Design and Analysis of Spare Tyre Handling Mechanism for Howo 336 Dump Truck

By

Pawlos Barud Jibo

A Thesis Submitted to the Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

Design and Analysis of Spare Tyre Handling Mechanism for Howo 336 Dump Truck

By

Pawlos Barud Jibo

Advisor: Alemayehu Wakjira Huluka (PhD)

A Thesis Submitted to the Department of Mechanical Engineering
School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

DECLARATION

I hereby declare that this Master Thesis entitled "*Design and Analysis of Spare Tyre Handling Mechanism for Howo 336 Dump Truck"* is my own 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.

Pawlos Barud Jibo	________________________	________________
Name of student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "*Design and Analysis of Spare Tyre Handling Mechanism for Howo 336 Dump Truck"* prepared under my guidance by Pawlos Barud Jibo submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Automotive Engineering. Therefore, I recommend the submission of a revised version of the thesis to the department following the applicable procedures.

Alemayehu Wakjira Huluka (PhD) ____________________ ______________________

Major Advisor Signature Date

APPROVAL PAGE

I, the advisor of the thesis entitled "*Design and Analysis of Spare Tyre Handling Mechanism for Howo 336 Dump Truck*" and developed by Pawlos Barud Jibo, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Alemayehu Wakjira Huluka (PhD) ____________________ ______________________

Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Pawlos Barud Jibo have read and evaluated the thesis entitled "*Design and Analysis of Spare Tyre Handling Mechanism for Howo 336 Dump Truck*" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Automotive Engineering.

______________________	______________________	______________________
Chairperson	Signature	Date
______________________	______________________	______________________
Internal Examiner	Signature	Date
______________________	______________________	______________________
External Examiner	Signature	Date

Final 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

ACKNOWLEDGMENT

First and foremost, I wish to extend my heartfelt appreciation to my teacher and advisor, Alemayehu Wakjira Huluka (PhD) for his precious contribution to laying the groundwork for this thesis. He motivated me to develop a title that resonates with and tackles issues within the community. Working under his guidance was a tremendous privilege and honour. I would also like to express my deepest gratitude to my teacher Ramesh Babu Nallamothu (Associate Professor) for everything he has done to help me during my thesis work. He has sparked new ideas and perspectives that I will carry with me throughout my academic journey. My heartfelt thanks go to Tsray Dagnew Berhe (Chemical Engineer) for unwavering support. I am grateful to my classmate Mr. Zekarias Girma Marie for his help.

Lastly, I would like to express my gratitude to my teacher, Getachew Alemayehu (PhD) for his significant advice.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ANSYS	Analysis of Systems
ASTM	American Society for Testing and Materials
CAD	Computer-Aided Design
CFD	Computational Fluid Dynamics
EN	European Norm
FBD	Free Body Diagram
HSLA	High-Strength Low-Alloy
ISO	International Organization for Standardization
OEM	Original Equipment Manufacturers
PTO	Power Take-Off
RHS	Rectangular Hollow Sections
SAE	Society of Automotive Engineers

NOMENCLATURE

A	Area of cylinder
B_x	Horizontal force at joint B
B_y	Vertical force at joint B
C_X	Reaction force along X-direction at a fixed point B
C_y	Reaction force along the Y-direction at a fixed point C
D	The bore diameter of the cylinder
E_x	Horizontal force at joint E
F_{BC}	Force along hydraulic cylinder
F_x	Total force in the X-direction
F_y	Total force in the Y-direction
M	Moment
N	Safety factor
P	Hydraulic cylinder pressure
R_{hc}	The rotational radius of the hydraulic cylinder
V_{hc}	Linear velocity of hydraulic cylinder
V_{vs}	Linear velocity of vertical structure
α	The tilting angle of the hydraulic cylinder
Δt	Change in time
$\Delta\theta_{vs}$	Change of an angle,
ω_{hc}	Angular velocity of hydraulic cylinder
ω_{vs}	Angular velocity of vertical structure
$\boldsymbol{\sigma}_w$	Working stress
$\boldsymbol{\sigma}_y$	Yield strength

