ADAMA SCIENCE ANDTECHNOLOGYUNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALSENGINEERING

MSc Thesis

Design Improvement on the brake clearance adjustment of Sino-truck

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering

By

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Abbreviations, Acronyms and Symbols

γ *Ratio of specific heats for air 1.4*

R $\quad$ $Constant\ for\ air\ 287\ J/kgK$

T_O $\quad$ $Stagnation\ Temperature, K$

P_b $\quad$ $Local\ presure\ inside\ the\ brake\ chamber\ , P_a$

P_O $\quad$ $Supply\ pressure, P_a$

A_P $\quad$ $Area\ of\ treadle\ valve\ opening\ , m^2$

C_D $\quad$ $Coefficent\ of\ dischagre$

V_{O1} $\quad$ $Initial\ volume\ of\ air\ in\ brake\ chamber\ m^3$

P_{th} $\quad$ $Push\ out\ pressure\ , P_a$

V_b $\quad$ $Volume\ of\ air\ inside\ the\ brake\ chamber\ m^3$

A_b $\quad$ $Area\ of\ brake\ chamber\ diaphragm\ \ m^2$

M_1 $\quad$ $Calibration\ Constant\ , 1.419e-6\ m^2\ m/Pa$

M_2 $\quad$ $Calibration\ Constant\ , 2.341e-8e\ m^2\ m/Pa$

Pct $\quad$ $Brake\ pad\ constant\ Presure, Pa$

Abstract

Braking system is one of the very important active safety system which helps in avoiding collisions of vehicles. Owing to its importance in avoiding collisions, it is time to time performance improvement is an utmost necessity. It is observed that Sino Trucks are meeting collisions frequently. Lower performing brake system or brake out of adjustment is one of the reasons behind such collisions, so in this thesis an attempt is made to improve the brake system of Sino truck by altering the design of the slack adjustment mechanism. In this project, I have developed a new model of an automatic slack adjuster body for the brake system of Sino truck. The model developed here uses a fluid as a media of the slack adjustment system. The model was corroborated with the measurement data collected from the truck foundation brake components i.e. the area of the brake chamber, the input pressure of the chamber, the length of the push rod, the original pad thickness and the arm span of the slack adjuster using CAD and analysis software ANSYS. Numerical results obtained are compared with the literature and found acceptable.

Keywords: *Collisions, brake shoes, brake drum, slack adjuster, brake pedal.*

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Chapter One

INTRODUCTION

1.1 Background

The construction industry in Ethiopia is a sector that opens the door for the growth of many additional industries such as different metal product industries, clay works, cement and cement product industries, etc.

As such, the growth of these industries will surely follow the growth of the construction industry. Similarly, when the construction and renovation of housing increase, the demand for transportation of construction materials increased; thereby, directly, opening the door for the growth of the transport industry. All in all, Sino truck has the greater role in these industries [1].Road traffic accidents are becoming a major public safety and development obstacle; various studies have indicated that Ethiopia has one of the highest fatality rates per vehicle in the world. It is in excess of 100 fatalities per 10,000 vehicles. This should be compared with Kenya and United Kingdom, where the figure is about 19 and 2 per 10,000 vehicles, respectively thus, Ethiopia loses about $65 million annually due to traffic accidents. In addition the victims are mainly public transport travelers in the working age group (18–30 years).

Brakes are required to stop the vehicle within the smallest possible distance and this is done by converting the kinetic energy of the vehicle into heat energy which is dissipated into atmosphere.

Air brake systems are used in heavy commercial vehicles like buses, straight trucks and combination vehicles such as tractor-trailers [1]. Proper functioning of the brake system of a commercial vehicle is critical not only from the safety view- point of the vehicle itself, but also for other vehicles and passengers in traffic. Any accident involving a commercial vehicle results not only in economic loss of the goods transported but also loss of life. As air brake systems are highly sensitive to maintenance, periodic maintenance and inspection procedures have to be strictly followed [3].

Accidents involving commercial vehicles rarely occur due to brake failures but occur frequently due to brake defects. Typical brake related defects include oversize drums, worn out brake linings, out-of-adjustment push rod strokes and leaks in the system.

The statistics from “befinfine zuria oromia liyu zone police report of 2007EC.” Indicate that heavy commercial vehicles accounted 23.33% of fatal crashes, 14.16% injuries & 62.51% property damage. From the above data, Sino truck accounted 79% of fatal crashes, 29% of injuries & 39% of property damage.

Figure 1.1 Accident caused by sinotruck at Gelan

Figure 1.2 Accident caused by sinotruck at Mojo

Figure 1.3 Accident caused by sinotruck at Batu

Figure 1.4 Accident caused by sino truck at Addis Ababa

Table 1.1 2007E.C annual report of "Befinfin ezuria oromia liyu zone police"

No.	*Type of truck*	*Type of damage*			*Total no of accident*
		Fatality	***Injury***	***Property***	
1	***Sino truck***	***22***	***5***	***29***	***56***
2	*IVECO turbo*	*1*	*3*	*11*	*15*
3	Mercedes truck	1	0	4	5
4	UD Truck	2	0	2	4
5	TRRAKKER	0	3	8	11
6	VOLVO Truck	1	1	5	7
7	FOTON Truck	0	1	3	4
8	MITSIBUSHI truck	0	2	6	8
9	NISSAN Diesel truck	0	2	6	8
10	SCANIA Truck	1	0	0	1
11	IVECO Trailer			1	1
	Total			**75**	**120**

Table 1.2 2007E.C annual report of "Befinfine zuria oromia liyu zone police"

No.	*Type of truck*	*Type of damage in Percentage*		
		Fatality	***Property***	***Total no of accident***
1	***Sino truck***	***79%***	***39%***	**47%**
2	*IVECO turbo*	*4%*	*15%*	13%
3	Mercedes truck	4%	7%	4%
4	UD Truck	7%	0%	3%
5	TRRAKKER	0%	4%	9%
6	VOLVO Truck	4%	0%	6%
7	FOTON Truck	0%	0%	3%
8	MITSIBUSHI truck	0%	0%	7%
9	NISSAN Deisel truck	0%	4%	7%
10	SCANIA Truck	4%	0%	1%
11	IVECO Trailer	0%	7%	1%

The study by the Ethiopian road & transport authority experts shows that most the accidents which are caused by Sino truck are brake out of adjustment problem.

Out-of-adjustment push rod strokes drastically decrease the maximum braking force that can be attained. This results in increased stopping distances, causing a safety hazard [5].

1.2 Statement of the problem

Most the accidents which are caused by Sino truck are brake out of adjustment problem. In the current brake system of Sino truck, the manual slack adjuster is used which needs frequent adjustment that has to be done by either the truck operator or by technicians. Out-of-adjustment push rod strokes drastically decrease the maximum braking force that can be attained, this results in increased stopping distances, causing a safety hazard thus, and there is a need to improve the design of brake system of Sino truck with automatic slack adjuster.

1.3 Objective of the thesis

1.3.1 General Objective

The general objective of this thesis is to design an automatic slack adjuster for the brake system of the truck.

1.3.2 Specific objectives

The study include the following specific objectives

- To study and identify the disadvantage of the manual slack adjuster used in the current brake system of the truck.
- To develop a model of automatic slack adjuster using CAD package.
- To analyses the stress and deformation of the slack adjuster at different operating conditions using FEM.

1.4 Significance of the study

The traffic accidents which are caused by Sino truck are increasing from day to day in the country thus; this study will help us to minimize the accident caused by the brake out of adjustment problem.

1.5 Scope of the study

The scope of this study is mainly on designing a new automatic slack adjuster that is suitable for the truck brake system. Finite Element method is used to predict the result.

1.6 Limitation of the study

Problems encountered while doing this thesis work are the following:

- Finding the exact material of the existing manual slack adjuster body was challenging because, the right material testing tools by which measurements can be done is not available everywhere.

1.7 Organization of the thesis

The thesis is organized in six chapters. Chapter one is the introduction and discuses back ground of the problem ,supporting literature scope and limitations of the thesis .The Second Chapter a brief overview of a typical air brake system found in commercial vehicles. In Chapter three describes the basic mathematical model for leaks in the system. A detailed explanation of the assumptions involved along with the methodology adopted will be presented. The fourth chapter Computer modeling using ANSYS is presented .In this chapter first the basic geometric modeling is done using AUTOCAD and model is imported to ANSYS for finite element method analysis. In Chapter five result obtained are discussed and comparison are made with some result obtained by other researchers. In the final Chapter Conclusion and recommendations are presented.

Chapter Two

LITRATURE REVIEW

2.1Literature review

The role of air brake adjustment in insuring adequate heavy vehicle stopping performance has long been established [11]. The U.S. National Highway Traffic Safety Administration (NHTSA) conducted an extensive field trial of automatic slack adjusters, and concluded that they were more reliable in maintaining airbrake adjustment than manual slack adjusters [12]. The U.S. National Transportation Safety Board (NTSB) examined the effect of poor airbrake adjustment on crashes in the early 1990's, and in 1992 recommended that automatic slack adjusters should be required on all vehicles with airbrakes [3].

MeenakshiKushal and Suman [1] Sharma optimized the design of Hero Honda Passion brake drum that they used through reverse engineering approach. Optimization is done by changing the material of the brake drum, under different braking time and operational conditions. Brake drum is optimized to obtained different stresses, deformation values, rise in temperature on different braking time and heat transfer rate. Optimized results obtained are compared for Aluminum and Controlled Expansion material alloys. It concludes that the Controlled Expansion alloys can be a better candidate material for the brake drum applications of light commercial vehicles and it also increases the braking performance.

Hankarram Coimbatore Subramanian [18] development of a model-based diagnostic system for air brake systems that are widely used in commercial vehicles, such as trucks, tractor-trailers, buses, etc.
The performance of these brake systems is sensitive to maintenance and hence they require frequent inspections.

Current inspection techniques require an inspector to go underneath a vehicle to check the brake system for possible faults, such as leaks, worn brake pads, out-of-adjustment of push rods, etc. Such inspections are time consuming, labor intensive and difficult to perform on vehicles with a low ground clearance. In this context, the development of an onboard/ handheld diagnostic tool for air brakes would be of significant value. Such a tool would automate the brake inspection process, thereby reducing the inspection time and improving the safety of operation of commercial vehicles. In this dissertation, diagnostic schemes are developed to automatically detect two important and prevalent faults that can occur in air brake systems – leaks and out-of-adjustment of push rods.

These diagnostic schemes are developed based on a nonlinear model for the pneumatic subsystem of the air brake system that correlates the pressure transients in the brake chamber with the supply pressure to the treadle valve and the displacement of the treadle valve plunger. These diagnostic schemes have been corroborated with data obtained from the experimental facility at Texas A&M University and the results are presented.

The response of the pneumatic subsystem of the air brake system is such that it can be classified as what is known as a "Sequential Hybrid System". In this dissertation, the term "hybrid systems" is used to denote those systems whose mathematical representation involves a finite set of governing ordinary differential equations corresponding to a finite set of modes of operation. The problem of estimating the push rod stroke is posed as a parameter estimation problem and a transition detection problem involving the hybrid model of the pneumatic subsystem of the air brake system. Also, parameter estimation schemes for a class of sequential hybrid systems are developed.

John R- LOUIS, Elyrla, ZoltallTormasi, Kecskemét; Mark J. Kromer, Huron, OH (US) [19] have improved self-adjusting automatic slack adjuster for reducing slack in the brake of a Vehicle is provided, in which an easily accessible external operating feature permits the automatic slack adjuster's one-Way clutch assembly to be readily disengaged to allow smooth release and retraction of the brake shoes of a Vehicle brake Without damage to the one-Way teeth of the clutch assembly. When the external feature is operated in a brake release direction, the motion of the feature is translated into a motion Which axially displaces an output part of the one-Way clutch a Way from an input part of the clutch a distance sufficient to disengage the parts' one-Way teeth, thereby disengaging the one-Way clutch to permit brake shoe retraction Without resistance from the one Way clutch.

