed control system is highly sensitive and can detect very tiny amounts of moisture. If there is even a slight amount of rain, the system will activate; if there is a greater amount of rain, the motor will speed up, implying the wiper will run faster, saving the driver from distraction and providing convenience and safety. As a result, this system assists the driver by reducing fatigue during the rainy season.

Yared A. (2019) presented a Sino truck automated brake control system based on several sensors and electrical components. Ultrasonic sensors are used to measure distance and function on the principle of reflected sound waves. By receiving an electrical signal from the ultrasonic sensors and transferring it to the relay to activate a solenoid, the microcontroller works as a bridge between the sensors and the solenoid, allowing the solenoid plunger to be actuated, pushed the foot valve, and have a brake in an emergency. This approach is only based on the vehicle's stopping distance and ignores other factors such as speed of vehicle and weight.

2.5. Auxiliary brake system

An auxiliary brake system is an additional brake system which equipped on a vehicle that support the main brake system of the vehicle by increasing the brake performance and efficiency of brake. For this study two auxiliary brake systems have been used electromagnet brake system and automatic wind deflector (drag force brake).Those auxiliary brake system integrated with electro mechanical control system and actuate automatically at emergency time.

2.5.1. Electromagnetic brake system

Electromagnetic brakes work in a relatively cool condition and satisfy all the energy requirements of braking at high speeds, completely without the use of friction. The base for electro magnet brake system is the development of electromagnet principle because this type of brake system works depending on magnetic strength of an electromagnet device. Electromagnetic Braking System is used which is efficient way of braking with high power to torque ratio and also provide less amount of friction. (Varun Kumar et.al 2018).

2.5.1.1. Development of Electromagnet

An electric current can be used for making temporary magnets known as electromagnets. An electromagnet works on the magnetic effect of current. It has been found that if a soft iron rod called core is placed inside a solenoid, then the strength of the magnetic field becomes very large because the iron ore is magnetized by induction (Kesavamurthy, 1959).British electrical engineer William Sturgeon, a former soldier who began to dabble in the sciences at the age 37, invented the electromagnet in 1825.Figure 2.15 show early electromagnet that invented by Sturgeon. Sturgeon’s device came a mere five years after a Danish scientist discovered that electricity emitted magnetic wave. Sturgeon harnessed this idea and conclusively demonstrated that the stronger the electric current, the stronger the magnetic force (Mary .B 2019).

- **Factors affecting strength of an Electromagnet**

The strength of an electromagnet is:

- Directly proportional to the number of turns in the coil.
- Directly proportional to the current flowing in the coil.
- Inversely proportional to the length of air gap between the poles.

2.5.1.2. Working principle of electromagnetic brake

Electromagnetic braking system consist of solenoid coil which is uses principle of electromagnetic effect of electrical current for Braking. This is combination of Electrical and Mechanical components here Electrical energy is used to apply braking torque or retardation Electromagnets can be constructed in various shapes, including the linear solenoid and horseshoe geometries (Heald.M 1988).It consist two basic component the rotary and stationary .the rotary part has ferromagnetic property and stationary par consist electromagnet coil winding then when the current is passing through winding it generate magnetic field against rotary part (disc).Finally the rotating disc start to decelerate or to slow rotating speed.

2.5.2. Literature review on Electromagnetic brake system

Abhijeet N. et.al (2017), suggested a Design and Analysis of Electromagnetic Disc Brake for Automobile. The goal of this study is to develop and analyze an electromagnet disc brake that will reduce maintenance costs, operating temperatures, and braking effort. This study discusses a new kind of electromagnetic disc brake that is used to slow down a vehicle's movement. This research presents a comprehensive design method for an electromagnetic disc brake to achieve maximum efficiency and effective braking. As a result of the project, maintenance were lowered, braking effort was reduced, and operating temperature was reduced due to less wear and tear.

Krunal p. et.al (2017), proposed Electromagnetic braking System: This study investigates a new braking system technology. The main working principle of the brake developed in this study is one rotating metal disc in between two magnets to apply the brake to induced electric current in circuit to induced magnetic field in armature to attract the magnet to the rotating metal disc and to stop the rotation in several times while applying brake. The electric power attracts the electromagnet aluminum disc by applying the magnetic coil to the magnetic field in the armature coil. As a result, this invention eliminates the risk of tire degradation and bursts owing to friction generated by direct impingement of air on the retarder caused by vehicle motion. Furthermore, there is no need to change brake oils on a regular basis, and there is no linkage of oil.

Naresh B. et.al (2017), Designed and Fabricated an Electro-Magnetic Disc Braking System: the goal of this study is to design an electro-magnetic disc braking system that would increase braking efficiency. This invention explains an electromechanical braking system that employs magnetic force to activate brakes and is powered by an electrical regulator switch. When electrical power is applied to an electromagnet, the electromagnet produces a very effective magnetic field, and these magnetic powers are utilized for braking. The paper addresses dynamic electromagnetic system calculations aided for various masses and wheel RPMs, as well as the influence on brake control. Electromagnetic braking is a sort of braking mechanism that does not require any touch. As a consequence, this brake system will be more dependable than the existing one.

Rhythm D. et.al (2016) presented a Design and Theoretical Study of Electromagnetic Brake System. The goal of this invention is to design and analyze an electromagnetic braking system. The research tests also aimed to determine the consequences of increasing the current induced into the electromagnet, which generates a drag force that slows the motion. As a consequence, he comes to the conclusion that while electromagnetic brakes function better than conventional brakes at high speeds, they cannot be applied at low speeds. As a result, it must be utilized as a backup brake at high speeds. The characteristics of aluminum and copper make them ideal for rotor material. With a reduced air gap, the magnetic flux traveling through the rotor increases, resulting in higher braking torque and a shorter braking time.

Stephen Z. et.al (2002) presented a magnetic brake that enables braking or locking capability and is operated remotely by electric power. A rotating shaft and a brake disc placed on the shaft make up the magnetic brake. A permanent magnet and a bipolar solenoid are housed in a non-rotating core housing assembly positioned around the shaft. A permanent magnet and a bipolar solenoid are included in a non-rotating core housing assembly positioned around the shaft. To prevent the shaft from rotating, a magnetic armature next to the core housing assembly can advance toward the core housing assembly and into interaction with a brake disc. The armature is pushed away from the core housing assembly and into contact with the braking disc by a spring. The brake does not require any electric power to keep it in set mode with the rotating shaft fully locked or released mode with the rotating shaft fully released. The permanent magnet is strong enough to retain the armature despite the spring's pushing until the solenoid supplies an opposite polarity.

Sevvel.P, et al. (2014) presented an Innovative Electro Magnetic Braking System to demonstrate that electromagnetic brakes are superior than existing brake systems. The benefits of using an electromagnetic braking system in an automobile are investigated in this research. These brakes can be used as an auxiliary brake in heavy vehicles. Controlling the current provided to create the magnetic flux allows electromagnetic brakes to be utilized in commercial cars. An Electromagnetic Braking system is used in this research to activate the brake using magnetic force, however the power necessary for braking is supplied manually. When electricity is supplied to the coil, a magnetic field is created across the armature as a result of the current running through it, which attracts the armature to the coil. As a result, a torque is created, and the car eventually comes to a stop. As a consequence, these electromagnetic braking systems will save maintenance costs while also eliminating the issue of brake fluid vaporization and freezing.

Vinodkumar S. et.al (2017) proposed Improvement of Braking Efficiency in Vehicle by using Fusion Braking Systems: The goal of this research is to enhance the braking efficiency of heavy vehicle brake systems by using disc brakes with permanent magnets. This paper is primarily concerned with improving the brakes of cars, particularly those in the higher segment with huge quantities of engine power. Disc brakes with ferrite magnets are used in this system. As a result, the vehicle's stopping power improves, allowing it to stop for a shorter distance in less time, making the ride more comfortable and smooth with confident braking. This system is designed for high-performance automobiles or bikes that require smooth and reliable braking at greater speeds. The project's major goal is to increase brake efficiency by utilizing a permanent ferrite magnet to induce a magnetic field on the disc brake.

Varun Kumar (2018) presented A Role of Electromagnetic Braking System in an Automobile. Electromagnetic brakes have been utilized as extra retardation equipment in addition to normal friction brakes on automobiles and big vehicles to assist the primary braking system as an auxiliary brake, according to the findings of this study. Friction brakes are less often employed and, as a result, rarely attain high temperatures. This improved braking system not only aids in efficient braking but also assists in the avoidance of accidents and the reduction of accident frequency to a minimum. Furthermore, electromagnetic brakes eliminate the risk of overheating that can occur when brakes are used for longer periods of time than they are capable of dissipating heat.

2.6. Automatic wind deflector of truck

Wind deflector is an accessory of vehicle which mount on different part of the vehicle to reduce air resistance (Aerodynamic effect) when the vehicle is moving. On the truck the wind deflector is mounted on roof to reduce air resistance and air turbulence.

2.6.1. Aerodynamic effect on heavy duty vehicle.

Aerodynamic drag, also called wind resistance is a retarding force exerted on a vehicle by the air through which it moves. As a truck moves forward it breaks up the flow of air, creating an area of low pressure behind the body .Since trucks have a large frontal area and the presence of a trailer also leads to the truck experiencing significant resistance which has to be overcome (Ramesh D.K, 2015). According to research conducted by U.S Department of energy (published in 2006); The amount of energy required to overcome aerodynamic drag is affected by the effective frontal surface area of the vehicle, the shape of the vehicle and the speed at which the vehicle is travelling.

The air resistance will be reduced through the use of wind deflectors (Xu Yan 2011). A well-designed wind deflector is one of the method that can reduce wind resistance to a certain extent. Optimizing the angle of the wind deflector also causes reduced drag force acting on the vehicle, thereby reducing the fuel Intake, save energy and to protect the global environment, is a primary concern of automotive development. In vehicle body development, reduction of drag is essential for improving fuel consumption and driving performance (Bernard T. et. al 2012).

2.6.2. Literature review about different types of wind deflector

Chaitanya et al. (2014) conducted a numerical analysis which deals with the effect due to change in profile of truck-trailer on aerodynamic drag and its repercussion on fuel consumption. The numerical analysis is done by using CFD software. The comparison has been done with respect to coefficient of drag, coefficient of lift, pressure contours, velocity streamlines and vectors between unmodified and modified profile. The profile modification was applied on basic truck-trailer model by providing wind deflector on truck's cabin, vortex trap, mini skirt, vortex strake and aerodynamic revolute. The researchers analyzed that, due to profile modification the reduction in aerodynamic drag is up to 21 %, which reduces the fuel consumption by 4 liters for 100 km for diesel powered truck.

Damissie & Ramesh (2017) modified the outer surface of the bus aerodynamically in order to reduce the effect of drag force of the bus which in turn results in reduction of fuel consumption of the bus. Their study was conducted for three wind speeds. Numerical tests have been conducted in CFD to prove the effectiveness of the new concept design. It is evident from the test result, that there is a considerable reduction in drag force of about 39.4% from the existing bus to the new concepts and 22.8% (5 to 6 liters) of fuel can be saved for the every 100 Km.

Harun Chowdhury et al. (2017) investigated the effects of different deflectors on truck drag reduction. The major goal of this paper is to utilize a wind tunnel to measure the amount of drag created by the wind deflectors used in Asian subcontinental trucks, particularly in Bangladesh and Pakistan in a wind tunnel area, and to compare the results to a baseline vehicle with no exterior modifications. It is possible to cut fuel consumption by 13% by replacing these deflectors with acronymic deflectors. Wind noise and dirt deposition are further contributed by the truck deflectors' complex exterior designs. However, a considerable quantity of greenhouse gas emissions will be reduced. A small alteration of these massive numbers of comparable current vehicles can provide enormous economic benefits to these countries.

Liu et al. (2013) carried out a research to reduce the aerodynamic drag of heavy-duty truck by adding four different shape and style of deflectors based on the original one. With the method of numerical simulation, the influence of deflector on the flow field of the cab and the vehicle was analyzed, and the mechanism of aerodynamic drag and the measures of drag reduction were discussed in the study. When driving at speed of 30m/s, the aerodynamic drag will be significantly reduced with the contributions of all the four deflectors. The optimal solution can reach a reduction about 14%

Prakash Shakti et.al (2017) conducted research on Commercial Vehicle Aerodynamic Drag Reduction (Tipper Truck) The main objective of this work was to design best roof deflector for tipper truck according to Indian truck market. The all work is done by 3D design and simulation software. Finally they conclude from the result of aerodynamic simulation of different truck model, that keeping roof deflector over Tipper level roof cabin with holder decreases aerodynamic drag by 22 % which thusly lead diminishment in fuel utilization by 1.5 to 2 %. It was accommodated that Wind weight impact the auxiliary durability of air deflector mounting section as a result of improved tipper aerodynamic or drag force they get better fuel efficiency, better tipper stability, improved road holding and reduction in wind noise level .

Ramesh e al. (2015) conducted a research on Aerodynamic analysis and optimization of wind deflector in a Commercial load transport vehicle. They stated that in the field of commercial goods transport, trucks have an important place. One of the main problems faced by truck manufacturers is the Air resistance associated with the highway running. Since trucks have a large frontal area and the presence of a trailer also leads to the truck experiencing significant resistance which has to be overcome. This can be reduced through the use of wind deflectors. A well-designed wind deflector can reduce wind resistance to a certain extent. Optimizing the angle of the wind deflector also causes reduced drag force acting on the vehicle, thereby reducing the fuel intake. Here the initial drag of 2050 N is reduced to 1688.453 N using a 1.75 m wind deflector at 45 degree angle resulting in the reduction of drag by 17.6%. To save energy and to protect the global environment, fuel consumption reduction is a primary concern of automotive development.

YIN Meng chen et.al (2011) conducted a study on vehicle aerodynamic braking based on CFD analysis. This research aims to improve vehicle braking performance by considering the effect of aerodynamic forces during the braking process. This paper uses the method of aerodynamics to perform a numerical simulation of the air current at the rear of the vehicle and designs a wind-assisted emergency brake by adding a retractable spoiler shaped to the car trunk, thereby assisting in the reduction of brake distance and duration by the additional air drag and down. CFD Analysis software takes into account and processes several possible scenarios based on the spoiler angle. According to the result, at a starting speed of 40 m/s and a spoiler angle of 60°, the brake distance is reduced by 4.8 percent and the braking duration is reduced by 3.3 percent.

2.6.3. Using drag force as brake of the vehicle

Conventional braking methods rely on the contact between the wheels and the ground. They can only be effective if the friction coefficient is high enough to secure a successful transfer of loads between these two surfaces, therefore a slippery or uneven road decreases its effectiveness. For this reason, it is interesting to investigate alternative methods of braking to overcome the aforementioned hazard conditions and to enhance traditional brakes to achieve a reduction in the braking distance (Krzysztof K. et.al 2019). Aerodynamic brake is one of the alternative braking system that used to support main brake system for reduction of stopping distance.

The aerodynamic brake consists of a physical structure on the exterior of a vehicle that will increase the vehicle's drag coefficient, and therefore slow it down.

The initial development of aerodynamic braking devices is closely connected to improvements of the aerodynamics of racing cars. When braking by means of aerodynamic forces is considered, its efficiency depends on the increase of the drag force that can be induced (Schuetz TC 2015).

The Bugatti Veyron's hydraulic rear spoiler/aerodynamic brake in the wing position that shown in Figure 2.18 is used to act as a brake to stop the vehicle in minimum stopping distance. The Bugatti Veyron, the fastest production car in the world features a rear spoiler which, at speeds above 200 km/h (120 mph), also acts as an air brake, snapping to a 55° angle in 0.4 seconds once the brake pedal is pressed, providing an additional 0.68 g (6.66 m/s2) of deceleration due to spoiler or the wind deflector mounted on rare of the vehicle. The predecessor of this car, the Bugatti Veyron 16.4 Super Sport not only had a rear wing acting as an airbrake but also had a spoiler placed beneath it, which enabled an even greater increase of the drag coefficient equal to 0.347 (Bugatii Veyron .spec 2019)

Kataoka.T (1991) studied Numerical simulation of road vehicle aerodynamics and effect of aerodynamic devices on new Mitsubishi HSR, this car is a concept car and it was equipped with movable aerodynamic elements such as a chin spoiler, a rear under flap and two pairs of canard wings and rear flaps . These elements were set to assist during maneuvers such as acceleration, cornering and braking. According to the presented experimental data, when active aerodynamic elements were used to enhance braking, the drag coefficient increased by 0.21 and the lift coefficient decreased by 0.42 as a result the braking efficiency of the vehicle increased due to additional aerodynamic element around body of the vehicle.

YIN Meng-chen et.al (2011) conduct research on vehicle aerodynamic braking based on CFD anal ysis this study Aiming at achieving higher vehicle braking performance, and taking the aerodyna mic force influence during the braking process into consideration, this paper carries out the numer ical simulation of the air current of the rear of the vehicle by using the method of aerodynamics, an d designs a wind-assisted emergency brake by adding a retractable spoiler shaped to the car trunk, thereby helping to shorten the brake distance and duration by the additional air drag and down. Sev eral different circumstances in accordance to the spoiler angle are considered and processed by CF D Analysis software .The results show that the brake distance is shortened by 4.8% and the brake duration by 3.3% at the initial speed of 40 m/s as the spoiler angle is 60°.

Krzysztof K. et.al (2019) conducted research on influence of different aerodynamic setups on enhancing a sports car's braking. This paper presents an analysis of several different aerodynamic setups that can be utilized to improve the braking performance of a sports car. The coefficients of aerodynamic forces and the flow properties of a target top car body were investigated with the use of wind tunnel data as well as the results of CFD calculations. The balance of the car body was investigated and it was shown how the load on the front and rear axles of the car can be affected by an aerodynamic brake placed in different locations. Due to the increase of the car's drag coefficient by 0.58 and the decrease of the lift coefficient by 1.1, the braking distance can be reduced up to 31%, depending on the vehicle's speed and driving conditions, which proves that active aerodynamics utilized in braking mode can contribute to the improvement of driving safety.

2.7. Summary of literature reviews

Most of the above researchers had focused on studying of improvement of braking efficiency. To achieve this they had used conventional pneumatic brake system and obstacle sensing, controlling and actuating devices. They had applied these devices in order to reduce occurrence of hazard due to car collisions in particular and prevention of car accidents at large. In their studies they employed use of different types of sensors for detecting and measuring of distance between moving vehicle and obstacle such as ultrasonic sensor, infrared sensor, radar, and cameras and also they used different types of microcontrollers for monitoring or controlling activity of brake at emergency time and give command for actuation unit; these commands can be hazard signal to the driver for reaction, brake application automatically, retard speed of vehicle and so on by using stepper motor, switches, buzzers LCD, and electro magnet valves. And also other groups of researchers had investigated different types of auxiliary brake systems that were used to support main brake system at emergency time and they had tried to reduce several brake system friction and heat factors by using contactless brake such as electro magnet brake system. Some other groups of researchers had also investigated and recommended that the wind deflector of the truck can be used only for the reduction of air resistance, fuel consumption and exhaust emissions. In conclusion several researchers had used this newly investigated brake system for automobiles and further studied its enhancement towards hazard reduction.

2.8. Research gap

From the review done that it has been discovered that some group of researchers had emphasized that the; the automatic brake system they designed was worked only by considering the distance between the vehicle and obstacle, they don't consider the speed of the vehicle. Wind deflector of the truck can only be used for the reduction of air resistance, fuel consumption and exhaust emissions. But in this thesis the researcher is going to design and develop the Advanced emergency brake system with electro mechanical control system and auxiliary brake systems and in this thesis the actuation system of electromagnetic brake system is converted from manual operated to automatically operated and wind deflector that can also be used as auxiliary brake system by using aerodynamic drag force as brake force on wind deflector by inclusion of appropriate actuating mechanisms; with this direction the researcher hopes to prove that there will be additional aid to the main brake system as well the reduction of accident and rollover of the truck during emergency braking which can be achieved due to increase of brake force and reduce reaction time of brake truck's by using auxiliary brake systems and automatically controlled brake system.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Introduction

In order to address the general and specific objectives of this work a well-designed methodology will be followed. The present study applies numerical and theoretical analysis as main approach which is used as methodology. Theoretical approach uses governing equation for design, sizing, selecting and formulation of the advanced emergency brake system for ISUZU truck. The braking performance of the modified brake system is evaluated numerically and theoretically and the working principle and electromechanical configuration of the new brake system is showed by using prototype.

3.2. Material used to develop prototype

Table 3.1 Material used to develop prototype

Type of Material	Name of material	Code of material	Number of material
Sensing unit	Ultrasonic sensors	HC-SR04	1
	Infrared Speed sensor	RKI-3141	1
Controlling unit	Arduino	Arduino uno	2
Actuating unit	Solenoid valve	3/2 24 v pneumatic solenoid valve	1
	Pneumatic cylinders	ISO15552FBC-standard cylinder	2
	LCD Display board	JHD-162A	2
	LED (Alert light)	5mm round type	2
	Car Battery(12V)	-	2
	Bread board	-	
	Aluminum sheet	-	
	AC motor	220 v Ac motor	1
	AC compressor	-	1
	jumper wire	-	50

3.3. Methods

3.3.1 Data source and collection methods

The necessary data collected by using primary or secondary data collection through visiting various websites and literatures.

To achieve the objectives, both primary and secondary sources will be used.

- The Primary sources
- The secondary sources

Among the primary sources:

- ✓ Visual observation of conventional air brake system operations
- ✓ Visual observation of ISUZU truck.
- ✓ Interview to technician, engineers

Among the secondary sources:

- ✓ Referring books
- ✓ Discussion with advisor
- ✓ Previous experience
- ✓ Referring different internet links.
- ✓ Using software such as Arduino, CATIA V5, CFD, and proteuse for coding simulating the system.

3.3.2 Literature review and problem identification

Literature survey about the conventional pneumatics brake system characteristics of commercial vehicle brake system and effect of conventional brake system in order to minimize accident at emergency time are the key methodology of this study that will help to design and develop advanced emergency brake system which used to minimize accident or collision before it happened .and also this study refer what others done and identified, where the limitations does exist so that this work will be based on the research gap.

3.3.3. Flow chart of the thesis

Flow chart of the thesis is the chart that show the progress and method that used to develop the required study. Flow chart for this study is shown in Figure 3.1.

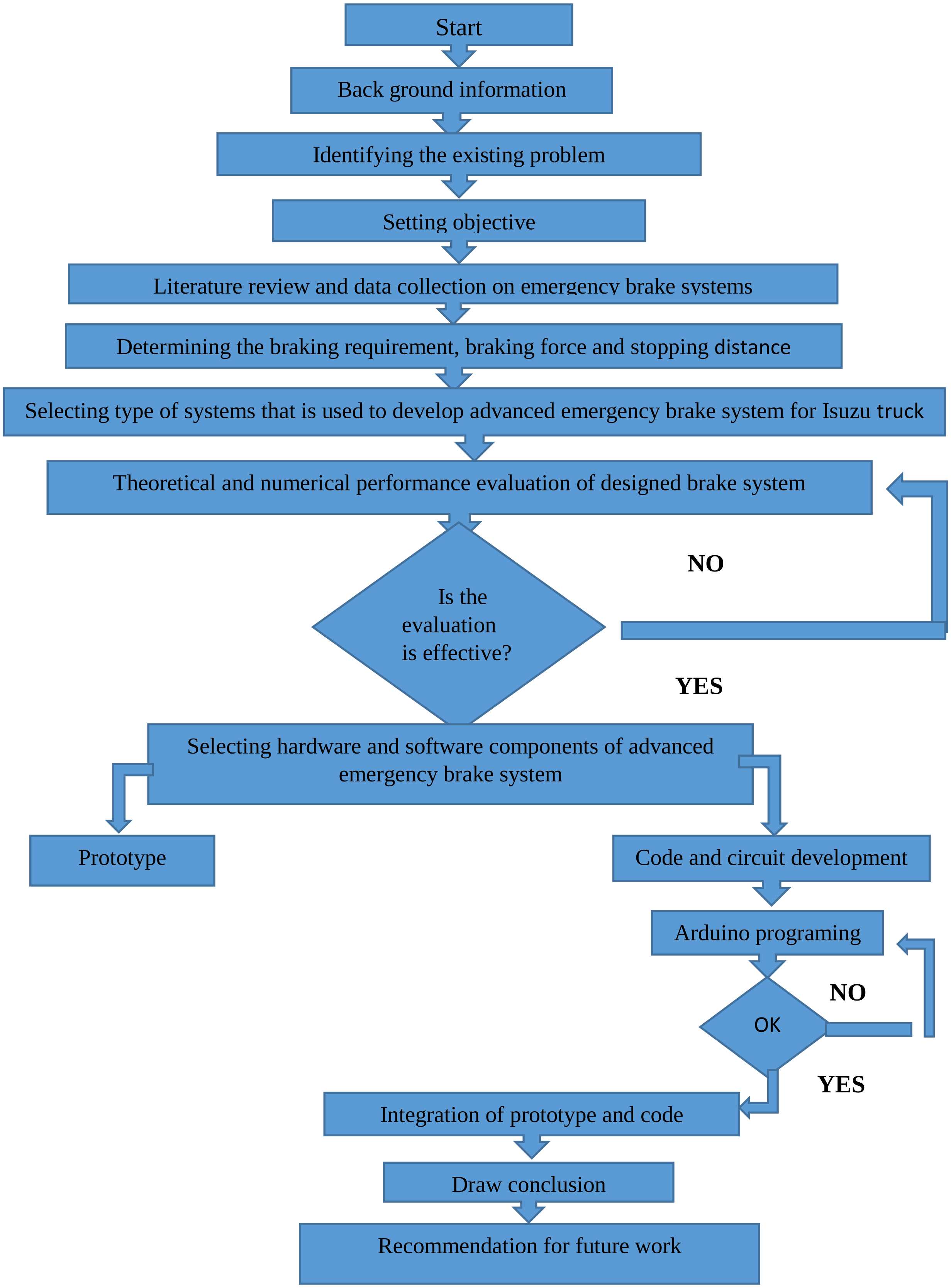


Figure 3.1: Flow chart of the thesis

3.4.Model development and simulation tools

In this thesis several software are used for designing, modeling, analyzing and performance evaluating of new designed advanced emergency brake for ISUZU vehicle. For designing and developing model of an appropriate aerodynamic brake system (Automatic wind deflector) CATIA V5 software is used .For writing of controller program (Arduino) Arduino programming software is used and for designing of circuit diagram of sensing and controlling unit Proteus software is used finally the simulation and Aerodynamic analysis of the Isuzu truck is done by using ANSYS CFD ANSYS software.

3.4.1. Justification about selected Truck

The selected truck for this study ISUZU F34-series truck. This truck is a commercial truck which is used to transport different types of good and product from city to city and it play a great role for development of country in transportation filed. The reason why this type of truck is selected for this study is this type of truck mostly used to deliver good or product as afresh from one place to another place there for it need high speed driving and driver not get enough rest as a result the occurrence of accident or collision is very high because of high speed driving and tiredness of a driver. So design advanced emergency brake system for this type of truck give more advantage to reduce the accident or Collison by control brake system and speed of truck automatically when the driver is not active.

3.5. Manufacturing prototype

To design the proper components, the following properties of materials are considered

- Durability
- Strength
- Machinability and
- Weldability

Factors are considered while selecting the material.

- Availability of the material
- Suitability of the materials for the working conditions and
- The cost of the material.

Once the design ,writing program ,working circuit diagram and simulation part are end up, the next thing will be manufacture the physical structure of the prototype by using appropriate material and integrate with sensing and controlling unit by circuit .finally Conduct taste and compare with conventional pneumatic brake system.

3.6. Electro-mechanical control systems of emergency brake systems

Most emergency brake system that innovated nowadays is based on configuration of electro mechanical control systems (Gissinger.G et.al 2003). The main component of electro mechanical control system of emergency brake that used to control activity and actuation of brake at emergency time are subdivided in to three units sensing unit, controlling unit and actuation unit.

3.6.1. Component of sensing unit.

Sensing unit is a combination of different sensor that required to measure and detect different physical characteristics of object and transmit the measured physical parameter to electrical signals. The sensing unit on this study include obstacle sensor (ultrasonic sensor) and speed of truck sensor (infrared sensor). American National Standards Institute state that sensor is a device which provides a usable output in response to a specified measurement. A sensor in Figure 3.2 acquires a physical quantity and converts it into a signal suitable for processing (e.g. optical, electrical, mechanical).

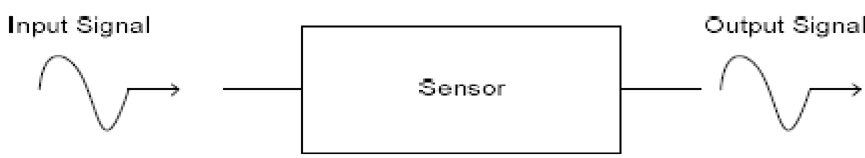


Figure 3.2: working principle of sensor

Nowadays common sensors convert measurement of physical phenomena into an electrical signal. Active element of a sensor is called a transducer.

3.6.1.1. Ultrasonic Sensor

Ultrasonic refers to inaudible sound waves above frequency of 20,000 hertz. The normal frequency range for human hearing is roughly 20 to 20,000 hertz. Ultrasonic waves travel faster than the speed of audible sound; i.e. the sound that humans can hear **(**Corso 1963).An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal that shown in Figure 3.3 The ultrasonic transducer produces ultrasonic signals. These signals are propagated through a sensing medium and the same transducer can be used to detect returning signals and it can detect ultrasonic sound that cannot be detect by human. There are two parts in an ultrasonic sensor transmitter and receiver, the transmitter which emits the sound using piezoelectric crystals and the receiver which encounters the sound after it has travelled to and from the target (Donald P. , 2020).

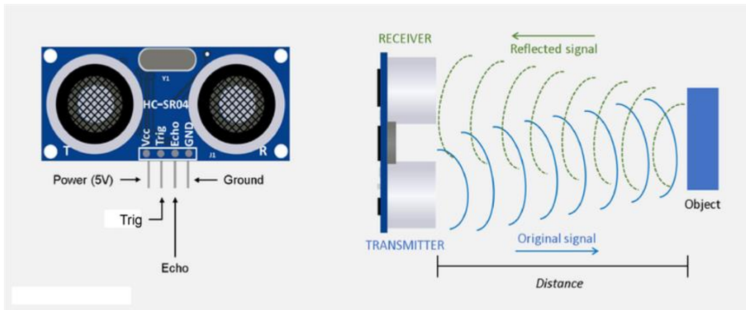


Figure 3.3: ultrasonic sensor (source: Osoyoo 2018 Micro bit lesson "Using the Ultrasonic Module")

Working principle ultrasonic sensor

Ultrasonic signals are like audible sound waves, except the frequencies are much higher. The ultrasonic transducers have piezoelectric crystals which resonate to a desired frequency and convert electric energy into acoustic energy and vice versa. An output signal is produced to perform some kind of indicating or control function. A minimum distance from the sensor is required to provide a time delay so that the "echoes" can be interpreted. Variables which can affect the operation of ultrasonic sensing include, target surface angle, reflective surface roughness or changes in temperature or humidity (Kirtan G. et.al 2016). As shown in figure 3.4 the targets can have any kind of reflective form even round objects. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object (Texas instrument, 2019).

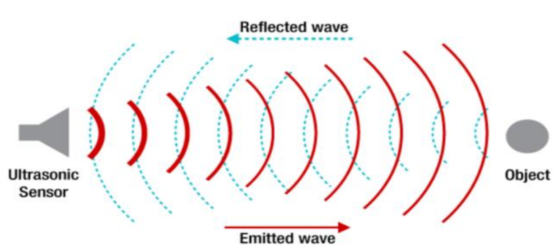


Figure 3.4: Working principle ultrasonic sensor (source:Texas instrument)

Calculation of distance between the sensor and the object

In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emissions of the sound by the transmitter to its contact with the receiver. The formula for this calculation is

$$\text{distance} = \frac{\text{speed of sound} \times \text{time taken}}{2} \qquad \ldots\ldots (2.2)$$

- **Speed of Sound:** The speed of sound is defined as the dynamic propagation of sound waves. This depends on the characteristics of the medium through which the propagation takes place. Speed of sound is used for describing the speed of sound waves in an elastic medium. The formula for speed of sound is given with respect to gases. It is the square root of the product of the coefficient of adiabatic expansion and pressure of the gas divided by the density of the medium. The mathematical representation is given as (Nicolau et al., 2009).

$$V = \sqrt{\frac{\gamma P}{\rho}} \qquad \ldots\ldots. (2.3)$$

Where, v = speed of sound

Γ = coefficient of adiabatic expansion

P = pressure of the gas

ρ = density of the medium

- Speed of Sound in Air: The speed of sound is an essential parameter used in a variety of field in Physics. The speed of sound refers to the distance travelled per unit time by a sound wave propagating through a medium**.** The speed of sound in air at 20^{o}C is 343.2 m/s which translates to 1,236 km/h (Frank et al., 2015).

There for the measured distance between ultrasonic sensor and object become

$$\text{distance} = \frac{343.2\text{m/s} \times \text{time taken}}{2} \qquad \ldots\ldots (2.4)$$

Ultrasonic Sensor's Target Considerations

Ultrasonic sensors can detect a variety of materials, regardless of shape, transparency, or color. The only requirement for ultrasonic sensing is that the target material is a solid or liquid. This enables contactless detection of Metal, Plastic, Glass, Wood, Rocks, Sand, Oil, Water other hard, non-sound absorbent materials. These materials are able to reflect sound back towards the sensor through the air. Certain objects can be more difficult to detect, like angled surfaces that direct the echo away from the sensor, or permeable targets like sponge, foam, and soft clothing. These absorb more reflected ultrasonic energy (Mubina T.and Akeem W. , 2020).

3.6.1.2. Infrared sensor (speed sensor)

An infrared sensor is an electronic device that emits in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. These types of sensors measure only infrared radiation, rather than emitting it that is called a passive IR sensor (Walchshausl et.al, 2006)**.** Figure 3.5 shows the physical state and component of infrared sensor that used for this study.

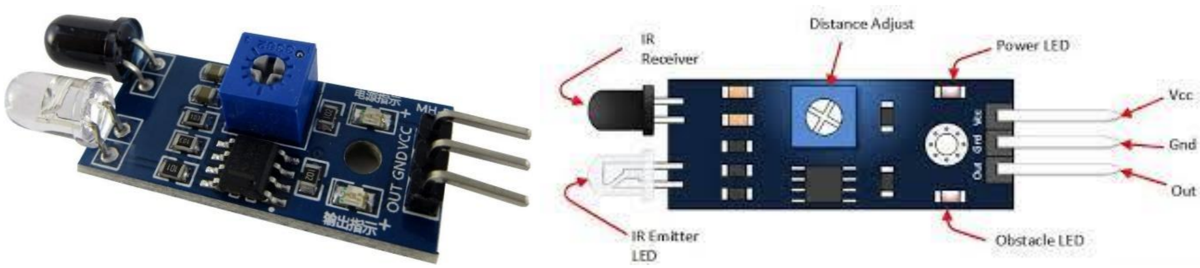


Figure3.5: Infrared sensor (Arduino project hub 2019)

IR Sensor Circuit Diagram: An infrared sensor circuit is one of the basic and popular sensor modules in an electronic_device. This sensor is analogous to human’s visionary senses, which can be used to detect obstacles and it is one of the common applications in real-time. This circuit comprises the following components and shown in Figure 3.6.

- LM358IC 2 IR transmitter and receiver pair
- Resistors of the range of kilo-ohms.
- Variable resistors.
- LED (Light Emitting Diode)

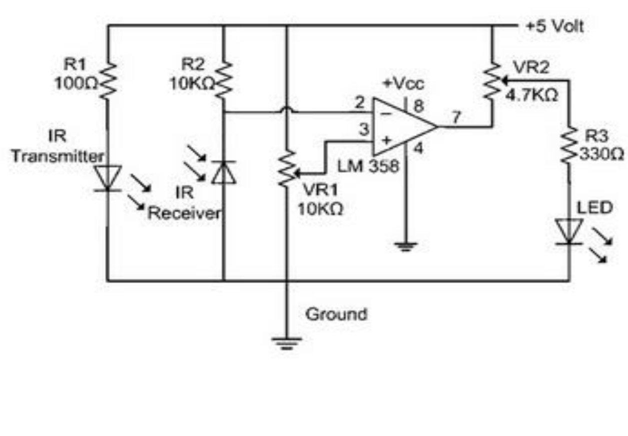


Figure 3.6: IR Sensor Circuit Diagram

Working Principle of Infrared sensor

The working principle of an infrared sensor is similar to the object detection sensor. This sensor includes an IR LED & an IR Photodiode, so by combining these two can be formed as a photo-coupler. The physics laws used in this sensor are planks radiation, Stephan Boltzmann & wine's displacement. This IR LED is one kind of transmitter that emits IR radiations and looks similar to a standard LED and which generate radiation that is not visible by the human eye. Infrared receivers mainly detect the generated radiation from an infrared transmitter. These infrared receivers are available in photodiodes form but IR Photodiodes are dissimilar as compared with usual photodiodes because they detect simply IR radiation.