ABSTRACT

Dump trucks are used to transport materials like sand, gravel, rocks, and dirt in construction, mining, and agricultural sectors. However, these trucks are not effective in terms of spare tyre handling mechanism since the currently existing spare tyre handling mechanism takes more time, is quite cumbersome, unreliable, and causes fatigue to the driver during spare tyre replacement. In previous research works, different attempts have been made to minimize such challenges for vehicles. But for dump trucks, these problems have not been improved yet. This thesis is mainly concerned about the design and analysis of the spare tyre handling mechanism for the Howo 336 Dump Truck. To meet the objectives of the thesis, steps which are included in the methodology like literature review, data collection, modelling of spare tyre handling mechanism using SOLIDWORKS, static and dynamic analysis using ANSYS workbench are followed. According to static analysis, the maximum equivalent stress of the structure is 128.69 MPa and the maximum shear stress is 66.67 MPa which is less compared to the yield strength of the material. The vertical structure of the mechanism rotates 86 degrees within 8 seconds to lift the spare tyre. When a new spare tyre handling mechanism is used, the time to lift and lower the spare tyre is decreased by 98.9% compared to a manual method and decreased by 66.9% compared to the chain block method. The newly developed mechanism is reliable, easy to access and minimizes downtime.

Keywords: *Downtime, Dump Truck, Mechanism, Spare Tyre Handling, Spare Tyre*

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The construction sector is a significant contributor to Ethiopia's economic growth. The nation is becoming one of the continent's best-performing economies thanks to significant government investment in residential construction and infrastructure. The swift pace of urbanization has resulted in a significant demand for enhanced infrastructure and a substantial backlog of housing (Falcioni, 2018).

Loads of materials from construction, mining, and agriculture like gravel, sand, and dirt, are transported by dump trucks or production trucks. These trucks have spare tyres, also known as stepneys, which are extra tyres kept in a vehicle as a backup in case of an emergency (Pavlenko et al, 2022). In Llanelli, Wales, Walter and Tom Davies created the spare tyre in 1904. Automobiles were not manufactured with spare wheels at the time. They distributed in Belgium, France, Italy, and the United States through agents of their company. In some former British Empire nations, like Bangladesh, India, and Malta, the term "stepney" is sometimes used interchangeably. Thomas B. Ramblers' cars were the first to be outfitted with an inflated spare wheel and tyre assembly (Shete, 2015).

A spare wheel lifting and lowering mechanism is provided for the vehicle. It is used for securely storing and providing access to the spare tyre in the event of a tyre failure. This is a method of assisting an individual to access a spare wheel (Valdes, 2017).

In most dump trucks, a spare tyre carrier is situated or mounted on the front part of the cargo box behind the cab of the dump truck. It is locked by bolt and nut. Lifting and lowering of spare tyres is done by using a chain block or by using manual method. As this is still the most popular way for storing spare tyre in dump trucks, it faced the problem of manually handling heavy spare tyre or attempting to lift loads that are too heavy, improper mounting of spare tyres, seeking assistance, and even at tyre repairing station around four or five workers are involved in lowering and lifting the spare tyre. Because using a chain block takes more time. The cab should also be tilted or raised. When changing tyres, this is typically a bad technique that gives headaches.

Without a mechanism, it is difficult for a single person to raise and lower of 150 kg mass of a tyre. This tiresome procedure lengthens the travel time to the destination and reduces the driver's driving effectiveness.

Figure 1.1: Lifting of spare tyre by using a chain block *(Je, 2021)*

Figure 1.1 shows the lifting of a spare tyre by using a chain block. During the chain block method minimum of two individuals are involved. One person should guide the spare tyre while another pulls the chain. Another activity that can be done here is, tilting the cab, raising up and down to unlock. This lengthens the duration of spare tyre replacement.

Figure 1.2: Lowering spare tyre

Figure 1.2 is taken from the tyre repairing station at Tullu Dimtu in Addis Ababa.

From Figure 1.2 some of the concerns related to lowering is working in a narrow area; as one person is pushing from the left side and another person was trying to support 150 kg mass of spare tyre alone which is unsafe and may cause injury to his feet; the tyre by its very nature is not easy to be grasped by hand, especially when it comes to large width heavy duty tyre; from the Figure 1. 2 this person is trying to hold it alone. After all, he will live on the ground. Due to its nature, the tyre moves forward and attempting to stop the unwanted movement of the tyre is an unnecessary situation that the workers face at the garage. Thus, this is unsafe handling of spare tyres.