Srivatsan Ramarathnam, SandeepDhar, SwaroopDarbha and K. R. Rajagopa Brake systems in trucks are crucial for ensuring the safety of vehicles and passengers on the roadways. Most trucks in the US are equipped with S-cam drum brake systems and they are sensitive to maintenance. Brake defects such as leaks are a major cause of accidents involving trucks. Leaks in the air brake systems affect braking performance drastically by decreasing the maximum braking pressure and also increasing the time required to attain the same, thereby resulting in terms of the mass flow rate of leak in air based on the input measurements of brake pressure for a full application of the brake pedal and the supply pressure. This scheme can be implemented using a simple look-up table.

M. KamelSalaani, Gary J. Heydinger, [4] in crashes between heavy trucks and light vehicles, most of the fatalities are the occupants of the light vehicle. A reduction in heavy truck stopping distance should lead to a reduction in the number of crashes, the severity of crashes, and consequently the numbers of fatalities and injuries. This study makes use of the National Advanced Driving Simulator (NADS). NADS is a full immersion driving simulator used to study driver behavior as well as driver-vehicle reactions and responses. The vehicle dynamics model of the existing heavy truck on NADS has been modified with the creation of two additional brake models. The three braking systems used in this study are the standard S-cam, the enhanced S-cam (larger drums and shoes), and the air-actuated disc brake system. A sample of 108 CDLlicensed drivers was split evenly among the simulations using each of the three braking systems. The drivers were presented with four different emergency stopping situations. The effectiveness of each braking system was evaluated by first noting if a collision was avoided and, if not, the speed of the truck at the time of collision. In the non-collision runs additional performance measures were also evaluated, including stopping distances, braking distances, brake pedal forces and decelerations. The results of this study show that the drivers who used either the air disc brakes or the enhanced S cam brakes had fewer collisions in the emergency scenarios than those drivers using standard S-cam brakes. The fundamental result this research validated is that reducing heavy truck stopping distance has strong potential to decrease the number and severity of crashes in situations requiring emergency braking.

Road accidents as a major cause of misery, morbidity and mortality in Africa particularly in Ghana have been of considerable concern to the general public. More worrying is the accidents involving Benz 207 buses. This is attributed to the fact that the Mercedes Benz 207 bus is originally made as a van for conveying goods. When brought into the country it is converted to passengers' bus by artisans in 'fitting workshops' in and around the country. This conversion increases the gross weight affects the suspension and the stability of the vehicle Also, a serious effect is that the performance of the braking system may be affected. This research highlights various modifications done to the Mercedes Benz 207 van at the Suamemagazine. The braking efficiency of the converted Mercedes Benz 207 bus as against that of the original and compared to the safest degree of efficiency required for these buses. It was observed that the alteration of suspension (leaf spring) and chassis frame, brake adjustments, body and spraying works, construction of seats and fixing of glass were the major modifications that are done on the buses. Average ground height of the bus was increased and was found to be between 60.9 cm to 76.2 cm(2 to 2.5 feet) due to suspension alteration.

To overcome several economic and environmental challenges, the Dutch transport sector has introduced the so-called "Langere Zwaardere Vracht auto combinations" abbreviated LZV's and also known as Ecocombi's or Gigaliners, on the Dutch roads. After some experiments where LZV's are allowed on Dutch road under several restrictions, an unrestricted "phase of experience" is started in November2007.

This thesis contributes to the research done on the dynamic behavior of LZV's at the Eindhoven University of Technology since 2006. Previous research focused on maneuverability and roll-over stability. The goal of this thesis is to gain insight on the braking performance of LZV's and extension of the roll-over research by means of multi-body models. To evaluate braking performance and roll-over stability, the previously developed "TU/e-Commercial

Vehicle Library" is improved and extended with a brake system and several brake and roll-over scenarios are defined. Scenarios used for braking performance evaluation are breaking in a straight line on different road conditions, breaking while driving a steady state circle and braking during a highway exit. A steady state circle, a spiral, a single and double lane change are simulated to analyze role-over stability.

After execution and evaluation of the braking scenario's the conclusion is drawn that each LZV and conventional heavy vehicle obeys legal demands regarding brake force distribution with the implemented brake system. It is also shown that ABS improves the performance in critical situations by shortening the stopping distance on a dry, wet and µ-split road and by preventing jackknifing when
braking on a µ-split road. For braking during a circle it is shown that the vehicles become over steered when the brakes are applied but no other conclusions can be draw because results contradict, the best performing vehicles regarding path deviation are the worst performing vehicles regarding needed steer adjustments and vice versa. When comparing the braking performance between LZV's and conventional commercial vehicles, it can be concluded that braking performance of LZV's is equal

to the braking performance of conventional vehicles. No distinct differences are found.

Evaluation of the roll-over scenario's show that the static roll-over thresholds are almost equal for all vehicles. By means of more dynamic roll-over scenario's, distinct differences between vehicles are identified. Vehicles having a low yaw damping perform worst regarding roll-over. When comparing LZV's and conventional vehicles it can be concluded that LZV's roll-over more easily. Another conclusion is that all vehicles are most sensitive to roll-over when the frequency of the disturbance lays within a band of 0.1Hz and 0.6Hz, which is well within the frequency band utilized by a human driver when performing a emergence steering man oeuvre. Steering frequencies above 2.5Hz do not cause roll-over.
John Louis and Elyria, improved automatic slack adjuster for reducing slack in the brake of a vehicle, in Which a one-Way clutch assembly is arranged at a side of the automatic slack adjuster housing, and one-Way motion-inhibiting pawls in the one-Way clutch assembly act on one-Way gear teeth disposed on an inner radius of a gear Wheel Within the assembly Whose outer circumference drives a slack adjuster unit. The incorporation of the one-Way clutch Within the anchor unit of the adjuster provides an automatic slack adjuster Which can be produced at a reduced cost, manufactured more easily, and provides for improved adjustment performance With much reduced dependence on the lubricity of grease used.

According to the statistics, driver error is the main reason for the road accidents: this has motivated an intensive research on intelligent vehicles equipped with automated driving technology, active safety and driver-assistance systems so as to enhance the safety of drivers, facilitate vehicle controllability and stability, and improve driving comfort.

One of the driver assistant systems currently under development by most automotive manufacturers is the Adaptive Cruise Control (ACC) system. The ACC system, which is an extension of the classic Cruise Control (CC) system, controls both speed and distance to preceding vehicles, the aim of ACC is not only provide the drivers with comfort and safety during driving, but also increase the capacity of roads and reduce fuel consumption.

One of the major drawbacks of ACC system solutions commercially available in the automotive industry is the limited performance in cornering situations, where the road presents current/future curvatures. In particular, the interaction between longitudinal and lateral controller systems has not been deeply studied. Moreover, in order to obtain both lateral stability and safe clearance to avoid rear end collisions in critical driving situations, coordinated control of the actuators is necessary without avoiding conflicts caused by the coupling of vehicle dynamics. Summarizing, an implementation of an integrated vehicle dynamics control is far
from definiteness.

A part of this thesis concerns the parametric vehicle model which is based on a set of vehicle parameters (mass, maximum torque etc.) with realistic nonlinearities in longitudinal and lateral dynamics of vehicle. The longitudinal and lateral control systems are designed to fulfill the objectives and requirements. Since driver acceptance of the proposed control systems are crucial, practical constraints are determined via experimental studies on human driving.

Furthermore, in order to allow the driver to personalize the control system in a desired manner, parameterization of control system is provided.

An appropriate control structure is adopted to create synergies and safe interaction between longitudinal and lateral controllers, taking into account the previous mentioned aspects, compromising between comfort and safety for various driving situations, in order to obtain both lateral stability and safe clearance of advanced autonomous driving vehicle. This MSc thesis mainly focuses on the design of an Integrated Vehicle Dynamics Control (IVDC) strategy for Adaptive Cruise Control with auto steering application intended to decrease driver's workload.

In severe driving situations, the proposed control strategy is designed based on indexes for driving situations to optimally coordinate the brake and steering actuators to avoid rear-end collision danger and unstable lateral motion of the vehicle.

Afterwards, the implementation of the designed controllers has been carried out. Simulations are conducted in Matlab/Simulink by using a set of traffic scenarios which are likely to occur in reality. From simulation results, the performances of designed controllers are evaluated with respect to determined performance specifications. Simulation results have shown that the proposed integrated controller satisfies the performance in terms of autonomous driving, path tracking and collision avoidance for a complete envelope of working conditions.

In this thesis considering only automatic brake adjusting for Sino truck.

2.2 Air Brake System

To move a vehicle, an internal combustion engine must convert its heat energy to mechanical energy. This mechanical energy goes from the engine to the driving wheel tires by means of a system of connecting rods, shafts and gears. The final factor that moves a vehicle is the amount of traction its tires have on the road surface.

Traction is the ability of a tire to grip the road surface on which it rolls. The vehicle's acceleration rate depends on the power the engine develops and the amount of traction the tires have on the road surface.

Friction is the force which resists movement between two surfaces in contact with each other. To stop a vehicle, brake shoe linings are forced against the machined surfaces of the brake drums, creating friction. This friction produces heat.

The engine converts the energy of heat into the energy of motion – the brakes must convert this energy of motion back into the energy of heat. Friction between brake drums and linings generates heat, while reducing the mechanical energy of the revolving brake drums and wheels. The heat produced is absorbed by the metal brake drums, which dissipate heat by passing it off into the atmosphere. The amount of heat the brake drums can absorb depends on the metal thickness of which they are made. When enough friction is created between brake linings and drums, the wheels stop turning. The final factor that stops a vehicle is not the brakes, but the traction between tires and road surface.

If a 200 horsepower engine accelerates a vehicle to 100 km/h in one minute, imagine the power needed to stop this same vehicle. Not only that, the vehicle might have to be stopped in an emergency, in as little as six seconds (just 1/10 of the time it took to reach 100 km/h).

To stop a vehicle in 1/10 the time it takes to accelerate requires stopping power of 10 times the acceleration power – equivalent to 2,000 horsepower.

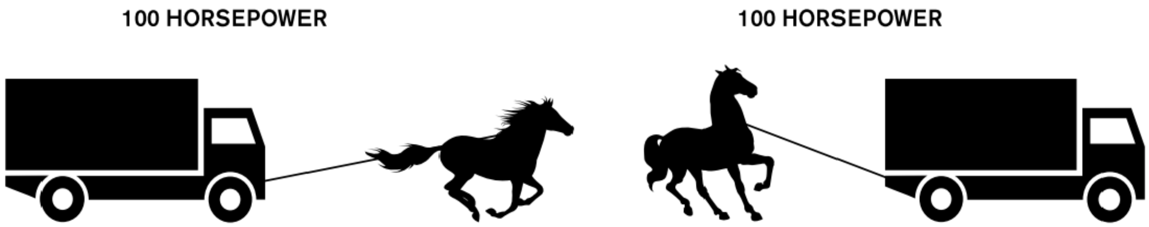


Figure 2.1 Horsepower.

If the vehicle had six wheels, each wheel would have to provide 1/6 of the braking power. If one or two wheels had brakes that were not properly adjusted, the other wheels would have to do more than their share of the braking, and that might be more than their brakes were constructed to stand. Excessive use of the brakes would then result in a build-up of heat greater than the brake drums could absorb and dissipate. Too much heat would result in brake damage and possible failure.

Most brake linings operate best around 250°C and should not exceed 425°C. It's important to understand that the power needed to stop generates heat which could ruin the brakes.

The distance required to stop a vehicle depends on its speed and weight in addition to the factors of energy, heat and friction. The brake power required to stop a vehicle varies directly with its weight and the "square" of its speed. For example, if weight is doubled, stopping power must be doubled to stop in the same distance. If speed is doubled, stopping power must be increased four times to stop in the same distance. When weight and speed are both doubled, stopping power must be increased eight times to stop in the same distance.