Different kinds of infrared receivers mainly exist depending on the voltage, wavelength, package, etc.Once it is used as the combination of an IR transmitter & receiver, then the receiver's wavelength must equal the transmitter (Chilton and Alexander 2013). Here, the transmitter is IR LED whereas the receiver is IR photodiode. The infrared photodiode is responsive to the infrared light that is generated through an infrared LED. The resistance of photo-diode & the change in output voltage is in proportion to the infrared light obtained. This is the IR sensor's fundamental working principle.

IR Sensor for speed measurement

Tachometer is a device used to measure the speed of the any rotating object. The measurement is done in revolution per minute or RPM. This paper mainly focuses on developing a contactless digital tachometer. It is built using microcontroller, an infrared system and LCD module. The infrared system senses the interruption in the beam of rays caused by rotating object and generates pulses which will be sent to the microcontroller and these pulses will be counted; as shown in Figure 3.7 this count will be displayed on the LCD in revolution per minute i.e. RPM. The system is economical and has wide applications in automobile industry and medical field (Shwetha.P et.al 2018).

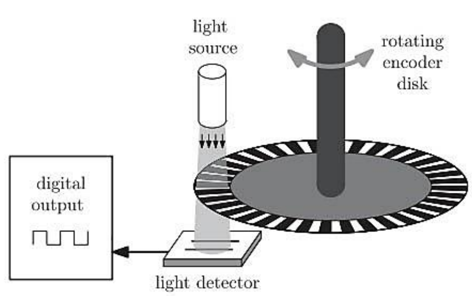


Figure 3.7: IR Sensor for speed measurement

3.6.2. Components of controlling unit

The controlling unit is the brain of electro mechanical controlled system because it control or monitor all electro mechanical system of controlled mechanism by receiving sensor feedback and giving the desired command for the actuator after analyzing the input signal. A controller, in a computing context, is a hardware device or a software program that manages or directs the flow of data between two entities. In computing, controllers may be cards, microchips or separate hardware devices for the control of a peripheral device. In a general sense, a controller can be thought of as something or someone that interfaces between two systems and manages communications between them. A device controller is a system that handles the incoming and outgoing signals of the CPU. Device controllers use binary and digital codes.

3.6.2.1. Arduino Uno

According to explanation of Arduino hardware and software development company Arduino is an open source platform that is used to program hardware using software. An Arduino board consists of a micro-controller and other electronic components shown in figure 3.8 That can be programmed using Arduino programming language to do different tasks. Micro-controller is a type of IC (integrated circuit) and it includes processor, memory and input/output peripherals on single chip. The micro-controllers used by Arduino are mostly from ATMEL. Arduino was born at the Ivrea Interaction Design and since then it is used in thousands of projects and applications. Unlike other micro-controllers, the code is easy to upload in it. It doesn't require a separate hardware to upload the code in it. The code can be uploaded by just using a USB cable. The code will be saved on the Arduino and will run until you will upload a new code.

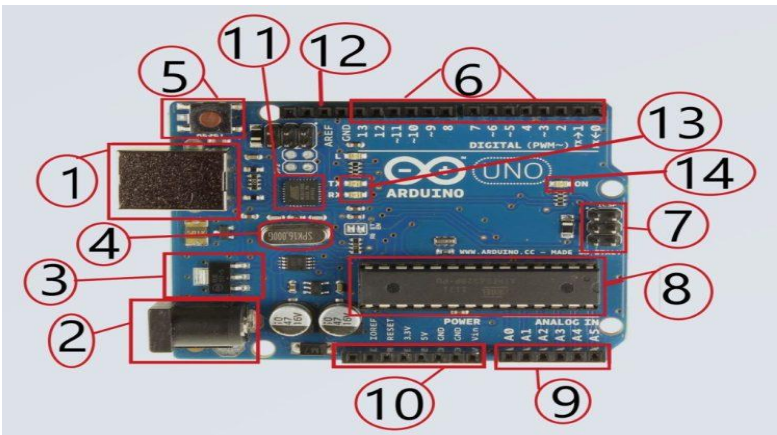


Figure 3.8: Arduino Uno Layouts (source: Arduino Uno specification)

Ports and port description of Arduino Uno

1. **USB Plug** Arduino Board can be powered by USB cable coming from your computer. Using this USB connection, we will upload our codes in the Arduino.
2. **Barrel Jack** Arduino Board can also be powered from wall power supply by connecting it to the barrel jack. For power supply users, the recommended voltage for mostly Arduino boards is between 6 to 12 Volts. The maximum voltage to use is 20 Volts.
3. **Voltage Regulator** it controls the amount of voltage going into the Arduino Board to sustain the voltage used by micro-controller and other components. It will cut off the extra voltage that might harm any component on the board. It has limitations and cannot control voltages greater than 20 Volts.
4. **Crystal Oscillator** It provides a clock signal to the micro-controller which helps micro-controller to calculate time. The frequency of this crystal oscillator is 16 MHz which means that it can make 16 million cycles per second.
5. **Reset Button**: It will restart you Arduino program.
6. **Digital I/O Pins** These pins are either used as input pins or as output pins. Arduino Uno has 14 digital pins from 0 to 13. Out of these 14 digital pins, 6 pins can also provide PWM (Pulse Width Modulation) output. The PWM pins have tilde sign (~) before the pin numbers. The PWM pins on the Arduino Uno are 3, 5, 6, 9, 10, and 11. The pins 0, 1 are RX and TX pins and these are used to receive and transmit the TTL serial data.
7. **ICSP** (In Circuit Serial Programming) Pins: It is one of the several way to program Arduino board. Normally, a boot-loader is used to program and Arduino but if it is missing or damaged, ICSP can be used instead.
8. **Micro-controller** is the brain of the Arduino. Micro controller is a type of IC (integrated circuit) and it includes processor, memory and input/output peripherals on single chip. Different Arduino Boards have different micro controllers. The Arduino Uno has ATmega328P micro controller.
9. **Analog Pins** These pins can read the signals from analog sensor such as LDR and convert them into digital. There are 6 analog pins on Arduino from A0 to A6.
10. **Power Pins**

- **Vin**: This pin is sometimes also labelled as “9V”. It can be used to power the Arduino and if you are giving power to the Arduino through the barrel jack, this can be used to access voltage.
- **GND**: Ground pins are used to ground the circuit. There are 3 ground pins on the Arduino Uno.
- **5V**: It supplies output of 5V.
- **3V**: It supplies output of 5V.
- Reset Pin: You can also use this pin to restart the Arduino by connecting a button at this pin.
- **IORE**F: This pin gives the output voltage corresponding to the I/O of that board. In case of Arduino Uno, this pin gives 5V.

11. **ATmega16U2 Chip**: This chip on your Arduino act as a bridge between the computer’s USB port and the main processor’s serial port. This helps us to upload the code from computer into the Arduino.
12. **AREF**: This is the external analog reference pin and we can use this to use it instead of the standard 5V reference as the upper limit for the analog input pins. For example, if you are getting a signal of 0-3.3 volt then you can get the full scale of ADC by connecting AREF to 3.3V signal.
13. **TX RX LED’s**: These are transmitter and receiver LED’s. They will blink whenever we will upload program or the Arduino will receive or transmit data.
14. **Power LED** this should light up whenever you will give power to your Arduino.

3.6.3. Component actuating unit (controlled unit)

The actuating unit is the combination of different actuators in electro mechanical control system .This unit convert electrical signal from the controller to physical or mechanical action of the system. A device that accomplishes this conversion is called actuator. Actuator plays a very important role while implementing control. The controller provides command signal to the actuator for actuation. There are many types of actuators available depending on the load involved. The term load is associated with many factors including force, torque, and speed of operation, accuracy, precision and power consumption. For this study various actuators are used, LCD display, relay switch, horn, LED, solenoid valve, and pneumatic cylinder.

3.6.3.1. LCD Display

A liquid-crystal display (LCD) is an electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it. Since their interface serial/parallel pins are defined so it's easy to interface them with many microcontrollers. All character LCD's performs the same functions (display characters numbers special characters, ascii characters etc.) (Dogan, 2012).

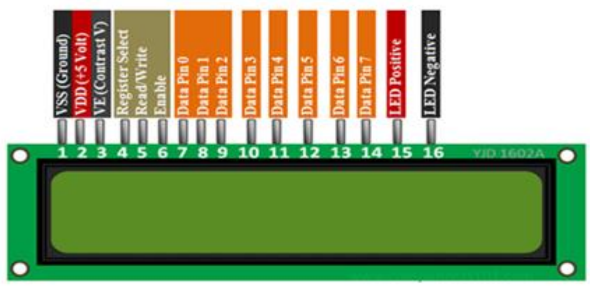


Figure 3.9: 16 x2 LCD display (source: STEMpedia "how to interface LCD")

LCD power pin and data pin are shown in Figure3.9. and the list of each pins are discussed below

- Vcc (Apply +5 volt here)
- Gnd (Ground this pin)
- Rc (Register select)
- Rw (read - write)
- V0 (set lcd contrast)
- En (Enable)
- Backlight (Bklt+ and BKlt-) pins:Turn on/off the LED backlight

All character LCD have The parallel interface consists of the following pins: Eight(8) data pins D0-D7 and 8 power and display pin as shown in figure 2.11 .The states of these pins (high or low) are the bits that writing to a register when you write, or the values you're reading when you read (Eric Franklin, 2012).

3.6.3.2. Relay switch

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch; it used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. Replays shown in Figure 3.10 is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low-power signal from a micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal.

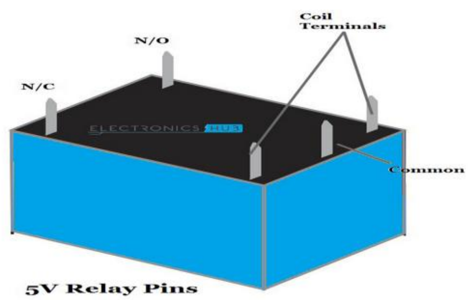


Figure 3.10: relay switch

And also a Relay is a device that helps microcontrollers (or microcontroller based boards) like Arduino to switch on or off different appliances like motors, lights, water heaters, television and fans, solenoid valves etc... .

3.6.3.3. Pneumatic solenoid Valve

Pneumatic Solenoid valve is an electromechanically controlled valve. It is used to control the flow direction of compressed air shown in Figure 3.11. A moving part inside the valve blocks or opens the ports of the valve. The valve features a solenoid, which is an electric coil with a movable ferromagnetic core in its center. This core is called the plunger. In the rest position, the plunger closes off a small orifice. An electric current through the coil creates a magnetic field.

The magnetic field exerts a force on the plunger. As a result, the plunger is pulled toward the center of the coil so that the orifice opens. This is the basic principle that is used to open and close solenoid valves (TAMSON 2019).By using this principle the new designed system can apply brake automatically by control the solenoid valve through relay switch to open the compressed air for conventional brake system of the truck.

Figure 3.11: Pneumatic solenoid valve (source: Zhejiagn Yufeng Pneumatic.co)

Solenoid valves eliminate the need for manual or pneumatic control of a pneumatic circuit and only require an electrical input (and air pressure for piloted valves) to operate, this makes them easy to program and install in a wide variety of applications. For this study the Pneumatic solenoid Valve is controlled by preprogrammed Arduino uno through relay switch and it used to control flow of air to wheel brake and new designed wind deflector of a truck.

3.6.3.4. Single acting Pneumatic cylinder

A single-acting pneumatic cylinder has one port, which allows compressed air to enter and for the rod to move in one direction only. The high pressure of the compressed air causes the rod to extend as the cylinder chamber continues to fill. When the compressed air leaves the cylinder through the same port the rod is returned to its original position (Majumdar, 1995). With only one line the action of the cylinder is determined entirely by the pressure on that one line. They often have a spring or magnet similar to push or retract the piston rod, but they might rely on the force on end to push it back. Simplicity is always good for equipment that needs to be rugged and reliable (TAMSON 2019)**.** The main component of single acting pneumatic cylinder is tube, cylinder cap, piston rod, piston, cylinder, and cylinder head that shown in Figure 3.12.

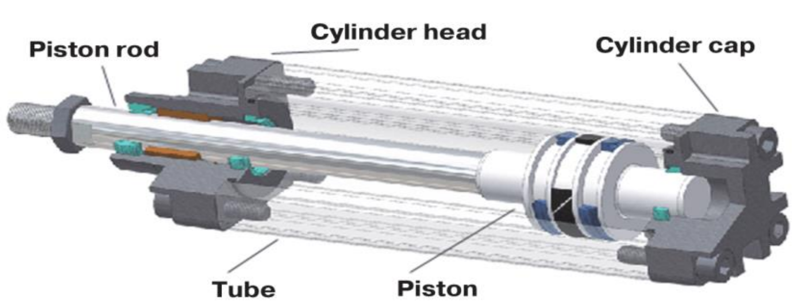


Figure 3.12: component of Single acting Pneumatic cylinder

CHAPTER FOUR

4. DESIGN OF ADVANCED EMERGENCY BRAKE SYSTEM

4.1. Introduction

This section consist two main sub section the first sub section present the designing of electro mechanical control unit in this section present obstacle sensing , controlling and actuating unit configuration and its type of components used and function of each components are discussed. Finally in this sub section present the final control circuit design and diagram that made on proteus 18.5 software. The second sub section of this chapter present the design of auxiliary brake system that used on advanced emergency brake system (design of electromagnet brake system and design of automatic wind deflector).In this chapter designing procedure and consideration of design for those two auxiliary brake system analytically and numerically is presented.

4.2. Design of electro mechanical control unit

Design of electro mechanical control unit include selection of appropriate device, developing the circuit diagram for each system and simulation of the developed circuit by using appropriate software. The electro mechanical control unit consist Sensing, Controlling and actuating unit. The sensing unit is part of this system which senses the existence object or obstruction in front of the car, measures the distance and the determine the velocity of moving car then sends necessary signals to the controller for this activity ultrasonic sensor and infrared ray sensor are used. The controller control over all activity of the system used in electromechanical control system for this study Arduino device is used. The Arduino device is coded by software called Arduino 1.6, a language promoted by the company of the same name, which acts as a free source coding. The actuating unit give the desired output based on controller command.

So to get the desired output of sensing, controlling and actuating unit the circuit diagram is developed. The circuit diagram and simulation of designed circuit is developed by using proteus 8 software. Proteus 8 software is used to Modelling and circuit simulation application; so for this study this software also used to build circuit diagram, modeling of sensing and controlling unit and show circuit simulation of the system. Figure 4.1 shows the flow data in sensing, controlling and actuating unit of an advanced emergency brake system to give the desired output from the actuator.

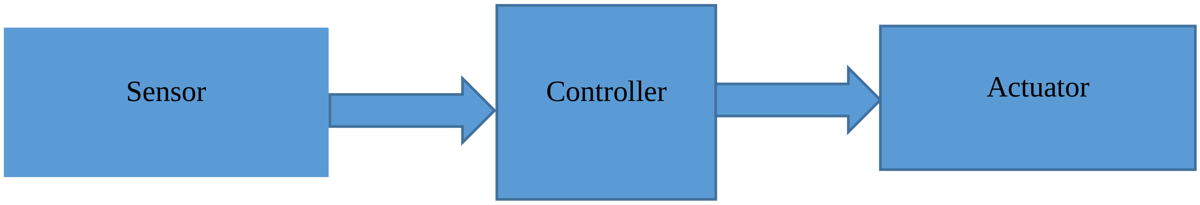


Figure 4.1: Flow of data in controlled system

4.2.1. Circuit development for electro mechanical control unit

To develop the circuit diagram of electro mechanical control unit of advanced emergency brake system for Isuzu truck the Arduino Uno device is programmed by using Arduino 1.6, a language on Arduino programming software. The reason why this controller is selected for this study is it is very cheap and available controller compared with other types of controller and also it is easy to use and easily programmable device. The program that developed for this study developed by considering different parameter of sensor input. For this study two Arduino device are used and program in different code for different activity.

So based on those output signal of sensor the Arduino is programmed to switch on or off the relay switch to apply the advanced emergency brake system automatically on emergency time to avoid occurrence of collision or accident. On this study the stopping distance of the truck is depending on the total brake force and speed of the vehicle. When the truck speed is vary the stooping distance also vary then the Arduino device is programmed to switch on the advanced emergency brake system to apply the brake at emergency time based on speed and stopping distance relation. This time is calculated as follow and it set on Arduino program as controlling and actuating feedback.

Speed is the time rate of change in distance so

$$V = \frac{S}{t} \qquad \ldots\ldots (4.1)$$

$$t = \frac{S}{V}$$

Where S = distance between truck and obstacle

V = speed of the truck

t = Arduino actuating time

There for by using the result of permissible stopping time result and relation of speed and distance, fix the time that required to the Arduino (Arduino two) to give the command for applying an advanced emergency brake system at emergency time(unexpected vehicle and object enter in front moving truck).

Finally the Arduino device programmed based on Arduino actuating time t, then when the time “t” become at desired time for applying emergency brake the Arduino give the command to actuating unit through relay switch and apply all brake systems, apply wheel brake system, rising up automatic wind deflector and give alert for the people who exist in front of the truck and stop the truck at minimum of stooping distance before any accident or collision is occurred.

- ❖ The programmed command for the first Arduino (Appendix Table E-1) is
  - ➢ To receive the output signals of ultrasonic sensor
  - ➢ To calculate the output signals of the ultrasonic sensors in term of distance
    - ▪ the output signal of ultrasonic sensor is distance between truck and obstacle
  - ➢ To display the distance between moving truck and obstruction
  - ➢ To give alert for the driver at desired pre determent distance
  - ➢ To activate electro magnet brake system at desired distance

- ❖ The programmed command for the second Arduino (Appendix Table E-1) is
  - ➢ To receive the output signals of ultrasonic and infrared sensor
  - ➢ To calculate the output signals of the two sensors in term of time
    - ▪ the output signal of ultrasonic sensor is distance between truck and obstacle
    - ▪ the output signal of infrared sensor is speed of the truck
  - ➢ To activate solenoid valve to apply main and auxiliary brake system(automatic wind deflector at desired distance(at emergency braking situation)
  - ➢ To turn on brake light and alert sound at emergency braking

The summarized flow of sensor, controller and actuator response is based on two separate Arduino microcontroller is presented in Figure 4.2.

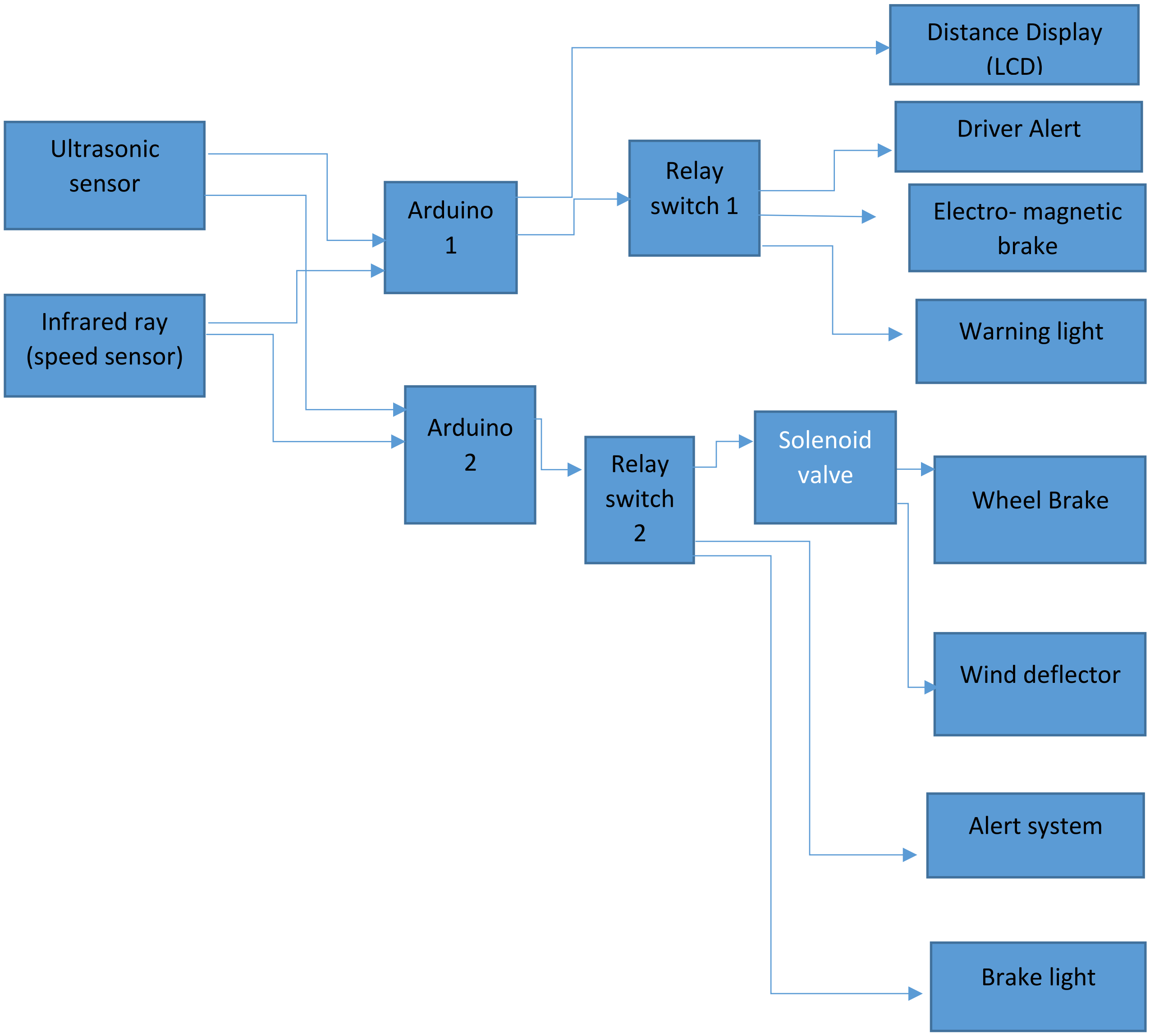


Figure 4.2: Flow of data on programmed Arduinos

The written program that upload to Arduinos device also consist selection of pins for each sensing and actuating device that used to power source, input signals ,output signals and ground and The program that upload to the control unit (Arduino device 1 and Arduinos device 2) of the advanced emergency brake system for Isuzu truck.

After writing and uploading the written program to the control units (Arduino device 1 and Arduinos device 2) the circuit diagram is developed by following the following steps

Steps to develop circuit diagram of sensing and controlling unit of advanced emergency brake system for Isuzu truck

Step 1-download and open the proteus 8 software for designing of circuit diagram

Step 2-open the new work bench suitable to develop circuit diagram

Step 3-select the appropriate device from the proteus 8 software library

- For circuit diagram 1 the selected device is -Arduino device 1 , ultrasonic sensor, LCD ,resistor, transistor, diode , relay switch, LED light, alert speaker
- For circuit diagram 2 the selected device is -Arduino device 2, ultrasonic sensor, infrared sensor, LCD, resistor, transistor, diode, relay switch, LED light, alert horn and solenoid valve. Where Resistor, transistor and diode is used to build relay switch module that used to maintain power output to protect sensing and actuating unit. Resistor For the purpose of current limitation, Transistor Acts as a switch when the signal comes from the Arduino microcontroller .It connects the collector and emitter to ground the circuit, Diode When the coil is energized with direct current, a diode is often placed across the coil to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to semiconductor circuit components.

Step 4-connect the Arduinos pins to sensing, power controlling and actuating device pins based on pre-determined pin connection Arduino program shown in Figures 4.3 -4.4.

Step 5-run the simulation to taste the working condition of developed circuit.

The circuit diagram developed by proteus 8 software is shown in Figure 4.3 and figure 4.4

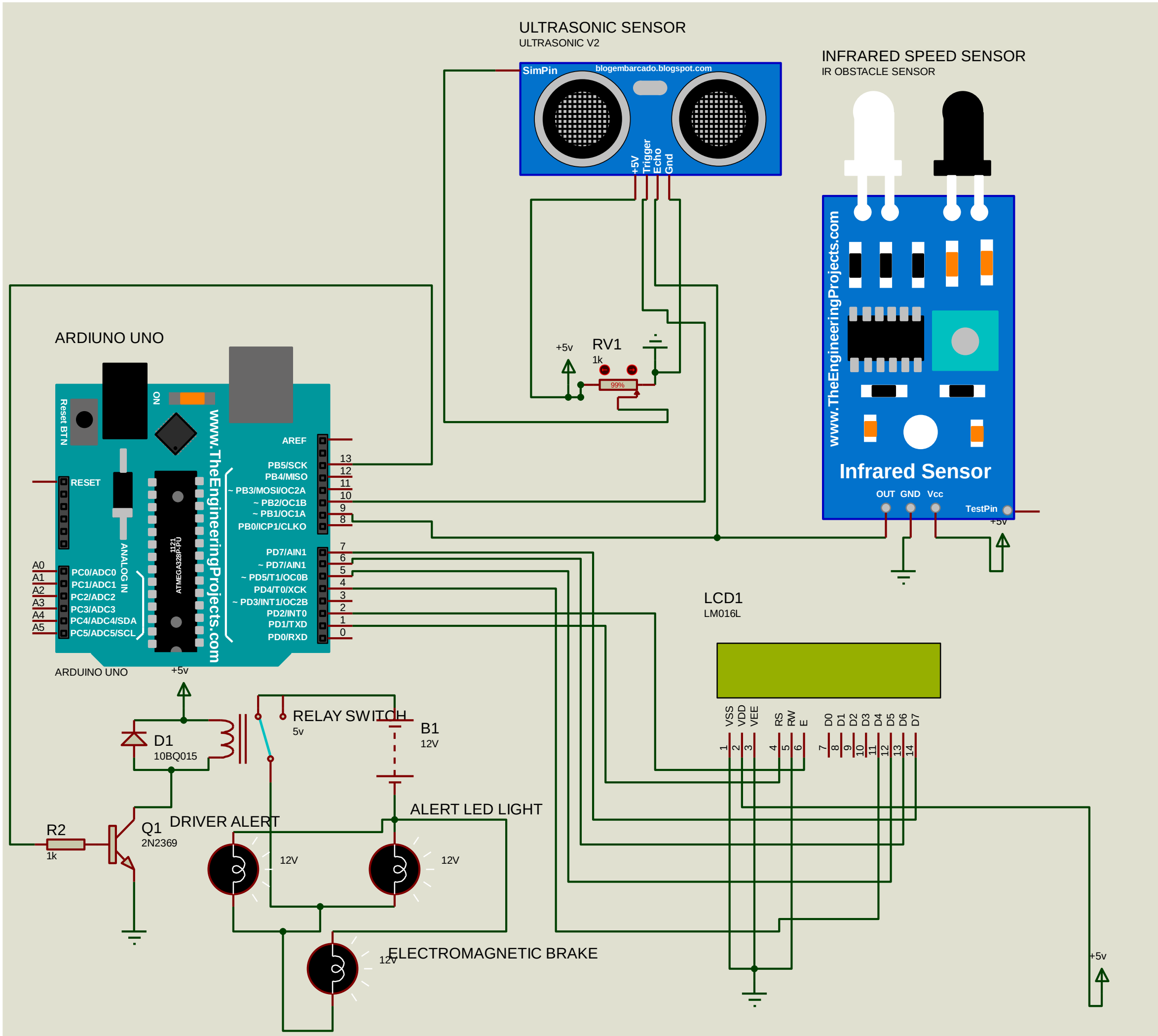


Figure 4.3: Schematic circuit diagram 1 (constructed based on program uploaded on first Arduino).

KEY: it describe the function of each device in this circuit

- The Arduinos Uno control all activity of the system
- Ultrasonic sensor measure the distance between vehicle and obstacle
- LCD displays measured distance from ultrasonic sensor
- The relay switched on /off driver alert, alert LED light and electromagnet brake based on command of Arduinos Uno.
- The electromagnet brake create magnetic field to create retardation force on propeller shat to control speed of the truck when relay switch become on.

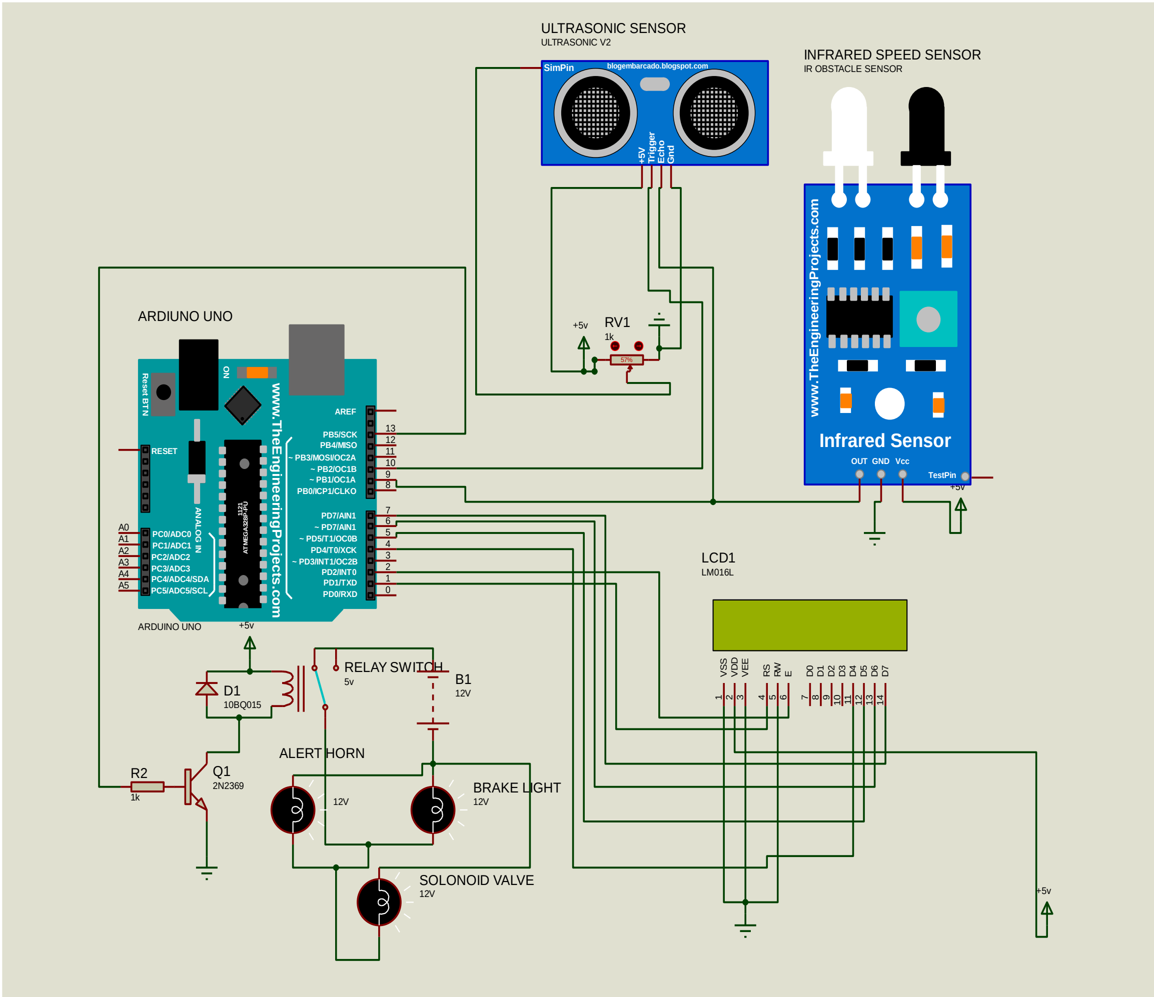


Figure 4.4: Schematic circuit diagram 2 (Constructed based on program uploaded on second Arduino).

Key: it describe the function of each device in this circuit

- The Arduinos Uno control all activity of the system
- Ultrasonic sensor measure the distance between vehicle and obstacle
- Infrared sensor measure the speed of the truck.
- LCD displays measured distance from ultrasonic sensor
- The relay switched on /off driver alert, alert LED light and electromagnet brake based on command of Arduinos Uno.
- The solenoid valve open and close the air flow from compressor to wheel brake and pneumatic cylinder of wind deflector based on relay switch

4.3. Design of Auxiliary brake systems

Auxiliary brake system for this study is used to increase the total brake force of the tuck at emergency time. The stopping distance of the vehicle at emergency time is acritical for reducing the occurrence of accident or collision. Minimizing the stopping distance by reducing the reaction time and by increasing total brake force of the truck is the main objective of this study.in this study Stopping distance is inversely proportional to brake force ,if brake force is increased the stopping distance become decreased.so in this study to increase the total brake force two auxiliary brake system are used ,electromagnet brake system and automatic wind deflector both auxiliary system operate automatically based on preprogrammed electromechanical control system that discussed on above section. Now this section present the designing progress of two auxiliary brake systems.

4.3.1. Design of electro-magnetic brake system

Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction brakes on heavy vehicles. Electromagnet works on the magnetic effect of current. It has been found that if a soft iron rod called core is placed inside a winding coil. For this study the electro magnet brake system is used to support the main brake system as auxiliary brake system to stop the vehicles at emergency time.it generate the magnetic force due to winding coil and battery to retard the rotation of propeller shaft when Advanced emergency brake system is activated due to existence of object or another vehicle.

Electromagnets brake which used for this study it consist of a large number of closely spaced turns of wire that create the magnetic field, mounting still and covering device. The wire turns are often wound around a magnetic core made from a ferromagnetic iron; the magnetic core concentrates the magnetic flux and makes a more powerful magnet. The strength of magnetic field generated is proportional to the amount of current.so the source of current for this brake system is 12V battery from the truck or alternator of the truck. This electromagnetic brake mounted on frame of truck and the propeller shaft rotate through electromagnet brake. Before start to design electromagnet brake components it is necessary to do some modification and changing some part of previous propeller shaft from non-magnetic material to magnetic material to get desired retardation force due to magnetic force. Design procedure of modified propeller shaft part is discussed below.

4.3.1.1. Design of modified propeller shaft

A driveshaft is a rotating shaft that transmits power from the engine to the differential gear of a rear wheel drive vehicles. Driveshaft must operate through constantly changing angles between the transmission and axle. A driveshaft that used for this study is the standard drive shaft which mounted in f series Isuzu truck but some modification is done on this shaft without affect its previous performance.as the Figure 4.5 shows the design modification is made on the first shaft which is located between the output transmissions shaft to the first universal joint. High quality steel (Steel SM45) is a material for construction of drive shaft of F series Isuzu truck (Isuzu byer guide line 2021).

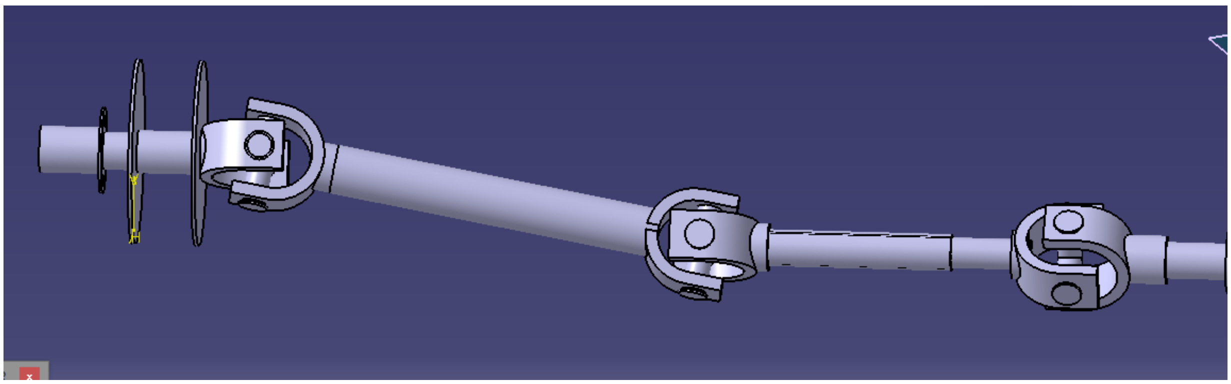


Figure 4.5: Schematic diagram of modified propeller shaft

But for this study SM45C is not used for designing of modified drive shaft part because the magnetic property of SM45C is very low so to design modified part the selected material is 1018mild steel. This steel has high ferromagnetic properties as it is derived from iron and it has almost the same mechanical property as SM45c steel. Alloy 1018 mild steel is the most commonly available of the cold-rolled steels. It has a good combination of all of the typical traits of steel – strength, some ductility, and comparative ease of machining.

Design data measured from the truck for designing of modified propeller shaft part

- inner diameter of shaft 30mm
- length of shaft 200mm with universal joint
- Material type 1018 mild steel

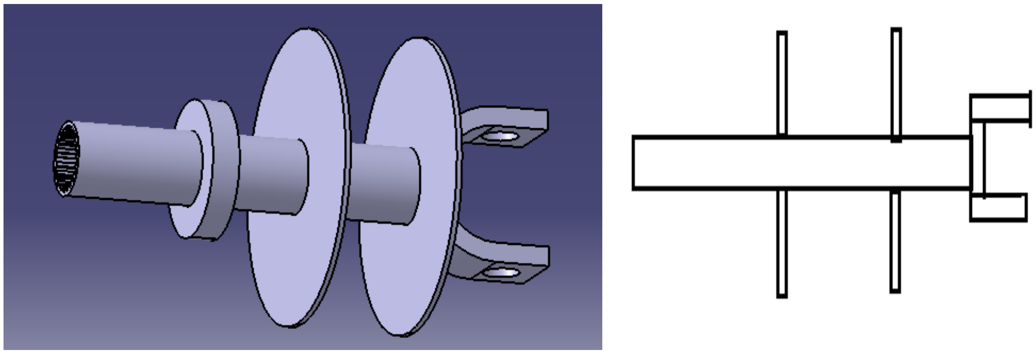


Figure 4.6: 3D and 2D view of modified female slip joint of propeller shaft

Figure 4.6 shows the diagram for modified propeller shaft that fitted with the previous main propeller shaft after shortening the length of main propeller shaft.