Figure 1.3: Manual lifting of spare tyre

The picture was taken from a tyre repair station around Tullu Dimtu in Addis Ababa.

Figure 1.3, shows manual lifting of the spare tyre, where five individuals were involved in lifting the spare tyre. They were attempting to lift a heavy spare tyre to one meter and seventy-centimeter height. As this is an off-road vehicle, one can imagine how difficult it is when an emergency of tyre occurs in a remote area or at night.

There are significant drawbacks when utilizing a chain block on the dump truck to store the spare tyre, including increased cycle time, diminished productivity, and driver fatigue. Thus, the use of other spare tyre handling mechanisms is not only an important decision but also a necessary condition to save time and simplify the handling of heavy spare tyre This is addressed by designing and analyzing an appropriate spare tyre handling mechanism for Howo 336 Dump Truck. Its design is modelled using SOLIDWORKS software and then transferred to ANSYS workbench for the study of static and dynamic analysis.

1.2 Statement of the Problem

Nowadays, there are plenty of dump trucks used in the construction, mining, and agricultural sectors. All of these dump trucks lack proper spare tyre handling mechanisms; because the complexity of the current spare tyre handling system has many limitations in terms of physical ergonomic aspects, time, and reliability. The efficient handling and management of spare tyres in dump trucks are crucial for ensuring operational readiness and minimizing downtime. Therefore, it becomes essential to design a mechanism which will simplify spare tyre lifting and lowering. It is known that spare tyre is an essential component of dump trucks when it comes to change a flat tyre or handling other emergencies. Most dump trucks have a chain block mechanism with some other accessories like bolts and nuts, round bar and plate for carrying the tyre. But this mechanism is quite cumbersome, ergonomically not good, time-consuming, and unreliable. Therefore, this research work aims to design and analyze an effective spare tyre handling mechanism rather than a chain block and manual methods to minimize the time to change tyre, reduce driver fatigue, increase reliability, and facilitate simple and safer spare tyre changing.

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis is to design and analyze the spare tyre handling mechanism for the Howo 336 Dump Truck.

1.3.2 Specific Objectives

The specific objectives of the thesis are:

- Design parts and the whole assembly of the spare tyre handling mechanism.
- Model the whole assembly of improved spare tyre handling mechanism i.e. (Geometric modeling).
- Analyze the spare tyre handling mechanism's static (stress and deformation) and dynamic (velocity) analysis.

1.4 Significance of the Study

The output of this thesis is to give a better contribution to Howo 336 Dump Truck manufacturers in terms of spare tyre handling mechanism. The improvement of the spare tyre handling mechanism will help drivers and workers at the tyre repair garage during tyre replacement. The mechanism is aimed at minimizing the time to lift and lower spare tyres, reducing fatigue to the driver, and facilitating easy and safer spare tyre lifting and lowering by designing and analyzing effective spare tyre handling mechanisms instead of chain block and manual methods.

1.5 Scope of the Study

The study focuses on design, static (stress and deformation) and dynamic (velocity) analysis of the spare tyre handling mechanism for the Howo 336 Dump Truck. The research will not extend to other types of vehicles or spare tyre handling mechanisms.

1.6 Organization of the Thesis

This thesis consists of six chapters. The first chapter is an introduction to the study. It includes the background of the study, statement of the problem, objectives, significance of the study, scopes of the study, and organization of the thesis. Chapter two focuses on different kinds of literature that emphasize on study of spare tyre handling mechanisms. Chapter three describes the materials and methods used to complete the thesis. Chapter four presents the design and analysis of the spare tyre handling mechanism. Chapter five presented results and discussions of both static and dynamic analysis. Then, the conclusion and recommendation are included in chapter six.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Spare Tyre of Vehicle