Stopping distance consists of three factors:

- Driver’s reaction time
- Brake lag
- Braking distance.

Reaction time: The time it takes from the moment a hazard is recognized to the time the brake pedal is applied, approximately 3/4 of a second.

Brake lag: The time air takes to travel through a properly maintained air brake system, about 4/10 of a second.

Braking distance: The actual distance a vehicle travels after the brake is applied until the vehicle stops. This distance depends on the ability of the lining to produce friction, the brake drums to dissipate heat and the tires to grip the road.

Professional drivers never take breaks for granted. The braking system must be tested and adjustment checked before placing a vehicle into service.

Professionals understand the braking system, realize its capabilities and limitations, and learn to use it to their advantage.

Heavy vehicles require powerful braking systems that are obtained by use of mechanical leverage and air pressure. Brakes must be used keeping in mind the heat generated by friction. If heat becomes too great, braking effectiveness will be lost. The heavier the load and the faster the speed, the greater the power needed to stop.

Stopping distance is also affected by the driver’s reaction time, brake lag and braking distance. The professional driver is well aware that the vehicle, even with properly adjusted brakes, will not stop as quickly as a passenger vehicle.

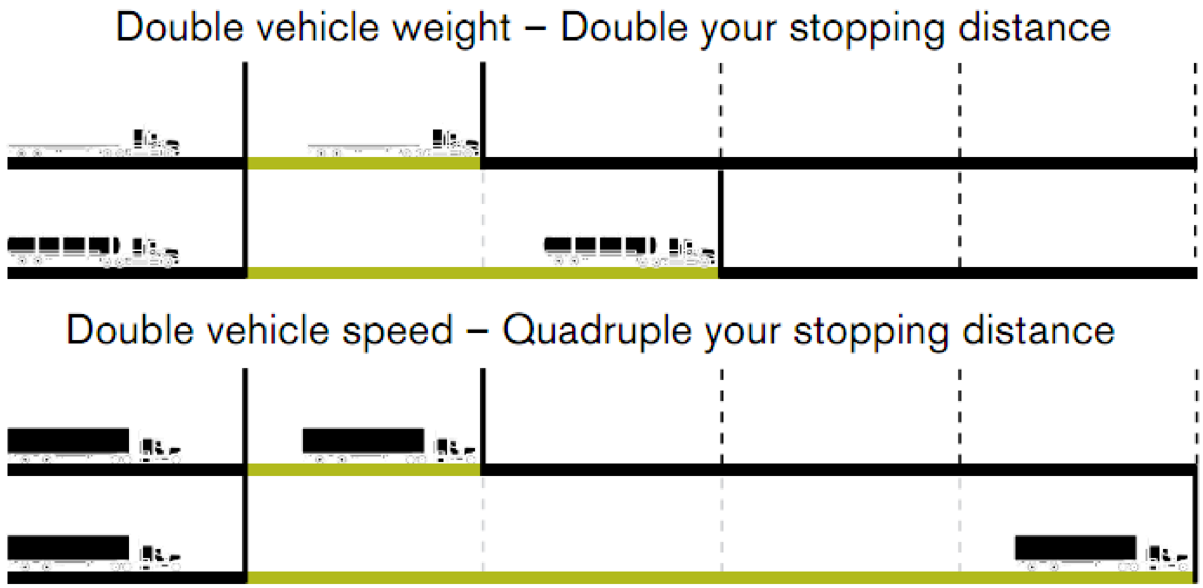


Figure 2.2 Vehicle weight vs. stopping distance

A typical brake system layout for a tractor trailer is presented in Fig.2.3. The air brake system layout is also called as a dual brake circuit. The braking circuit is designed in such a way that, in case of a failure of one of the circuits, partial braking is possible with the help of the other. The two circuits are highlighted in green and yellow colors in Fig.2.3. Some of the major components of an air brake system are described below:

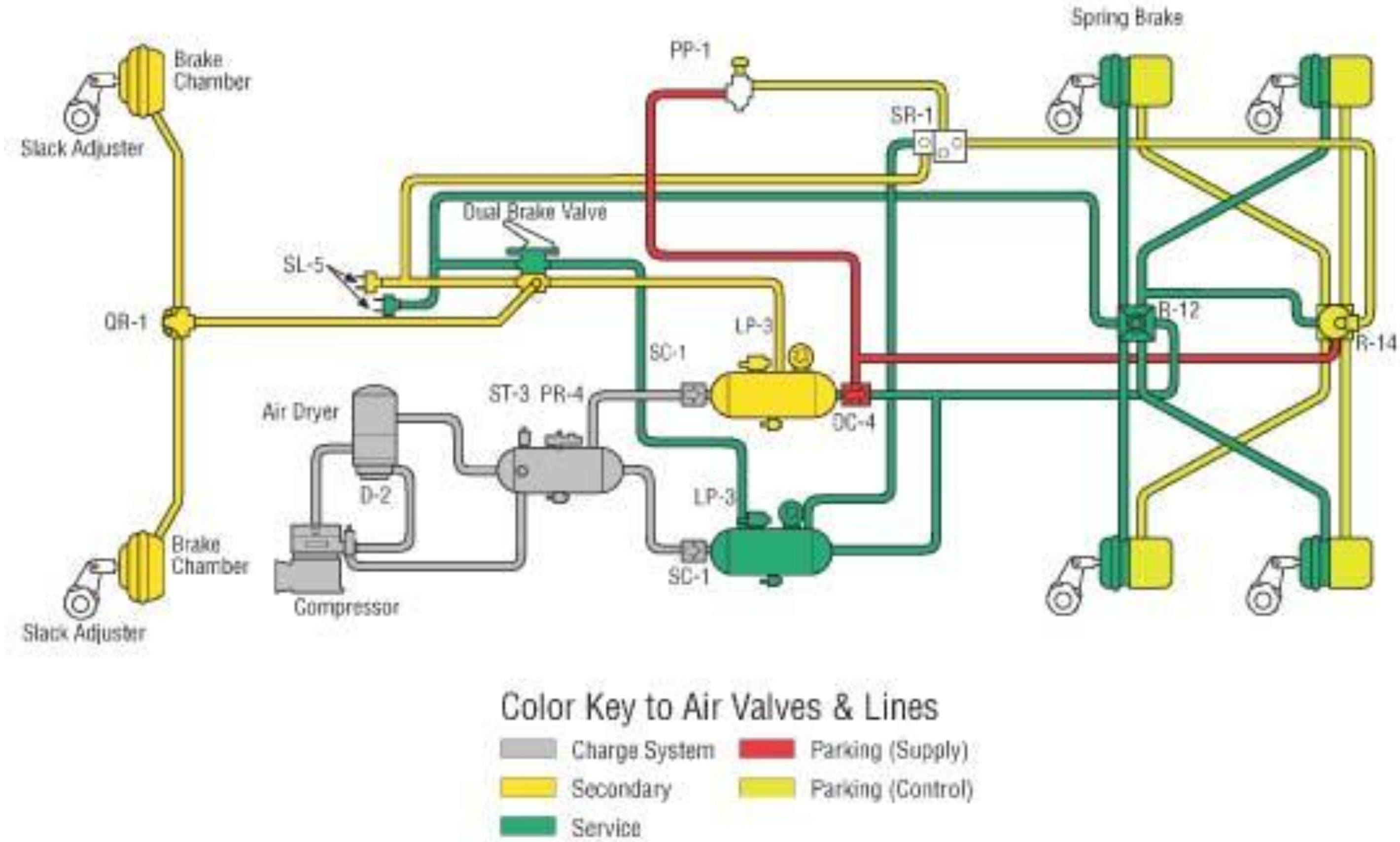


Figure 2.3: Air brake systems

1. Compressor and reservoirs: The compressor is the energy source for the whole braking system. The compressor is driven by the engine crankshaft through belt drives or gears. Compressed air is stored in the reservoirs. Typical operating pressures of the brake system are around 8 to 10 bars (100psig to 130psig). The reservoirs are equipped with a purge valve to drain moisture and contaminants. The reservoirs also have safety valves to prevent excessive pressure build up. A low pressure switch is also installed in the reservoir to warn the driver whenever the pressure

in reservoirs drops below 65 psig. Compressed air is generally passed through air filter, air dryer units to remove moisture and contaminants, so that clean air is fed to the system.

2. Brake valve/Treadle valve: The brake valve (also known as the treadle valve) is the heart of the braking system. Air supplied from the reservoirs is controlled and modulated by the brake valve and supplied to the brake chambers. The brake valve has a primary circuit and a secondary circuit. The primary circuit is actuated by the driver's foot on the brake pedal. Compressed air is supplied to brakes mounted on the rear axles through a relay valve. The secondary circuit is actuated by the primary circuit and supplies air to brakes on the front axle through a quick release valve.

3. Quick release and relay valves: A quick release valve is used to quickly exhaust the air from front brake chambers once the brake pedal is released by the driver. A relay valve is used to actuate the rear brakes at the same time as the front brakes. Both the primary circuit of the brake valve and the supply from the reservoir are connected to the relay valve. Once the air from brake valve reaches the relay valve, a vent is opened to connect the supply reservoir to the rear brakes. Hence any delay in the travel of air from brake valve to the rear axles is eliminated by the relay valve even though the brake valve is located close to the front axles.

4. Drum brakes: S-cam drum brakes are the most commonly used brake configuration in commercial vehicles. They are also commonly referred as foundation brakes as they perform the actual braking function in the system. The drum brakes are mounted on the drive shaft of the axles.

5. Brake chambers: Brake chambers are used to convert the air pressure to braking force through the push rods. Pressure builds up in the brake chamber and results in the forward motion of the push rod, which rotates the automatic slack adjuster connected to it. The slack adjuster in turn, rotates the S-cam shaft tube and the S-cam, thereby expanding the brake linings to contact the drum.

Brake chambers on the rear brakes are also called as spring break chambers as parking brakes are also incorporated into them.

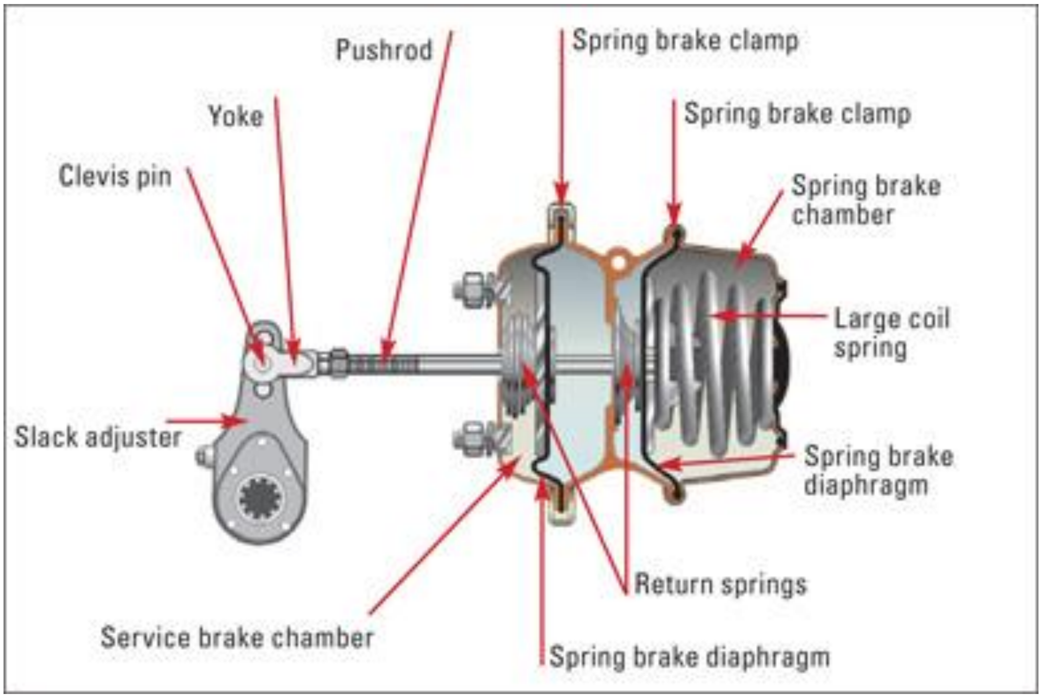


Figure 2.4 Brake chamber & slack adjuster

6. Automatic slack adjusters: A slack adjuster is designed to serve two functions. Firstly, the linear motion of the push rod is converted to rotational motion of the S-cam by the slack adjuster. Typically, out of adjustment pushrods can be easily identified if the angle between the push rod and the slack adjuster is more than 90◦ during a brake application. Secondly, the clearance between the brake drum and the brake linings is maintained as the linings get worn out.