- **Torque at Propeller Shaft**

The maximum torque on the truck Propeller Shaft is the product of engine torque and final $gear$ driver r$atio$.

There for by Using final gear ratio T=$engine\ torque$∗final gear $gear$ drive $ratio$

$$T_p = \frac{P*60}{2*\Pi*N} \quad \text{……… (4.2)}$$

$$T_p = Te * G_f \quad \text{……... (4.3)}$$

Where T_p = propeller shaft torque

T_e = engine maximum torque

P = maximum power transmitted

N=maximum rotation of engine

G_f = final drive gear ratio (5.571)

From engine maximum torque and final drive gear ratio from truck specification (Appendix Table A-1)

T_p = 706Nm∗5.571

T_p = **3,933 Nm**

- **Stress analysis**

Maximum shear stress theory/Guest's theory: it is used for ductile materials

$$T_e = \sqrt{M^2 + T^2} \quad \text{..…... (4.4)}$$

$$\frac{Tp}{Ip} = \frac{\tau}{y} \quad \text{...…. (4.5)}$$

Where T_p = propeller shaft torque

I_p= moment of inertia ($I_p = \frac{\Pi}{32} d^4$)

Y= distance of external shaft to center (y= $\frac{d}{2}$)

τ = allowable shear strength = 370Mpa)

Then by rearranging above equations the maximum diameter of new modified propeller shaft which designed for this study is determined as follow

$$Tp = \frac{\pi}{16} * \tau * D^3 \qquad \text{……… (4.6)}$$

$$D^3 = \frac{16 \times Tp}{\tau\, \Pi} \quad = \frac{16 * 3933\text{Nm}}{370 * 10^6\, pa \times 3.14}$$

D =38 mm

The maximum diameter of shaft is 38 mm where the shaft is in solid so it is not necessary to calculate the maximum diameter of shaft according to yield strength, hence the yield strength of selected material is similar with the shear strength. The inner diameter of the shaft is already known from previous propeller shaft of f34-series Isuzu truck Now calculate the outer shaft diameter based on maximum diameter of shaft and maximum torque .where Inner diameter of shaft is (Di= 30mm)

By using the following equation outer diameter of shaft is calculated

$$\tau = \frac{\text{Tp} * \text{y}}{Ip} \qquad \text{…….. (4.7)}$$

But in this case $I_p = \frac{\Pi}{32} Do^4 - Di^4$ ...…… (4.8)

Y= D/2 …… (4.9)

And designed torque (T_d) is product of maximum torque transmitted and safety factor

$T_d = Tp * fs$ …… (4.10)

Designed torque in other relation

$$T_d = fs\, \frac{Ip}{Y} \qquad \text{…….. (4.11)}$$

$$T_p * fs = \frac{\Pi(Do^4 - Di^4)}{16\, D} \times fs \qquad \text{……. (4.12)}$$

Where D = maximum diameter

D_o = outer diameter

D_i = internal diameter

F_s = safety factor

$$D_o^4 = \frac{Tp * 16 * \text{d}}{\Pi} + di^4 \quad = \frac{3933 * 16 * 0.038 \text{ m}}{\Pi} + 0.03^4\text{m}$$

D_o = 35.1mm ≈ 35 mm

- **Maximum Rotational force at modified Propeller Shaft**

Rotational force at Propeller Shaft is the ratio of maximum torque per radius of the propeller shaft

$$T = F * r \qquad \ldots\ldots (4.13)$$

$$F_p = \frac{T}{r} \quad = \frac{3933\text{Nm}}{0.0175m}$$

F_p = 224.7 KN

- **Spline Design (straight sided spline) (Robert L. Mott, 2004)**

They are axial keys machined on a shaft and inside the hub which are used to transmit torque from shaft to another component shown in Figure 4.7. The spline dimensions on the shaft are determined for efficient and reliable power transmission by the shaft in the RBS.

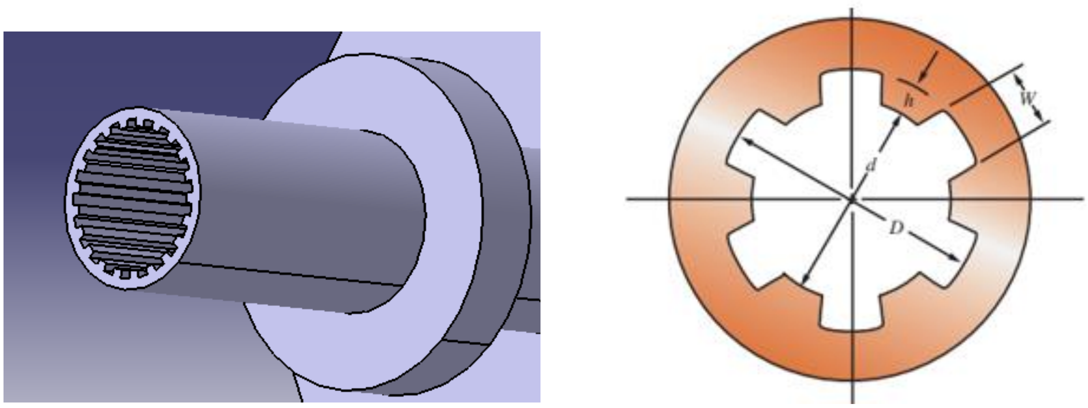


Figure 4.7: Spline (Robert L. Mott, 2018)

- **Calculating the spline dimensions:** using the calculated torque and standard from Appendix **Table C-2** the dimensions of the spline (i.e., D, d, h and w) had determined. Number of teeth and each dimension of female spline is designed based on f34-series Isuzu truck output shaft. There for the designed spline is must connect with the output shaft

$$T = \frac{1000 * N * R * h}{60} \qquad \ldots\ldots.. (4.14)$$

Where N = Number of splines

R = Mean radius of the spline $= \frac{1}{2}\left(\frac{D+d}{2}\right) =$

h = Depth of spline $= \frac{D-d}{2}$

Since the shaft diameter calculated is perfectly connect with the output shaft so the designed diameter is correct.

- **Width of the spline (w):** the dimension can be calculated using the relation by using the spline numbers.

$$w = 0.25 * D \qquad \text{……... (4.15)}$$
$$= 0.25 * 33\text{mm}$$
$$w = 8.25\ mm$$

From the standard table width of spline is 9 mm

- **Depth of the spline (h):** the dimension can be calculated using the relation using the spline numbers.

$$h = 0.059 * D \qquad \text{………. (4.16)}$$
$$= 0.050 * 33mm$$
$$h = 1.96\ mm \approx 2mm$$

The value of the spline depth is approximated for machining convenience. And the designed depth is perfectly connect with the transmission output shaft.

4.3.1.2. Designing of circular plate.

The circular plated is casting on modified propeller shaft this shaft circular plate is used to increase the cross-sectional area that used to retard the rotation of main propeller shaft due to magnetic force of electromagnet brake system at emergency braking of the advanced emergency brake is activated. The electromagnet brake is mounted between the two circular plates and ,when the electromagnet winding coil activate/energies' duet to emergency brake system controller the magnetic force created on winding coil and that created magnetic force retard the rotation of propeller shaft through the circular plate that casted with the new designed propeller shaft.

Design consideration and Assumed dimension

- Outer diameter of plate 175mm(available space around transmission)
- Inner diameter of plate is 35 mm (it is equal with outer diameter of shaft)
- Thickness of material assumed to be 4 mm
- Material type 1018mild steel
- Machining process casting with modified shaft
- Number of plates 2

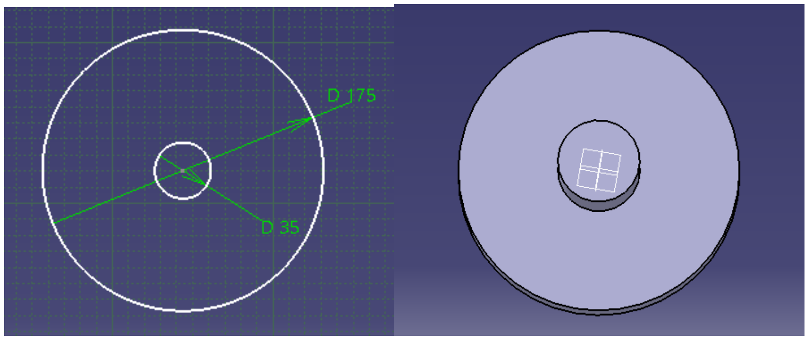


Figure 4.8: Modified propeller shaft's circular plates with their dimension

- The tangential force acting on circular plate is

  The maximum rotational force acting on circular plate due to transmitted torque from the modified propeller shaft design is from equation *4.3 is* (T_p=3,933Nm)

$$T_{pn} = F_{cp} * R \qquad \text{........ (4.17)}$$

Where T_p = maximum torque on modified propeller shaft

F_{cp} = tangential force on circular plate

R = radius of circular plate

$$F_{cp} = \frac{Tp}{r} = \frac{3933*10^3 \text{ Nmm}}{87.5\text{mm}}$$

Fcp = 44,948 N

- The maximum rpm of propeller shaft (Np_{max}) is achieved at the minimum gear ratio and using the from Appendix Table A-1 ISUZU NPR specification (i.e. maximum rotation of engine =2400rpm and minimum Gear ratio =0.722).

  :. Maximum rpm of propeller shaft $= \frac{\text{maximum engine rpm}}{\text{minimum gear ratio}}$ .. (4.18)

$$Np_{max} = \frac{2400}{0.722} rpm$$

$$NP_{max} = 3{,}324 \text{ rpm}$$

- **Mass of circular plate**:-Mass of circular plate is designed based on density of constructed material and dimension of rotating circular plate. Density of material from Appendix (Table B-2, ρ = 7870Kg/m^3)

From equation of moment of inertia based on the outer radius of rotating circular plate

$$I = \frac{mR^2}{2} \qquad \text{............ (4.19)}$$

Where I = moment of inertia

R = outer radius of circular plate

r = inner radius of circular plate (17.5mm)

But moment of inertia based on density of material calculated

$$I = \frac{\Pi}{2} \times \rho \times t \times (R - r)^4 \quad \text{……. (4.20)}$$

$= 3.14/2 * 7870 kg/m^3 * 0.004 m * (0.0875 - 0.0175 m)^4$

$I = 0.0012 kg.m^2$

Then mass of the disc become

$$M = \frac{2*I}{R^2} \quad \text{………. (4.21)}$$

$$= \frac{2*0.0012}{(0.0875-0.0175)^2} = 0.45 \text{ Kg}$$

There are two circular plate there for the total mass of two circular plate (M_t) is

$$M_t = m_1 + m_2 \quad \text{………. (4.22)}$$

$= 0.45Kg + 0.45kg$

$M_t = 0.9$ Kg

- **Stress analysis on rotating circular plate**

There are two principal stresses in the rotating circular plate that shown in figure 4.9 (Thakur 2013).

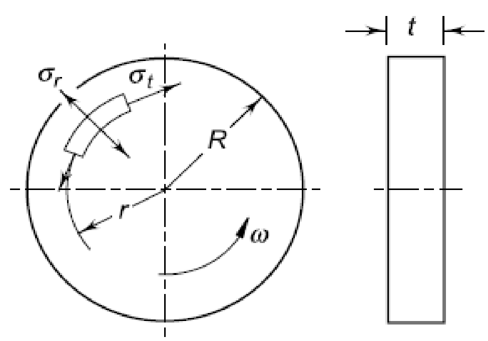


Figure 4.9: principal stresses in the rotating circular plate

General equation for the stress at a radius r is:

$$\sigma_t = \frac{\rho v^2}{10^6}\left[\frac{\mu+3}{8}\right]\left[1 - \left(\frac{3\mu+1}{\mu+3}\right)\left(\frac{r}{R}\right)^2\right] \quad \text{……… (4.23)}$$

$$\sigma_r = \frac{\rho v^2}{10^6}\left[\frac{\mu+3}{8}\right]\left[1 - \left(\frac{r}{R}\right)^2\right] \quad \text{…….. (4.24)}$$

Where σ_t = Tangential stress

σ_r = Radial stress

V = peripheral velocity

μ = Poisson's ratio =0.29 (for mild steel)

ρ = density of materil ($\frac{7870\text{kg}}{\text{m3}}$)

- **Peripheral velocity calculated**

$$V = \frac{2\prod N}{60} \times R \qquad \text{…….. (4.25)}$$

Where Np_{max} = 3324rpm and R= 0.0875m

$$= \frac{2*3.14*3324}{60} \times 0.06m$$

V = 22.87m/s

Then the tangential stress and radial stress of circular plate on modified propeller shaft calculated by using equation 4.23 and 4.24 respectively as follow

$$\sigma_t = \frac{\left(\frac{7870kg}{m^3}\right)(22.87m/s)^2}{10^6}\left[\frac{0.29+3}{8}\right]\left[1-\left(\frac{3(0.29)+1}{0.29+3}\right)\left(\frac{0.035m}{0.087m}\right)^2\right]$$

σ_t = 1.87 MPa

$$\sigma_r = \frac{\left(\frac{7870kg}{m^3}\right)(22.87m/s)^2}{10^6}\left[\frac{0.29+3}{8}\right]\left[1-\left(\frac{0.035m}{0.06m}\right)^2\right]$$

σr = 1.91 MPa

- The maximum tangential and radial stress are equal and both occur at (r=0).

$$\sigma_{tmax} = \sigma_{rmax} = \frac{\rho v^2}{10^6}\left[\frac{\mu+3}{8}\right] \qquad \text{……….. (4.26)}$$

$$= \frac{\left(\frac{7870kg}{m^3}\right)(20.87m/s)^2}{10^6}\left[\frac{0.29+3}{8}\right]$$

$\sigma_{tmax} = \sigma_{rmax}$ = 1.93 Mpa

There for the designed circular plate on rotating propeller shaft is safe according to above explanation

4.3.1.3. Selection of propeller shaft

After designed modified propeller shaft the length of main propeller shaft must be shorten from previous size then for this study another propeller shaft is selected from standard propellers shaft of Isuzu truck that can fit with the modified propeller shaft and propeller shaft between center bearing and differential of the truck. Figure 4.10 show the new selected propeller shaft that connect with the new modified propeller shaft part.

Figure 4.10: Isuzu truck propeller shaft

The selected propeller shaft part has the same mechanical, chemical, physical and thermal property with the previous one and it can transmit the same rotational force and torque. The only difference between the new selected propeller shaft and previous one is length.

4.3.1.4. Electromagnetic brake system component design

Assumed on by judgment of the designer (researcher) for designing of electromagnet brake system component

- Selected material foe coil winding of electromagnet is Iron
- Outer Diameter of iron rod=30mm
- inner Diameter of iron rod=15mm
- Length of coil =46 mm
- Diameter of copper wire =1mm
- Voltage from truck battery 24V
- Number of winding coil 8

In designing of electromagnetic brake system selection of material is critical thing to get desired retardation force of propeller shaft so for this study selection of material is based on the required output brake force of the truck at emergency braking time. For designing of electro magnet brake system Iron is an extremely well-known ferromagnetic metal (Naoum K. 2003). There are many aspects that contribute to iron's magnetism. In addition to its net electron spin at the atomic level, its crystalline structure also plays an important role (David C. et.al (1998). There for this study circular solid Iron bar that show in the figure 4.1a is used to produce magnetic force due to winding wire and copper wire is used as coil winding which is used to produce magnetic force by using battery .the reason why the copper wire used as winding for this study is it has low resistance ($1.68*10^{-8}$ohmmeters), easily available and it has low cost. And the winding structure of the electromagnetic coil is show in Figure 4.11 b.

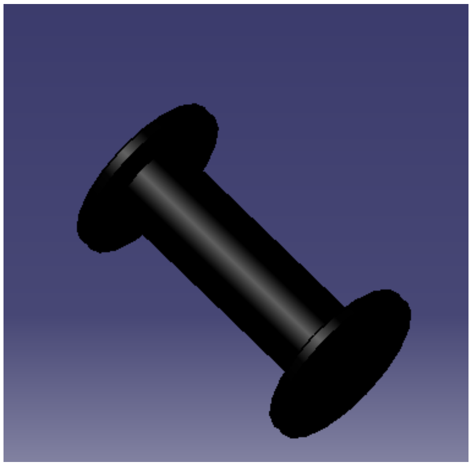
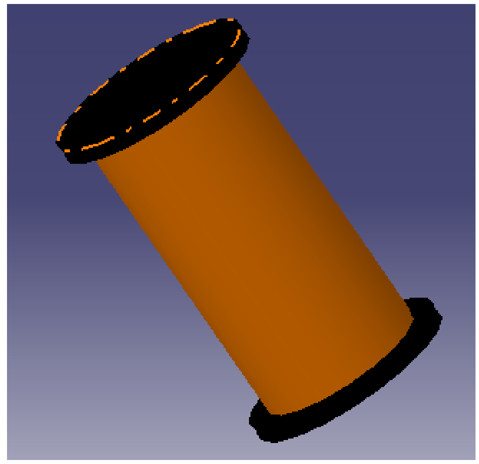
a  b 

Figure 4.11: Model of iron bar and winding structure of the electromagnetic brake.

4.3.1.5. Design of electromagnetic brake winding coil.

- **Magnetic field strength on coil winding Iron pole(B)**

Magnetic field strength in current carrying wire winding on iron pole is determine by the following formula (Paul (2004).

$$B = \mu nI \qquad \text{..........} \quad (4.27)$$

Where B = magnetic field strength

N = number of turns per unit length (N/L)

μ = permeability

I =current

In the above expression for the magnetic field B, n = N/L is the number of turns per unit length, sometimes called the turns density. The magnetic field B is proportional to the current I in the coil. The expression is an idealization to an infinite length solenoid, but provides a good approximation to the field of a long solenoid magnet.

- **Permeability (**μ_0) is the ability to support formation of magnetic fields in a material. Permeability is measured in H/m (Henries/m) or Newtons/ampere^2 (N/A^2).The permeability of free space μ_0 (the permeability constant or the magnetic constant) is

$$\mu_0 = 4\pi\ 10^{-7}\ (H/m) \approx 1.257\ 10^{-6}\ (H/m, N/A^2 \qquad \text{.....} \ (4.28)$$

- The **relative permeability(μ)** is the ratio of the permeability of a specific medium to the permeability of free space

$$\mu = \mu_r \times \mu_0 \qquad \text{……. (4.29)}$$

Where μ = permeability of the medium (H/m)

μ_r = the relative permeability

μ_0 = permeability of free space

The permeability of Iron rod is where the relative permeability of iron from appendix (k_{iron} =5000) is calculated by equation (4.29).

$$\mu = 5000 * 4\pi\ 10^{-7} \text{ (H/m)}$$

$$= 6.28 * 10^{-3} \text{ H/m}$$

- Number of turn in winding coil (N)

$$N = \frac{lc}{dw}\left(\frac{do - di}{2dw}\right) \qquad \text{………. (4.30)}$$

Where: l_c = length of coil (m)

d_w = coil wire diameter (mm)

d_o = outer diameter (mm)

d_i = inner diameter (mm)

$$= \frac{46mm}{1mm}\left(\frac{30mm - 15mm}{2*1mm}\right)$$

N = 345 turn

- Length of wire (L_w)

$$L_w = \prod\left(\frac{do + di}{2}\right) * N \qquad \text{………. (4.31)}$$

$$= 3.14\left(\frac{30mm + 15mm}{2}\right)345$$

L_w = 24.3 m

- Cross sectional area of the wire (A_w)

$$A_w = \frac{\prod dw^2}{4} \qquad \text{………… (4.32)}$$

$$= \frac{3.14*1mm^2}{4} =$$

$$A_w = 7.85\times10^{-7}\, m^2$$

- Resistance of coil winding (R_w)

$$R_w = \frac{\rho w * lw}{Aw} \qquad \text{………. (4.33)}$$

Where ρw = Resistivity of copper wire =1.68*10^-8ohmmetr

A_w = cross sectional area of wire

L_w = length of wire

$$= \frac{1.68*10\text{^}-8\text{ohmmetr}*24.3}{7.85\times10\text{^}-7\text{ m2}}$$

R_w = 0.52 Ω

- Current flow through coil winding of electro-magnet (I)

$$I = \frac{v}{Rw} \qquad \text{…………. (4.34)}$$

Where R_w = resistance of wire (Ω)

V = voltage delivered to system (v)

$$= \frac{24v}{0.52\Omega}$$

$$I = 23.2\ A$$

- Now calculate the magnetic field strength(B) by using equation 4.27

B = µ x n x I => µ*N/L *I

= 6.28 *10^{-3} H/m * 345turn/24.3m *23A

B = 2.015 Tesla

- Magnetic flux density (Φ)

$$\Phi = B \times A_w \qquad \text{…..……. (4.35)}$$

$$= 2.015T * 7.85\times10^{-7}\, m^2$$

$$\Phi = 1.51 * 10^{-6}\ T/m^2$$

4.3.1.6. Electromagnetic brake housing construction

Assumed dimension by researcher based on new modified propeller shaft art

- Housing external diameter 210 mm
- Internal diameter 177 mm
- Thickness of housing 50 mm
- Material stainless steel
- Manufacturing process casting

The material used to construct housing of electro magnet brake is stainless steel it has nickel which modifies the physical structure of the steel and makes it theoretically non-magnetic. The reason why nonmagnetic material select for housing is to increase magnetic strength concentration on modified propeller shaft to make high retardation force of propeller shaft. And also it has high Corrosion resistant, high tensile strength, Very durable, Temperature resistant and Easy formability and fabrication. The selected material for construction of housing of electromagnet brake system has high yield strength, tensile strength, and module of elasticity.it has efficient physical and nonmagnetic property to construct housing shown in figure 4.12. There for it is not necessary to check its strength based on applied force due to electromagnet strength and force e because effect of electro magnet winding coil weight and magnetic force is very small compare with the critical load of the material.

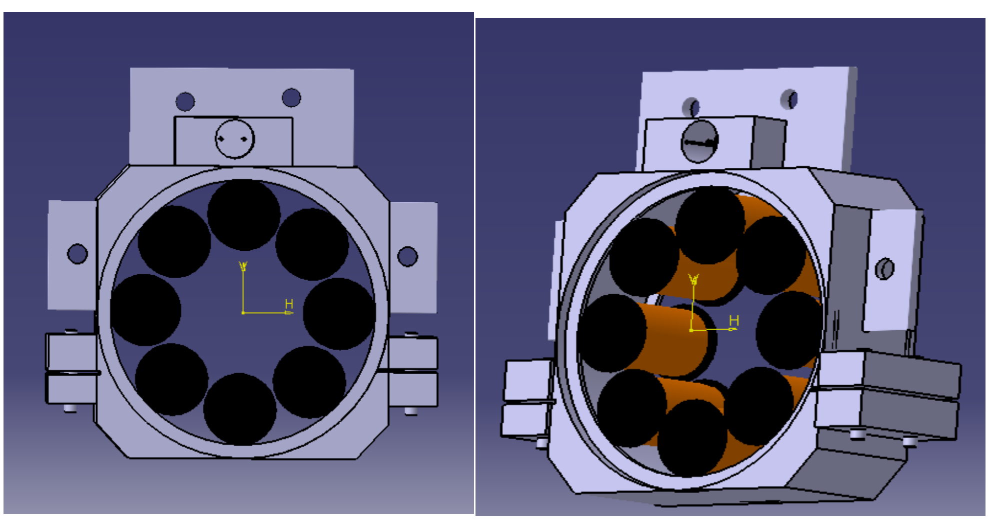


Figure 4.12: CATIA model of magnetic brake housing and winding coils

4.3.1.7. Magnetic force of electromagnetic brake system

Magnetic force (Retardation force) is the amount of force that required to retard or slow rotation of propeller shaft by using electromagnet brake. The electromagnet brake use magnetic force to create retardation force on rotating circular plate .the retardation of rotation of propeller shaft is required to support the main brake system by minimizing transmitted rotation force of propeller shaft to the rotating wheel, so this brake system reduce the overheating of drum brake ,fade of drum brake and wear of drum. But in this study electromagnet brake system is used on emergency braking to support main brake system and stop the vehicle at small stooping distance to reduce the occurrence of collision or accident of vehicle. The electromagnet brake system is used In this study, is not stop the rotation of propeller shaft completely but it need to be retard the rotation of propeller shaft. The amount of retardation force due to electromagnet brake system is calculated as follow.

- **Maximum retardation force**

The maximum retardation force of electro magnet brake on circular plate of new designed propeller shaft part is

$$F_{em} = B \times I \times L_w \qquad \text{.........} \ (4.36)$$

Where F_{em} = retardation force (N)

B = magnetic field strength (tesla)

I = current (A)

L_w = length of wire (m)

= 2.015 tesla x 23.2A x 24.3m

F_{em} = 1,136 N

- **Total retardation force**

On this study the number of coil winding is 8 and there is two circular plate that mounted perpendicular to of magnetic field of electromagnetic brake. Then the total retardation force delivered by electromagnet brake system to retard rotation of propeller shaft at desired time is calculated as follow

$F_{emt} = F_{em} \text{ x } n_w \text{ x } n_{cp}$ ……. (4.37)

Where F_{emt} = total retardation force

F_{em} = retardation force of each coil winding

n_w = number of coil winding

n_{cp} = number of circular plate

= 1,136N x 8 x 2

F_{emt} = 18,176 N

- **Retardation torque(T_r)** calculation

$T_r = F_t * R$ …..…. (4.38)

Where F_t = total retardation force

R = radius of circular plate

= 18,176* 0.0875m

T_r = 1,590 Nm

There for 18,176 N and 1,590 Nm is the total retardation force and retardation torque respectively that exert to circular plate on propeller shaft due to magnetic force of electromagnet brake system.

- **Gap between electromagnetic coil and circular plate**

Gap between electromagnetic coil and circular plate on modified propeller shaft:-Gap between electromagnetic coil and circular late on modified propeller shaft is calculated by using the following equation (Mohamed F. 2019).

$$F = \frac{\mathbf{B}^2 \, \mathrm{Aw}}{\Phi \, \mathrm{G}^2} \quad \text{………} \quad (4.39)$$

Where F = force produced

B = magnetic force produced

Φ = magnetic flux density

A_w = cross sectional area of the wire

G_t = total gap between magnet and the iron

By rearranging above equation

$$G_t^2 = \frac{\mathbf{B}^2\ \mathrm{Aw}}{\Phi\ \mathrm{F}}$$

$$= \frac{(\mathbf{2.015T})^2 * 7.85 * 10-7\mathrm{m}2}{1.51 * 10-6\ \mathrm{T/m}2 * 18176\mathrm{N}}$$

G_t = 0.01m =10mm

- But the gap that got in above equation is the total gap between electromagnetic coil and circular plate on modified propeller shaft so to get the gap between each side of electromagnetic coil and circular plate on modified propeller shaft divided the total gap in to two.

$$G = \frac{\mathrm{Gt}}{2} \qquad \text{……… (4.40)}$$

$$= \frac{10\mathrm{mm}}{2} = 5\mathrm{mm}$$

- **Retardation Efficiency of electro magnet brake**

Maximum rotation of propeller shaft when the vehicle move at maximum seed is calculated in equation then by using the result calculate the efficiency of electro magnet brake Where, Maximum rotational torque of propeller shaft and Maximum retardation torque of electromagnet brake 3393Nm and 1,590 Nm respectively.

$$\eta = \frac{\text{Maximum retardation torque of electromagnet brake}}{\text{Maximum rotational torque of propeller shaft}} \times 100 \quad \text{…. (4.41)}$$

$$\eta = \frac{1{,}590\mathrm{Nm}}{3{,}933\mathrm{Nm}} * 100$$

η = 40 %

There for the aim of using the electro-magnet brake system to the truck as auxiliary brake is to retard the rotational force of propeller shaft.so depending on above calculations the maximum retardation of rotation of propeller shaft is 40%.The reduction of rotation of propeller shaft is used to reduce the braking distance at emergency time before collision or frontal vehicle accident is occurred.

4.3.2. Automatic wind deflector design

Aerodynamic drag, also called wind resistance is a retarding force exerted on a vehicle by the air through which it moves. As a truck moves forward it breaks up the flow of air, creating an area of low pressure behind the body the high- pressure air surrounding the wake then moves into the low pressure area, exerting a force that pulls the vehicle backwards. The amount of energy required to overcome aerodynamic drag is affected by the effective frontal surface area of the vehicle, the shape of the vehicle and the speed at which the vehicle is travelling (Ramesh D K 2015).

There for A well-designed wind deflector is required to reduce wind resistance to a certain extent. In this thesis the wind deflector is not only use to reduce aerodynamic drag of the truck, but it used as aerodynamic brake by using pneumatic cylinder and electro-mechanical control system of Advanced emergency brake system of the truck to reduce the occurrence of accident or collision of truck. The wind deflector which used in this study is reduce the aerodynamic drag force of the vehicle at normal condition as show on Figure 4.13 , placed on appropriate angle but at emergency time the wind deflector rise up by pneumatic cylinder and increase the frontal area of the truck to increase the aerodynamic drag force on the truck to use drag force as auxiliary brake. The rising up of the wind deflector shown on Figure 4.14, at emergency time is use to compensate the weight transfer of the truck from rear to front part of the truck during emergency braking and also it reduce the rollover of the truck during emergency braking.

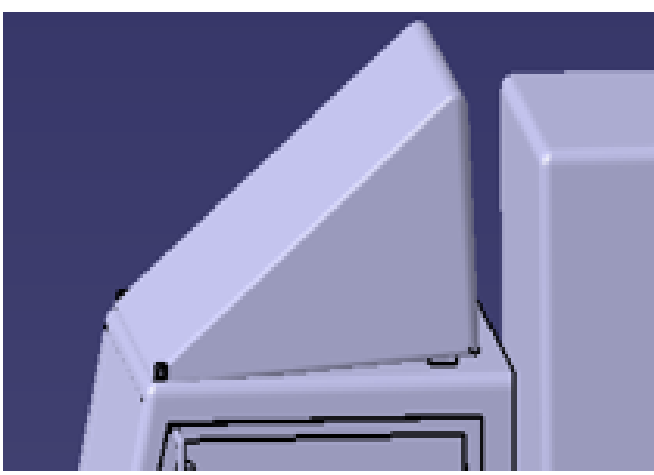


Figure 4.13: Wind deflector at normal condition

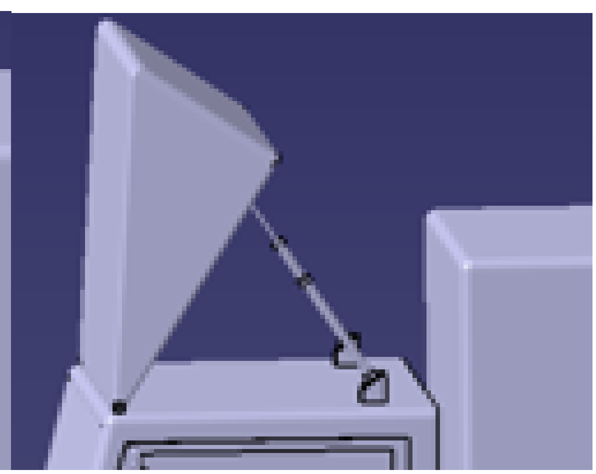


Figure 4.14: Wind deflector at emergency brking

The above figure show that the model which based on commercially available truck (ISUZU truck) built using CATIA V5 software. This model was subjected to external flow of at different speed. Its initial drag obtained and flow around the body analyzed. These geometry parameters were systematically modified using design of experiments to obtain different geometries of the simplified car model. The computational fluid dynamics (CFD) simulations were performed on these geometries to obtain drag force and effect of wind deflector to increase drag force when it rise up during emergency braking. Once the results of CFD simulations were available, compare the result of the CFD simulation in different speed and discuss the effect of automatic wind deflector during emergency braking.

4.3.2.1 Design consideration for automatic wind deflector

Before start designing of wind deflector it is important to know the frontal dimension and the height of rear surface of the truck. After measuring the dimension of the truck it is also important comparing of material which used to construct wind deflector because the wind deflector constructed must be aerodynamic drag force resistant, anti-corrosion property, temperature resistant, and low weight. There for this thesis the dimension of wind deflector is assumed based on ISUZU truck external dimension specification from appendix Table A-2.

For this study the selected material to construct the wind deflector is Aluminum alloy 6061 T6 and the structure of automatic wind deflector is shown in Figure 4.15.This alloy features medium to high strength. It also has good corrosion resistance, weldability, workability, and machinability. This aluminum alloy is available in plate, sheet, and extrusions, including custom shapes. Used routinely in the manufacture of auto components and parts, 6061 aluminum possesses high strength-to-weight ratio. It also possesses good workability in the annealed condition. The property and chemical composition is listed on Appendix Table B-1.Type 6061 aluminum is one of the most widely used aluminum alloys. Its weld-ability and formability make it suitable for many general-purpose applications. Its high strength and corrosion resistance lend type 6061 alloy particularly useful in architectural, structural, and motor vehicle applications

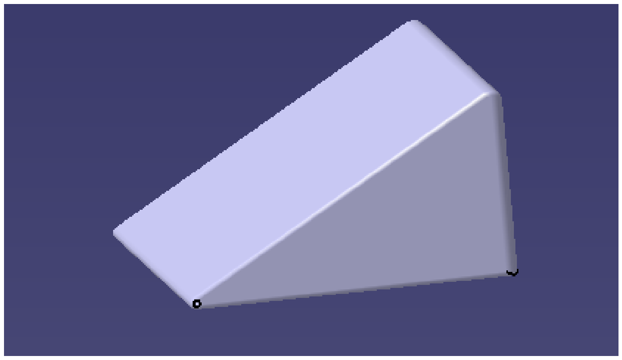


Figure 4.15: Schimatic model of wind deflector

Assumed dimension of Automatic wind deflector based on truck dimension

Width of wind deflector (W) =1.4m

Length of wind deflector (L) = 2.2m

Height of wind deflector (H) = 0.750m

Base of wind deflector (B) = 1.32m

Angle of inclination of wind deflector = 30^0

Area calculation of wind deflector when it rise up at emergency braking as the figure 4.16 show. When the wind deflector is raised up it frontal surface is changed and it get rectangular shape.

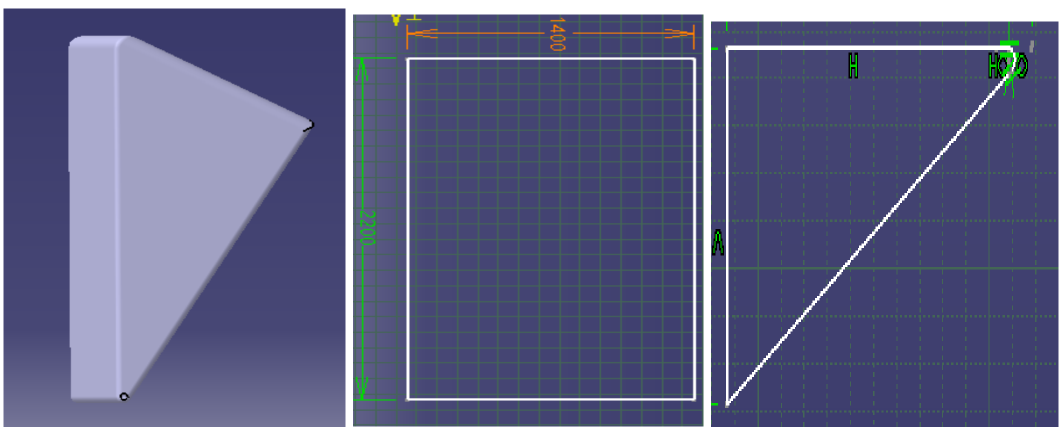


Figure 4.16:Actuated wind deflector frontal and side viw

- Frontal area (A_f) of wind deflector when it rise up

$A_f = L*W$ ………. (4.42)

$= 2.2m * 1.4m$

$= 3.08\ m^2$

➢ Side area (A_s)of wind defelector when it rise up

A_s = ½ BH ………… (4.43)

= 1/2*1.320m*0.750m

= 0.495 m^2

4.3.2.2 Airodynamic force calculation for automatic wind deflector

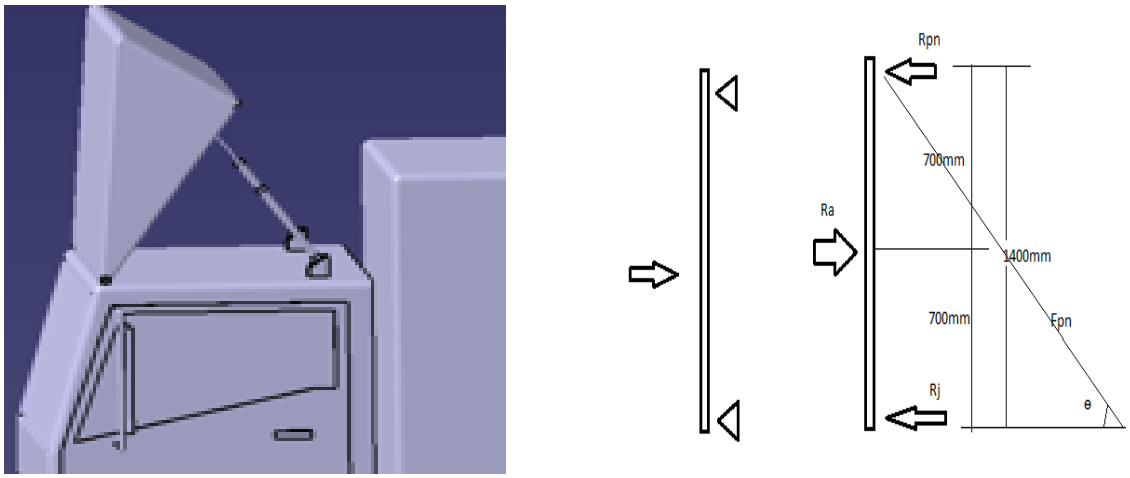


Figure 4.17: Freebody diagram of wind deflector when it rise up (Raw=airodynamic drag force of automatic wind deflector,Rpn =pneumatic cylinder reaction force ,Rj reaction force on joint and Fpn =pneumatic cylinder force)

➢ **Airodynamic force on actuated wind deflector (R_{aw})**

Airodynamic force (Raw) is the force which act on actuatd wind deflector when advanced emeregency brake system is activated at emeregency braking and wind deflector become rise up throgh pneumatic cylinder shown in figure 4.17 then arodynamic drag force is calculated as follow

$$R_{aw} = \frac{1}{2} \times \rho_a \times C_D \times A_{FP} \times v^2 \quad \text{....... (4.44)}$$

Where ρ_a = density of the local air ($\rho_a = \frac{P_a}{R_a \times T_a}$ ≈ 1.225 kg/m^3)

C_D ≈ 1.15-1.90is the drag coefficient for rectangular flat plate;

(From appendix Table C-4 ,C_D =1.16)

$A_{FP} = W \times H \times sf$ Is the Projected Frontal area in 'm^2(sf shape factor 0.75-0.85)

v = maximum speed of truck

➢ **Maximum vehicle speed (v)calculation**

$$v = \frac{\omega}{GR_i \times GR_{fd}} \times r_W \qquad \text{………... (4.45)}$$

Where ω = angular velocity ($\omega = \frac{2\pi \times N}{60}$)

N = rotational speed of the engine in 'rpm'.