In Ethiopia 15741 dump trucks were registered (Redi, 2015). These trucks have spare tyre which is called stepney. A tire, known as "tyre" in British English and "tire" in American English, is a circular vehicle part that encases the wheel's rim to safeguard it and enhance vehicle performance. It’s made up of a tread that offers grip and a body that holds a specific amount of pressurized air (Wofuru-Nyenke, 2020). The majority of tyres, like those designed for cars and bikes, create a grip between the vehicle and the road, serving as a pliable cushion that absorbs impact. A spare tyre also called a spare tyre stepney, is an extra tyre that is kept in a car in case one blows out, goes flat or experiences another emergency. The spare tyre storage system on the vehicle's roof has many significant drawbacks, including increased cycle time, physical strain on the driver, and a decline in productivity (Cheah et al., 2015). Spare tyre lifting and lowering mechanism was designed for dump truck, but it uses two hydraulic cylinders (Simaite, 2015)

2.2 Storage System

When a spare tyre is not in use, it is kept in a spare tyre well or holder. It is typically an unconventional method that gives a headache when changing tyres. One of the storage options is to keep the spare tyre in a cradle beneath the car's back end. In addition to saving space in some applications, this arrangement has advantages over storing the tyre inside the trunk or casing of spare tyre, such as the ability to access the wheel. However, there are drawbacks. First, the tyre gets dirty, which makes changing tyre more unpleasant. Secondly, older cars may have rusted a mechanism, which makes it harder to free the spare. Since the cradle would obstruct the rear axle on the majority of rear or four-wheel drive cars, the cradle arrangement is only practical on front wheel drive vehicles. On trucks, where the spare tyre is frequently kept under the truck bed, a similar setup is also frequently observed (Kaustubh, 2015).

2.3 Material Handling

The act of handling objects is collectively referred to as material handling. There is a need for automated solutions because human labour done by hand is frequently expensive and has capacity and speed restrictions. The future of material handling will depend on the specific customer, driverless cars, and alternative energy sources. The client would rather automate solutions for their current infrastructure than construct brand-new, cutting-edge facilities (Andersson, 2018).

Material handling systems control the motion, storage, and protection of materials within a production system. From simple hand trucks that are pushed by operators to autonomous intelligent vehicles that are self-guided with no human intercession have a significant impact on the productivity, safety, and sustainability of manufacturing operations. It accounts for 30% to 75% of the total production costs (Soufi et al., 2023). Autonomous mobile robots can be used in hazardous, dangerous, or contagious environments (Harsh, 2023).

Experienced workers have better material handling ability (Jasmin et al., 2023). This will reduce industrial injury (Gagnon et al., 1992). Footstep strategies play an essential role in reducing the risks of injury. Because load mass, asymmetry angle, horizontal location and deposit height have the most substantial effect on different parts of the body during lifting (Blafoss et al., 2021).

2.4 Original Equipment Manufacturers' Spare Tyre Well

Original equipment manufacturers' (OEM) spare tyre wells are ineffective for off-road enthusiasts who require an additional oversized tyre in case of an emergency (Philips, 2019). They only accommodate tyres up to a certain size (Marrs, 2016).

2.5 Lifting Mechanism

Mechanism is collection of solid objects that are connected by movable joints to create a movement, with certain link being stationary, all to convert motion (John.et al, 2016). For example, a load-lifting platform that has eight linked lever mechanisms uses a hydro cylinder. This mechanism is reliable also it minimizes time to install, and materials are lifted to the needed altitude by hydro cylinder pressure (Tanzharikova et al., 2013). Loads up to 3.5 tons can be lifted to a certain height for maintenance purposes using a scissor-like structure and a single hydraulic cylinder (Matus et al., 2021). In Ethiopia, hydraulic scissor lifts have been designed to be operated by hydraulic force to a height of 8 m carrying a maximum load of 1000 kg (Samuel et al., 2021).

A folding mechanism under pneumatics to tilt the trolley of the dump truck was used to optimize the long hydraulic cylinder (Kumar et al., 2017). Also lifting mechanism that will not affect the driver's field of vision to lift goods was designed for forklifts. This structure uses steel cable to lift (Wang et al., 2010). However, a parallel lifting mechanism of the stereoscopic parking robot was designed to obtain both vertical and horizontal motion (Jiang et al., 2022).