Unlike a manual slack adjuster, an automatic slack adjuster does not require manual rotation of the adjuster nut for maintaining the lining to drum clearance.

For a complete and detailed description of all the components, their specifications, working principles, maintenance and testing details of the air brake system, the reader is requested to refer [11], [5] and [6].

2.3 Slack Adjuster

A slack adjuster makes it possible to adjust the clearance between brake shoes and the brake drum. It is a part that connects the brake chamber push rod to the foundation brake camshaft. It also provides torque to rotate the cam shaft when pressing the brake pedal.

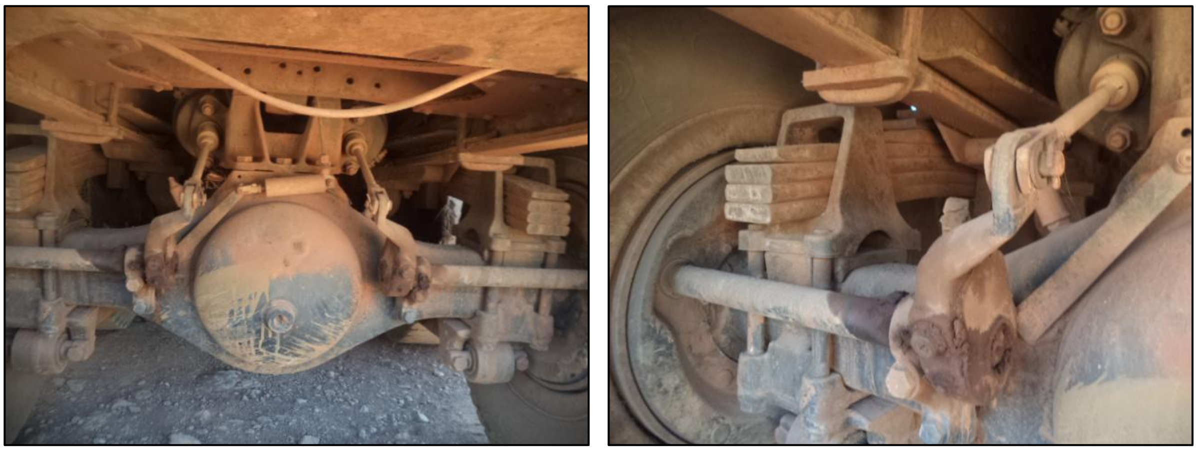


Figure 2.5 Existing manual slack adjuster mounted on the brake system of Sino truck

Chapter Three

METHODOLOGY AND MATERIAL USED

3.1 A mathematical model for the air brake system without the presence of leaks

Before we consider a mathematical model for the air brake system, we will present a brief description of the "fault-free" model developed in [12] as it forms the basis for the mathematical model that is desired. As the name implies, the "fault-free" model predicts the pressure response of the brake system in the absence of any faults such as leaks etc. This model describes the evolution of pressure in the brake chamber in response to the treadle valve plunger displacement and the supply pressure to the system. The model was developed for a brake system configuration where one of the front brake chambers was directly connected to the primary delivery port of the treadle valve. A lumped parameter approach was employed to develop the model.

The governing equations of the "fault- free" model were developed using the following assumptions:

- ❖ Friction at all sliding surfaces of the valves may be assumed to be negligible since all components were well lubricated.
- ❖ Inertial forces were assumed to be small compared to the pressure forces and spring forces.
- ❖ The primary inlet valve opening of the treadle valve may be assumed to behave like a nozzle.
- ❖ Thermal properties in the supply chamber of the treadle valve were assumed to be the stagnation properties for the inlet of the nozzle.
- ❖ Flow through the treadle valve opening was assumed to be one-dimensional and isentropic.
- ❖ Air was assumed to behave like an ideal gas with constant specific heats.

- ❖ Uniform fluid properties were assumed at all sections in the nozzle. Also, the peak Mach number of the compressed air flow in the system was measured and found to be less than 0.2.

For a complete list of assumptions involved in the development of the governing equations, the reader may refer to [12]. The governing equations for determining the pressure response of the brake system is based on an application of balance of mass and energy for the pneumatic subsystem as shown in Fig.3.1. For a detailed derivation, the reader is referred to [13]. The governing equations are:

$$\left[\frac{2\gamma}{(\gamma-1)RT_O}\left\{\left(\frac{P_b}{P_O}\right)^{\frac{2}{\gamma}}-\left(\frac{P_b}{P_O}\right)^{\frac{\gamma+1}{\gamma}}\right\}\right]^{\frac{1}{2}} A_P C_D P_O sgn(P_O - P_b) = \frac{V_{o1} P_O^{\frac{\gamma+1}{\gamma}}}{\gamma RT_O P_b^{\frac{\gamma-1}{\gamma}}} P_b \; if P_b < P_{th}, \ldots\ldots\ldots \text{(eq.1)}$$

$$\left[\frac{2\gamma}{(\gamma-1)RT_O}\left\{\left(\frac{P_b}{P_O}\right)^{\frac{2}{\gamma}}-\left(\frac{P_b}{P_O}\right)^{\frac{\gamma+1}{\gamma}}\right\}\right]^{\frac{1}{2}} A_P C_D P_O sgn(P_O - P_b) = \left[\frac{V_{o1} P_O^{\frac{\gamma+1}{\gamma}}}{\gamma RT_O P_b^{\frac{\gamma-1}{\gamma}}} + \frac{P_b^{\frac{1}{\gamma}} A_b M_1 P_O^{\frac{\gamma+1}{\gamma}}}{RT_O}\right] P_b \quad if\ P_{th} \leq P_b < P_{ct}, \ldots\ldots\ldots \text{(eq.2)}$$

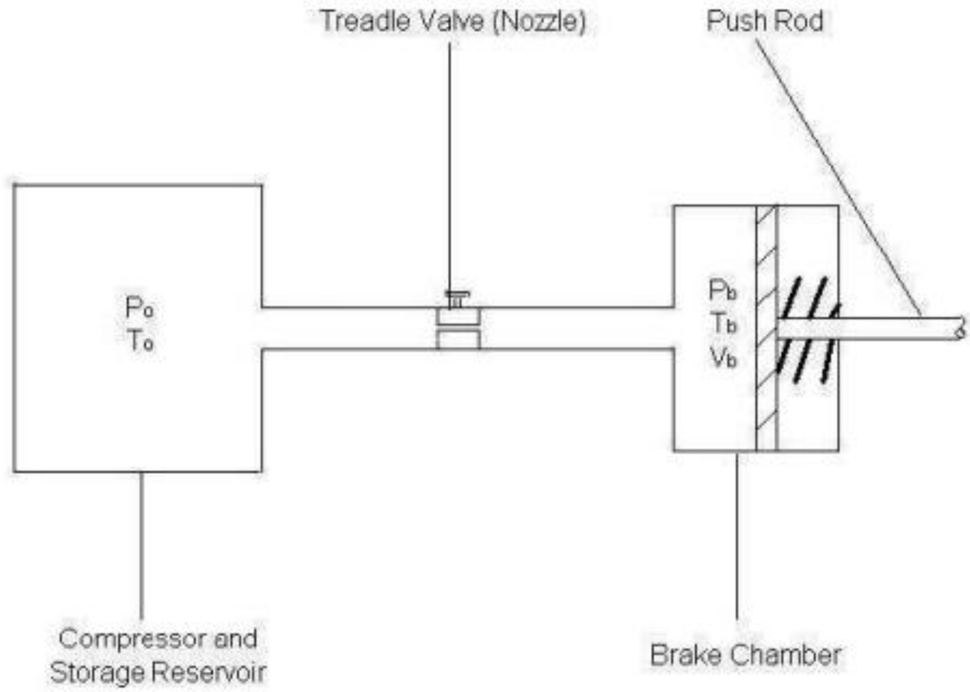


Figure 3.1 Schematic of the pneumatic subsystem

The following are the important features of the "fault-free" model:

- ✓ The pressure increases until the preload on the spring in the brake chamber is overcome. Once the preload of the spring is overcome, the system switches from the first mode to the second mode in which the pushrod moves until the gap between the brake pads and the drum is cleared and the brake shoes contact the brake drum. Once the brake shoes contact the drum, the system switches from the second mode to the third mode and the pressure increases in the brake chamber to the steady state value. Only after the brake shoes contact the drum (i.e. the system is in the third mode), braking action occurs.
- ✓ The governing equation in each mode is a nonlinear first order ordinary differential equation.

- ✓ The governing equation for each mode is different.
- ✓ The system shifts from one mode to another based upon the transition conditions, which are linear in-equalities.

The above set of equations may be solved using the fourth order Runge-Kutta numerical method to obtain the pressure response in the brake chamber. Treadle valve plunger displacement was the input to the numerical scheme.

3.2 Principle of operation of the existing manual slack adjuster

Most manual slack adjusters have a spring-loaded locking sleeve that must be pressed in and held so the adjusting bolt can be turned. The camshaft will rotate slightly as the bolt is being turned, continuing turning until solid resistance is met. This indicates that the brake linings have contacted the brake drum.

If the brake has no dust shields, or if you can see the brake shoes and linings through an inspection slot, you can visually verify that the linings have contacted the drum.

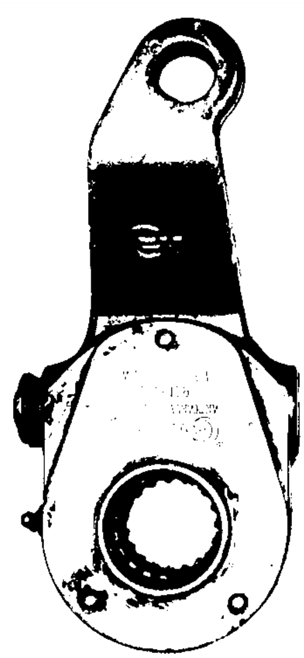


Figure 3.2 Existing manual slack adjuster

Backing off the adjusting bolt about 1/3 of a turn should establish correct running clearance between the lining and drum. Be sure the locking sleeve re-engages the bolt so that the adjustment will not back off.

3.2.1 Adjusting Manual Adjusters

When a slack reaches 1 inch (2.54 cm), the brakes must be adjusted by the following steps:

- Turn the adjusting bolt until you feel solid resistance. If you are turning the bolt the right way, the cam will turn in the same direction as it does when you apply the brakes. Watch the chamber push rod and slack adjuster arm. If you detect outward movement, you're turning the bolt the wrong way.
- Back off the bolt one third of a turn to restore the clearance.
- Now recheck the correct push rod travel.

3.2.2 Disadvantage of the manual slack adjuster

When the gap between the brake drum and the brake lining is increased due to the brake lining wear, the slack adjuster is rotated manually by the technicians so as to rotate the "S" cam and adjust the gap between brake drum and the lining. This requirement increases service need, out of order time and air consumption of the vehicle. Additionally, if the clearance adjustment is not performed in time or in proper manner, brake security will be in danger.

3.3 Principle of operation of the newly designed automatic slack adjuster

Setting the brake chamber stroke measurement, this is the correct shoe-to-drum clearance which is the range between 35mm and 40mm and the thickness of the shoe lining which is 12mm. When linings wear, this clearance increases, and the fluid chamber push rod return stroke must exceed design limits and move farther to apply the brakes.