GR_i = Gear ratio (i=1^{sr}, 2^{nd}, 3^{rd}, etc.).

GR_{fd} = gear ratio of the Final drive.

r_W = Effective wheel in 'm'.

From truck spesfication of APPendex N=2400rpm,G_{ri}=0.722, G_{Rfd}=5.571 and r_w=0.53m

$$v = \frac{2\pi \times N}{60 \times GR_i \times GR_{fd}} \times r_W = \frac{2 \times 3.14 \times 2400 rpm}{60 \times 0.722 \times 5.5\ 71} \times 0.53m \times 3.6$$

v = 120 Km/hr = 33.3 m/s

➢ Frontal area of wind deflector at emergency braking

$$A_{PF} = W \times H \times sf \qquad \text{…….. (4.46)}$$

$$= 2.2m \times 1.4m \times 0.85$$

A_{PF} = 2.681 m^2

Finally airodynamic drag force on automatic wind deflector at maximum speed and wind deflector rising up is calculated as follow

$$R_{aw} = \frac{1}{2} \times 1.225 Kg/m^3 \times 1.16 \times 2.681 m^2 \times (33m/s))^2$$

R_{aw} = 2,074 N

➢ **Overall Airodynamic force on atruck with actuated wind defelctor**

the overall airodynamic force of the truck when the wind deflector has been actuated is calculated as follow by using equation 4.44.

$$R_{aw} = \frac{1}{2} \times \rho_a \times C_D \times A_{FP} \times v^2$$

Where the drag coefficient is between 0.65 -0.8 but for this study Cd=0.7 ,$= 1.225\ kg/m3$,maximum truck speed v=33.3m/s and frontal area of the truck with wind deflector is summation of area of actuated wind deflector (2.681 m^2)and frontal area of the truck (4.6 m^2).

A_{PF} = $(2.68 + 4.6)$ m^2

A_{PF} = 7.28 m^2

Then over all airodynamic forceof the truck with actuated wind deflector (Ra_{oa})become

$$R_{aoa} = \frac{1}{2} \times 1.225Kg/m^3 \times 0.7 \times 7.28m^2 \times (33m/s))^2$$

R_{aoa} = 3,400 N

- **Overall Airodynamic force on atruck <u>without</u> wind defelctor**

over all airodynamic forceof the truck without wind deflector also calculated by using equation 4.44; where $\rho_a = 1.225Kg/m^3$, Cd=0.7, Vmax =33.3 m/s ,and frontal area of the truck without wind deflector is sum of frontal area of truck (4.6 m^2) and fronal area of van (1.66m^2)

A_{PF} = $(4.6 + 1.66)$ m^2

A_{PF} = 6.26 m^2

Then over all airodynamic forceof the truck without wind deflector is become

$$R_{aoa} = \frac{1}{2} \times 1.225Kg/m^3 \times 0.7 \times 6.26m^2 \times (33m/s))^2$$

R_{aoa} = 2,922 N

There for airodynamic drag force on automatic wind deflector ,(R_{aw} = 2,074 N) is the drag force which act as auxilery brake syste to support the main brake system at emeregency braking of the truck.this force is created when automatic wind deflector rise up due to force of pneumatic cylinder throgh advanced emeregency brake system.and the Overall Airodynamic force on atruck <u>without</u> wind defelctor ,and Overall Airodynamic force on atruck with actuated wind defelctor is 3400 N and 2922 N respectvely.

- **Reaction force due to pneumatic cylinder(R_{pn})**

Reaction force due to pneumatic cylinder is the reaction force which requred to rise up and down the wind deflector depending on input siginal from the controller. Single acting pneumatic cylinder converts a compressed air pressure from the air compressor when the solenoid valve opens, so to select the approprate pneumatic clindert for the syetem first the reaction force due to pneumatic cylinder is calculeted by using force and moumentum equlibrum equestion as follow .

Based on freebody diagram on figure 4.17 force and moumentum equlibrum equestion become

$$\Sigma Fx = 0 \Rightarrow Ra\text{-}2Rj + 2Rn = 0 \qquad \text{........ (4.47)}$$

$$\Sigma M_J = 0 \Rightarrow 700mm * Ra - 1400mm*2R_{pn} = 0 \qquad \text{....... (4.48)}$$

From above equlibrum equestions solve for Reaction force due to pneumatic cylinder

$$R_{pn} = \frac{700mm * Ra}{2(1400mm)} \qquad \text{........ (4.49)}$$

$$= \frac{700mm * 2{,}074N}{2(1400mm)}$$

$$R_{pn} = 519 \text{ N}$$

There for the drag force and reaction force that got from above calculation is the maximum force which exerted on pneumatic cylinder of automatic wind deflector at emeregency braking condtion so by using this force it is possible to do stress analysis of wind deflector.

4.3.2.5.Stress analysis of wind deflector

stress analysis of wind deflector is done by using analytical method and neumerical method (Ansyis software).The stress analysis of wind deflector is done by considering the airodynamic force of a truck when the truck move at maximum speed and emeregency brake system is Activated, hence the wind deflector become rise up and frontal area of wind deflector fully subjucted to airodynamic drag force .

- **Bending Stress in wind deflector**

In engineering practice, the machine parts of structural members may be subjected to static or dynamic loads which cause bending stress in the sections besides other types of stresses such as tensile, compressive and shearing stresses. Working Bending Stress analysis on wind deflector is done to determine the desired thickness of wind deflector by using the following calculation thickness of wind deflector is determined. Bending stress of wind deflector can be calculated as follow (William F.et.al 2009)

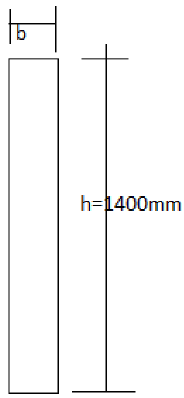
$$\sigma_B = \frac{MY}{I} \qquad \text{.......... (4.50)}$$

Where σ_B = bending stress

M = Bending moment acting at the given section

I = Moment of inertia of the cross-section about the neutral axis,
y = Distance from the neutral axis to the extreme fiber

The ratio I/y is known as ***section modulus*** and is denoted by Z. In this case the section of wind deflector is rectangular section (Apendix Table C-1)



$$Z = \frac{I}{Y} = \frac{hb^2}{6} \quad \text{……… (4.51)}$$

$$\sigma_b = \frac{M}{Z} = \frac{M \times 6}{hb^2}$$

Where M = Bending moment

H = distance from neutral axis

b = thickness of material

Bending moment (M) acting at the center of the wind deflector ($R_{pn} = R_j$) from the free body diagram on figure 4.17.

$$M = \frac{1}{2}h * R_{pn} \quad \text{……….. (4.52)}$$

$$= 700\text{mm} * 519\text{N}$$

$$= 363{,}300\text{N.mm}$$

By rearrnging above equetsion thikness of almunim is calculated.(where σ_b =145 Mpa from Aluminum 6061 T4 specification (Appendix Table B-1).

$$b = \sqrt{\frac{M \times 6}{\sigma b \times h}}$$

$$= \sqrt{\frac{363{,}300 \times 6}{145\text{N/mm2} \times 1400}}$$

b = 3.15mm

There for the desired thickness of Almunium that used to construct the automatic wind deflector from standard thkiness of almunium sheet metal is **4 mm.**

- **Bending sheet metal allowance**

When sheet metal part are bend metal is deformed plasticaly to change its shape after bending, the total length (length+ height)of sheet metal part is not equal to flat length this increse over all length this phenomina is known as bending allowance so for this study the bending allowance of sheet metal almunium is calculated because the flat almunium sheet is bent in different section to give desired wind deflctor shape.

$L_b = \alpha(R + Kb)$ ……… (4.53)

Where Lb =bending allowance

α = bend angle of almunium metal (90^0)

R = bend radius (10 mm)

K = factor of bending (0.33 ,R<2b or 0.5, R>2b)

B =thikness of metal (where b=3.2mm)

$L_b = 1/180^0(90^0 * 3.14)*(10mm+ 0.5*4mm)$

L_b =31.4 mm

There for the bending alowance of almunium metal to manifacture the automatic wind deflector for this study is approximetly 32 mm.

4.3.2.6.Selection of pneumatic cylinder

The reason for selection of pneumatic cylinder for activation of automatic wind deflector is the avalibleblty of air force from the main brake system.

- **Force analysis of pneumaic cylinder**

Two pneumatic cylinder are used in this study to support the automatic wind deflector to give stable support against aerodynamic drag force on wind deflector at different speed of the truck. The pneumatic cylinder piston force is calculated based on above free body diagram from figure 4.17.

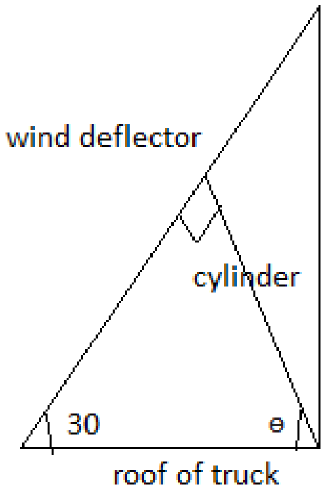
$R_{pn} = F_{pn} \cos\theta$ ...……… (4.54)

Where F_{pn} = pneumatic cylinder force

R_{pn} = reaction force due to pneumatic cylinder

θ = inclination angle of pneumatic cylinder

Where θ is the angle that formed between the pneumatic cylinder and roof of the truck which can be calculated by using triangle rules. The angle of inclination of wind deflector is 30 degree so θ calculated as follow



$180^0 = 30^0 + \theta + 90^0$ …… (4.55)

$\theta = 60^0$

$F_{pn} = \frac{Rpn}{\cos\theta} = \frac{\mathbf{519N}}{\cos 60^0}$ but $\cos 60^0 = 0.5$

$F_{pn} = 1{,}038$ N

For each pneumatic cylinder the force is calculate by dividing total force of pneumatic cylinder to number of pneumatic cylinder (F_{pn1})

$F_{pn1} = \frac{\mathbf{1038N}}{2} = 519$ N

Figure4.18: free body diagram of pneumatic cylinder force

After calculating the required pneumatic cylinder piston force now calculate the desired diameter piston by using general formula of pressure as follow. Generally the actuating force of pneumatic cylinder depends up on

- Pressure applied from air compressor P
- Bore diameter of the piston of pneumatic cylinder

Piston force on pneumatic cylinder is the product of air pressure and piston area.the free body diagram for piston force calculation is shown in figure 4.19.

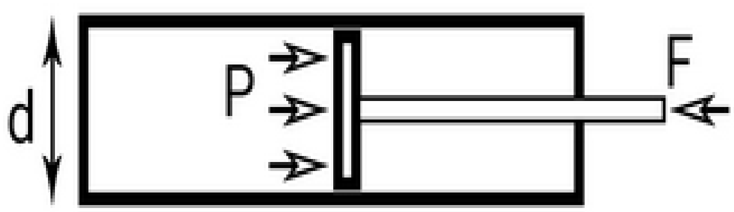


Figure 4.19: piston force anaysis diagram (https://www.omnicalculator.com/physics/piston-force)

$P_{pn} = \frac{\mathbf{Fpn}}{Apn}$ ……… (4.56)

Where P_{pn} = air pressure delivered to pneumatic cylinder

F_{pn} = piston force

A = piston area where ($A = \frac{\pi d1^2}{4}$)

d1 = piston diameter

- **oprating air pressure for pneumatic cylinder**

Before determineing the the minimum operating air pressure delivered from the compressor to the pneumatic cylinder throgh solonoid valve, that requred to rise up the wind deflector during emeregency braking it is neccessrey to determine an unused air pressure from brake chamber.so from air brake manuals ; Most current air brake systems operate with a pressure between 552 KPa to 890 KPa. There needs to be a way to stop compressing air once a certain maximum air pressure has been reached. And, if the air pressure in the tanks drops below a certain level Vehicle safety standards re quire that the governor must be set to restart the compressor (air brake manual 2010). The working range of air pressure for brake chamber to stop the truck is applied with air pressure between 138 kPa to 690 kPa.

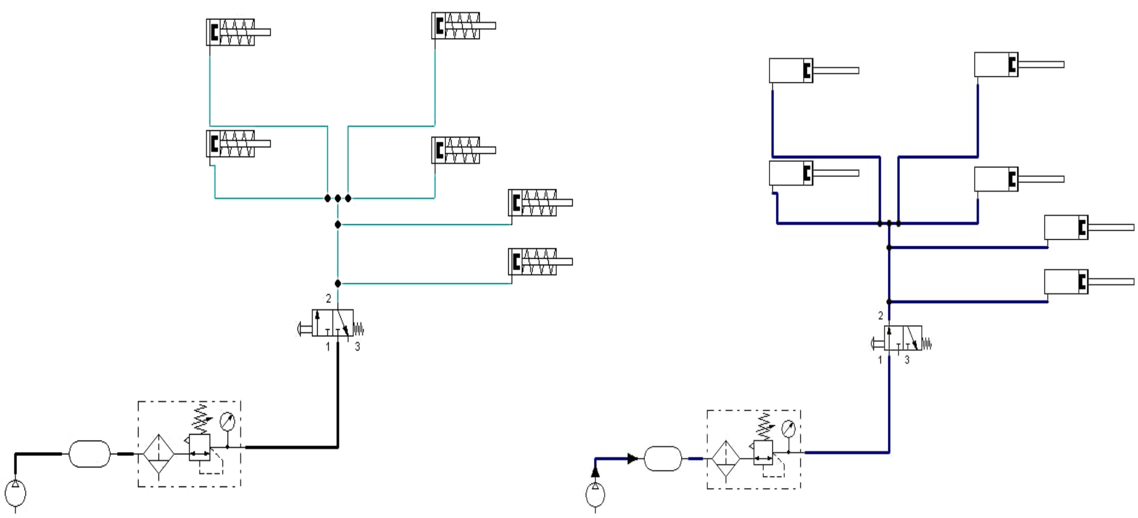


Figure 4.20 Flow of compressed air from compressor to brake chamber and pneumatic cylinder of wind deflector

Depending on above description and figure 4.20 oprating air pressure for pneumatic cylinder of automatic wind deflector is detrmined by using the following realtion

- The average produced compressed air pressure in air brake system is (P_{ac})

P_{ac} = 1/2(minimum produced pressure +maximum produced pressure) …… (4.57)

= 1/2(552 KPa + 890 KPa)

P_{ac} = 721Kpa

- The Average operating air pressure of brake chamber to stop the truck is (P_{abc})

  P_{abc} = 1/2(minimum operating pressure +maximum operating pressure) …. (4.58)

  =1/2(138 KPa + 690 KPa)

  P_{abc} = 414 Kpa

- Unused air pressure(P_{pn}) (minimum pressure acted on pneumatic cylinder of wind deflector),the is the diffrence between average produced compressed air pressure in air brake system and The Average operating air pressure of brake chamber to stop the truck.

  $P_{pn} = P_{ac} - P_{ab}$ ……. (4.59)

  = 721 Kpa - 414 Kpa

  P_{pn} = 307 Kpa

From equestion 4.68 the piston force become

$$F_{pn1} = P_{pn} * \Rightarrow P_{pn} * \frac{\pi d^2}{4} \quad \text{…….. (4.60)}$$

After rearenging the equestion the disired diameter of the pneumatic cylinder piston become

$$d = \sqrt{\frac{\mathrm{Fpn} \times 4}{\mathrm{Ppn} \times \pi}} \quad \text{…….. (4.61)}$$

Amount of force and average air pressure requred to rise up the wind deflector is calculated in previous calculation($F_{pn=}$ 1,038 N and P_{pn} = 0.32 N/mm^2).then the diameter of piston of pneumatic cylinder is calculated as follow by using above relation

$$\mathrm{d} = \frac{519\ \mathbf{N} \times \mathbf{4}}{3.14 \times 0.307\ \mathrm{N/mm2}}$$

d = 46.5mm

There for from cylinder sepfication from appendex Table D-3 the selected pneumatic cylinder is ISO 15552 STANDARD FBC type cylinder with 50 mm diameter and 500 mm stroke length**.**

Table 4.1: selected Pneumatic cylinder to support automatic wind deflector

Parameter	Quantity
Diameter of piston	50mm
Srtoke length of piston	500mm
Working air pressure of piston	0.05Mpa-1Mpa
Proof air pressure of piston	1.5Mpa
Avalable speed range	(50- 500)mm/sec
Number of pneumatic cylinder	2

Figure 4.21: Selected pneumatic cylinder (source:MCVC pneumatic cylinder menifacturer)

From above table take the average operating air pressure of pneumatic cylinder then it become

$$p_{av} = \frac{(0.05+1\ )Mpa}{2} \qquad \ldots\ldots\ (4.62)$$

P_{av} = 0.525Mpa

- **Pneumatic solenoid valve selection**

The type of solenoid required will depend on several factors.

- What is the pressure of the line? This will dictate how much power is required. It will also tell you whether a direct acting, internally or externally piloted valve is needed.
- How quickly does the valve need to open or close?
- What is the required flow rate, port size and number of ports? As with any valve, these factors depend entirely the valve function and what system it is being integrated into.

After considering above criteria the desired pneumatic solenoid valve is selected from the standard and its specification is attached at appendix Table D-1.

4.3.2.7.Hinge selection

To join the automatic wind deflector and the truck roof, Hinge is needed so for this study the selected hinge is based on the rotational force of wind deflector due to pneumatic cylinder actuating force. Then the selected hinge for this study is listed as follow

Consideration of hinge selection

- Light in weight
- Easley connect the Isuzu roof and automatic wind deflector
- Easley rotate the automatic wind deflector
- Outer diameter of hinge 35mm
- Inner diameter hinge 10mm
- Pin diameter hinge 9.9mm

Figure 4.22: Aluminum hinge (https://www.alibaba.com/product)

4.3.2.8.Support design for pneumatic cylinder

To support the pneumatic cylinder of automatic wind deflector on roof of the truck it is necessary to design supporting beam

Design consideration and assumed dimension for Support design of pneumatic cylinder

- Its upper width and length is equal to base of pneumatic cylinder (W=76mm L=126mm)
- It has inclined structure at angle of 60^0
- It joined by welding
- Height 100mm
- Thickness 1mm
- selected material Aluminum 1061 T6

The supporting is made of sheet metal by bending and join to roof of the truck by welding

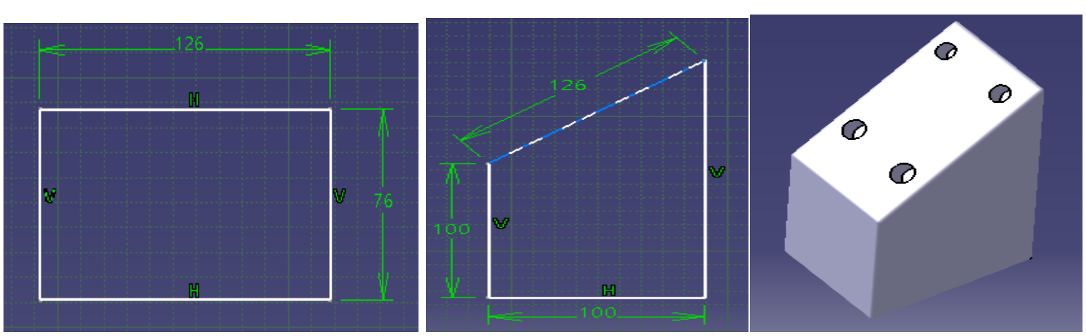


Figure 4.23: 2D and 3D diagram of pneumatic cylinder support

Figure 4.23 shows the dimension and final designed support of the pneumatic cylinder. On this design the main and critical thing is critical bulking and the critical bulking load on this support is calculated on below equation (Julius et .al (1936).

$$P_{cri} = \frac{\pi^2\, EIy}{KL^2} \quad \text{and} \quad P_{cri} = \frac{\pi^2\, EIx}{KL^2} \qquad \text{…….. (4.63)}$$

Where P_{crt} = maximum or critical force

E= modulus of elasticity (for Aluminum 1061 T4from appendix Table B-1, E=68.9 GPa)

L= unsupported length of column

K = column effective length factor

Ix = moment of inertia at X direction

Iy = moment of inertia at X direction

Column effective length factor (K) value depends on the conditions of end support of the column from appendix Table C-2,(k=0.5) (Elishakoff, I. et.al 2001). Moment of inertia calculation at x and at y direction

$$Iy = \frac{hb^3}{12} = \frac{0.126m*0.001m^3}{12} \qquad \text{………… (4.64)}$$

I_y= 1.05*10^{-11} m^4

$$Ix = \frac{bh^3}{12} = \frac{0.076m*0.001m^3}{12} \qquad \text{………….. (4.65)}$$

= 6.3 *10^{-12} m^4

- Maximum bulking load at y and x direction

At y $\quad P_{cri} = \frac{\pi^2\, EIy}{(KL)^2} = \frac{3.14^2 *68.9*10^9*1.05*10^{\wedge}-11m4}{(0.5*0.1m)^2}$

Pcri = 3,000 N

At x $\quad P_{cri} = \frac{\pi^2\, EIy}{(KL)^2} = \frac{3.14^2 *68.9*10^9*6.3*10^{\wedge}-12m4}{(0.5*0.1m)^2}$

Pcri = 1,680N

The maximum critical load which cause buckling on pneumatic cylinder support is 3000N but on designed pneumatic cylinder the maximum load act on this support is the summation of load due to actuated wind deflector through pneumatic cylinder and weight of pneumatic cylinder.

From equation 4.66 the load on pneumatic cylinder (F_{pn} 1038 N) and weight of pneumatic cylinder is calculated as follow based on standard mass of pneumatic cylinder (m=2.5 kg)

$$W_{pn} = mg = 2.5\ Kg*9.81m/s^2 \qquad \text{……..}\ (4.66)$$

$$W_{pn} = 24.52\ N$$

The total load on support is

$$F = W_{pn} + F_{pn} = 25.52N + 1{,}038\ N \qquad \text{……}\ (4.67)$$

$$= 1{,}064\ N$$

There for based on above result the designed support can resist the applied load due to wind deflector without buckling is occur.

- **Stress analysis of pneumatic cylinder support**

$$\sigma_y = \frac{F}{A} \qquad \text{………}\ (4.68)$$

Where σ_y = yield stress

F = total load on support

A = area of pneumatic cylinder support (H * W)

$$= \frac{1038\ N + 24.52N}{0.126\ m * 0.076m}$$

$$\sigma_y = 111.4\ Mpa$$

And the standard yield strength of the selected material from appendix is 145 Mpa so the designed support of the pneumatic cylinder is in safe condition to support the wind deflector drag force when the automatic wind deflector is actuated.

4.3.2.9.Numerical (Computational fluid dynamics) analysis of automatic wind deflector

The Numerical Analysis of the truck with and without Automatic wind deflector is done by using CFD ANSYS fluent software and compare the drag and lift coefficient results based on the output of the simulation. And also in this portion pressure contour, velocity distribution are discussed at different truck speed and conditions.

Computational fluid dynamics (CFD) is a scientific tool capable of producing information about the main structures of a flowing fluid. As a knowledge area, it finds its origins in the discrete solution of the fundamental equations used in fluid dynamics, such as the mass conservation equation, the momentum conservation equations (based on Newton's second law), and the energy conservation equation (based on the first law of Thermodynamics). All the equations are solved in an approximate way using iterative algorithms to solve lineal algebraic equations systems using matrices (CFD lab guide manual 2020).A CFD model has three sequential stages known as

1. preprocessing,
2. solving, and
3. Post-processing.

In the first stage or preprocessing, the governing equations, properties, and boundary conditions are defined within a domain composed by small interconnected volumetric elements to model the fluid movement. During the second stage or solving process, the adequate selection of discretization schemes (temporal and spatial) for the governing equations is carried out. Also, the convergence criteria or number of iterations, relaxation factors, and pressure and velocity coupling algorithm are set up at this stage. Finally, the post-processing stage involves the analysis and interpretation of the obtained solutions using flow, temperature, and pressures fields.

Nowadays, there are different commercial codes developed in a friendly interface, such as ANSYS FLUENT, OPEN FOAM, CFX, X-FLOW, and COMSOL. All of them are capable of helping researchers and engineers at the three aforementioned CFD stages. Generally, the modules of these commercial software's have been validated comparing the results obtained for specific information such as separation point, circulation length, drag and lift coefficients, and velocities, with experimental and/or analytical results. In order to analysis numerical result of this study of effect of automatic wind deflector on the truck at different condition the following step is done.

I. Geometry Creation

The geometry of the truck is created using CATIA V5 and imported to ANSYS workbench in IGS format. The fluid flows around the truck is the domain of interest, hence a fluid enclosure is created around the truck. The dimensions of the enclosure is three truck lengths in front of the truck, two truck lengths to the side of the truck and five lengths behind. In order to control the volume mesh near the truck two inner boxes are created. The first box extends about a truck length in front, to the sides and to the top and about twice a truck length in the wake. The second box extends about half a truck length in front, to the sides and to the top and about a truck length in the wake. Figure 4.24 - 4.26 show the created geometry of model Isuzu truck at different condition of wind deflector

- **Geometry of the truck without wind deflector**

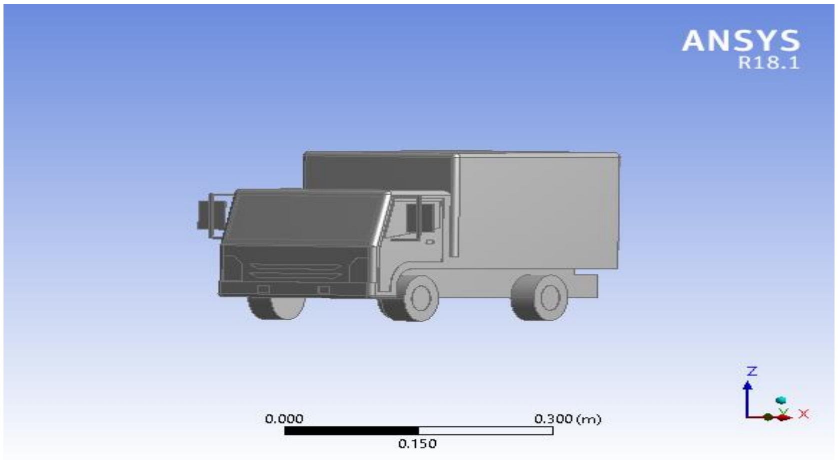


Figure 4.24: Imported model to ANSYS workbench

- **Geometry of the truck with normal wind deflector**

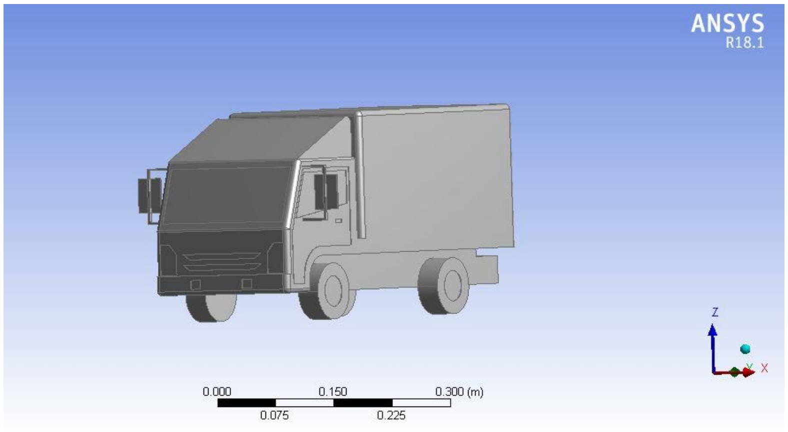


Figure 4.25: Imported model to ANSYS workbench

➢ **Geometry of the truck with actuated wind deflector**

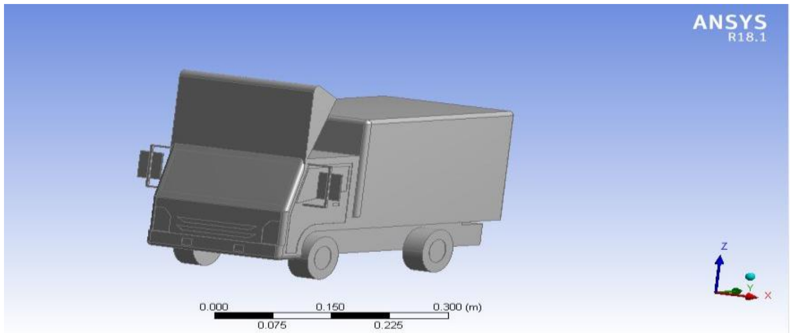


Figure 4.26: Imported model to ANSYS workbench

II. Mesh Generation

After geometry creation boundary for the model is created and import the geometry to the created boundary. Then In order to capture the flow physics near the truck, a fine mesh of unstructured triangles was put on the boundary of the truck. These fine element sizes will be used to capture the vortices and the flow separation near the truck body. For the analysis, several meshing parameters should be adjusted to obtain a finer mesh. The accuracy of the result depends on the quality of the mesh. As it is mentioned in Fluent User's Guide the quality of the mesh plays a significant role in the accuracy and stability of the numerical computation. Checking the quality of the mesh is, therefore, an important step in performing a robust simulation. After checking the quality of mesh give the name for the mesh as shown in figure 4.27.

According to Fluent User's Guide Minimum orthogonal quality is an important indicator of mesh quality. Values for orthogonal quality can vary between 0 and 1 with lower values indicating poorer quality cells. In general, the minimum orthogonal quality should not be below 0.01 with the average value significantly larger.

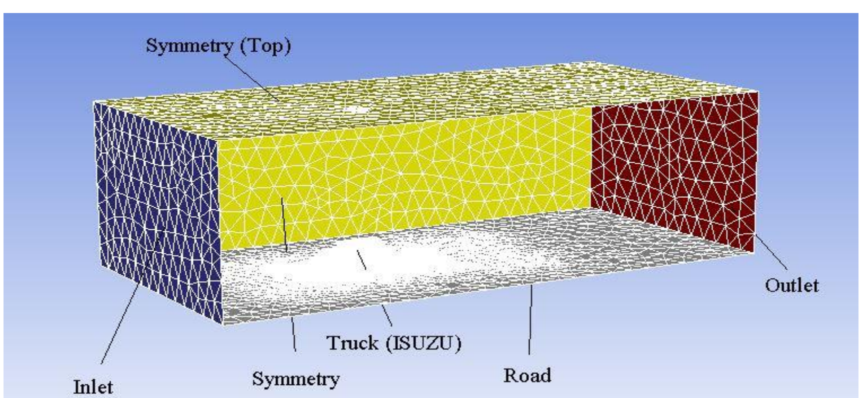


Figure 4.27: Named selection of the mesh

➢ **Generated mesh for truck with wind deflector**

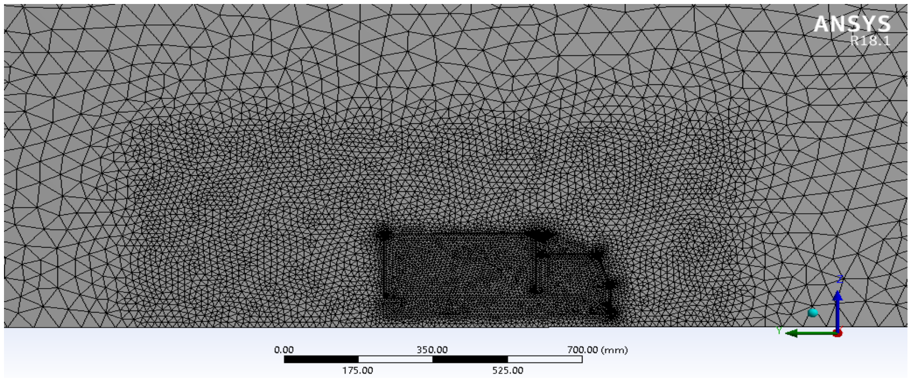


Figure 4.28: Generated mesh for truck with wind deflector

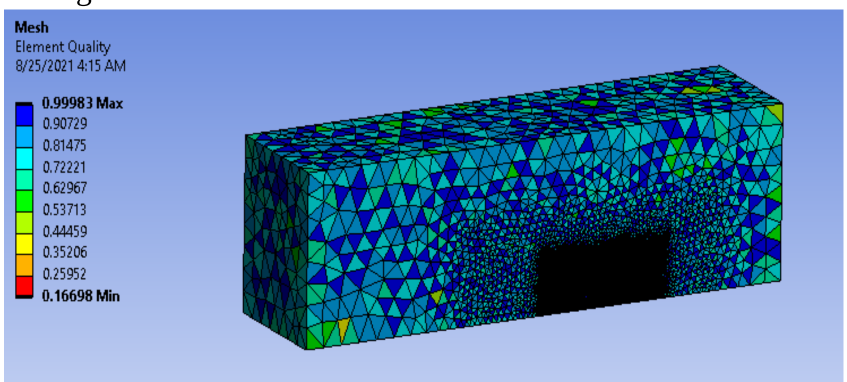


Figure 4.29: Quality of mesh for truck with wind deflector

The generated mesh for the truck with normal condition of wind deflector is shown in figure 4.29.The quality of mesh is critical to get the exact fluent output after simulation of the object. As it is shown in the figure 4.31 the minimum quality of the mesh is 0.15438 and the maximum value is 0.99. Therefore, the quality of the mesh is sufficient.

➢ **Grid Independence Test**

Grid independent test is carried out because choice of mesh size is always a critical thing in most of the numerical analysis hence it is one of the most influencing factors which determines the computational time and accuracy. The test is conducted with an element of 1 million to 1.8 million. To get accurate result a very fine mesh is used near the truck and the outer volume is meshed with coarse element.

Table 4.2: Grid Independence Test

	Mesh	Node	Element	Drag Coefficient (C_d)	Lift Coefficient (C_l)
Truck Without Wind Deflector	1	183719	1052665	0.621	0.124
	2	249813	1443384	0.615	0.113
	3	318890	1835114	0.610	0.181
Truck With Wind Deflector	1	184589	1056514	0.587	0.057
	2	250587	1447112	0.569	0.046
	3	319489	1837299	0.558	0.045
Truck With Actuated Wind Deflector	1	184136	1052414	0.929	0.196
	2	250046	1442165	0.927	0.204
	3	322032	1849142	0.921	0.184

As it is seen from the table 4.2, the difference between the values obtained from 1.4 million elements with those of 1.8 million elements is very less (less than 1.9%). Therefore, in order to reduce computation time mesh 3 is applied for all the cases.

III. Fluent Solver

The solver used for this simulation is Fluent 18.1 and SST k-w turbulence modeling is used for the simulation because according to ANSYS Fluent manual the SST k-w model is recommended choices for standard case. Where highly accurate resolution of boundary layers is critical, such as applications involving flow separation or finely resolved heat transfer profiles, SST k-w is preferred. The simulation was considered at three different vehicle speed of 30, 60, 120 kmph. Zero gauge pressure was applied at the outlet with operating pressure as atmospheric pressure. The courant number was set to 50 and the relaxation factors were taken as 0.25. For inlet condition the turbulence intensity was set to 1% and turbulent viscosity ratio as 10. For outlet, they were set to 5% and 10 respectively. A short description of the boundary conditions is presented in the table 4.3, given below.