When this happens, the slack adjuster will automatically adjust the return stroke to maintain the correct shoe-to-drum clearance, and reset the stroke to the correct length. If the air brake chamber pushrod stroke is within limits during operation, no adjustment will occurs. The detailed schematic diagram of the working principle of the newly modified slack adjusting mechanism is shown below:

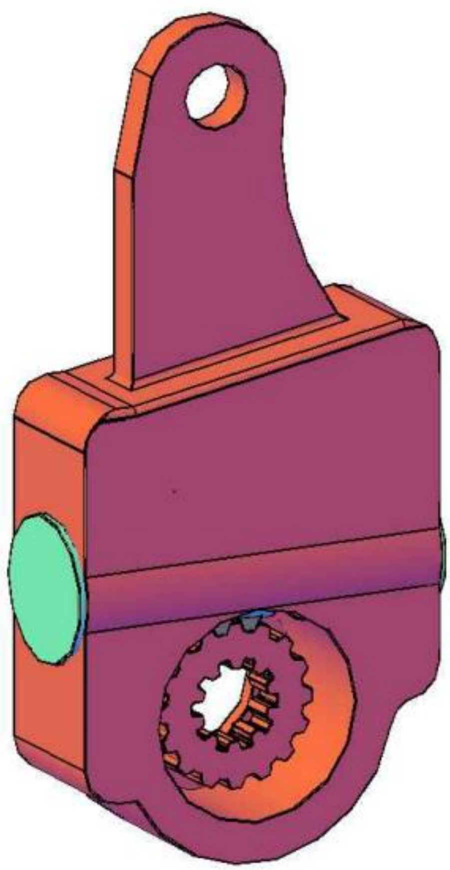


Figure 3.3A Modified automatic slack adjuster

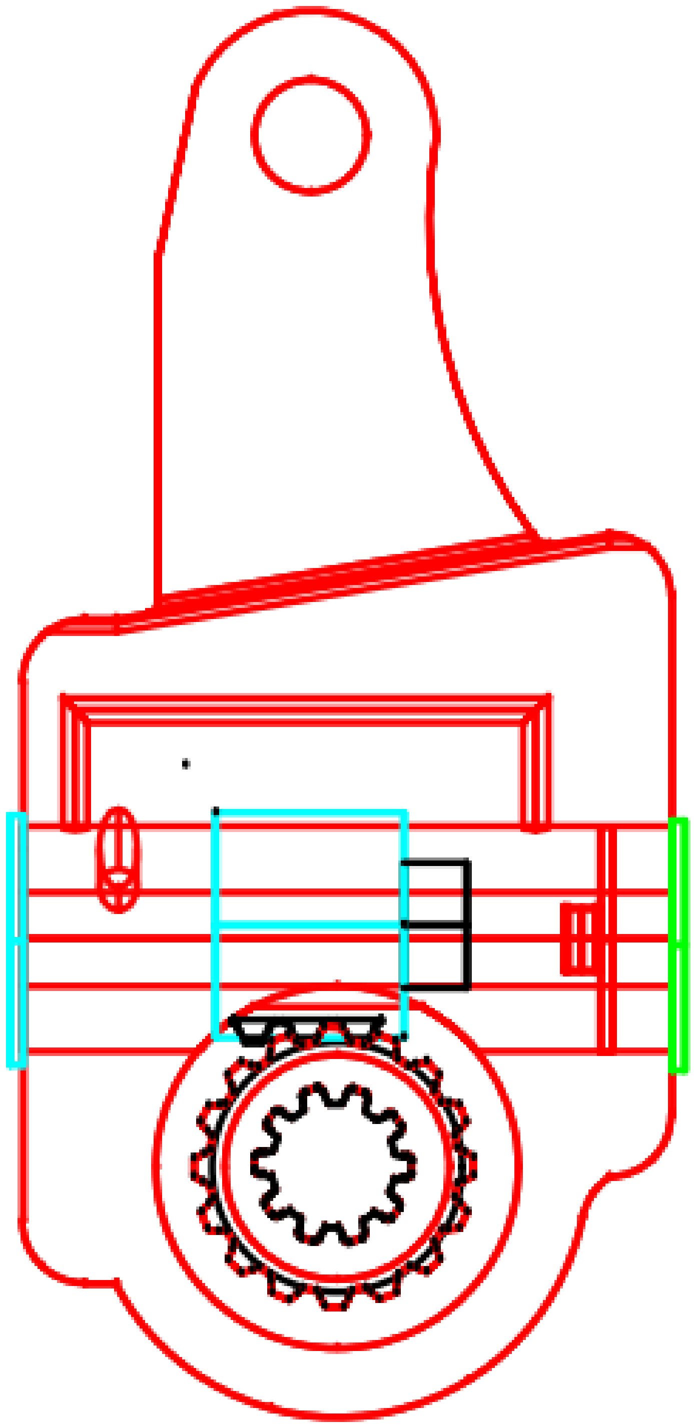


Figure 3.3 B Modified Automatic Slack adjuster

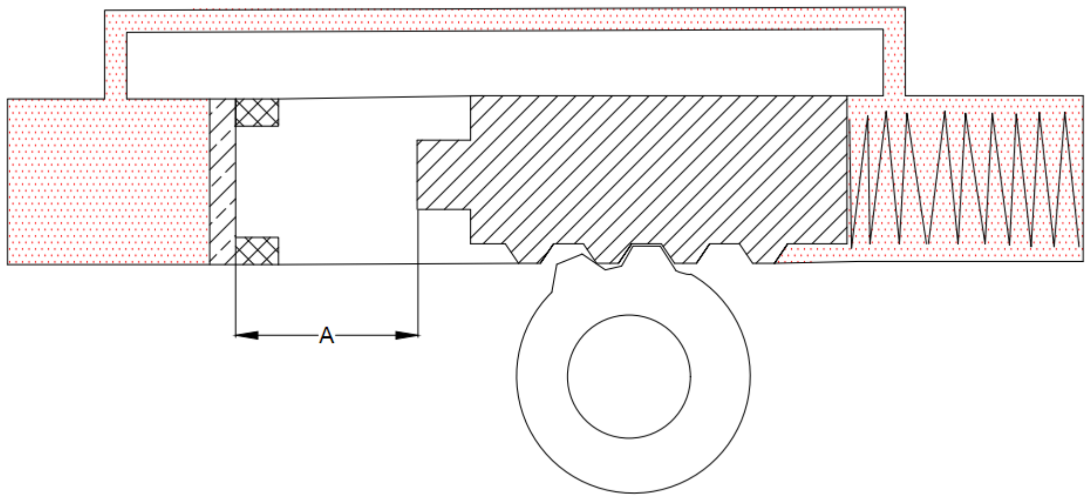


Figure 3.4 Schematic Diagram brake off position

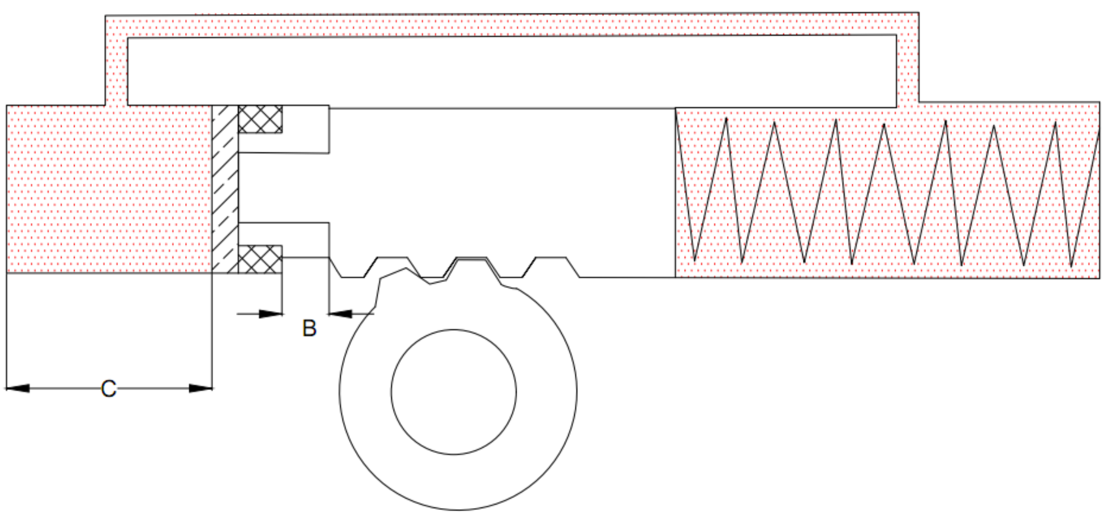


Figure 3.5 Break On stroke

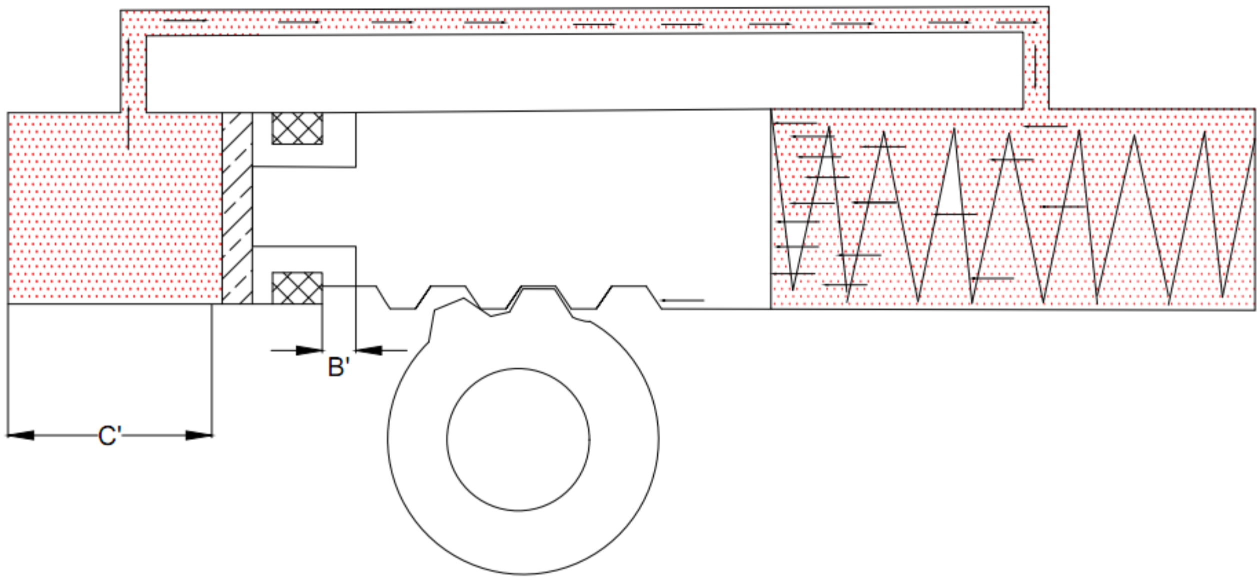


Figure 3.6 Break during wear

3.4 Main Components of modified Slack adjuster

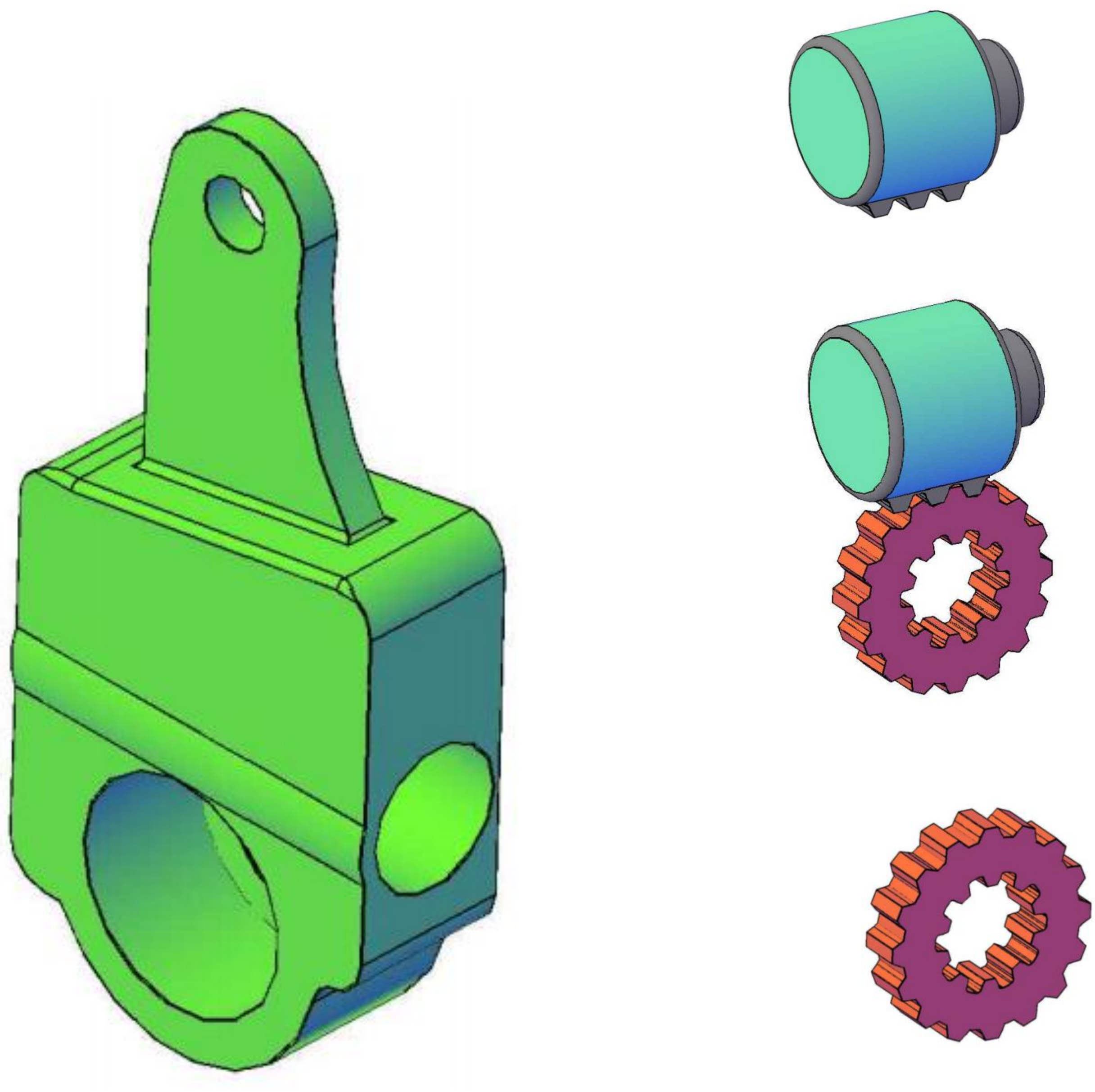


Figure 3.7 Main Components of Modified Slack Adjuster

Table 3. Component parts of the newly designed slack adjuster

SN.	*Component*	*Material Type*	*Dimensions(mm)*	*Quantity*
1	Main Body	MS	180X60X240	1
2	Spur Gear	MS	40X30	1
3	Rack	MS	20X50	1
4	Spring	HCS		1
5	Piston	Al	Dim 38mm	1
6	Piston Ring	CI	Dia. 38mm Thickness 4mm height	2
7	One way valve	GM		2
8	Oil	Dot 4	-----------------------	
9	Bolt	MS	8MX1.5	6
10	Nut	MS		
11	Set Screw	MS		
12	Cover	CI	Dim 60mm	2
13	Gasket	Asbestos	48mm X 38mm	2

3.5 Stress and strain characteristic

To create the CAD model of the automatic slack adjuster we find the existing Manuel Slack adjuster of Sino Truck for reverse engineering. We measure all the visible dimensions manually with specified measuring instruments to create accurate and scaled model. To find out accurate feature location like holes plane angles etc. Using CAD software we can create CAD model of Main body Automatic Slack adjuster as per measurement data. We Import the CAD Model (IGES) in the ANSYS Workbench 15 for pre-processing and then the stress and deformation analysis is done on the main body. The Analysis involves the discretization called meshing, boundary conditions and loading. For analysis we take ductile iron. The medium carbon steel has been selected based on the properties required for the existing Slack adjuster.

The material composition of the slack adjuster body used in the current manual slack adjuster of the truck has tested at Hibret metal engineering and the test result shows that it is made up of ductile iron.

3.6 Some feature of software Used

3.6.1 ANSYS

It is the name commonly used for ANSYS Mechanical, general purpose finite element (FEA) computer aided engineering (CAE) software tools developed by ANSYS, Inc. ANSYS Mechanical is a self-contained analysis tool incorporating pre-processing (geometry creation, meshing), solver and post processing modules in an unfired graphical users interface. ANSYS is a general purpose finite element modeling package for numerically solving a wide variety or mechanical and engineering problem.

3.6.2 CAD

AutoCAD tools are widely used to model the geometry. It is mainly used to model different types of shapes and also it is friendly with ANSYS and other design software.

3.7Procedure Follow

Having developed the mathematical modeling of the braking system of Sino truck, the next procedure is expected to be finding the solution for the required stress and deformation analysis of the main body.

Like solving any problem analytically, it is required to define

- ❖ Physical model
- ❖ The physical properties
- ❖ Boundary condition and the solution domain

Then the problem is solved and the results are presented. The main difference in numerical method is the extract step called mesh generation. This is the, step that divides complex method into small elements that becomes solvable in an otherwise too complex situation. The procedure that is followed to accomplished the required solution is discussed below

3.7.1 Geometric Modeling

For the analysis purpose the geometries selected the main body of the automatic slack adjuster and gear .The geometric modeling using finite element analysis software for complicated parts like irregular shape is difficult. To avoid this difficulty, the method used here is to develop the model in modeling software and to import the geometry to FEM software. AUTOCAD is the software that is used to model the slack adjuster body.

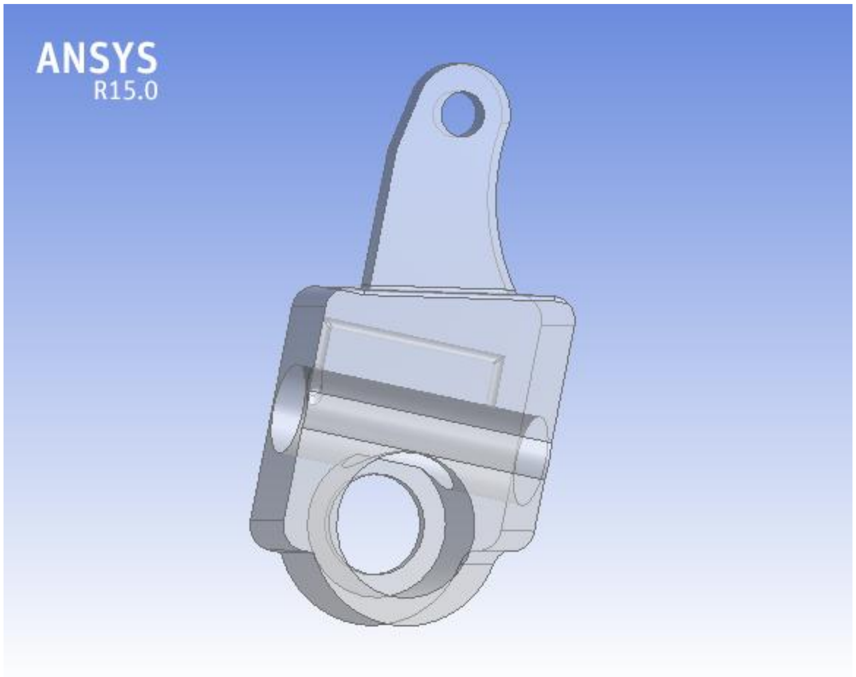


Figure 3.8 Modified main body

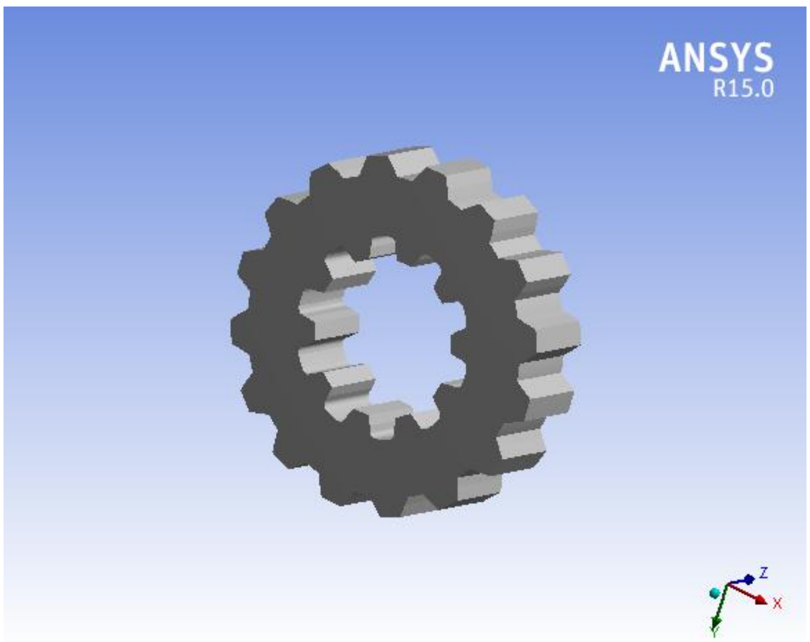


Figure 3.9 splined gear of the modified slack adjuster body

3.7.2 Define Material properties

Material Property:

Material: Ductile iron

Young's Modulus 1.7e 5 N/ mm^2 =1.7e 11 N/ m^2

Passions Ratio: 0.23

Density: 0.00000734 kg/mm^3 =7340 kg/m^3

Yield Strength: As Cast: 320 Mpa = 320 N/mm^2

(Proof stress 0.2%)

Tensile Strength: As Cast: 500 Mpa = 500 N/mm^2

3.7.3 Calculation

Density: Cast iron Specific weight (SW) =0.072 N/cc (from PSG data book page no 1.1) Density=SW/g

$=0.072/(9.81 \times 10^3)$

$=0.000000734$ kg/mm^3

ρ =7339.5kg/m^3

Force & Torque:

Inlet pressure of the brake chamber = 8.1 bar (max)

$= 8.1 \times 10^5$ N/m^2 Take 30 sq.in Brake chamber Effective area = 30 sq.in = 0.0194m^2

Force = Pressure x Area

$= 8.1 \times 10^5 \times 0.0194$

F = 15714 N

Torque = Force X Radius

= 15714 X 160

$T = 2.51424 \times 10^6$ N-mm

= 2514.24 N-m

3.7.4 Mesh Generation

At this point ANSYS understands the makeup of the model. And this step defines how modeled system should be broken down into finite pieces, known as FEM.

3.7.5 Apply load

The last task is to burden the system with constrain, as physical loadings and boundary condition. It is root end is constrained from all degrees of freedom.

3.7.6 Obtain the solution to the problem

At this step the type of analysis is to be performed is selected, and the state for solving the problem must be specified, model analysis is used for solving the problem.

3.7.7 Presentation of the Result

After the solution has been obtained, there are a number of ways to present ANSYS results out of which tabular presentation, animation, and contour plots are selected.

Chapter Four

RESULT AND DISCUSSION

The various parameters like displacement, shear stress plane XY and von misses stress are obtained.