Table 4.3: Boundary Conditions for fluent solver

Boundary	Boundary conditions	Values
Inlet	Constant velocity Turbulent intensity Viscosity ratio	V= 8.33 m/s, 16.67m/s, 33.33 m/s 1 % 10
Outlet	Pressure outlet Turbulent intensity Viscosity ratio	Constant pressure=0 Pa 5% 10
Road	Moving (translational)	V= 8.33 m/s, 16.67m/s, 33.33 m/s
Bus body	No slip- stationary wall	-
Symmetry top and symmetry sides	Stationary wall specified shear	Shear stress=0

The numerical computation was done with second-order scheme to ensure numerical stability and the simulation is carried out for 1000 iterations so as to prevent the solution from divergin

CHAPTER FIVE

5. BRAKING FORCE AND STOPPING DISTANCE CALCULATION

5.1. Introduction

Braking force and stopping distance calculation is the basic calculation part that used to determine the effectiveness of the study so in this portion the brake force and stopping distance of the truck at different condition is calculated and presented. This chapter has two main portions first portion present different equation that helps to determine the braking force and stopping distance of the truck based on Automobile technology hand book and the second portion of the section present the calculated parameters of the truck which related to braking force and stopping distance of the tuck at different conditions. Finally in this section braking force and stopping distance of the truck with and without advanced emergency brake system is calculated and presented.

5.2. Equation of brake force and stopping distance

5.2.1. Energy of Motion.

Kinetic energy is the force that keeps the vehicle moving. This energy is provided by the engine in order to accelerate the vehicle from a standstill to desired speed. Kinetic energy is dissipated as heat by the brakes during application of breaks as shown in figure 5.1.

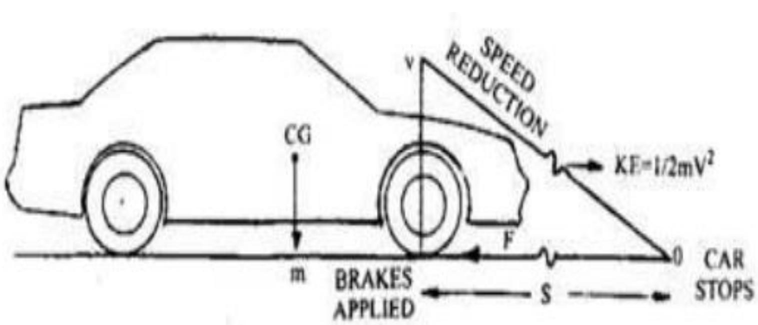


Figure 5.1. Illustration of braking (automobile technology)

KE = $\frac{1}{2}M(U^2 - V^2)$ ……….. (5.1)

Where U = initial velocity, m/s

V = final velocity, m/s

M = mass of the vehicle, kg

g = acceleration due to gravity, m/s^2

5.2.2 Power absorbed by the brakes

The power absorbed by the brakes during a stop can be calculated as:

$$P = \frac{KE}{t} \qquad \text{…….. (5.2)}$$

Where: P = power absorbed, w

K_E = kinetic energy, Nm or J

t = time, s

There for the power absorbed by the brake during braking is depend on kinetic energy and braking time.

5.2.3 Brake force of vehicle

The force applied during braking of a vehicle opposes the motion of the wheels, as a result reduces the vehicle speed or brings it to a standstill. Therefore the braking force is the force of resistance applied to stop a vehicle or reduce its speed. The maximum vehicle braking force (Fb max) is equal to the coefficient of road adhesion times the weights normal to the roadway surface.

$$F_B = W\mu \; => mg\mu \qquad \text{……… (5.3)}$$

Where W = weight of the vehicle N

μ = coefficient of friction

m = mass of vehicle, Kg

g = gravitational force,m/s^2

5.2.3.1 Coefficient of friction

When braking torque is applied to a wheel, a braking force F B is generated between the tire and the road surface that is proportional to the braking torque under stationary conditions (no wheel acceleration). . The ability of a vehicle to stop depends on the coefficient of friction between the contacting surfaces. Maximum useable coefficient of friction occurs between the tire and road surface. Commercial truck brakes have coefficient of friction 0.3 to 0.7.The braking force transmitted to the road (frictional force FR) is proportional to the vertical tire force R.

$$\mu = \frac{F}{R} \qquad \text{…….. (5.4)}$$

Where μ = Coefficient of Friction

F = friction force

R = Normal load

The factor μ is the coefficient of friction. It defines the frictional properties of the various possible material pairings between tire and road surface and the environmental conditions to which they are exposed. The coefficient of friction is thus a measure of the braking force that can be transmitted. It is dependent on the nature of the road surface, the condition of the tires, the vehicle's road speed, and the weather conditions. The coefficient of friction ultimately determines the degree to which the braking torque is actually effective.

5.2.4 Work Done in Braking

The kinetic energy possessed by a moving vehicle depends on the weight and speed of the vehicle. This energy must be partially or totally dissipated when the vehicle is slowed down or brought to a standstill. The brake converts the kinetic energy possessed by the vehicle at any one time into heat energy by means of friction.

The work done in bringing the vehicle to rest is given by:

$$W_d = F_B S \qquad \text{……… (5.5)}$$

Where: W_d = work done, J

S = distance travelled, m

F_B = Braking force,N

When braking a moving vehicle to a standstill, the work done by the brake drums must equal the initial energy possessed by the vehicle so that

$$W_d = K_E \qquad \text{………… (5.6)}$$

$$F_B.\, S = \frac{1}{2} M U^2 \qquad \text{………… (5.7)}$$

5.2.5 Braking distance

From the above relation the braking distance (Sb) become

$$S_b = \frac{Mu^2}{2FB} \qquad \text{...……… (5.8)}$$

Where M = mass of the vehicle, Kg

u = initial velocity, m/s

F_B = braking force, N

μ = coefficient of friction

5.2.6. Braking torque

When the brakes are applied, the brake shoes press against the brake drums in the case of drum brakes. This generates frictional forces, the level of which can be controlled by the driver by the pressure applied to the brake pedal. The product of the frictional forces and the distance at which they act from the axis of rotation of the wheel is the braking torque TB. Brake torque on the front wheels is absorbed by the knuckle and suspension control arm. In rear, it is absorbed by the axle housing and the leaf spring or control arm. Braking torque during an emergency stop is much higher than accelerating torque at full throttle.

Braking Torque (TB) is the moment of braking force about the center of rotation.

$$T_B = F_B \cdot r_e \qquad \text{……….} \; (5.9)$$

Where: F_B = braking force

r_e = is the effective drum radius.

5.2.7. Brake Balance and weight transfer

The braking of a vehicle occurs at ground level, so affective braking force acts on the ground. Vehicle weight and kinetic energy of the vehicle act through center of gravity, which are above ground level. This causes the vehicle to pitch forward as the brakes are applied. As a result of this action some of the vehicle weight is effectively transferred from the rear wheels to the front wheels. Consequently, the front brakes must absorb more kinetic energy than the rear brakes (Automobile technology hand book page 1200).

The maximum transfer of weight amounts to

$$W_t = \frac{\mu h}{b} W \qquad \text{………..} \; (5.10)$$

Where W_t = weight transferred, N

μ = coefficient of friction

h = height of C.G. from the ground, m

W= vehicle gross weight, N

B = wheel base, m

g = acceleration due to gravity, m/s^2

5.2.8 Stopping distance calculation

Stopping distance, is the distance a vehicle covers from the time of the full application of its brakes until it has stopped moving. Both the brake reaction time and the braking distance are used in the calculation of the stopping sight distance. Stopping distance is extremely important for emergency braking. Stopping distance is the sum of thinking (reaction) distance (Sr) and braking distance (Sb) (James, 2009).

$$S = S_b + S_r \qquad \text{……….} \ (5.11)$$

5.2.8.1 Reaction distance

Reaction distance is the product of speed of the truck and reaction time of the drive to apply the brake at desired condition and time. Reaction time is the amount of time that takes between the recognition of an object or in the roadway of the vehicle. The application of the brakes the distance traveled during the brake reaction time can be calculated by using Equation 2.1.

$$Sr = U * t_r$$

5.2.8.2 Braking distance

Braking distance refers to the distance a vehicle will travel from the point when its brakes are fully applied to when it comes to a complete stop. It is primarily affected by the original speed of the vehicle and the coefficient of friction between the tires and the road surface, and negligibly by the tires' rolling resistance and vehicle's drag. From equation 5.8 braking distance is calculated by

$$Sb = \frac{M\mathbf{u}^2}{2FB}$$

Based on above equation of reaction distance and braking distance then stopping distance become

$$S = (U \times t_r) + \left(\frac{M\mathbf{u}^2}{2FB}\right) \qquad \text{……….} \ (5.12)$$

Where S = stopping distance

U = initial speed

t_r = reaction time

M = mass of vehicle

F_B = braking force

5.2.9 Braking Efficiency (η)

The braking efficiency of a vehicle is defined as the braking force produced as a percentage of the total weight of the vehicle. The braking efficiency is generally less than 100% because of insufficient road adhesion, the vehicle is on a down gradient or ineffective brake system. The braking efficiency of a vehicle is defined as the braking force produced as a percentage of the total weight of the vehicle. So the braking efficiency of Isuzu truck without advanced emergency brake system is calculated as follow.

$$\eta = \frac{\text{Braking force}}{\text{Weight of vehicle}} \times 100 \qquad \text{……….. (5.13)}$$

5.3 Calculation of braking force and stopping distance for ISUZU truck without advanced emergency brake system

To calculate brake force and stopping distance of ISUZU truck **without** advanced emergency brake system for this study only consider the wheel brake force(four wheel braking) because there is no auxiliary brake is applied on conventional brake system of the truck .

5.3.1 Kinetic energy of the ISUZU truck without advanced emergency brake system

Kinetic energy is dissipated as heat by the brakes during application of brakes. There for the kinetic energy formed during braking of ISUZU truck **without** advanced emergency brake system is calculated by using equations 5.1.

$$KE = \frac{1}{2}M(U^2 - V^2)$$

Since the linear maximum speed of the vehicle is calculated on equation 4.56 (U=33.3m/s) and the final speed of the truck is 0 m/s because of braking force of the truck then the kinetic energy of the truck without Advanced emergency braking become

$$KE = \frac{1}{2}MU^2 = \frac{1}{2} * 11{,}000\text{Kg} * (33\text{m/s})^2 \qquad \text{……… (5.14)}$$

$$KE = 5{,}989.5 \text{ KJ}$$

There for the kinetic energy of moving f34 series Isuzu truck during braking is 5,989.5 KJ

5.3.2 Brake force of the ISUZU truck without advanced emergency brake system

The maximum **vehicle braking force** of the ISUZU truck is equal to the coefficient of friction times the weight of the truck normal to the roadway surface. The coefficient of friction between ISUZU truck tire and road surface for dry clean road **μ=0.7** (J. Hui and M. Zhou 2014**).** So from equation (5.4) the braking force is given by and calculated as follow.

$$F_B = M*g*\mu \quad = 11{,}000kg * 9.8m/s^2 *0.7$$

$$F_B = 75{,}460N$$

5.3.3 Braking Torque of the ISUZU truck without advanced emergency brake system

Braking Torque (TB) is the moment of braking force about the center of rotation. Brake torque is the force applied at the brake wheel to stop the motion of the moving vehicle. And it can be calculated by using equation 5.4.drum size if f-series Isuzu truck is 370mm x 150mm.

$$T_B = F_B .r_e \quad ,\text{but} \quad re= 370/2= 185mm = 0.185m$$

$$= 75{,}460N \text{ X } 0.185m$$

$$T_B = 13{,}960Nm$$

5.3.4 weight transfer during braking of Isuzu truck without advanced emergency brake system

During braking vehicle weight is effectively transferred from the rear wheels to the front wheels. And also on the Isuzu truck there will be additional load carrying on the rear part of the vehicle so more weight is transfer from rear to front part of the truck, this can cause skidding of the truck during braking consequently, the front brakes must absorb more kinetic energy than the rear brakes. From isuzu truck specification Coefficient of friction μ= 0.7, wheel base = 5000mm, over all height of truck= 750mm+2475 =3225mm, deceleration rate =6.89m/s^2 gravitational force =9.81 m/s^2 and the maximum transfer of weight during braking is calculated by using equation 5.10.

$$W_t = \frac{\mu h}{b} W$$

$$= \frac{0.7*3.225m}{5m} 11000Kg * 9.81 \ m/s2$$

$$W_t = 48{,}721 \ N$$

There for 48,721N weight is transfer from rear to front during braking

5.3.5 Stopping distance of Isuzu truck without advanced emergency brake system

5.3.5.1 Maximum stopping distance

The maximum stopping distance of the truck without advanced emergency braking is calculated based on maximum speed of the truck and maximum brake force of the truck that applied to stop the truck. The stopping distance of the truck is calculated by using equation 5.11

$$S = (U * t_r) + \left(\frac{KE}{FB}\right) \text{ or } S = (U * t_r) + \left(\frac{M\mathbf{u}^2}{2FB}\right) \text{ ….. (5.15)}$$

Where maximum truck speed (u= 33.3m/s), Maximum brake force (F_B =75.45KN), Kinetic energy (KE=5989KJ) and Brake reaction time normally used in this study is (tr=1 s)

$$S = (U * t_r) + \left(\frac{KE}{FB}\right) = (33.3\text{m/s} * 1 \text{ s}) + \left(\frac{5989\text{KJ}}{75.45\text{KN}}\right)$$

$$S = 112 \text{ m}$$

There for the maximum stooping distance of the truck without advanced emergency brake system is 112m.when it goes at maximum speed .the stooping distance which calculated in this portion is essential to compare the stopping distance of ISUZU truck without advanced emergency braking system and with advanced emergency braking system .

5.3.5.2. Stopping distance of the truck at various speed

In this section the stopping distance is calculated in various speed of the truck because the stopping distance become vary in different speed of the truck. The stopping distance of the truck at different speed of the truck is calculated as follow when speed of the truck is (20km/hr, 40km/hr, 60km/hr, 80km/hr, and 100km/hr).by using equation 5.12 the stopping distance of the truck at various speed is calculated.

$$S = (U * t_r) + \left(\frac{M\mathbf{u}^2}{2FB}\right)$$

5.3.6 Braking efficiency of truck without Advanced emergency brake

Braking efficiency of Isuzu truck without advanced emergency brake system is calculated as follow.

$$\eta = \frac{\text{braking force}}{\text{Weight of vehicle}} \times 100.$$

$$= \frac{75{,}460}{11000\text{Kg} * 9.81\text{m/s2}} \times 100$$

$$\eta = 69.9\ \%$$

5.4. Calculation of braking force and stopping distance for ISUZU truck with advanced emergency brake system

When an advanced emergency brake system is mounted on previous conventional brake system of f-series Isuzu truck various additional future and advantage is add that support the main brake system by adding auxiliary brake systems for the trucks (automatic wind deflector and electromagnet brake system) and reduce the stress and fatigue of driver in any driving condition by using automatic brake actuation mechanism for emergency time when something is enter accidentally. Adding an advanced emergency brake system for f-series Isuzu truck is only affect the braking force and stopping distance of the truck the kinetic energy ,weight transfer, wheel brake torque is not changed so in this portion only calculate the total brake force and stopping distance

5.4.1 Brake force calculation for ISUZU truck with advanced emergency brake system

Braking force for ISUZU truck with advanced emergency brake system is the sum of the main brake system (conventional brake system), aerodynamic drag force of automatic wind deflector, and retardation force of electro magnet brake on propeller shaft.

$$F_{aebs} = F_B + R_{aw} + F_{em} \qquad \text{……….} \ (5.16)$$

Where F_{aebs} = over all advanced emergency brake system force

F_B = wheel brake force, N (FB= 75450N)

R_{aw} = aerodynamic drag force due to automatic wind deflector (R_{aw}=2,074N)

F_{emt} = electromagnet brake system total retardation force

(F_{emt}=18,176 N)

Then the overall advanced emergency brake system force apply at maximum speed of the truck at emergency time is calculated as follow

$$F_{aebs} = F_B + R_{aw} + F_{em}$$

$$= 75{,}460\text{N} + 2{,}074\ \text{N} + 18{,}176\ N$$

$$F_{aebs} = 95{,}710\ \text{N}$$

When an advanced emergency brake system is activated automatically if something is enter into the front of the truck the total force apply to stop the truck is 95,710 N. this force is very high compare with the truck without advanced emergency brake system.

5.4.2 Stooping distance calculation for ISUZU truck <u>with</u> advanced emergency brake system

When truck use advanced emergency brake system the brake system operate automatically without driver command, means when accidental obstacle is detect in front of moving truck the control system manage that accident its own by using controlling mechanism and give the desired command for the actuators based on received data from the sensor units. The receiving and actuation of the controller take very small mile second there for the reaction time for the controller is 0.1 second to apply the brake at emergency time. The stopping distance of the truck with advanced emergency brake system considered reaction distance and brake distance.

5.4.2.1 Maximum stopping distance of ISUZU truck <u>with</u> advanced emergency brake system

Then the maximum stopping distance of the truck with advanced emergency brake system at maximum speed of the truck (120Km/Hr) is calculated as follow by using equation 5.11.

$$S = (U * t_r) + \left(\frac{KE}{FB}\right)$$

But in this case $\mathbf{F_B = F_{aebs}}$

So maximum stopping distance of the truck with advanced emergency brake system is become

$$S = (U * t_r) + \left(\frac{KE}{Faebs}\right) \qquad \text{……………} \ (5.17)$$

Where maximum truck speed (u= 33.3m/s), Maximum brake force (F_{aebs}=95.71 KN) , Kinetic energy (KE=59,89KJ), and Reaction time (tr=0.1 s)

$$S = (33.3\text{m/s} * 0.1\text{ s}) + \left(\frac{5989\text{KJ}}{95{,}710\text{KN}}\right)$$

$$S = 65.8 \text{ m}$$

There for the maximum stopping distance of the truck with advanced emergency brake system using this system when the truck move at high speed and apply maximum brake force is 65.8m this stopping distance is reduced approximately by half when compare with the previous truck brake system.so for high speed truck this type of brake system is best to avoid collision or accident and to maintain an appropriate vehicle to vehicle distance by minimizing reaction time and by using automatic actuation system.

5.4.2.2 Stopping distance of the truck <u>with</u> advanced emergency brake system at various speed

In this portion the stopping distance of the truck with advanced emergency brake system at different speed of the truck is calculated (20km/hr, 40km/hr, 60km/hr, 80km/hr, 100km/hr).when speed of the truck changed kinetic energy and aerodynamic drag force also changed so to calculate stooping distance in different speed kinetic energy and aerodynamic drag force of wind deflector also considered.

Equation of stopping distance of the truck with advanced emergency brake system at various speed From equation (5.17)

$$S = (u * tr) + \left(\frac{\mathbf{Mu^2}}{2 * Faebs}\right)$$

But $F_{aebs} = F_B + R_{aw} + F_{em}$

Then $$S = u * tr + \frac{\mathrm{Mu^2}}{2(\mathrm{FB+Raw+Fem})} \qquad \text{……… (5.18)}$$

Aerodynamic drag force due to automatic wind deflector (R_{aw}) is changed depending on speed of the truck and by Substitute constant values to above formula R_{aw} become

$$R_{aw} = \frac{1}{2} \times \rho_a \times C_D \times A_{FP} \times U^2$$

$$= \frac{1}{2} \times 1.225 Kg/m^3 \times 1.16 \times 2.681 m^2 \times (U)^2$$

$$R_{aw} = 1.9 * \times (U)^2 \qquad \text{…………(5.19)}$$

Where R_{Aw} = Aerodynamic drag force at various speed

U = speed of the truck

There for stopping distance of the truck with advanced emergency brake system at various speed after substituting the results Where (FB=75,460N, F_{emt}=18,176N, tr =0.1 s, and M=11000Kg) it become;

$$S = 0.1U + \frac{5500Kg*U^2}{(93,636+(1.9*U^2))} \quad \text{...... (5.20)}$$

By using equation 5.20 the stopping distance at different speed calculated

5.5 Effect of individual auxiliary brake system on stopping distance of the truck

The auxiliary brake system of an advanced emergency brake system that used on this study has its own effect on brake force and stopping distance.so the effect of using auxiliary brake system on reduction of stopping distance as well as reduction of accident is on this study is presented on this section.

5.5.1 Effect of electromagnet brake system on stopping distance of the truck

The effect of Using electro magnet brake system in addition to main brake of truck with electro mechanical control system on stopping distance of the truck is presented by using the total retardation force of electro magnet brake system that calculated in equation(4.37) ,so this retardation force affect the stopping distance of the truck when emergency brake system is activated then effect of electromagnet brake system on stopping distance of the truck at different vehicle speed (20km/hr,40km/hr,60km/hr,80km/hr,100km/hr) is calculated as follow where (tr=0.1 s, F_B=75,460N and F_{emt}= 18,176 N)

$$S = u * 0.1\,s + \frac{Mu^2}{2(FB+Femt)} \Rightarrow 0.1u + \frac{11000kg*u^2}{2(75460N+18176N)}$$

$$S = 0.1U + \frac{5500Kg*U^2}{(93,636N)} \quad \text{......... (5.21)}$$

Maximum stopping distance of the truck with advanced emergency brake system equipped with only electro magnet brake system at maximum speed of the truck is 67m.

5.5.1.1 Effect of electromagnet brake system in speed of rotation of propeller shaft

The electromagnet force created on electro magnet brake system create retardation force on rotating propeller shaft through modified propeller shaft part and slow the rotation of propeller shaft, then effect of electromagnet brake system on propeller shaft is calculated in different rotation of propeller shaft by using the following equation. The reason why the efficiency is multiply by 1000 is because of the rotation of propeller shaft is take out of 1000 rpm then the equation of new rotational speed of propeller shaft when electromagnet brake system is activated become

$$N_{pn} = N_p - (\eta * 1000) \qquad \text{……….} \ (5.22)$$

Where Npn = new rotational speed of propeller shaft

η =retardation efficiency (η=40%)

N_p=propeller shaft rotational speed

New rotational speed of propeller shaft after electromagnet brake system is activated is calculated between 1000rpm up to 3500 rpm in 500rpm increasing interval

5.5.1.2 Braking efficiency of electromagnet brake system

Braking efficiency of Isuzu truck with electromagnet brake system of advanced emergency brake system is calculated as follow.

$$\eta = \frac{\text{electro magnet retardetion force}}{\text{Weight of vehicle}} \times 100 \qquad \text{……..} \ (5.23)$$

$$= \frac{18{,}176\text{N}}{11000\text{Kg} * 9.81\text{m/s2}} \times 100$$

$$\eta = 17\ \%$$

5.5.2 Effect of automatic wind deflector on stopping distance of the truck

Automatic wind deflector on roof of the truck in this study use for two main reason the first reason is to reduce aerodynamic drag force effect on moving truck by giving aerodynamic frontal shape for the truck and secondly it use as auxiliary brake when it rise up by using piston force of pneumatic cylinder through advanced emergency brake system. Then effect of automatic wind deflector on reducing of stopping distance at emergency time at different speed of truck is (20km/hr, 40km/hr, 60km/hr, 80km/hr, 100km/hr, 120 km/hr) is calculated as follow.

The aerodynamic drag force is changed when the speed of truck is vary so the aerodynamic drag force on automatic wind deflector when it actuated at emergency braking is from equation 5.19.

$$R_{aw} = 1.9 * \times (U)^2$$

Then stopping disance of th truck with automatic wind deflector of an advaneced emeregency brake system where (tr=0.1 s and F_B =75460 N,M= 11000 Kg) become

$$S = u * 0.2\ s + \frac{Mu^2}{2(FB+Raw)} \quad = \quad 0.1 * u + \frac{11000kg*u^2}{2(75460N+(1.9*u^2)}$$

$$S = 0.1 * u + \frac{5500Kg*u^2}{(75{,}460N+(1.9*(u^2))} \quad \ldots\ldots\ldots (5.24)$$

Maximum stopping distance of the truck with automatic wind deflector at maximum speed of the truck is 84.6 m.

5.5.2.1 Braking efficiency of automatic wind deflector

Braking efficiency of automatic wind deflector when it actuated through electro control system of an advanced emergency brake system at emergency time is calculates as follow

$$\eta = \frac{\text{Airodynamic drag force of automatic wind deflector}}{\text{Weight of vehicle}} \times 100 \ \ldots\ldots (5.25)$$

$$= \frac{2074N}{11000\ Kg*981\ m/s2} \times 100.$$

$$\eta = 2\%$$

There for the braking efficiency of automatic wind deflector during emergency braking is 2%.the braking efficiency of automatic wind deflector seem to small but effect of this wind deflector to reduce rollover of the truck during emergency braking is very high so the automatic wind deflector on roof of the truck play great role in reduction of rollover of the truck due to weight transfer during braking.

5.5.3 Over all Braking efficiency of truck with advanced emergency brake system

Braking efficiency of Isuzu truck with advanced emergency brake system is calculated by using the following equation.

$$\eta = \frac{\text{total braking force of truck with AEBS}}{\text{Weight of vehicle}} \times 100 \qquad \ldots\ldots (5.26)$$

Where the baking force is the total braking force act on the truck due to main and auxiliary brake system so the total braking force is summation of wheel brake force, electromagnet brake retardation force, and aerodynamic drag force of automatic wind deflector.

So from equation 5.16; $F_{aebs} = F_B + R_{aw} + F_{em}$

$$= 75{,}460N + 2{,}074\ N + \mathit{18{,}176\ N}$$

$$F_{aebs} = 95{,}710\ N$$

Then the Braking efficiency of Isuzu truck with advanced emergency brake system is calculated as follow

$$\eta = \frac{95{,}710N}{11000Kg * 9.81m/s2} \times 100$$

$$\eta = 88.8\ \%$$

There for the braking efficiency of the truck with advanced emergency braking system is 88.8% this braking efficiency is higher than the braking efficiency of the truck without advanced emergency braking system. And the increasing efficiency of braking is very important to stop the vehicle at minimum stopping distance and time at emergency time as a result of this reduction of accident or collision also increased.

CHAPTER SIX

6. RESULT AND DISCUSSION

6.1 INTRODUCTION

This chapter presents the results obtained from the material design, analytical and numerical analysis of the automatic wind deflector, electromagnetic brake system with modified propeller shaft, and main brake system of the advanced emergency brake system of the F34 series ISUZU truck. The first section presents the brake force and stopping distance results of the truck's conventional brake system without an advanced emergency brake system, which are used to compare the braking performance of the previous system and the modified system, On The second section, the sensing, controlling and actuating circuit diagram and simulation of circuit diagram of advanced emergency brake system on proteus 8 software had presented as well as the designing results, total retardation force and aerodynamic drag force results of the electro magnet brake system and automatic wind deflector respectively .In addition, the results of a numerical analysis of an automatic wind deflector performed on CFD ANSYS fluent are presented in this section. Finally, in the third section, the braking force and stopping distance of the F34 series truck with and without the advanced emergency brake system are presented and compared.

6.2 Analytical results of brake force and stopping distance calculation of truck without advanced emergency brake system

On brake force calculation of truck many different useful parameters of braking were calculated in previous chapter such as kinetic energy, braking force, braking torque, weight transferred, and stopping distance by only considering brake force generated through drum brake of the truck.

6.2.1 Analytical results of brake force of truck without advanced emergency brake system

As table 6.1, shown when the truck not equipped an advanced emergency brake system the maximum brake force and maximum stopping distance is 75,460N and 112m respectively. The stopping distance of the truck for emergency brake is very high and it should be reduced. Finally the braking efficiency of the truck without advanced emergency brake system is 69.9 %.

Table 6.1: Analytical results of brake force calculation of truck <u>without</u> advanced emergency brake

Determined parameters	Obtained result
Maximum truck speed,(Km/Hr)	120 Km/Hr
Kinetic energy,(KJ)	5989 KJ
Maximum Brake force ,(N)	75,460 N
Maximum wheel brake torque,(Nm)	13,960 Nm
Maximum weight transferred ,(N|)	48,721 N
Maximum reaction distance ,(m)	33 m
Maximum braking distance,(m)	79 m
Maximum stopping distance,(m)	112 m
Maximum braking efficiency	69.9 %

6.2.2 Analytical Result of stopping distance of the truck without advanced emergency brake system

The result that obtain from calculation of Stopping distance of the truck without advanced emergency brake system in different truck speed is used to show the effect of braking force, truck speed and reaction time of braking of the truck at emergency time and to find the best solution for the problem of conventional brake system finally by using the gap made modification on previous brake system of the truck and compare the result of old design and new designed system then determine the increased performance of the new modified brake.

Table 6.2: Result of reaction, braking and stopping distance of the truck in different truck speed

Truck speed ,(Km/Hr)	Reaction distances ,Sr(tr= 1sec),m	Braking distance ,Sb	Stopping distance, s (S=Sr +Sb),m
0	0	0	0
20	5.5	2.2	7.7
40	11.1	9	20
60	16.6	20	36.7
80	22.2	36	58
100	27.7	56	83.7
120	33.3	79	112

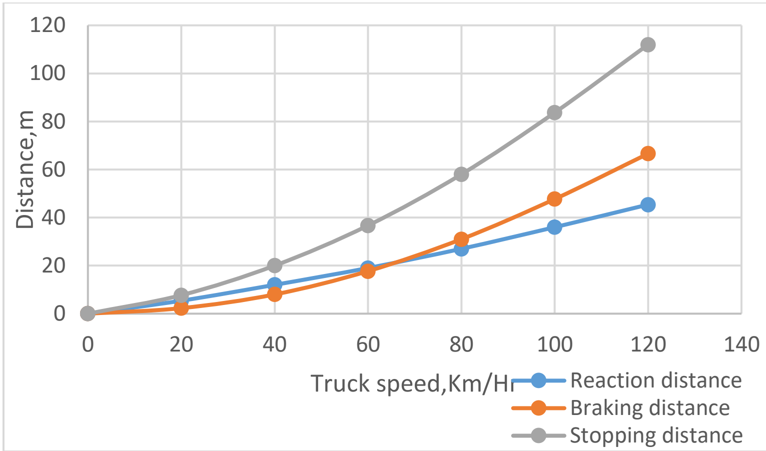


Figure 6.1: effect of reaction and braking distance on total stopping distance of the truck

Stopping distance is the distance which the vehicle move after the brake is applied and it depend on reaction and braking distance of the truck. As shown in figure 6.1 the reaction distance is higher than braking distance when the truck moves at lower speed (0-60km/hr) but as the truck speed increases (>65km/hr) it is observed that the braking distance has increased gaining a value higher than the reaction distance of the truck because when the speed of the truck is low the brake force required to stop the truck is higher; then due to this reason the braking distance is smaller than the reaction distance. Finally the stopping distance of the truck is directly proportional to square of the speed of the truck based on the result shown in the Table 6.2.

6.3. Analytical and numerical result of new designed advanced emergency brake system (AEBS)

For new designed advanced emergency brake system (AEBS) **of** this study two auxiliary brake systems is designed to support main brake system of the truck at emergency time. Those two auxiliary brake systems are electromagnet brake system with modified propeller shaft and automatic wind deflector. Both auxiliary brake systems is controlled by electromechanical and electrical control mechanisms through Arduino controller on advanced emergency brake system. both auxiliary brake system on advanced emergency brake system is work combined with the main wheel brake system but the main and auxiliary brake systems is monitor by electro-mechanical controller there for the reaction time for the actuation of the system is very small compared with the reaction time of conventional brake system of the truck.

6.3.1 Result and Discussion on electro mechanical control system of AEBS

- **Simulation of the system when obstacle is <u>not detected</u> at minimum braking distance of the truck**

On advanced emergency brake system development, circuit diagram design for sensing, controlling and actuating unit is important things because it is the brain of the system which helps to monitor or control the overall braking activity at emergency time.

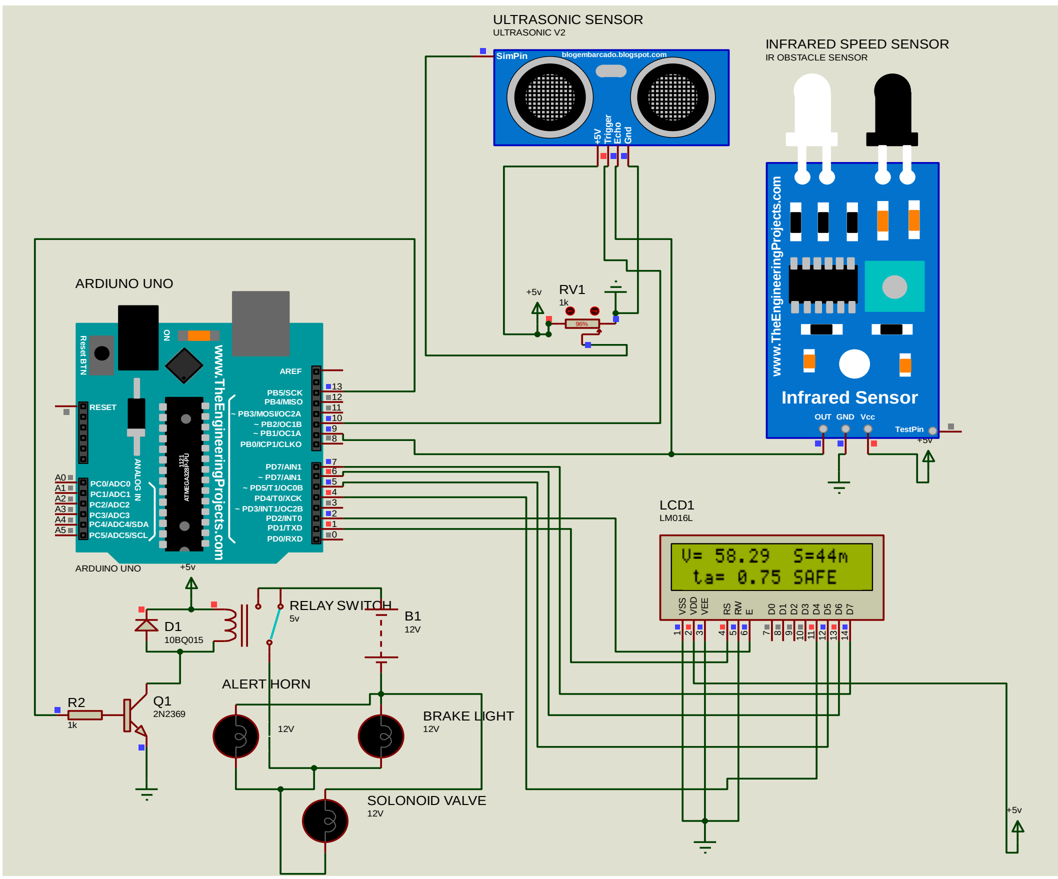


Figure 6.2: Simulation of the system when **obstacle is not detected** at minimum braking distance of the truck

The simulation of the circuit diagram is done by using proteus 8 helps, and the simulation is helps to check the connection is correct or not, to check the workability of sensor, controller and actuators, to check the programmed file input and output, and to check the command of the controller for the actuators is based on detected signal or not.

Figure 6.2 shows the simulation result of electro mechanical control system circuit diagram of advanced emergency brake system for Isuzu truck when obstacle is not detected at minimum braking distance of the truck .on this simulation the sensors measure distance between vehicle and object, measure speed of the truck, and send signal to the controller then the controller analysis the input signal from the sensor based on input program to give command to the actuators .based on the result of the simulation range shown in the figure when there is no obstacle detect at minimum braking distance the LCD display measured distance and speed of truck and give information for the driver the condition is "SAFE" and the relay switch remain switched off as a result of this alert horn, brake light, electromagnet brake, and pneumatic solenoid valve remain deactivated.

- **Simulation of the system when obstacle is detected at minimum braking distance of the truck**

The designed circuit diagram consist ultrasonic sensor (detect existence of obstacle), infrared sensor (measure speed of truck), Arduino controller (control all activity of the system),relay switch module (on –off actuators),alert horn(give sound alert for the driver),brake light(light on during emergency braking), solenoid valve(control air flow depending on command of controller),and 12V battery (power source) .so based on this connection the electro mechanical control system monitor braking activity of truck by sensing ,controlling and actuating devices.

When the sensor detect existence of obstacle at minimum braking distance of the truck the controller receive measured data from the sensor and give the command for the actuator based on preprogrammed data through the relay switch and the LCD display measured speed, measured distance between vehicle and obstacle and give alert information for the driver "FOCUS".at this time all actuator become activated to give sound alert and to apply main and auxiliary brake system. Finally the system stop the truck at minimum stopping distance and stopping time by applying main brake and auxiliary brake system (electro magnet brake system and automatic wind deflector) in minimum reaction time as Figure 6.3 shown.