4.1Results for Modified Body:

4.1.1 Displacement Plot:

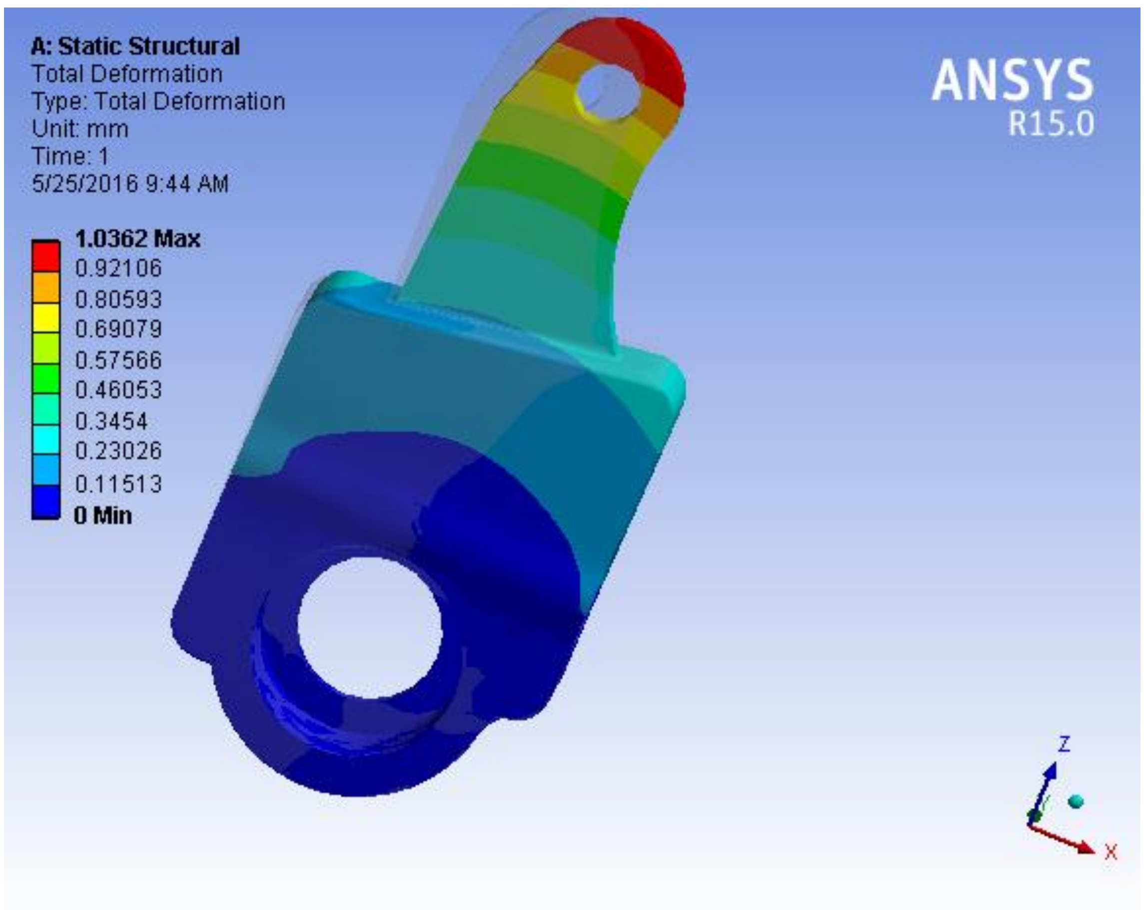


Figure 4.1 Deformations for Modified Model

4.1.2 Stress Plot:

The Figure below shows the von mises stress

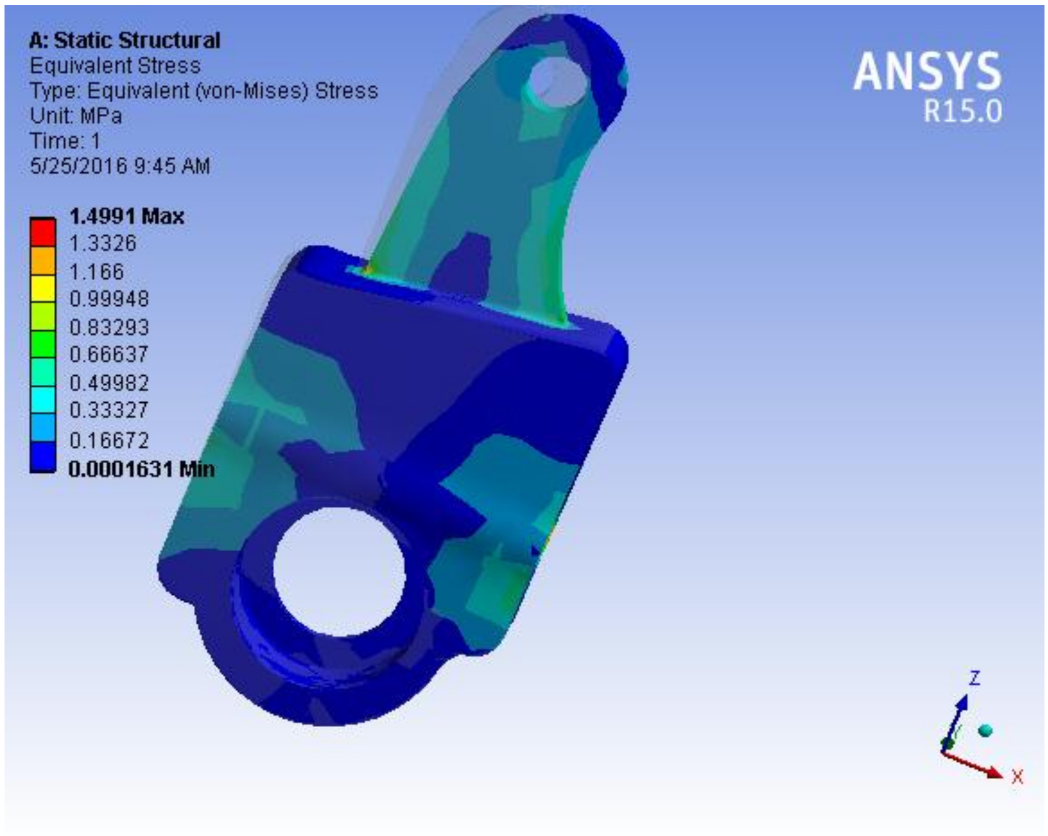


Figure 4.2Von-Mises stress for Modified model

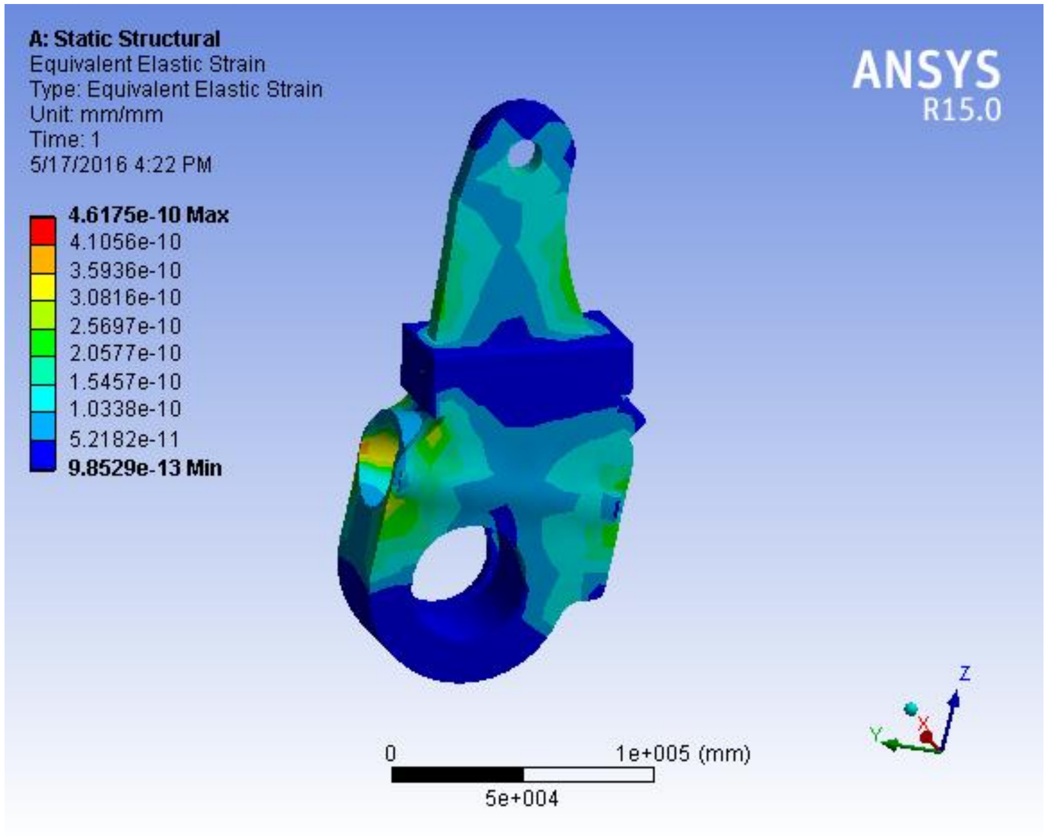


Figure 4.3 Equivalent Elastic strain for modified diagram

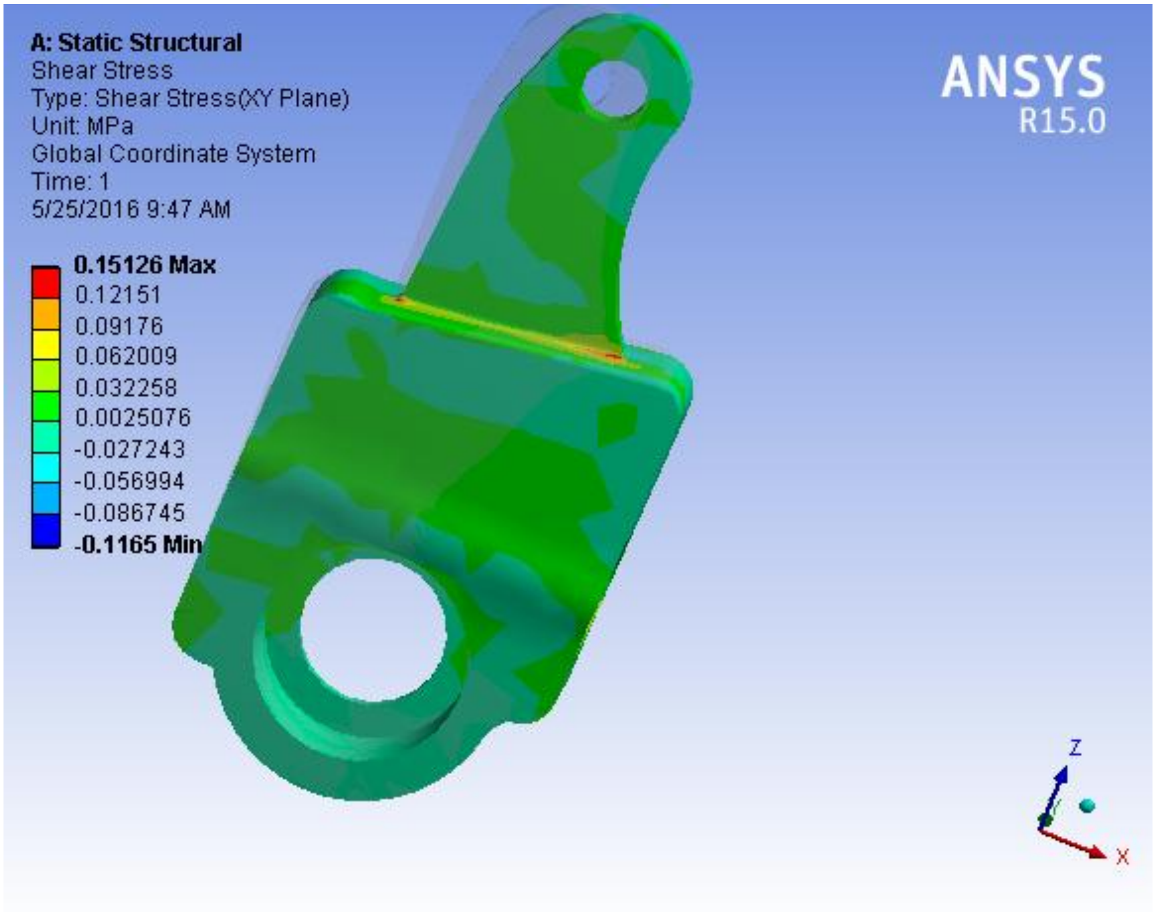
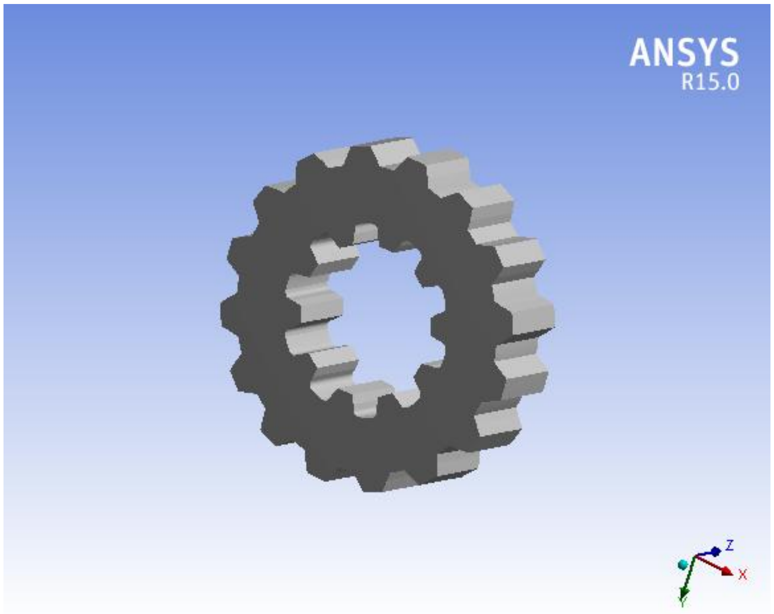


Figure 4.4 Shear stress for modified diagram

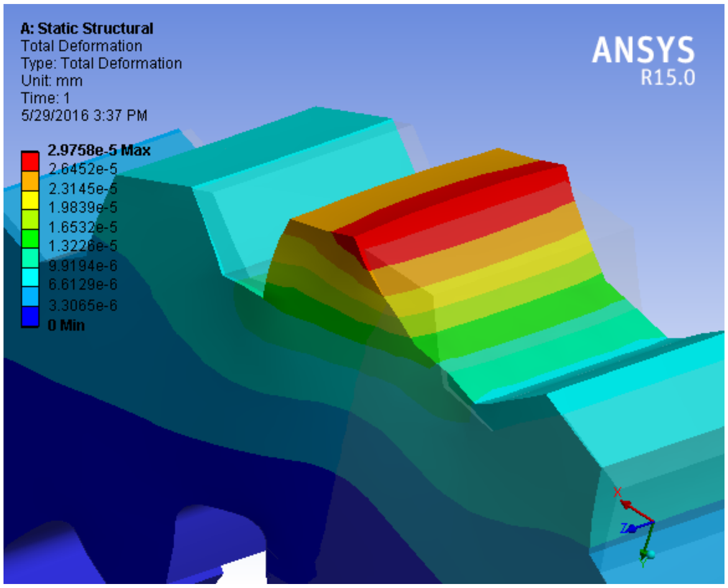
The different results which are found for new modified slack adjuster body is the approximately the same as the previous researchers has done.

Yield strength (EN-GJS-SG500/7): 320 Mpa = 320 N/mm^2 (Proof stress 0.2%) It is found that all the stress values are lesser than the actual yield strength of SG Cast iron body (EN-GJS- SG500/7) so the new design is safe**.**

4.2 Results for Gear analysis:



4.5 Gear



4.6 Total Deformation of the gear

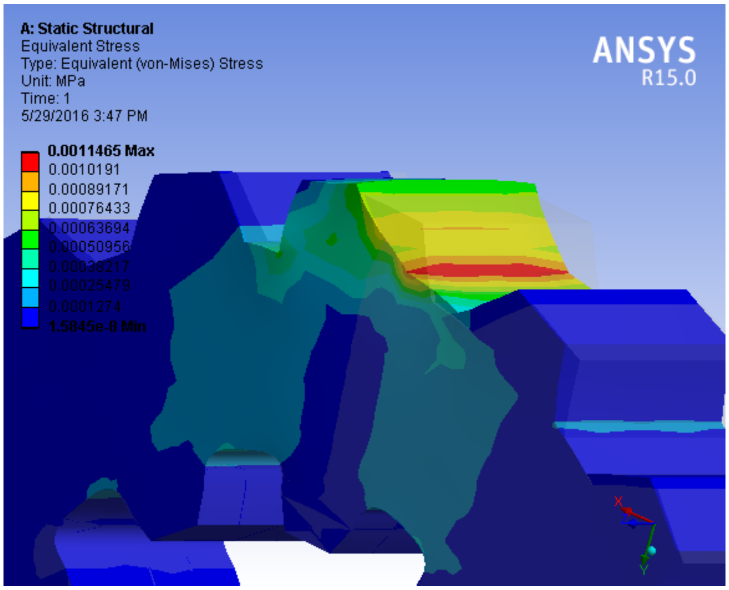


Figure 4.7 Von-Mises stress for Modified model

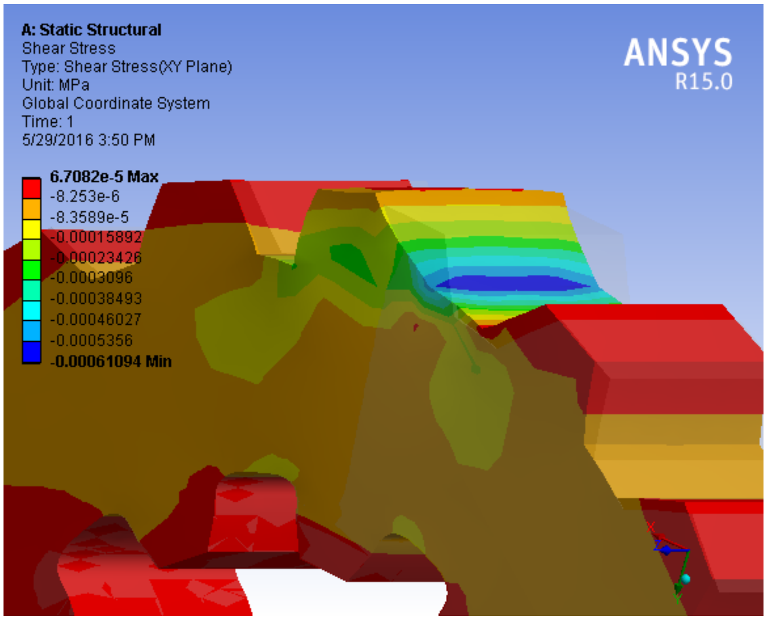


Figure 4.8 Shear stress for Modified model

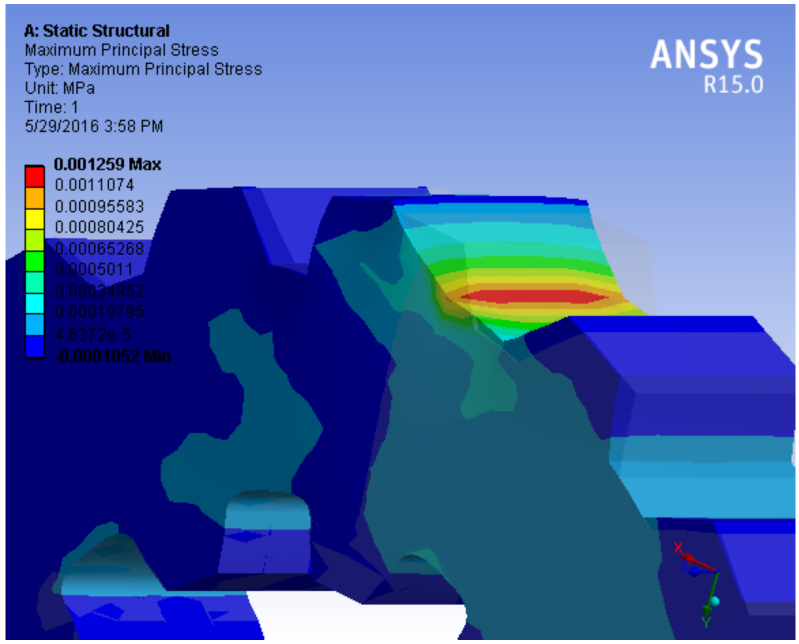


Fig 4.9 Maximum principal stress

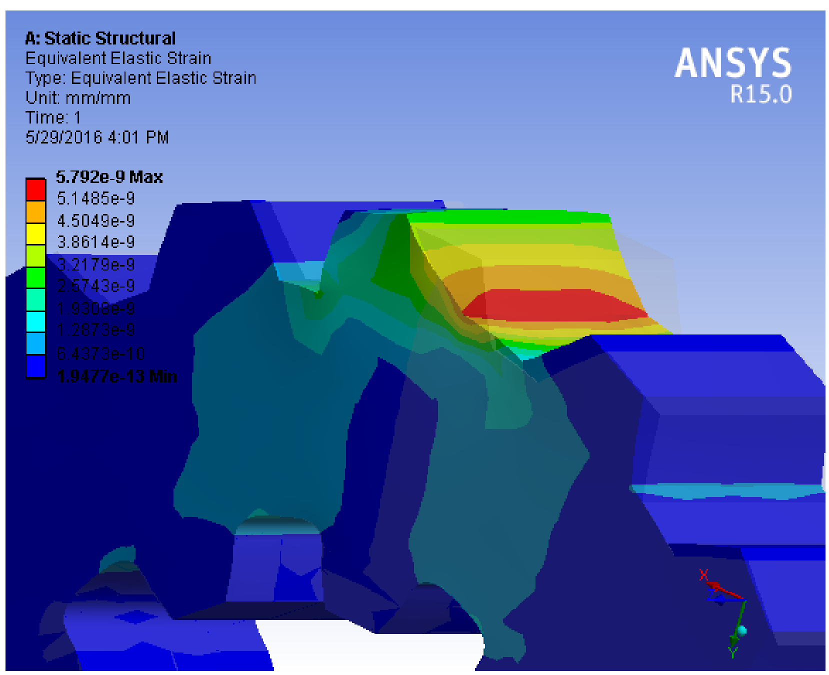


Figure 4.10 Elastic strain

The deformation and the stress induced in the Splined gear alloy and drums during the application of brake force have been determined using finite element analysis. It is observed from the analysis that the deformation of splined gear is considerably less than the allowable deformation.

The different stresses in the splined gear are found to be almost same of the previous researchers

Chapter Five
CONCLUSION & RECOMENDATIONS

5.4 Conclusion

It can be observed that the Sino truck was made maximum number almost 50% of total accident of truck and 90% the Sino truck accidents are almost because of break system. We observe that the suggested model responded well to various supply pressures. The model responds well to periodic applications of the brake pedal.

The next model which is proposed the body of Slack adjuster the CAD models of the existing and newly modified slack adjuster body (self-setting type) are parametrically developed using CAD software. Then the Analysis of main body of slack adjuster is done using the ANSYS software and various parameters displacement, shear stress (plane XY) and von misses stresses are found and compared with other researchers. It is found that displacement, shear stress (plane XY) and von mises tresses are similar to the most researchers done suggested body model better than the Manuel adjuster model and all the stress values are lesser than the actual yield strength. Thus automatic slack adjuster provides better performance. The experimental results show that the system runs stably and measures accurately. Consequently, it meets the design requirements well.

5.2 Recommendations

Some suggestions for future investigations are

- To model and analysis of all components of the adjuster
- To consider the effect of temperature on the initiation and propagation of wear on the lining shoe.
- To Analysis of irregular wear of lining shoe and drum.

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