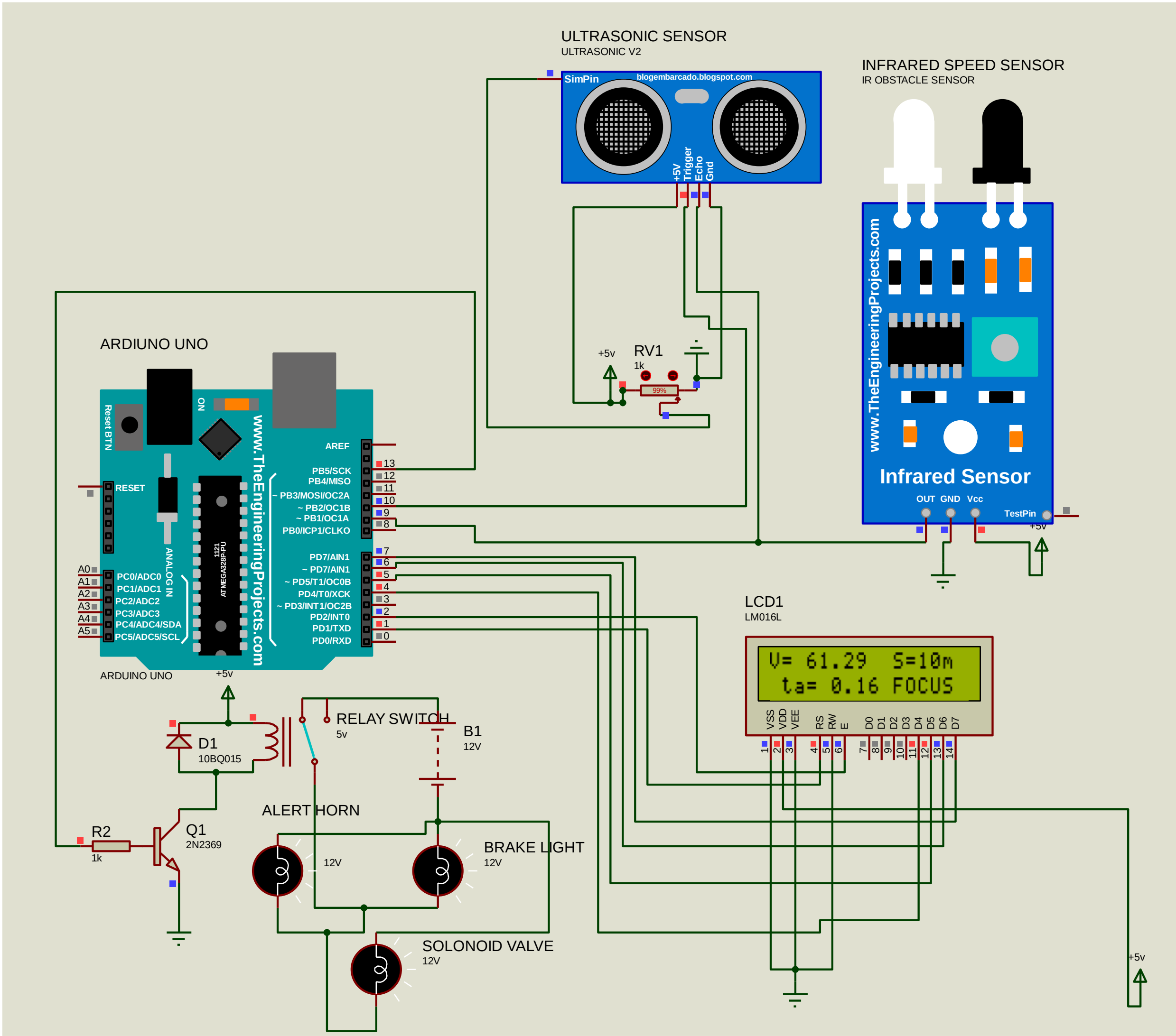


Figure 6.3: Simulation of the system when **obstacle is detected** at minimum braking distance of the truck

6.3.1.1 Effect of electro mechanical control system of AEBS on reaction distance

Stopping distance is the sum of reaction distance and braking distance. Effect of reaction time on a truck stopping distance without and with advanced emergency brake system is calculated on previous chapter. The reaction time for stopping distance is reduced from 1 second to 0.1 second because of electro mechanical control mechanism of the system. In this section compare the reaction distance of the truck according to different vehicle speed by using table and graph as follow.

Table 6.3: Effect of electro mechanical control system of AEBS on reaction distance

Truck moving speed (Km/Hr)	Reaction distance without advanced emergency brake system,(m)	Reaction distance with advanced emergency brake system,(m)
20	5.5	0.55
40	11.1	1.11
60	16.6	1.66
80	22.2	2.22
100	27.7	2.77
120	33.3	3.3

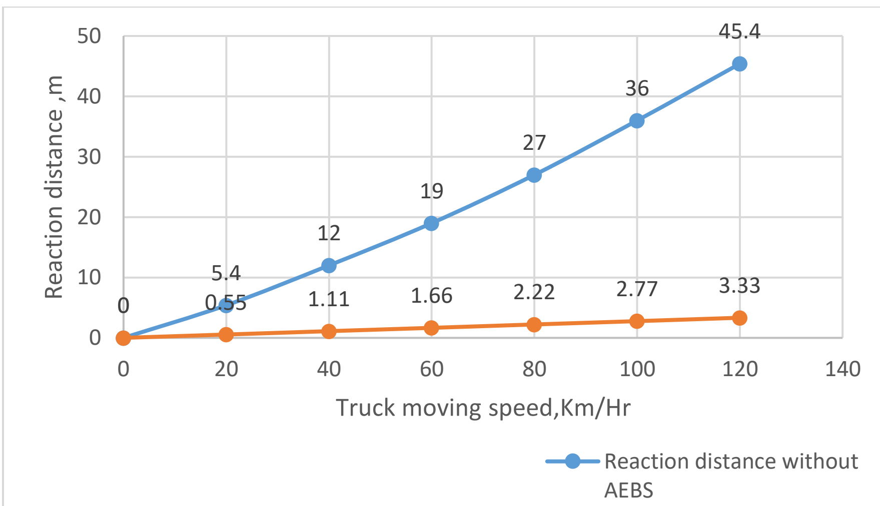


Figure 6.4: comparison of reaction distance between truck with and without AEBS

The brake reaction distance is the amount of distance that elapses between the recognition of an object or hazard in the roadway and the application of the brakes. In Figure 6.4 is shown the reaction distance of the truck with and without advanced emergency brake system (AEBS); it is observed from the graph that the reaction distance of the truck with AEBS is very small when compared to the truck without AEBS; hence the trucks equipped with advanced emergency brake system the reaction time required to apply the brake at emergency time is become smaller the compared with the truck without this new designed system.

6.3.2 Analytical result of Electromagnet brake system

The electro magnet brake system generate the magnetic force to create the retardation force against rotating propeller shaft of the truck and the maximum magnetic field strength ,total retardation magnetic force is calculated in previous chapter.in this section the analytical result of new designed electro magnet brake system device and its component, working principle and effect of electro magnet brake system on rotation of propeller shaft and stopping distance of the truck during braking is presented.

6.3.2.1 Discussion about working principle of electromagnet brake system on AEBS

The electro magnet brake system with modified propeller shaft mounted on rotating main propeller shaft and it consist stationary and rotating part, the stationary part contain 8 current carrying winding coil with iron rod to produce retardation magnetic force on rotating propeller shaft to retard or slow vehicle speed when current flow through winding coil depending on controller command through advanced emergency brake system at emergency time and this part mounted on frame of the truck and the rotating part of the system is located between transmission output shaft and main propeller shaft and it contain fixed disc on rotating shaft which is used to transmit rotational torque from transmission output shaft to main propeller shaft and the disc used to create retardation force due to magnetic force created by winding coil of electromagnet brake system at emergency time.

When the truck sensing unit detect existence of obstacle in front of moving vehicle the controller switched on electromagnet brake system through relay switch and current flow through winding coil of iron bar and magnetic force is created on the stationary part of the system then the created magnetic force retard the rotation of propeller shaft through modified propeller shaft rotating circular plate.

6.3.2.2 Analytical result of new modified propeller shaft

To use electro magnet brake system on propeller shaft of Isuzu truck the some modification on propeller shaft that located between output shaft of the transmission and main propeller shaft of the truck is required so for this study the schematic diagram shown and designed result of the modified part of the propeller shaft is listed on Figure 6.5 and Table 6.4 respectively.

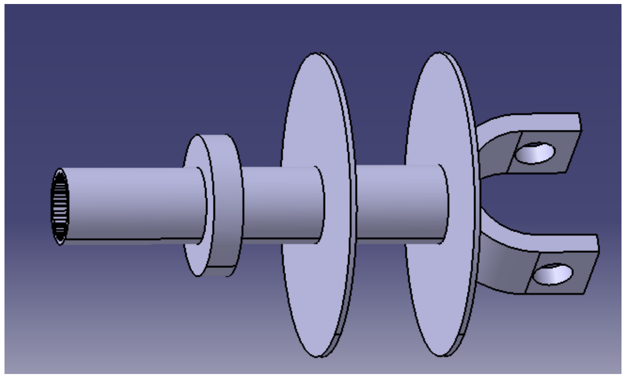


Figure 6.5: Schematic diagram of modified propeller shaft

As figure 6.5 show the modified propeller shaft consist two rigged circular plate that constricted from ferromagnetic material which helps to give perpendicular cross sectional area for produced retardation magnetic force due to activated electromagnet brake system. This circular cross section produce high retardation torque to slow or retard the rotation propeller shaft during emergency braking as a result it increase over all brake force of the truck.

Table 6.4: Analytical result of new modified propeller shaft

Part	Dimension	
Shaft	Overall length	200mm
	Inner diameter	30mm
	Outer diameter	35mm
	Thickness	5mm
Circular plate on shaft	Inner diameter	35mm
	Outer diameter	150mm
	Thickness	5mm
	mass	0.9 Kg
Spline	Depth	3mm
	Width	8.5mm
Winding coil cover	Thickness	6mm
	Inner diameter	150mm
	Outer diameter	156mm

6.3.2.2. Numerical result of new modified propeller shaft

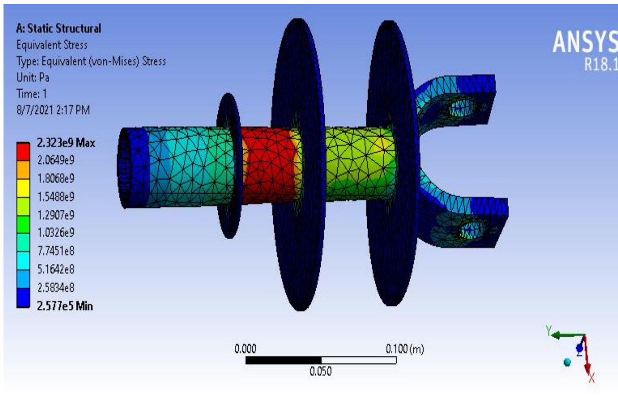


Figure 6.5(A): equivalent stress

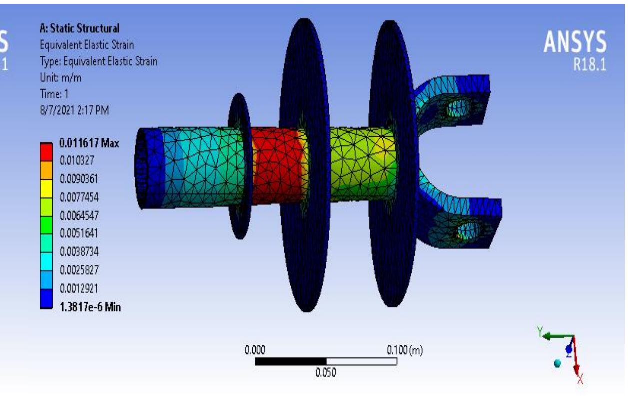


Figure 6.5(B): equivalent strain

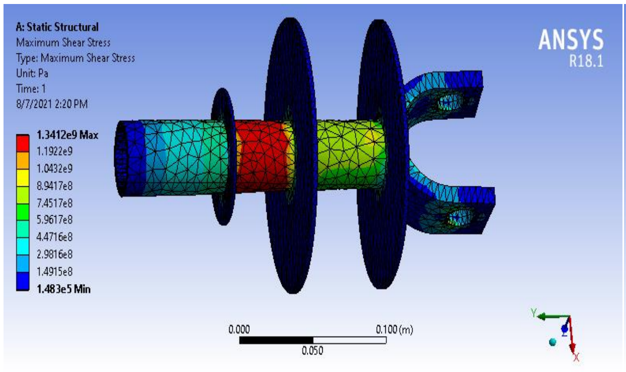


Figure 6.5(C): maximum shear stress

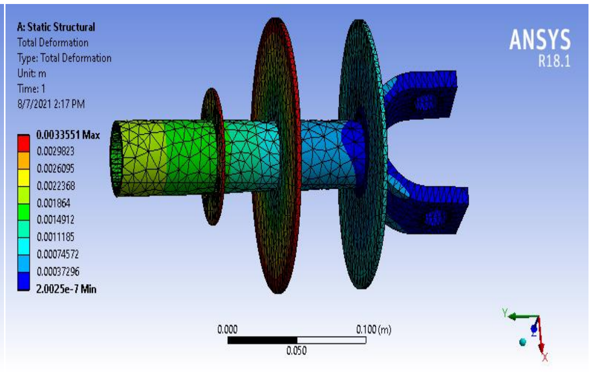


Figure 6.5(D): total deformation

As shown in Figures 6.5 A-D the equivalent stress, equivalent strain, maximum shear stress, and maximum deformation for new modified propeller shaft part is checked by using CFD ANSYS software to decide the selected material is good or not. So based on above figure equivalent stress, equivalent strain, maximum shear stress, and maximum deformation is 2.4 GPa, 0.11,1.4 GPa, and 0.0033 m. There for based on obtained results the selected material for new modified propeller shaft is good for required purpose.

6.3.2.3 Analytical result of winding coil of electromagnet brake system

Winding coil is the main part of electro magnet brake system, it generate magnetic force due to current flowing through the winding. For this study 8 winding coil is constructed to produce required retardation magnetic force against rotation of propeller shaft. The designed winding coil and winding coils on housing of electro magnet brake system is shown on figure 6.6.

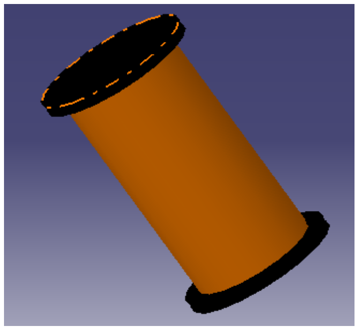
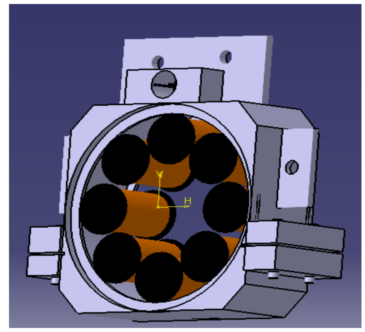
A  B 

Figure 6.6: (A) single winding coil (B) several wing coil in housing

Table 6.5: Analytical result of winding coil of electromagnet brake system

Part	Parameters	Dimension(quantity)
Iron bar	Length	50mm
	inner diameter	15mm
	Outer diameter	30mm
Wire	Diameter	1mm
	length	24,300mm
	area	$0.758mm^2$
Winding coil	Number of turn	345 turn
	Length of coil	46mm
	Resistance of coil	0.52Ω
	Voltage from battery	12V
	current	23.56A

Table 6.5 present that the design result of electromagnet brake system winding coil and iron bar that used to produce magnetic force due to flow current. The performance of the electro magnet brake system is depend on those newly designed device and its parameters.

6.3.2.4 Magnetic field strength and magnetic force result of electromagnet brake system

Magnetic force (Retardation force) is the amount of force that required to retard or slow rotation of propeller shaft by using magnetic force principle. The total retardation magnetic field strength and magnetic force of electromagnetic brake system is calculated in previous chapter and the result is presented as follow.

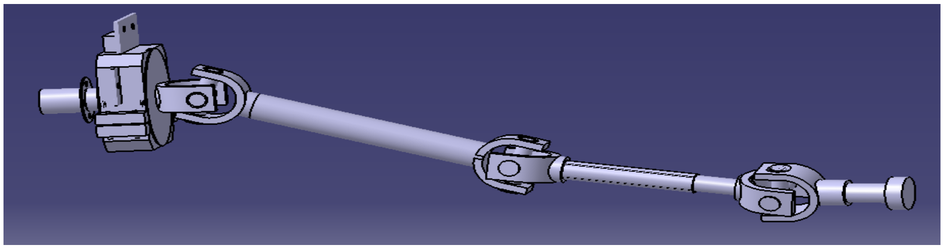


Figure 6.7: propeller shaft equipped with electromagnetic brake system

As shown in Figure 6.11 the electromagnetic brake system is mounted on frame and the modified propeller shaft is free to rotate through electromagnetic assembly when the system is not activated .The electromagnet brake is mounted between the two circular plates and ,when the electromagnet winding coil activate/energies' duet to emergency brake system controller the magnetic force created on winding coil and that created magnetic force retard the rotation of propeller shaft through the circular plate that casted with the new designed propeller shaft.

Table 6.6: Magnetic field strength and magnetic force result of electromagnetic brake system

Determined parameter	Obtained results On each winding coil	Obtained results On total number of winding coil (8)
Magnetic field strength (B),Tesla	2.015 Tesla	16.12 Tesla
Magnetic field density (Φ)	$1.51*10^{-6}$ T/m^2	$1.2 *10^{-5}$ T/m^2
Magnetic force acting on two rotating circular plate of propeller shaft (B),N	1,136 N	18,176N
Gap between electro-magnetic coil and circular late on modified propeller shaft	-	5mm
Retardation torque due to magnetic force of the system ,(Nm)	170Nm	1,363Nm
Retardation efficiency	-	40%

Table 6.6 presented that Magnetic field strength, magnetic force result and retardation efficiency of electromagnet brake system based on the table the maximum magnetic field strength and magnetic force on each winding coil is 1,136 N and 2.015 tesla respectively. Finally the retardation efficiency of the electromagnetic brake system is 40%.

6.3.2.5 Effect of electromagnetic brake system in rotation of propeller shaft

Effect of electromagnet brake system in rotation of propeller shaft is calculated on previous chapter, then on this portion the result of calculation and effect of electromagnet brake system in rotation of propeller shaft is stated by using table and graph

Table 6.7: Effect of electromagnet brake system in rotation of propeller shaft

Original rotational speed of propeller shaft,(rpm)	Retardation torque due to magnetic force,(Nm)	New rotational speed of propeller shaft after electromagnetic activated (Np -(η * 1000rpm), η= 0.34
0	0	0
1000	1,363	660
1500	1,363	1,160
2000	1,363	1,660
2500	1,363	2,160

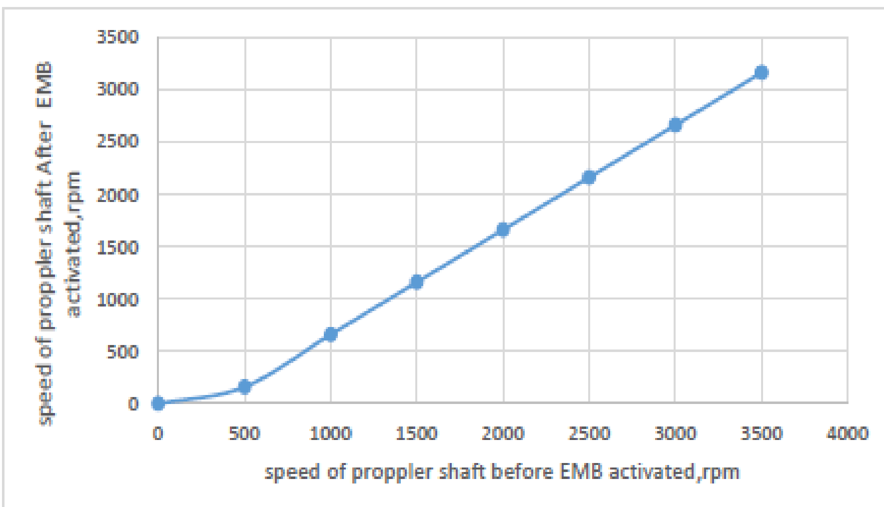


Figure 6.8: Graph of speed of propeller shaft before and after EMB system is activated

In Figure 6.8 is shown that effect of electromagnetic brake system on rotation of propeller shaft. The electromagnet brake system is one of the auxiliary brake system on this study and when it is activated it produce magnetic force that reduced the rotation of propeller shaft so based on above graph when constant electromagnetic force apply on rotating disc of modified propeller shaft the rotation of propeller shaft start to reduce from previous rotational speed.

6.3.2.6 Effect of electromagnetic brake system on stopping distance

The stopping distance of the truck is dependent on initial speed of the truck and brake force of the truck, in this section the stopping distance of the truck with and without electromagnetic brake system is discussed by using the following table and graph

Table 6.8: Effect of electromagnetic brake system on stopping distance

Truck moving speed , (km/Hr)	Stopping distance **without** electro-magnet brake system ,(m)	Stopping distance **with** electro-magnet brake system, (m)	Reduced stopping distance due to electro-magnet brake system, (m)
0	0	0	0
20	7.7	2.3	5.4
40	20	8	12
60	36.7	17.7	19
80	58	31	27
100	83.7	47.7	36
120	112	66.6	45.4

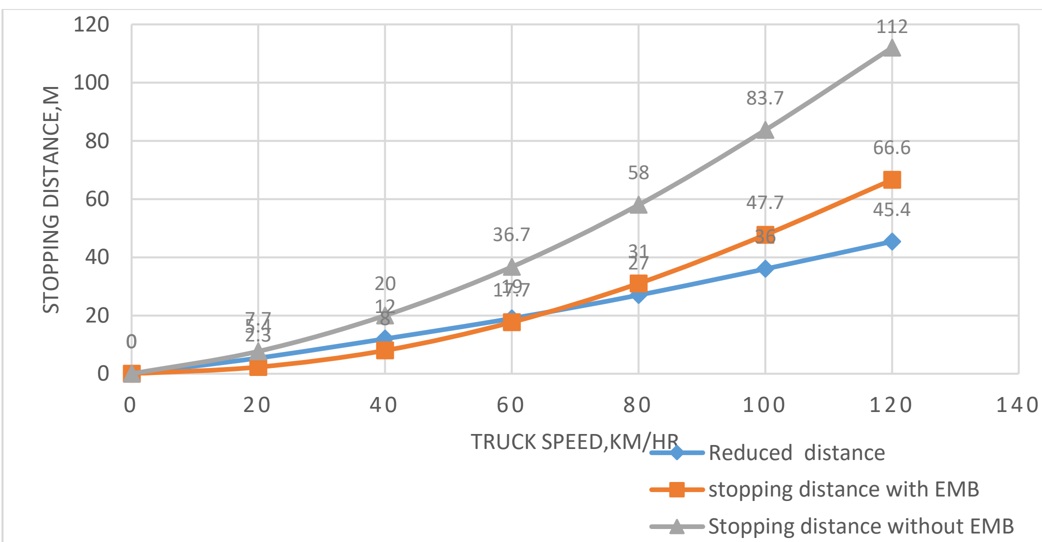


Figure 6.9: Graph of Effect of electromagnetic brake system on stopping distance

The retardation force due to electromagnetic force in addition to main brake system of the truck affect the stopping distance of the truck. Figure 6.9 shown that effect of using electro magnet brake system as auxiliary brake for reduction of stopping distance. The electro magnet brake system reduce the stopping distance by reducing the reaction distance due to automatic actuating mechanism and by adding retardation force as brake force, due to those factor the electro magnet brake system reduce stopping distance of the truck at emergency braking.so based on above figure the reduced stopping distance is an average of 39.5 % from stopping distance of the truck without electromagnet brake system. There for using electro magnet brake system as auxiliary brake has a great advantage for reducing of stopping distance, and occurrence of collision or accident at emergency braking.

6.3.3 Analytical and numerical result of automatic wind deflector

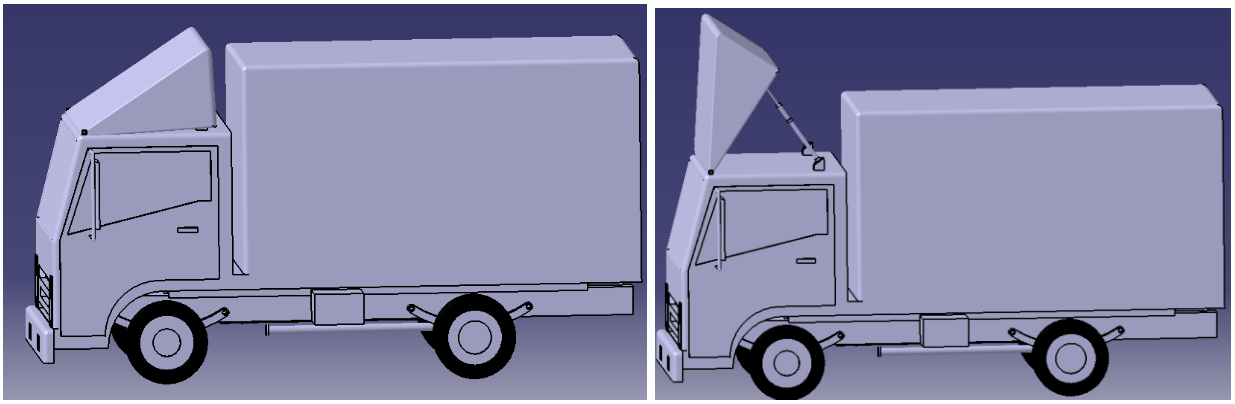
The automatic wind deflector on this study used for reduction of aerodynamic drag and auxiliary brake. The designed parameter of this automatic wind deflector, its effect on reduction of aerodynamic drag and lift (when it operate at normal condition) ,its effect on stopping distance and total brake force of the truck is presented on this section .

6.3.3.1 Discussion about working principle of automatic wind deflector

The automatic wind deflector on advanced emergency brake system is one of the auxiliary brake system that used to support the main brake system by using aerodynamic drag force on wind deflector. The aerodynamic drag force is a force that occur in front of the truck and it make resistant for moving trucks and it affect fuel consumption and emission of the trucks due to resistant force.

Automatic wind deflector used in this study is used for two main purpose the first purpose is to reduce the effect of aerodynamic drag force on a truck by giving aerodynamic effective shape for the truck secondly by using an electro-mechanical control system change the angle of inclination of wind deflector from 30^0 to 90^0 through pneumatic cylinder to increase frontal area of truck and using the drag force as additional brake force for the truck to stop the truck at desired or optimum stopping distance to reduce occurrence of accident or collision at emergency time.

When the truck sensing unit detect existence of obstacle in front of moving vehicle the controller switched solenoid relay switch and solenoid valve open the compressed air pressure to the main brake stem (wheel brake camber) and pneumatic cylinder of automatic wind deflector. Then the air pressure from compressor to pneumatic cylinder start to push piston of pneumatic cylinder and rise up the wind deflector and hold the wind deflector. The action of wind deflector at normal condition and at emergency braking is shown in figure 6.10.



A **B**

Figure 6.10: selected truck with automatic wind deflector ((A) wind deflector at normal condition and (B) wind deflector at emergency braking)

6.3.3.2 Analytical result of automatic wind deflector

Table 6.9: analytical result of new designed automatic wind deflector

part	Parameter	Result
Wind deflector	length	2200 mm
	Height	1400 mm
	Base	1100 mm
	Thickness	3 mm
	Angle of inclination	30^0
	Bending allowance	11.7 mm
Piston	Piston outer diameter	60 mm
	stroke	500 mm
	Cylinder area	2,826 mm^2

Table 6.9 shown that the analytical result of automatic wind deflector and selected pneumatic cylinder those results is obtained based on dimension of selected ISUZU truck. The new designed automatic wind deflector is mounted on roof of the truck and give the aerodynamic shape for the truck and when it actuated it increase frontal area to use drag force as brake force for moving truck.

6.3.3.3 Aerodynamic drag force due to actuated wind deflector

Aerodynamic drag force due to actuated wind deflector is used as brake force to support main brake system, hence reduce stopping distance and stopping time of truck at emergency time. The maximum aerodynamic drag force, required pressure and force of pneumatic cylinder when emergency brake system is activated is calculated in previous chapter and the result is stated on table 6.10

Table 6.10: Aerodynamic drag force due to actuated wind deflector and required pressure and force of pneumatic cylinder

Determined parameter	Obtained results On each winding coil
Aerodynamic drag force on automatic wind deflector ,N	2,074 N
Average air pressure acted on pneumatic cylinder, KPa	324 KPa
Maximum force of pneumatic cylinder to rise up and hold wind deflector	1,038 N
Braking efficiency of automatic wind deflector	2%

The drag force on actuated wind deflector produce resistance on moving truck then this resistance force slow the speed of the truck. When the wind deflector is actuated the total aerodynamic force at maximum truck speed is 2,074 N and it increase the Braking efficiency of the truck by 2%. Therefore this much force is added to the previous main brake system force in order to reduce stopping distance and stopping time of the truck at emergence so and also using automatic wind deflector as brake is essential to reduce rollover of the truck due to emergency braking.

6.3.3.4 Effect of automatic wind deflector on stopping distance

Effect of aerodynamic drag force on stopping distance of the truck is calculated and in this section the stopping distance of the truck with and without automatic wind deflector is discussed based on table 6.11 and graph

Table 6.11: Effect of automatic wind deflector on stopping distance

Truck moving speed ,(Km/Hr)	Stopping distance **without** automatic wind deflector ,(m)	Stopping distance **with** automatic wind deflector,(m)	Reduced stooping distance due to automatic wind deflector,(m),(m)
0	0	0	0
20	7.7	2.7	5
40	20	10	10
60	36.7	22	14.7
80	58	37	21
100	83.7	57	26.7
120	112	84.5	27.5

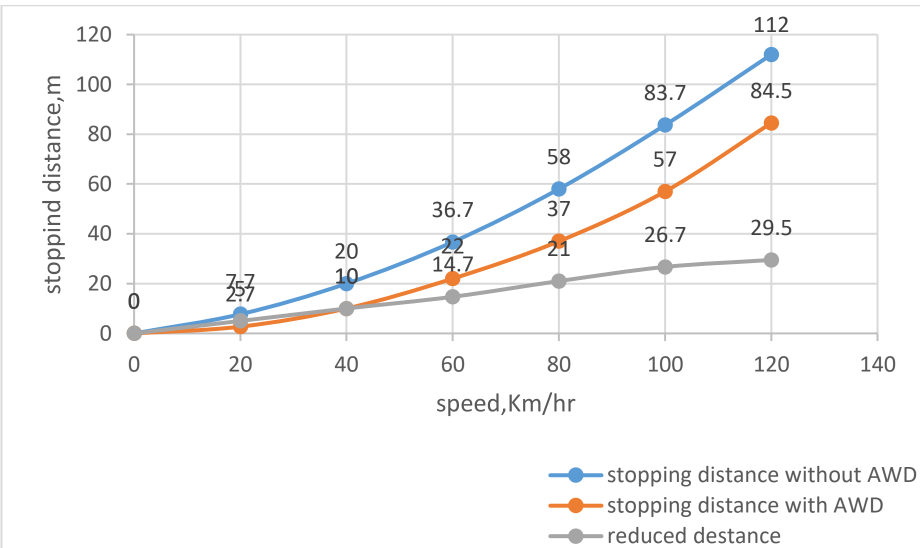


Figure 6.11: Comparison of stopping distance between truck with and without automatic wind deflector

Figure 6.11 shown that the effect of presence of automatic wind deflector on roof of the truck at emergency braking on different truck speed and Comparison of stopping distance between truck with and without automatic wind deflector.so based on above graph the advanced emergency brake system with automatic wind deflector has a great role in reduction of stopping distance compared with the truck without automatic wind deflector. The reduced amount of stopping distance is an average of 22.9 % compared with the truck without an advanced emergency brake system.

6.3.4 Analytical result of fully advanced emergency brake system

6.3.4.1 Brake force of fully advanced emergency brake system

Fully advanced emergency brake system on a truck consist main wheel brake system, automatic wind deflector, electromagnet brake system and it consist control mechanism by using sensing, controlling and actuating mechanism. The total brake force of the truck with fully advanced emergency brake system is summation of wheel brake force, aerodynamic drag force due to wind deflector and electro magnet brake system and stopping distance at different speed of the truck is calculated on previous chapter, and the result is listed on table 6.12.

Table 6.12: Brake force of fully advanced emergency brake system

Brake system component on fully advanced emergency brake system	Brake force result	Maximum Brake force of fully advanced emergency brake system
Maximum Main brake force due to wheel brake	75,460 N	95,710 N
Maximum Drag force due to automatic wind deflector	2,074 N	
Maximum Retardation force due to electro magnet brake system	18,176 N	

Table 6.12 shown that maximum brake force that act at emergency time when an advanced emergency brake system is activated. The total amount of brake force applied to stop the truck at desired point is summation of brake force of each main and auxiliary brake system forces. The Maximum Main brake force due to wheel brake, Maximum Drag force due to automatic wind deflector, and Maximum Retardation force due to electro magnet brake system is 75,460N,2,074 N and 18,176 N respectively so based on this the total brake force of this new designed system is 95,710 N.

6.3.4.2 Comparison of brake force and braking efficiency of truck with and without advanced emergency brake system at maximum speed

Table 6.13: Comparison of brake force and braking efficiency of truck with and AEBS for Isuzu truck

Brake system component	Brake force on without **advanced emergency brake system**	Brake force on with **advanced emergency brake system**
Maximum Main brake force due to wheel brake	75,460 N	75,460 N
Maximum Drag force due to automatic wind deflector	-	2,074 N
Maximum Retardation force due to electro magnet brake system	-	18,176 N
Total brake force	75,460 N	95,710 N
Maximum stopping distance	112 m	69.9 m
Braking efficiency	68.6 %	88.8 %

From table 6.13 ,the maximum braking efficacy of a truck with advanced emergency brake system is increased by 20.2% by increasing brake force of the truck and the maximum stopping distance of the truck is reduced from 112m to 69.9m then the reduced stopping distance of the truck is 42.1.so using advanced emergency brake system for the truck is one of the best way to reduce occurrence of accident or collision because at emergency time this braking system is not driver dependent, the system itself apply brake and stop the vehicle at minimum stopping distance by using main brake and auxiliary brake systems(electromagnet brake system and automatic wind deflector).

6.3.4.3 Effect of advanced emergency brake system on braking force and stopping distance of the truck

Brake force is one of the main parameter that used to determine the stopping distance and stopping time of the truck. The stopping distance of the vehicle is inversely proportional to brake force of the truck. If a truck has high brake force the stopping distance of the truck reduced and vise verse. Using fully advanced emergency brake system that designed on this thesis has great effect on increasing of brake force as shown in table 6.14 and reduction of stopping distance of the vehicle. The brake force of the truck increased due to electro magnet brake system and automatic wind deflector and the stopping distance of the truck reduced due to auxiliary brake systems and automatic brake control system of electro mechanical control system.

Table 6.14 Effect of advanced emergency brake system on braking force

Truck moving speed ,(Km/Hr)	automatic wind deflector brake force,F_w,(N)	Electro-magnet brake Force,F_{emt},(N)	Wheel Brake force,F_B,(N)	Total brake force on advanced emergency brake system $F_{Bt}=F_w+F_{emt}+F_B$,(N)	Braking efficency η	Stopping distance with advanced emergency brake system,(m)
0	0	0	0	0	0	0
20	58	18,176	75,460	93,694	86.82%	2.3
40	235	18,176	75,460	93,871	86.9%	8.3
60	524	18,176	75,460	94,160	87.2%	17.7
80	937	18,176	75,460	94,573	87.64%	30.8
100	1,458	18,176	75,460	95,094	88.12%	47.1
120	2,074	18,176	75,460	95,710	88.69%	65.8

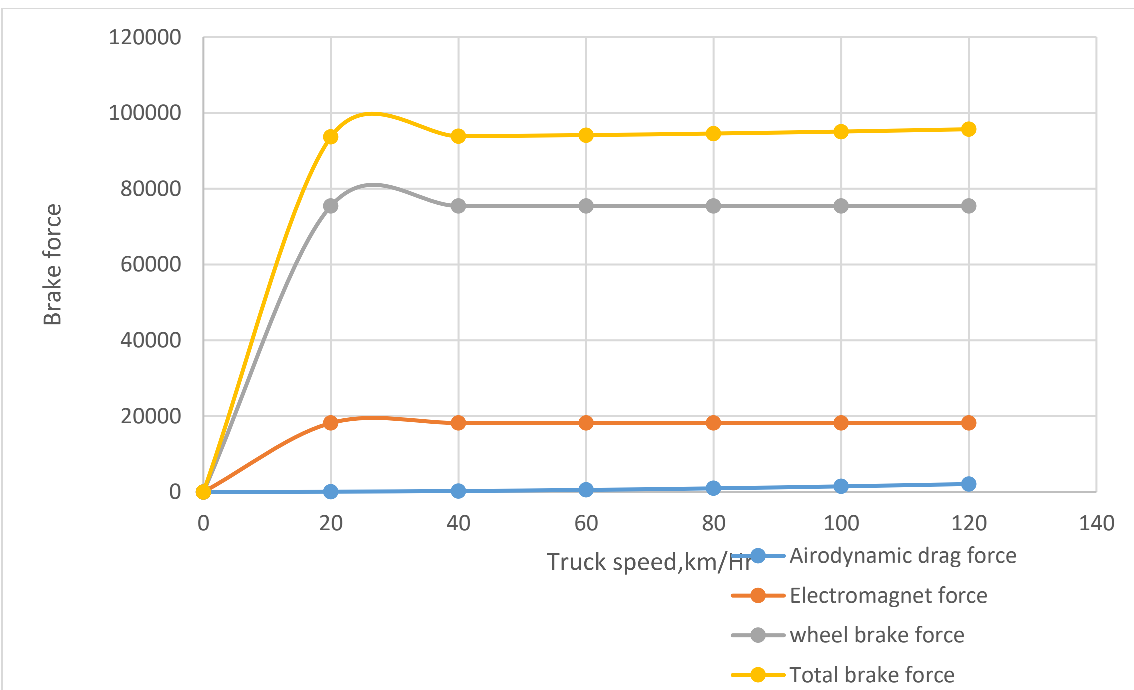


Figure 6.12 Effect of advanced emergency brake system on braking force of the truck

As Figure 6.12 show effect of using advanced emergency brake with auxiliary brake system on braking force of the truck.so based on above graph the braking force of the truck with advanced emergency brake system is increased compared with the truck without advanced emergency brake system. The increasing amount of a system due to auxiliary brake system is an average of 21.1%. This increased amount of brake force due to advanced emergency brake system also the increasing of total brake force of the truck used to increase the efficiency of the brake.

6.3.4.4 Comparison of stopping distance between a truck with and without advanced emergency brake system at different vehicle speed

Table 6.15: Comparison of stopping distance between a truck with and without advanced emergency brake system at different vehicle speed

Truck moving speed ,(Km/Hr)	Stopping distance without advanced emergency brake system,(m)	Stopping distance with advanced emergency brake system,(m)	Reduced stopping distance due to advanced emergency brake system,(m)
0	0	0	0
20	7.7	2.3	5.4
40	20	8.3	11.7
60	36.7	17.7	19
80	58	30.8	27.2
100	83.7	47.1	36.6
120	112	65.87	46.2

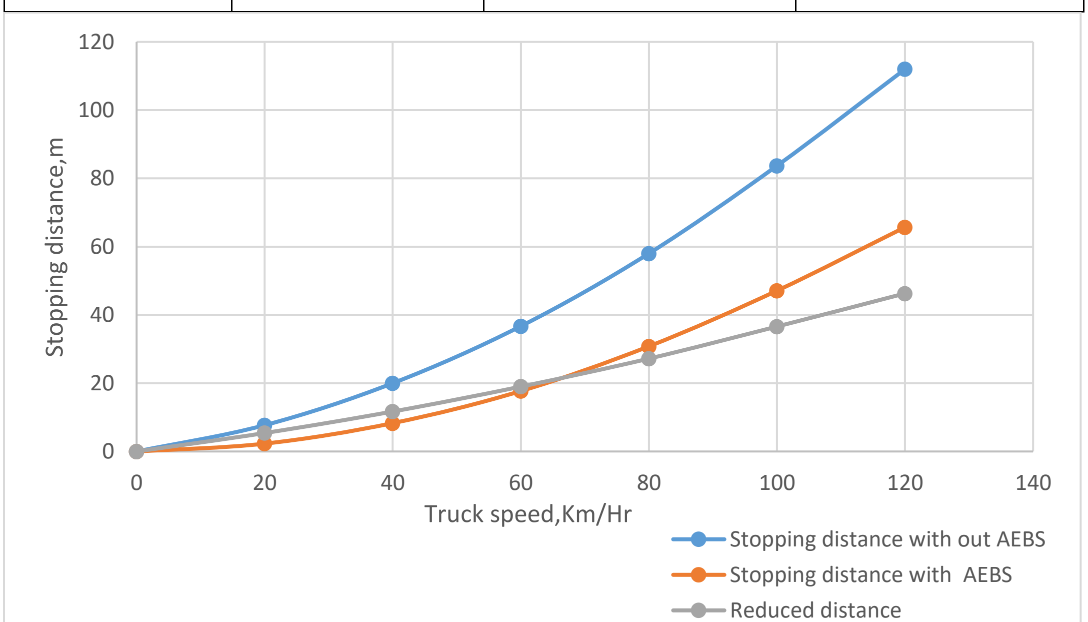


Figure6.13: Graph of Comparison of stopping distance between a truck with and without AEBS at different vehicle speed

Stopping distance of the vehicle during braking is depend on reaction and braking distance of the vehicle. The reaction distance during braking is the thinking distance of the driver to decide and apply the brake when the vehicle need to apply the brake at any condition so reaction distance can vary from driver to driver and driver condition. Reducing stopping distance of the truck is one of the main measure that take for the reduction of collision or accident.

Figure 6.13 shown that effect of advanced emergency brake system on stopping distance of the truck and comparison of stopping distance with the truck without advanced emergency brake system. Based on the graph the stopping distance of the truck with advanced emergency brake system is much smaller than the truck without advanced emergency brake system and due to the new system the reduced stopping distance of the truck at emergency time is an average of 44.2%.The reason why this system reduce this much stopping distance is it use two auxiliary brake system in addition to main brake system and it reduced the reaction distance of the truck during braking by using automatic brake response system .so using an advanced emergency brake system for the truck has a great role in reduction of stopping distance and time of the truck at emergency time as a result of this it play a great role in reduction of accident or Collison during emergency time.

6.3.4.5. Effect of individual auxiliary brake systems on advanced emergency brake system for Isuzu truck

Table 6.16: Effect of each auxiliary brake systems on advanced emergency brake system for Isuzu truck

Truck moving speed ,(Km/Hr)	Stopping distance of advanced emergency brake system with only EMB,(m)	Stopping distance of advanced emergency brake system with only AWD,(m))	Stopping distance of advanced emergency brake system with only EMB and AWD,(m)
0	0	0	0
20	2.3	2.7	2.3
40	8.7	10	8.3
60	17.7	22	17.1
80	31	37	30.8
100	47.7	57	47.1
120	66.6	84.5	65.87

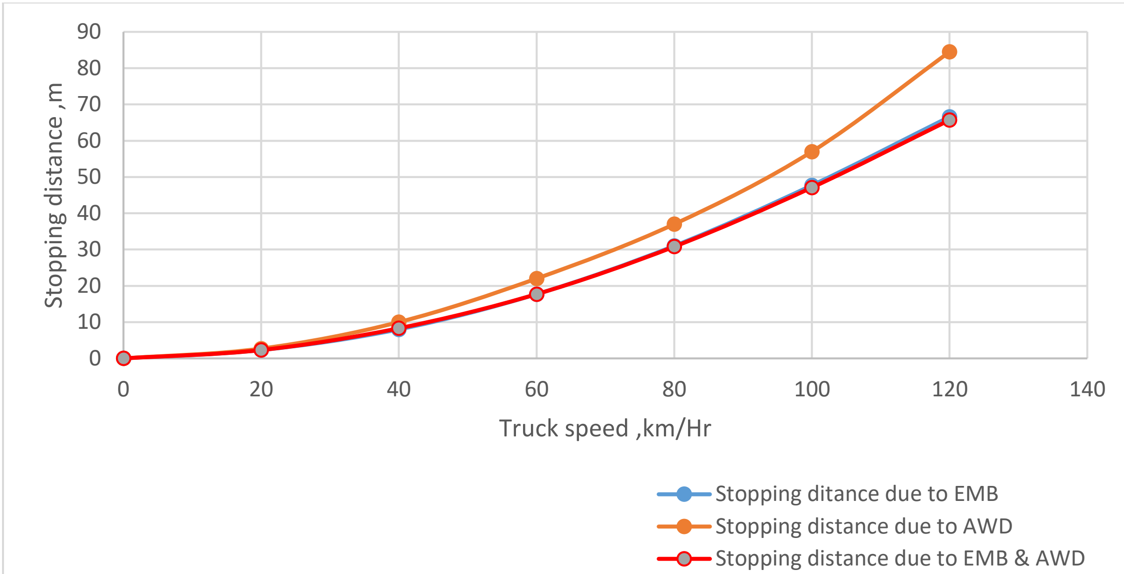


Figure 6.14: Effect of each auxiliary brake systems on advanced emergency brake system for Isuzu truck

When the truck equipped an advanced emergency brake system for avoidance of accidental collision or accident, each auxiliary brake system (automatic wind deflector and electromagnet brake system) has its own role in addition to main brake system of the vehicle (wheel brake of the truck).the automatic wind deflector used to reduce speed of the truck and the rollover of the truck at emergency braking by using aerodynamic drag force in front of the moving truck as a brake. Electro magnet brake system in advanced emergency brake system used to retard rotation of propeller shaft by using electromagnetic principle based on controller command. The auxiliary brake system has effect on stopping distance of the truck at different truck speed has shown on table and graph. Then based on above graph shown on figure 6.14 the average stopping distance due to automatic wind deflector, due to electromagnet brake system and due to both auxiliary brake systems is 34m, 28.5, and 28m respectively.

6.3.4.6. CFD Results of ISUZU truck at different conditions

There are three conditions that used on this study to check effect of automatic wind defector on aerodynamic drag, aerodynamic lift, pressure contour, and velocity contour. Those conditions are ISUZU without automatic wind deflector, ISUZU truck with automatic wind deflector and ISUZU truck with actuated automatic wind deflector. And also on each condition effect of automatic wind deflector is analyzed on three different truck speed (30 km/hr, 60 km/hr, and 120 km/hr)

I. CFD Results of ISUZU without automatic wind deflector

A. Residual history

Analyzing the residual trends is one of the most fundamental measures in determining whether a solution is converge or not.it directly quantify the error in the solution of the system of equation. The convergence criteria were satisfied when all the value goes constant without make difference. Residual history of ISUZU without wind deflector at speed of 30kmphr, 60kmphr, and 120kmphr is shown in below graphs.

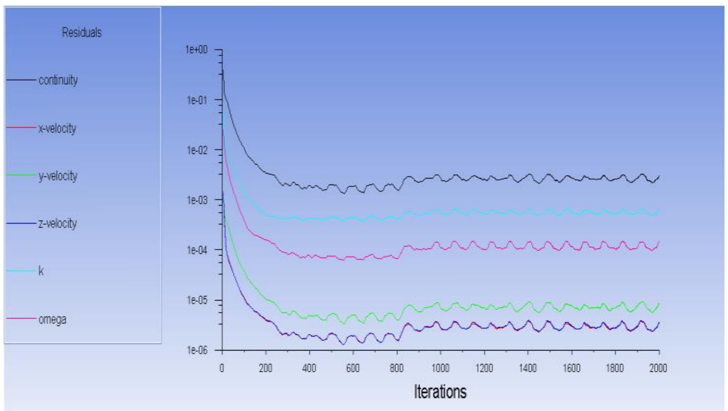


Figure 6.15: Residual history of the truck without wind deflector at 120 kmp

The scaled residual graph shown in Figures 6.15 for the truck without wind deflector at 30kmphr, 60kmphr, and 120kmphr show how the parameter converge with each iteration .It is sure that the convergence for this case was already achieved after 500 iteration.

B. Drag Coefficient

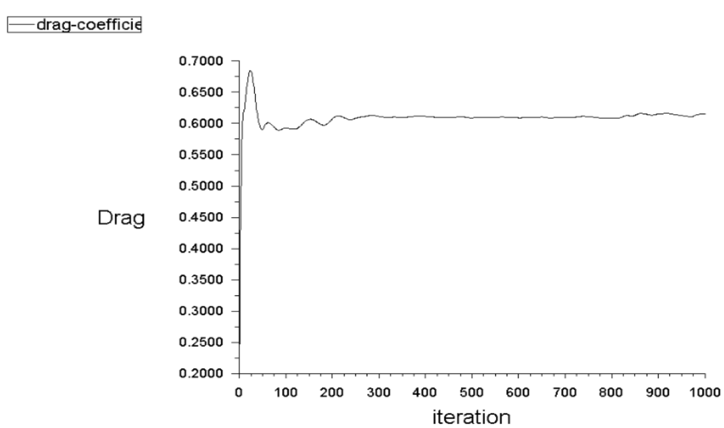


Figure 6.16: Drag coefficient of the truck without wind deflector at 120 kmph

C. Lift Coefficient

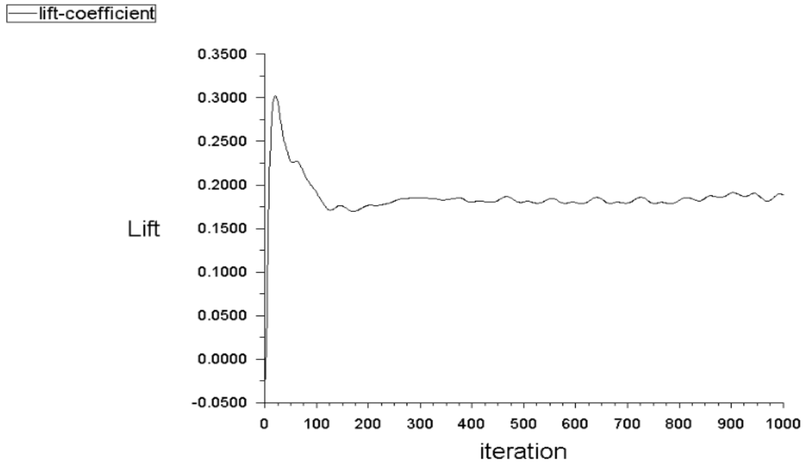


Figure 6.17: Lift coefficient of the truck without wind deflector at 120 kmph

All above graph indicate Figure 6.17 the drag and lift coefficient of the Isuzu without wind deflector at speed of 120kmphr.The lift and drag coefficient start to converge start from 500 iteration here the drag and lift coefficient are summarized below table 6.17.

Table 6.17: Drag and Lift coefficient of truck without wind deflector at various speeds

Truck	Speed of truck	Drag Coefficient	Lift Coefficient
Truck without wind deflector	30 Km/hr	0.638	0.214
	60 Km/hr	0.636	0.224
	120 Km/hr	0.632	0.231

As shown in the table 6.17 the drag and lift coefficient of the truck without wind deflector were listed. Then based on this result the drag coefficient of the truck without wind deflector is decreasing with increasing of speed .However the lift coefficient of the truck without wind deflector is increasing with increasing of speed of the truck. The increasing of lift coefficient with increasing of truck speed can be cause instability of truck at high speed.so it need some modification to reduce lift coefficient to reduce instability of truck when it move at high speed.

D. Pressure Contour

Pressure contour is one of the parameter of aerodynamic analysis that used to determine the pressure distribution on body of the truck.

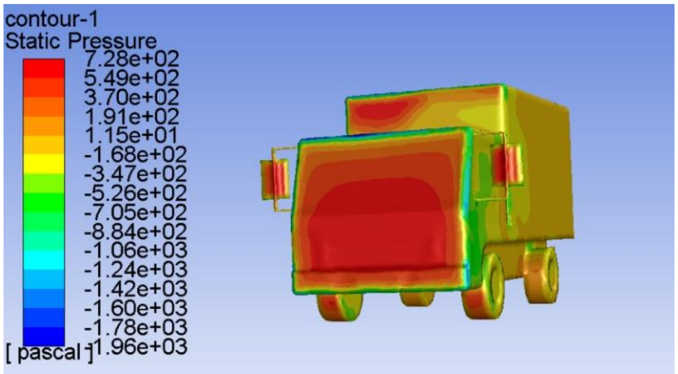


Figure 6.18: Pressure contour of the truck without wind deflector at 120 kmph

From the Figure 6.18 observed that the pressure distribution at different speed on the body of the truck without wind deflector. The pressure contour plot on above figures indicate that the pressure on the front end of the truck is maximum as the air flowing toward the truck. And pressure distribution on the rare of the truck is very small (negligible) which compared with the front part of the truck. With increasing of the speed the pressure distribution and flow separation zone on the frontal end of the truck is increased as above figures shown.

E. Velocity Contour

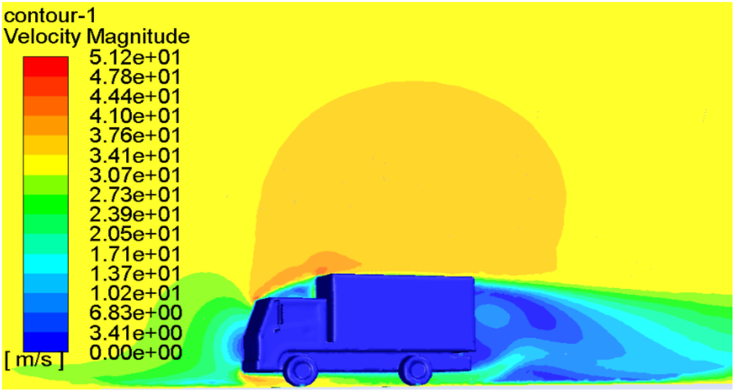


Figure 6.19: Velocity contour of the truck without wind deflector at 120 kmph

Velocity contour is one of CFD analysis parameter which is used to make analysis based on visualization of an air flow around body of the truck. Visualization of path line provide important information about the flow structure. On velocity contour it's possible to determine streamed line flow, separation and recirculation, and voracity generation. In Figure 6.19 shown that the velocity contour of the truck without wind deflector. The color indicate the magnitude of velocity .blue color of contour represent the minimum velocity, the green color in the contour represent the velocity close to input truck velocity and the red color represent the maximum velocity area.so based on a above three figures the maximum velocity for truck without wind deflector in the flow filed due to flow separation were nearly and also the air velocity distribution around a truck is maximum at upper part of the truck and it is minimum on side and lower part of the truck.

II. CFD Results of ISUZU with wind deflector

On this condition the wind deflector act as reducer of aerodynamic drag force by giving aerodynamic shape for the moving truck.

A. Residual history

The residual history on CFD analysis is used to determine the convergence of the result at different iteration point. The graph shown below is the residual history of a truck with wind deflector.

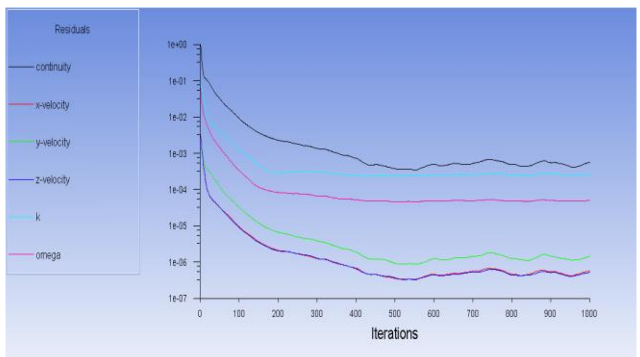


Figure 6.20: Residual history of the truck with wind deflector at 120 kmph

Figures 6.20 show the convergence of the truck with wind deflector at speed of 120 km/hr .so Based on above figures the convergence of the result is begin on iteration 500. The Residuals show the difference of some quantity from one solution iteration to the Next.

B. Drag Coefficient

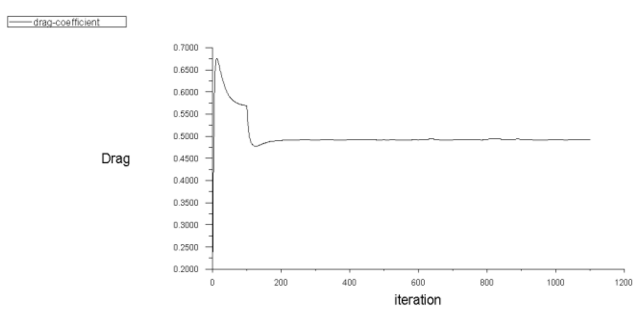


Figure 6.21: Drag coefficient of the truck with wind deflector at 120 kmph

C. Lift Coefficient

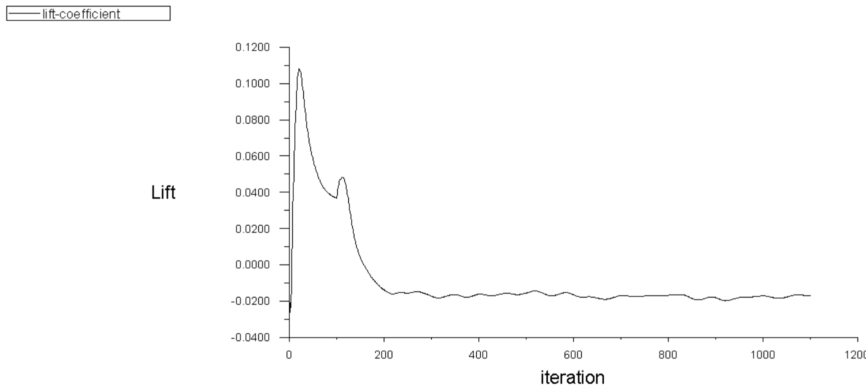


Figure 6.22: Lift coefficient of the truck with wind deflector at 120 kmph

Drag coefficient is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment, such as air or water. It is used in the in which a lower drag coefficient indicates the object will have less aerodynamic. And lift coefficient is a dimensionless coefficient that relates the lift generated by a lifting body to the air density around the body, the air velocity and an associated reference area.

Table 6.18: Drag and Lift coefficient of truck with wind deflector at various speeds

	Speed	**Drag Coefficient**	**Lift Coefficient**
Truck with wind deflector	30 Km/hr	0.485	-0.019
	60 Km/hr	0.482	-0.0189
	120 Km/hr	0.479	-0.0191

As shown in the table 6.18 ,the drag and lift coefficient of the truck with wind deflector were found to be 0.485,0.482,0.481, and -0.019,-0.0189,-0.0191 respectively then based on this result the drag coefficient and lift coefficient of the truck with wind deflector is decreasing with increasing of speed. The decreasing amount of drag and lift coefficient due to wind deflector is 0.153, 0.154, 0.156 and 0.233, 0.243, 0.251 respectively at speed of 30kmphr, 60kmphr, and 120kmphr . Due to wind deflector the decreasing of lift coefficient is greater with increasing of truck speed then it can be used for stability of truck and comfort ride. There for based on the above table and figure results using wind deflector on top of the truck is very important to minimize drag and lift coefficient and also it is important for truck stability in high driving speed at normal condition.

D. Pressure Contour

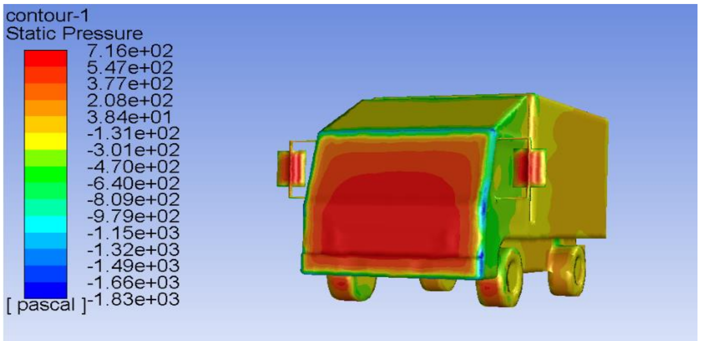


Figure 6.23: Pressure contour of the truck with wind deflector at 120 kmph

Pressure contour on CFD analysis used to determine pressure distribution of air around the truck. Figure 6.23 show the pressure distribution around the truck when he truck move at 120kmphr.It is depicted from the above figures that, magnitude of pressure on the truck is more in front surface than that of the incoming flow stream. The maximum static pressure distribution created on front portion of the truck is increased when the speed of the truck is increased. But compared with the truck without wind deflector the static pressure distribution of the truck with wind deflector on front end of the truck is reduced. There for using wind deflector also important to reduce pressure distribution on front end of the truck.

E. Velocity Contour

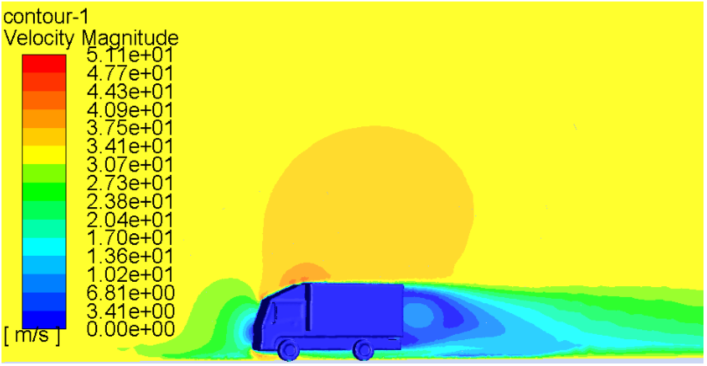


Figure 6.24: velocity contour of the truck with wind deflector at 120 kmph

Figure 6.24 show cross section contours of velocity and indicates that the velocity above the upper surface is greater than the lower surface and the velocity distribution increase with increase speed of truck. But the velocity distribution of the truck with wind deflector around the truck is reduced as compared with the truck without wind deflector.so using wind deflector for truck has also great advantage in reducing of velocity distribution.

III. CFD Results of ISUZU with actuated wind deflector

The main aim of this analysis portion is to show effect of wind deflector at emergency braking time on drag and lift coefficient, pressure and velocity contour, and stability of truck at emergency braking time.as mentioned before at emergency time the advanced emergency brake system activate all main and auxiliary emergency braking systems to reduce occurrence of collision or accident at emergency time. The wind deflector at emergency braking time become rise up through pneumatic cylinder and increase frontal area of truck to use the drag force as brake force then the effect of wind deflector at different truck speed is discussed below by using CFD analysis graphs.

A. Residual history

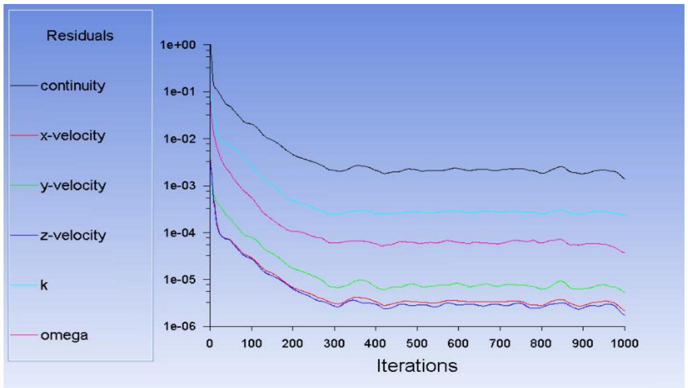


Figure 6.25: Residual history of the truck with actuated wind deflector at 120 kmph

The residual result of the CFD analysis of the truck with actuated wind deflector that show the convergence of the result is plotted in Figure 6.25.so based on this result the convergence of the results for simulation of truck with actuated wind deflector is start at 600 iteration after this iteration the results become converge.

B. Drag Coefficient

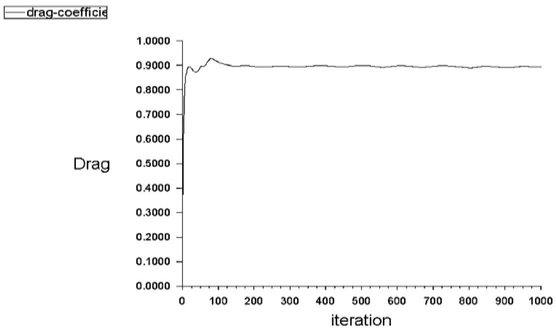


Figure 6.26: Drag coefficient of the truck with actuated wind deflector at 120 kmph

C. Lift Coefficient

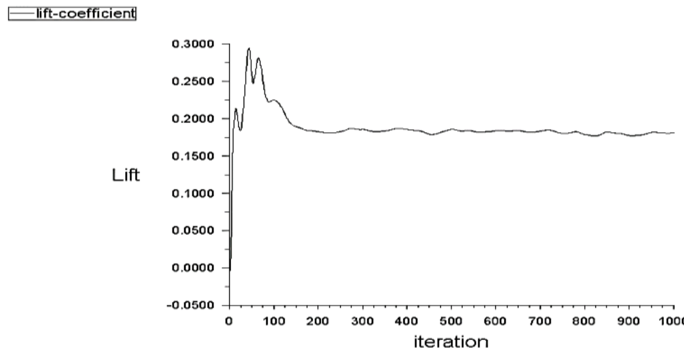


Figure 6.27: Lift coefficient of the truck with actuated wind deflector at 120 kmph

Figure 6.26 and 6.27 shown the result of drag and lift coefficient of truck with actuated wind deflector at different speed of truck(120kmphr).as mentioned before when the wind deflector rise up it increase frontal area of truck and the drag force then the value of drag coefficient increased and lift coefficient will decrease. Here the drag and lift coefficient are summarized below table

Table 6.19: Drag and Lift coefficient of truck with wind deflector at various speeds

Truck	Speed of truck	Drag Coefficient	Lift Coefficient
Truck with actuated wind deflector	30 Km/hr	0.801	0.187
	60 Km/hr	0.892	0.185
	120 Km/hr	0.910	0.184

As shown in the Table 6.19, the drag and lift coefficient of the truck with wind deflector were listed based on this result the drag coefficient and lift coefficient of the truck with wind deflector is increasing and decreasing with increasing of speed respectively. The average increasing amount of drag coefficient is 34.8 % and decreasing amount of lift coefficient is 73.1% due to actuated wind deflector and 73. %.But compared with the truck without wind deflector the lift coefficient of the truck with actuated wind deflector is reduced an average of 17 % then truck stability during braking is good when the truck equipped wind deflector .and also the drag coefficient is increased an average of 28.1 % which compared with the truck without wind deflector. There for based on the above table and figure results using wind deflector as auxiliary brake system has great role on supporting of the conventional (main)brake system ,reduction of stopping distance reduction of stopping time as well as reduction of accident or collision of truck at emergency time.

D. Pressure Contour

One of the main aim of using automatic wind deflector is to increase pressure distribution by increasing aerodynamic drag force on front part of the truck increased during emergency brake .when the pressure distribution of air increased on front head of the truck the moving speed of the truck start to reduced and reduce the rollover of the truck that caused due to weight transfer during braking.

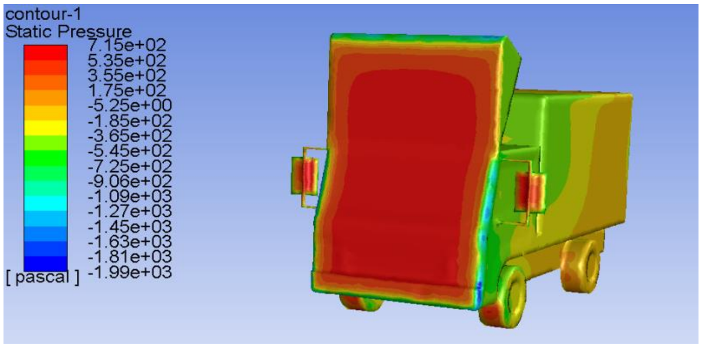


Figure 6.28: Pressure contour of the truck with actuated wind deflector at 120 kmph

The Pressure contour shown in Figure 6.28 indicate the level of pressure distribution effect on the surface of the truck with actuated wind deflector and based on those figure the pressure distribution is maximum on front end of the truck with actuated wind deflector and the pressure distribution is become increasing with increasing of speed. When the pressure distribution on the truck of with actuated wind deflector is compared with the truck without wind deflector and truck with normal acting wind deflector, it is smaller because when the truck wind deflector is actuated it increase frontal area of the truck so in general sense the pressure distribution is decreased with in increasing of area.

E. Velocity Contour

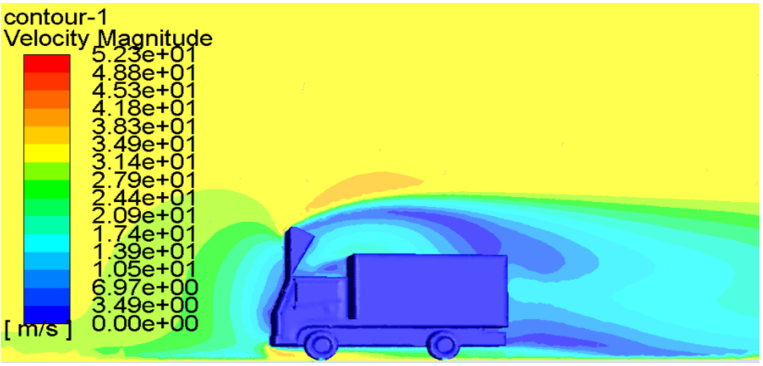


Figure 6.29: velocity contour of the truck with actuated wind deflector at 120 kmph

Figure 6.29 shows velocity contour of the truck with actuated wind deflector at maximum speed of the truck. Similar with the previous trucks the velocity distribution around a truck is maximum on the top and become decreasing on orange, yellow, green and blue color region as shown on the figures. The velocity distribution on a truck with actuated wind deflector is increasing with increasing of speed of the truck. And it has high velocity distribution which compared with another truck models that discussed above.

6.3.4.7. Comparison of lift and drag coefficient of the truck at different wind deflector conditions.

The wind deflector has two major roles these are:

- ✓ During normal driving condition it improves the aerodynamic performance of the truck; for the reduction of lift and drag coefficient.
- ✓ Whereas the second role is when the wind deflector is actuated during emergency braking it will increase the drag force to prevent the truck from rolling over and increase brake force of the truck.

The comparison between drag and lift coefficient of the truck without wind deflector, with wind deflector and with actuated wind deflector are summarized in table 6.20.

Table 6.20: Drag and Lift coefficient at different condition and various speeds

	Speed	**Drag Coefficient**	**Lift Coefficient**
Truck without wind deflector	30 Km/hr	0.638	0.214
	60 Km/hr	0.636	0.224
	120 Km/hr	0.632	0.231
Truck with wind deflector	30 Km/hr	0.485	-0.019
	60 Km/hr	0.482	-0.0189
	120 Km/hr	0.479	-0.0191
Truck with actuated wind deflector	30 Km/hr	0.801	0.187
	60 Km/hr	0.892	0.185
	120 Km/hr	0.910	0.184

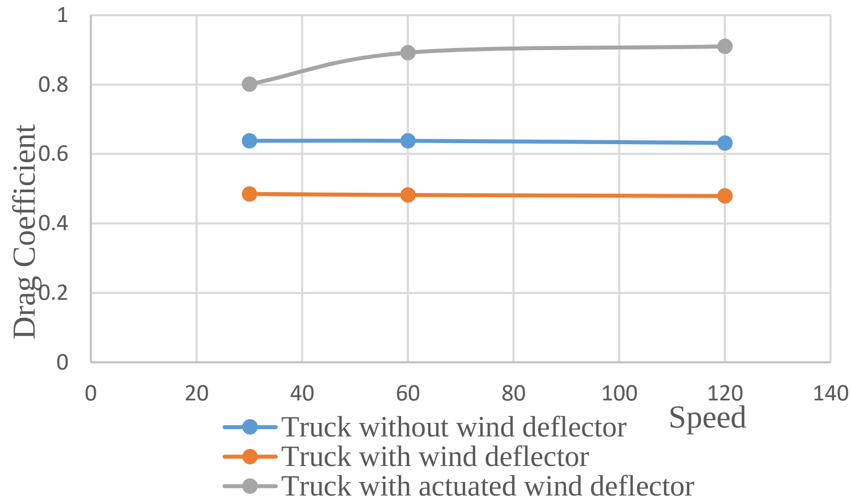


Figure 6.30: comparison of drag coefficient

Drag coefficient has effect on truck aerodynamic resistance. Figure 6.30 show the drag coefficient on different truck speed and the effect of wind deflector on a truck.so based on the graph the drag coefficient of moving truck is higher on the truck with actuated wind deflector when emergency brake system is activated then the additional drag coefficient due to actuated wind deflector help the main brake system by using drag force as brake force to minimize the rollover of the truck. And also the wind deflector at normal condition used to reduce the drag force of the truck by giving aerodynamic shape for the truck Based on this relation the average reduction of drag and lift coefficient as a result of using wind deflector is 23.6 % and 108.15% respectively then the drag and lift coefficient of the truck is smaller than the truck without wind deflector.

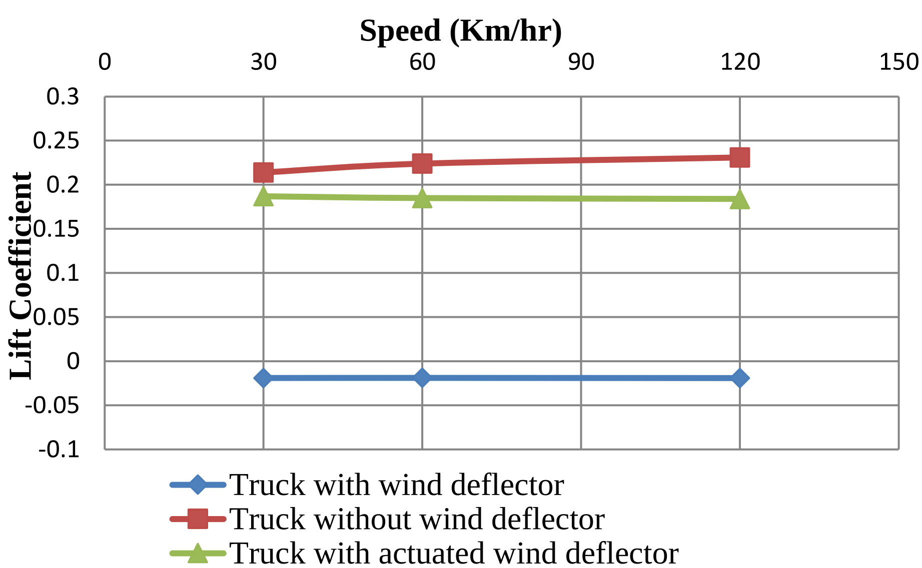


Figure 6.31: Comparison of lift coefficient

Figure 6.31 shown the lift coefficient of the truck at different speed and truck condition. The lift coefficient of the truck at different driving condition affect the stability of the vehicle so it must be minimized to reduce its effect and consequence. Based on above graph the lift coefficient of the truck with normal wind deflector position on a truck is smaller than another conditions of a truck with increasing of truck speed.

6.3.4.8. Average Drag and Lift coefficient

Therefore as it is seen from table 6.21 the result the drag and lift coefficient does no vary significantly so the average value can be considered.

Table 6.21: Average Drag and Lift coefficient

	Drag Coefficient	**Lift Coefficient**
Truck without wind deflector	0.63	0.223
Truck with wind deflector	0.481	-0.019
Truck with actuated wind deflector	0.90	0.17

Based on table 6.21 Impact of the wind deflector on improvement of drag and lift coefficient at normal condition and Impact of the actuated wind deflector on increasing of drag force is calculated as follow.

Impact of the wind deflector on improvement of drag and lift coefficient at normal condition

$$\%\ \text{Drag coefficient reduced} = \frac{0.63 - 0.481}{0.63} * 100 = 23.6\ \%$$

$$\%\ \text{lift coefficient reduced} = \frac{0.23 + 0.019}{0.23} * 100 = 108.3\ \%$$

Therefore, the wind deflector improves the drag and lift coefficient by 23.6 % and 76.19 respectively.

Impact of the actuated wind deflector

$$\%\ \text{Drag coefficient increase} = \frac{0.90 - 0.63}{0.63} * 100 = 42.85\ \%$$

$$\%\text{lift coefficient decrease} = \frac{0.223 - 0.17}{0.223} * 100 = 23.76\ \%$$

The result of CFD fluent analysis that used to check the efficiency and performance of Automatic wind deflector on truck. According to the results obtained from CFD analysis it is shown that the wind deflector improves the drag and lift coefficient of the truck. In addition to this, when it is actuated it deliver the required amount of force which is needed to prevent the truck from rolling over. Based on this result using new designed automatic wind deflector as reducer of aerodynamic drag and lift coefficient and maintaining of stability of truck at higher speed driving is effective. Wind deflector improves the drag and lift coefficient by 23.6 % and 108.15% respectively. And also using new designed automatic wind deflectors as auxiliary brake system to support main brake system is effective due to increasing of drag coefficient when it actuated at emergency braking. Actuated wind deflector increases the drag coefficient by 42.85 %.

CHAPTER SEVEN

7. CONCLUSION AND RECOMMENDATION

7.1. SUMMARY

Generally this thesis presents the implementation of advanced emergency brake system for Isuzu truck Forward Collision Avoidance, intended to use in vehicles where the drivers may not brake manually, but the vehicle can be stopped automatically due to the sensing of the obstacles. It reduces the accident levels and tends to save the lives of so many people by reducing stopping distance and increasing brake force of the truck. The Advanced emergency brake system that designed on this study consist electro mechanical control system and auxiliary brake system for reduction of stopping distance and for increasing of brake force during emergency braking.

The electro mechanical control system is used to control braking activity of truck at emergency time it is responsible for detection of obstacle, measuring speed of truck, and depending on input pulse it give command to apply brake to avoid collision or accident at emergency time. The auxiliary brake system that have been discussed on this study is used to support the main brake system of the truck at emergency time and two auxiliary brake system have been used named electro magnet brake system and automatic wind deflector.

The electromagnetic brake system used in this thesis is used only for emergency purpose to retard (slow) rotation of propeller shaft by using magnetic field created due to winding coil and current flowing through it. The outcome of the electromagnet brake system have been used as a supplementary retardation of speed of the truck in addition to regular main brake; it has higher braking efficiency and has potential regular energy lost in braking. Automatic wind deflector is another auxiliary brake system designed on this study that used to support main brake system by using drag force as brake to minimizing rollover of the truck during emergency braking and give aerodynamic shape for the truck to reduce aerodynamic drag force by using principle of electro mechanical control system as a result the fuel consumption and emission of the truck become reduced.

There are certain aspects that make this thesis different from another similar type of study those are

- its braking distance will vary depending on the speed and weight of the vehicle
- It maintains appropriate stopping distance for the emergency breaking
- It uses an automatic wind deflector as an auxiliary brake
- It use electromagnetic brake system as auxiliary brake
- It displays the length of the gap of an existing object or vehicle
- When the vehicle speed is below 20 km/hr it does not respond

7.2. Conclusion

Based on the design, modification, simulation and analytical results obtained in this study the following conclusions are drawn; it was found that:

- Reaction time of truck reduced from 1sec to 0.1 sec due to new designed electro-mechanically controlled system of advanced emergency brake system.
- Reaction distance reduced from 33.3 m to 3.3 m due to new designed electromechanically controlled system of advanced emergency brake system is from 33.3 m to 3.3 m.
- Propeller retardation efficiency of the electro magnet brake system is 40%.
- The stopping distance of the truck due to advanced emergency brake system was reduced from 112 m to 66 m; the stopping distance of the truck with advanced emergency brake system is much smaller than the truck without advanced emergency brake system and due to the new system the reduced stopping distance of the truck at emergency time is an average of 44.2%
- Braking force of truck with advanced emergency brake system increased from 75,460 N to 95,710 N due to new designed auxiliary brake system (electro magnet brake and automatic wind deflector); where Additional brake force due to electro magnet brake system and automatic wind deflector are 18,176 N and 2,074 N respectively.
- Additional brake force due to auxiliary brake system is 20,250 N; compared with brake force of the truck without advanced emergency brake system.
- Braking efficiency of truck increased from 68.6 % to 88.8% due to new designed advanced emergency brake system on a truck; the increasing amount Braking efficiency of truck is an

average of 21.1%;where Braking efficiency of truck increased due to electro magnet brake system and automatic wind deflector are 19.1% and 2% respectively.

- Average Drag coefficient of the truck without wind deflector, with aerodynamically set wind deflector (wind deflector at normal driving condition), and actuated wind deflector (wind deflector during emergency braking) is 0.63, 0.481, and 0.9 respectively. The drag coefficient of the truck when the wind deflector is at normal setup due to new designed Automatic Wind deflector improves by 23.6 % compared with the truck without wind deflector and the drag coefficient of the truck when wind deflector is actuated at emergency braking it increased by 42.2%.This increased amount of drag coefficient had great role for reduction of stopping distance at emergency braking.
- Average lift coefficient of the truck without wind deflector, with aerodynamically set wind deflector, and actuated wind deflector is 0.21, -0.019, and 0.17 respectively. The lift coefficient of the truck when the wind deflector is at normal condition it reduced by 108.15% .The lift coefficient of the truck when wind deflector is actuated at emergency braking it increased by 23.76%. The reduction of lift coefficient is necessarily used for the stability of the truck.

Finally these newly designed components to the case vehicle ISUZU truck will be of paramount importance for reduction of car collision or accident avoidance remarkably by using its intelligence electro mechanical controlled system and new designed auxiliary brake systems and the effective operating condition of the system can be vary by using the controller program based on different road, loading, traffic condition and speed limit.

7.3. RECOMMENDATION

If truck equipped with advanced emergency brake it will play a great role for reduction of collision or accident that caused by over speed driving and delay of the driver to apply the brake at emergency time by giving the responsibility to Intelligence Sensors, controller and actuators. it will apply main brake and auxiliary brake automatically and stop the Vehicle in advanced as a result it stop the truck at lower stopping distance by using higher braking force due to auxiliary brake systems.; as well as it used to support the driver to reduce the fatigue in different driving condition by give warning alarm first and take decision if distance of impact is closing.

There for by using this newly designed advanced emergency brake system for ISUZU truck for our country it is possible to reduce the occurrence of collision and accident that occur in different region and city due to over speed driving and driver errors. And also by using this study it is also possible to reduce the consequence of accident such as loss of several life, injuries, and economic loss. Finally I recommend that every responsible organization such as Adama science and Technology University, Ethiopia road authority, small or medium microenterprises to take the responsibility to implement this newly designed emergency brake systems in real truck and reduce the occurrence of accident or collision because of discussed reasons.

7.4. SCOPE OF FUTURE RESEARCH

The primary goal of this project has been to develop an advanced emergency brake for Isuzu truck. The research objectives for the development of the newly designed advanced emergency brake; design and development of control system and auxiliary brake systems were fulfilled, but the system has some limitations that could not be addressed within the project timeframe the limitation include effectiveness of the system is not tested on real truck, the meshing node for CFD ansys to get the maximum efficiency of the new designed wind deflector was small due to computer system limitation ,and cooling system for electromagnetic brake system is not designed. Therefor for the future work researcher can work on the following scope.

- Teste the system in real truck; the system itself works as it was designed, but the electronic components are only suitable for a prototype in laboratory conditions. Before the system can be tested in real application the electro mechanical control system must be designed based on real truck and driving condition.
- Taste the performance and evaluate the effectiveness of this newly designed emergency brake system in real truck according to reduction of accident or collision and doing some further modification using this system for other types of vehicle may have a good outcome.
- Conduct research on optimization of the efficiency of this newly designed electromagnetic brake system and
- Conduct research on Optimization of effect of wind deflector in different angle of attack, different shape and different vehicle that not covered on this study.
- Design cooling system for the electromagnetic brake system.

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APPENDIX – A

The following tables contains the specifications of the selected truck for this study (ISUZU f34-series truck) and external body dimension of selected truck.

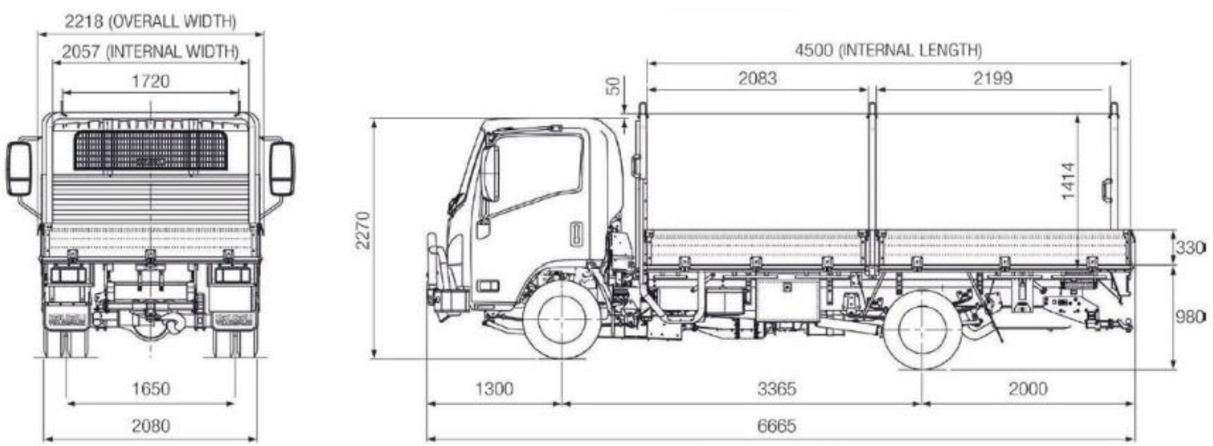
Table A -1. ISUZU FSR 34-N Technical Specifications

Performance	
Max Power	237 bhp
RPM at Max Power	2400 rpm
Max Torque	706 Nm
Displacement	7790 cc
RPM at Max Torque	1450 rpm
Fuel Type	Diesel
Dimensions & Capacity	
Gross Weight	11000 Kg
Payload	7100 kg
Overall Height	2680 mm
Fuel Tank Capacity (litres)	200
Wheelbase	4770 mm
Overall Length	8155 mm
Suspension & Brakes	
Rear Suspension	Multi-Leaf
Chassis Type	Chassis with Cabin
Brakes	Air Brakes
Parking brakes	Yes
Tiltable Cabin	No
Front Suspension	Multi-Leaf
Cabin Type	Day Cabin
Seat Type	Standard
Wheel & Tyre	
Front Tyre	8.25-R20-14PR
Rear Tyre	8.25-R20-14PR

Engine Details	
Number of Engine Cylinders	6
Engine	6-Cylinder In-Line, Common-Rail Direct Injection,
TRANSMISSION gear ratio	
1st	6.615
2nd	4.095
3rd	2.358
4th	1.531
5th	1.000
6th	0.722
Reverse	6.615
Final	5.571

Table A-2. Body dimension of Isuzu f-34 series Truck

0.22+0.12



Part	Dimension
The overall width of the truck(OAW)	2,218 mm
The overall height of the truck(OAH)	2,270 mm
The extra height of luggage space	750 mm
Front over hang	1,000 mm
Wheel base	3,365 mm

APPENDIX - B

The following table contain approximate value for chemical composition, mechanical property and other general characteristics of material that used on this study to design different material.

Table B-1 property of 6061 Aluminum 6061 T4 and 6061 T6

Chemical Composition of 6061 Aluminum		
Element	Minimum %	Maximum %
Magnesium	0.8	1.2
Silicon	0.4	0.8
Iron	No Min	0.7
Copper	0.15	0.4
Manganese	No Min	0.15
Chromium	0.04	0.35
Zinc	No Min	0.25
Titanium	No Min	0.15
Other Elements	No Min	0.05 each0.15 in total
Mechanical property		
Property	6061-T4	6061-T6
Density	2.70 g/cc | 0.0975 lb/in³	2.70 g/cc | 0.0975 lb/in³
Tensile Strength	241 MPa | 35000 psi	310 MPa | 45000 psi
Yield Strength	145 MPa | 21000 psi	276 MPa | 40000 psi
Modulus of Elasticity	68.9 GPa | 10000 ksi	68.9 GPa | 10000 ksi
Thermal property of aluminum		
Property	6061-T4	6061-T6
Coefficient of Thermal Expansion @ 20.0 - 100 °C Temp	23.6 µm/m-°C | 13.1 µin/in-°F	23.6 µm/m-°C | 13.1 µin/in-°F
Thermal Conductivity	154 W/m-K | 1070 BTU-in/hr-ft²-°F	167 W/m-K | 1160 BTU-in/hr-ft²-°F
General Characteristics		
Characteristic	Appraisal 6061 T4	Appraisal 6061 T6
Strength	Medium to High	Medium to High
Corrosion Resistance	Good	Good
Weldability	Good	Good
Workability	Good	Good
Machinability	Good	Good

Table B-2. 1018 Mild (low-carbon) Steel properties

Chemical composition	
Iron (Fe)	98.81 - 99.26%
Carbon (C)	0.18%
Manganese (Mn)	0.6 - 0.9%
Phosphorus (P)	0.04% max
Sulfur (S)	0.05% max
Mechanical property	
Ultimate Tensile Strength	440 Mpa
Yield Strength,	370 Mpa
Shear strength	370Mpa
Elongation	15.0%
Modulus of Elasticity	205 GPa
Bulk Modulus	140 GPa
Poisson Ratio	0.290
Machinability	70 %
Shear Modulus	80Gpa
density	7870k g/m^3

Table B-3. Mechanical properties of table 316L stainless steel

Chemical composition	
Ni	11.21 %
Cr	17.28 %
Mo	2.36 %
Mn	1.86 %
Si	0.51 %
Other	0.34 %
Mechanical properties	
Yield point. MPa	332
Tensile strength. MPa	673
Modulus of Elasticity. GPa	165
Strength at break, KPa	586
Elongation at break, mm	35.5

APENDIX –C

The following table contain formulas and constants of moment of inertia,column effective length , magnetic permility and speed of sound in dry and humid air.

Table C-1.crosssectional property (moment of inertia and section modulus)

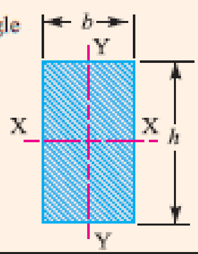
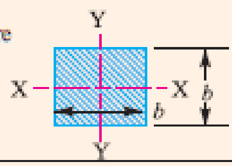
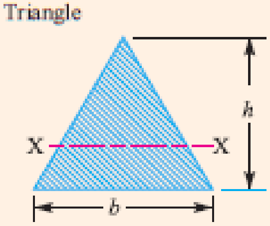
Section	Area (A)	Moment of inertia (I)	*Distance from the neutral axis to the extreme fibre (y)	Section modulus $\left[Z=\frac{I}{y}\right]$
1. Rectangle 	bh	$I_{xx}=\frac{b.h^3}{12}$ $I_{yy}=\frac{h.b^3}{12}$	$\frac{h}{2}$ $\frac{b}{2}$	$Z_{xx}=\frac{b.h^2}{6}$ $Z_{yy}=\frac{h.b^2}{6}$
2. Square 	b^2	$I_{xx}=I_{yy}=\frac{b^4}{12}$	$\frac{b}{2}$	$Z_{xx}=Z_{yy}=\frac{b^3}{6}$
3. Triangle 	$\frac{bh}{2}$	$I_{xx}=\frac{b.h^3}{36}$	$\frac{h}{3}$	$Z_{xx}=\frac{bh^2}{12}$

Table C-2. Formulas for SAE Spline (Robert L. Mott, 2018)

		A: Permanent fit		B: To slide without load		C: To slide under load	
No. of Splines	W, for all fit	H	D	H	D	h	D
Four	0.241D	0.075D	0.850D	0.125D	0.750D		
Six	0.250D	0.050D	0.900D	0.075D	0.850D	0.100D	0.800D
Ten	0.156D	0.045D	0.910D	0.070D	0.860D	0.095D	0.810D
Sixteen	0.098D	0.045D	0.910D	0.070D	0.860D	0.095D	0.810D

Note: this formula gives the maximum dimensions for W, h, and d.

Table C-3. Column effective length factor (K) for bulking calculation

Condition of end support	Column effective length factor(K)
For both ends fixed	0.5
For both ends pinned (hinged, free to rotate	1
For one end fixed and the other end pinned	0.77
For one end fixed and the other end free to move laterally	2

Table C- 4. Permeability and relative permeability of different material

Medium	Permeability -μ - (H/m)	Relative permeability -μ -/ μ_o
Air	$1.25663753\ 10^{-6}$	1.00000037
Aluminum	$1.256665\ 10^{-6}$	1.000022
Austenitic stainless steel[1)]	$1.260\ 10^{-6}$– $8.8\ 10^{-6}$	1.003 –7
Bismuth	$1.25643\ 10^{-6}$	0.999834
Carbon Steel	$1.26\ 10^{-4}$	100
Cobalt-Iron (high permeability strip material)	$2.3\ 10^{-2}$	18000
Copper	$1.256629\ 10^{-6}$	0.999994
Ferrite (nickel zinc)	$2.0\ 10^{-5}$-$8.0\ 10^{-4}$	16 – 640
Ferrite stainless steel (annealed)	$1.26\ 10^{-3}$-$2.26\ 10^{-3}$	1000 – 1800
Hydrogen	$1.2566371\ 10^{-6}$	1
Iron (99.8 % pure)	$6.3\ 10^{-3}$	5000

Table C- 5. Drag coefficient for rectangular plate in different size

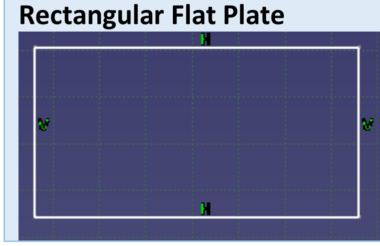
Description	L/d	C_d
Rectangular Flat Plate	1	1.15
	2	1.16
	5	1.20
	10	1.22
	30	1.62
	∞	1.98

Table C- 6. Speed of sound in dry and humid air.

θ (˚C)	C_D (m/s)	C_E (m/s)		C_S (m/s)	
	RH= 0%	RH= 30%	RH= 100%	RH= 30%	RH= 100%
20	343.210	343.592	344.489	343.800	344.696
30	349.015	349.721	351.392	350.180	351.824
40	354.725	355.977	358.970	356.754	359.596
50	360.344	362.481	367.677	363.581	368.213

APPENDIX –D

The following table present the specification of selected material that used to develop advanced emergency brake system.

Table D-1 specification of selected pneumatic solenoid valve

model	pneumatic solenoid valve BTF-SV-083
Picture	
7Usage	Flow control
Material type	Aluminum alloy
Operating pressure	0.15- 1 Mpa
Maximum pressure resistance	1.5 Mpa
Operating temperature	$(20\text{-}70)^0$ c
Power supply	Ac or Dc
Voltage	220v Ac or 12v DC

Table D-2.Technical Specification of Arduino Uno

Brand name	Arduino Uno
Height	25mm
Width	5.5 cm
Weight	91 Grams
Dimensions	8x5.5x2.5 cm
RAM size	8kb
Voltage	5v
Digital pins	14

Table D-3. Specification of selected pneumatic cylinder (MCQV2)

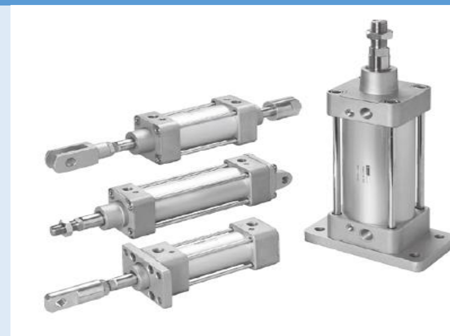
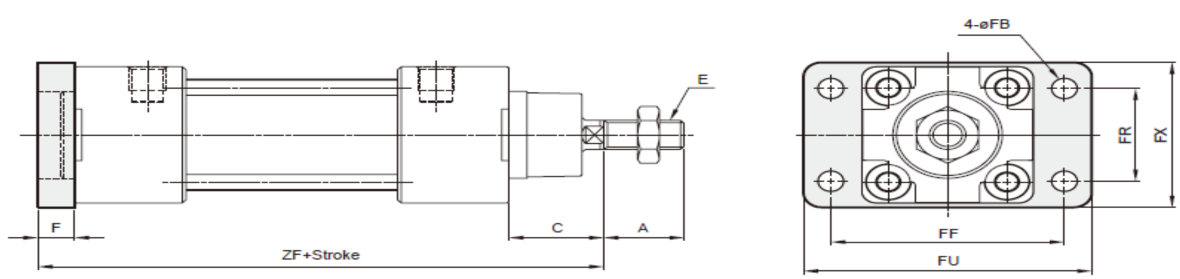
Model	MCQV2		MCQV			
Picture						
Tube I.D. (mm)	32,40	50,63	80,100	125	160	200
Stroke, (mm)	50 - 500	600	600-700	600-700	600 - 700	600-1500
Medium	Air					
Operating pressure range	0.05~1 MPa					
Proof pressure	1.5 MPa					
Ambient temperature	-5~ +60°C (No freezing)					
Available speed range	50~500 mm/sec					
Sensor switch	RCA					
Sensor switch holder	HV1	HV2	HV3	HV4	PM16	HA5V

Table D-3.1. Dimension of selected pneumatic cylinder



Code Tube I.D.	A	C	E	F	FB	FF	FR	FU	FX	ZF
32	22	26	M10×1.25	10	7	64	32	79	50	130
40	24	30	M12×1.25	10	9	72	36	90	52	145
50	32	37	M16×1.5	12	9	90	45	110	65	155
63	32	37	M16×1.5	12	9	100	50	125	76	170
80	40	46	M20×1.5	16	12	126	63	154	94	190
100	40	51	M20×1.5	16	14	150	75	180	112	205

APPENDIX – E

Appendix E show the Arduino programing of the study that used to control over all activity of advanced emergency brake system for Isuzu truck at emergency braking

Table E- 1. Arduino programming code

Arduino **programming code for circuit 1**	Arduino programming code for circuit 2

#include <LiquidCrystal.h> // includes the LiquidCrystal Library
#define RELAY1 13 //Defining the pin 13 of the Arduino for the relay module
LiquidCrystal lcd(1, 2, 4, 5, 6, 7); // Creates an LCD object. Parameters: (rs, enable, d4, d5, d6, d7)
const int trigPin = 10;
const int echoPin = 9;
float value=0;
float rev=0;
float ta;
int rpm;
long duration;
int oldtime=0;
int time;
int distance ;
void isr() //interrupt service routine
{
rev++;
}
void setup() {
	#include <LiquidCrystal.h> // includes the LiquidCrystal Library
	#define RELAY1 13 //Defining the pin 13 of the Arduino for the relay module
	LiquidCrystal lcd(1, 2, 4, 5, 6, 7); // Creates an LCD object. Parameters: (rs, enable, d4, d5, d6, d7)
	const int trigPin = 10;
	const int echoPin = 9;
	float value=0;
	float rev=0;
	float ta;
	int rpm;
	long duration;
	int oldtime=0;
	int time;
	int distance ;
	void isr() //interrupt service routine
	{
	rev++;
	}
	void setup() {

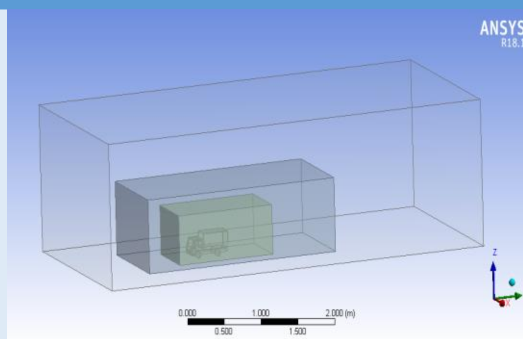
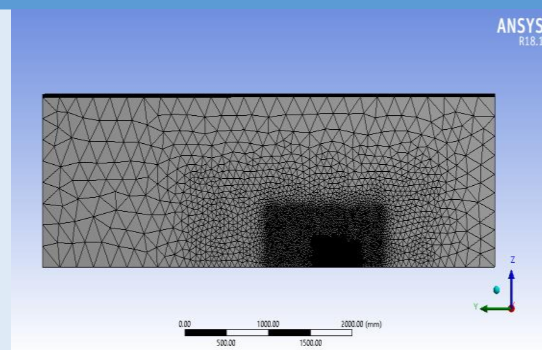
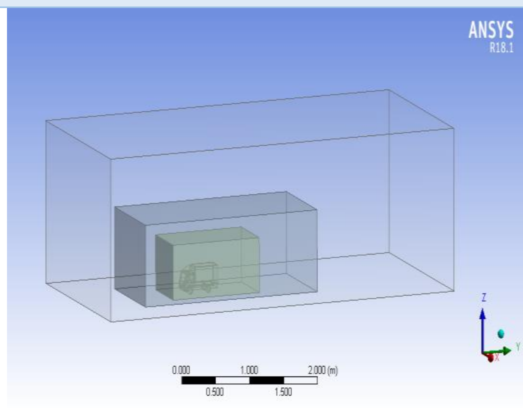
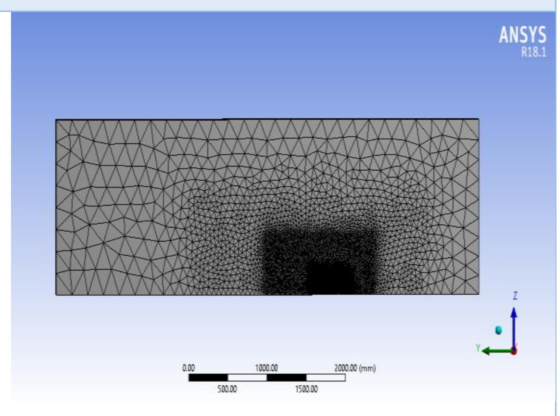
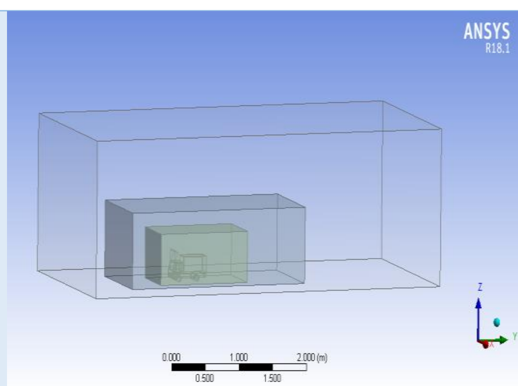
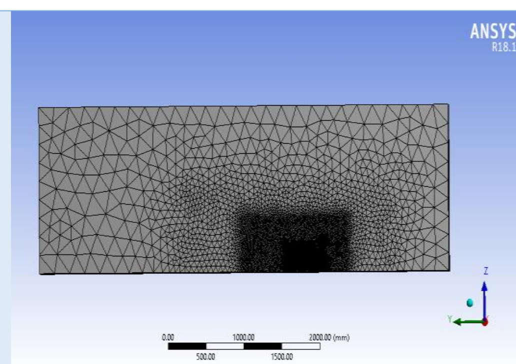
lcd.begin(16,2); // Initializes the interface to the LCD screen, and specifies the dimensions (width and height) of the display	lcd.begin(16,2); // Initializes the interface to the LCD screen, and specifies the dimensions (width and height) of the display
pinMode(trigPin, OUTPUT);	pinMode(trigPin, OUTPUT);
pinMode(RELAY1, OUTPUT);	pinMode(RELAY1, OUTPUT);
pinMode(echoPin, INPUT);	pinMode(echoPin, INPUT);
}	}
void loop() {	void loop() {
delay(1000);	delay(1000);
detachInterrupt(0); //detaches the interrupt	detachInterrupt(0); //detaches the interrupt
time=millis()-oldtime; //finds the time	time=millis()-oldtime; //finds the time
rpm=(rev/time)*60000; //calculates rpm for blades	rpm=(rev/time)*60000; //calculates rpm for blades
oldtime=millis(); //saves the current time	oldtime=millis(); //saves the current time
rev=0;	rev=0;
lcd.clear();	lcd.clear();
lcd.setCursor(0,0);	lcd.setCursor(0,0);
lcd.print("V= ");	lcd.print("V= ");
lcd.print(0.03*rpm);	lcd.print(0.03*rpm);
attachInterrupt(0,isr,RISING);	attachInterrupt(0,isr,RISING);
digitalWrite(trigPin, LOW);	digitalWrite(trigPin, LOW);
delayMicroseconds(2);	delayMicroseconds(2);
digitalWrite(trigPin, HIGH);	digitalWrite(trigPin, HIGH);
delayMicroseconds(10);	delayMicroseconds(10);
digitalWrite(trigPin, LOW);	digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);	duration = pulseIn(echoPin, HIGH);
distance= duration*0.034/2;	distance= duration*0.034/2;
lcd.setCursor(8,0);	lcd.setCursor(8,0);
lcd.print("S=");	lcd.print("S=");

lcd.print(distance); // Prints string "Distance" on the LCD	lcd.print(distance); // Prints string "Distance" on the LCD
lcd.print("m");	lcd.print("m");
lcd.setCursor(1,1);// Sets the location at which subsequent text written to the LCD will be displa	lcd.setCursor(1,1);// Sets the location at which subsequent text written to the LCD will be displa
lcd.print("ta= ");	lcd.print("ta= ");
ta=distance/(0.03*rpm);	ta=distance/(0.03*rpm);
lcd.print(ta);	lcd.print(ta);
delay(10);	delay(10);
if ((0.03*rpm)>20)	if ((0.03*rpm)>20)
{	{
if(ta<0.85)	if(ta<0.51)
lcd.setCursor(10,1);	lcd.setCursor(10,1);
lcd.print("FOCUS");	lcd.print("FOCUS");
delay(10);	delay(10);
digitalWrite(RELAY1,HIGH); // This will Turn the Relay Off	digitalWrite(RELAY1,HIGH); // This will Turn the Relay Off
delay(200);	delay(200);
}	}
else	else
{	{
lcd.setCursor(10,1);	lcd.setCursor(10,1);
lcd.print("SAFE");	lcd.print("SAFE");
delay(10);	delay(10);
digitalWrite(RELAY1,LOW); // This will Turn ON the relay	digitalWrite(RELAY1,LOW); // This will Turn ON the relay
delay(200);}	delay(200);}
}	}

APPENDIX-F

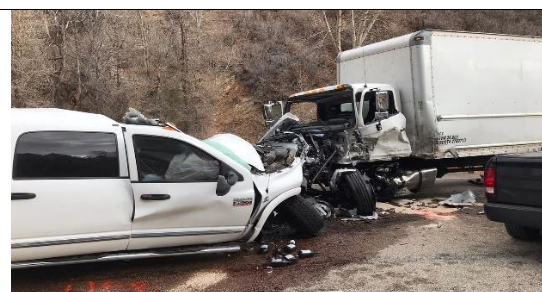
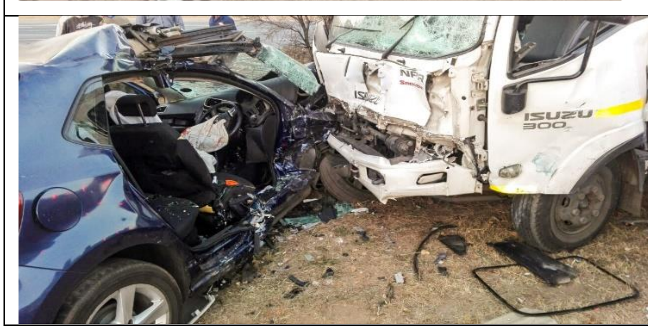
The following table contain the model of the truck inside an enclosure and inner box and generated mesh of CFD analysis.

Table F-1 the model inside an enclosure and inner box and generated mesh of CFD analysis

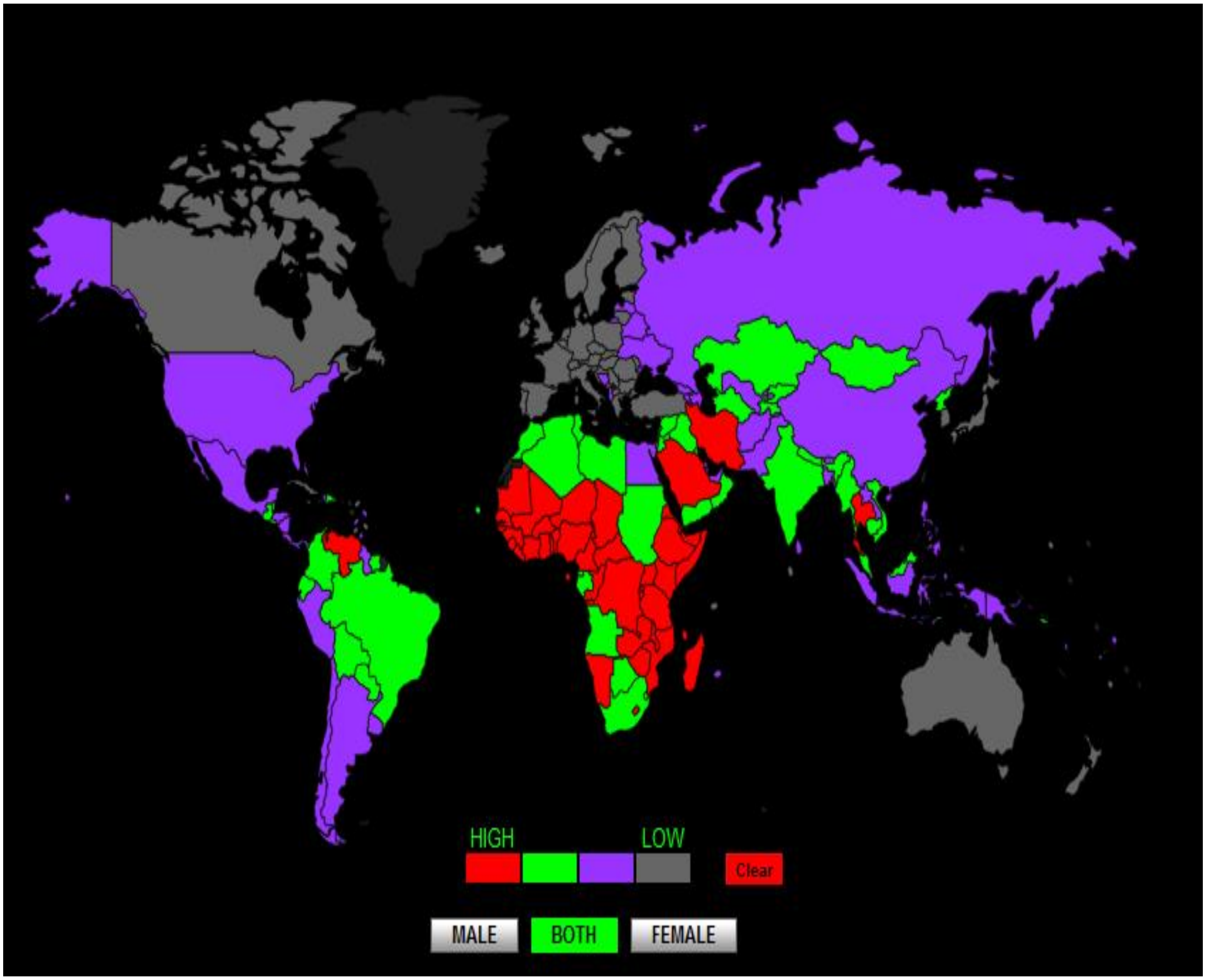
Truck	model inside an enclosure and inner boxes	Generated mesh inside an enclosure and inner boxes
Truck without wind deflector		
Truck with wind deflector		
Truck with actuated wind deflector		

APPENDIX-G

This appendix portion cover different truck accident in different country and it show the world health organization Death Rate Per 100, 000 by traffic accident rate on 2018.

Road Traffic Accidents death rate and rank of different country of the world



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