2.6 Previous Investigations on Related Topics

Some of the related works which are intended to improve spare tyre handling mechanisms are discussed as follows:

In 2019, Philips discussed the importance of original equipment manufacturers' (OEM) spare tyre wells. This helps the vehicles to handle their spare tyre. In 2016, Marris designed and manufactured a device that is capable of carrying tyres for off-road trucks. The drawback of this work is the design was complex as it allows for carrying two bikes and a gas tank. Here optimization of spare tyre storage was done to carry oversize tyre. In a study conducted by Simaite, in 2015, analysis and design of a truck spare wheel lifting mechanism was designed. The study encompassed the design and modelling of the spare tyre handling mechanism. This design uses two hydraulic cylinders to lift and lower spare tyre. However, the new design uses one hydraulic cylinder. This makes the mechanism simpler. It minimizes downtime during spare tyre lifting and lowering.

2.7 Research Gap

As discussed above, researches which were intended to improve spare tyre handling mechanisms have been done for vehicles. Analysis and design of a truck spare wheel lifting mechanism was done. This mechanism was specifically designed to securely hold the spare tyre in place, ensuring it is accessible in case of a flat tyre or emergency. However, for Howo 336 Dump Truck the problem of spare tyre handling is not solved yet. Because this lifting mechanism is complex as it uses two hydraulic cylinders and also it is not compatible with Howo 336 Dump truck. Therefore, addressing this gap is crucial to enhance the effectiveness, safety, and convenience of spare tyre handling in Howo 336 dump trucks.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

The geometrical design of the spare tyre handling mechanism is carried out using SOLIDWORKS, whereas static and dynamic analysis is done by ANSYS workbench. The hydraulic circuit is designed using FluidSIM.

The thesis has undergone various stages of study. These include; a review of the literature on spare tyre handling mechanism, data collection, the conceptual design stage, geometric modelling, static analysis, and dynamic analysis.

3.2 Methods

To address the general and specific objectives of this work a well-designed methodology should be followed. Various steps which are included in the methodology are listed below.

a) Literature review

The latest kinds of literature and research work relevant to the design and analysis of spare tyre handling mechanisms for dump trucks have been reviewed.

b) Data collection

To do the numerical analysis, the necessary data about the existing dump truck is collected by using primary or secondary data collection methods. The data is collected from:

I. Construction Machinery Production Industry
II. Metals Fabrication Industry (MFI)

I. Construction Machinery Production Industry

The Construction Machinery Production Industry is one of the governmental organizations located in Addis Ababa Ethiopia. It’s is involved in the design, assembly, production, and after-sell servicing of heavy-duty machinery. In this company secondary data collection method is used to collect data. The data mainly focused on the following points:

- Dimension of the cargo box for dump truck which is 6812×2482 mm.
- Dimension of the chassis for the dump truck that is 5613×2300 mm.
- Material used to build chassis and dump box of dump truck that is mild steel.

II. Metals Fabrication Industry (MFI)

The Metals Fabrication Industry is also a governmental organization located in Addis Ababa Ethiopia. It manufactures different products like trailers, towers, silos, heavy and light-duty workshops etc. In this company primary data collection method is used to collect data. That is observation was used to collect data. The data mainly focused on the following points:

- Performance of the dump truck, it lifts the cargo box in 10 seconds.
- The maximum weight carried by a dump truck, is 15000 -25000 kg.
- Tyre specification which is 1100 mm outer diameter, 600 mm rim diameter, and 260 mm width.

c) Design of spare tyre handling mechanism

After reviewing the literature and collecting necessary data spare tyre handling mechanism has been modelled using SOLIDWORKS software.

d) Geometric modelling is carried out using SOLIDWORKS. That is the geometric modelling of each component, subassembly and assembly.

e) Static analysis is carried out using ANSYS workbench. Static analysis focuses on determining the stresses and deformations in a structure when subjected to static loads.

f) Dynamic analysis, which considers the position and velocity of the mechanism with respect to time is conducted using ANSYS workbench.

3.2.1 Research Methodology

This includes those major procedural activities which have been accomplished from the beginning to the end of the thesis work.

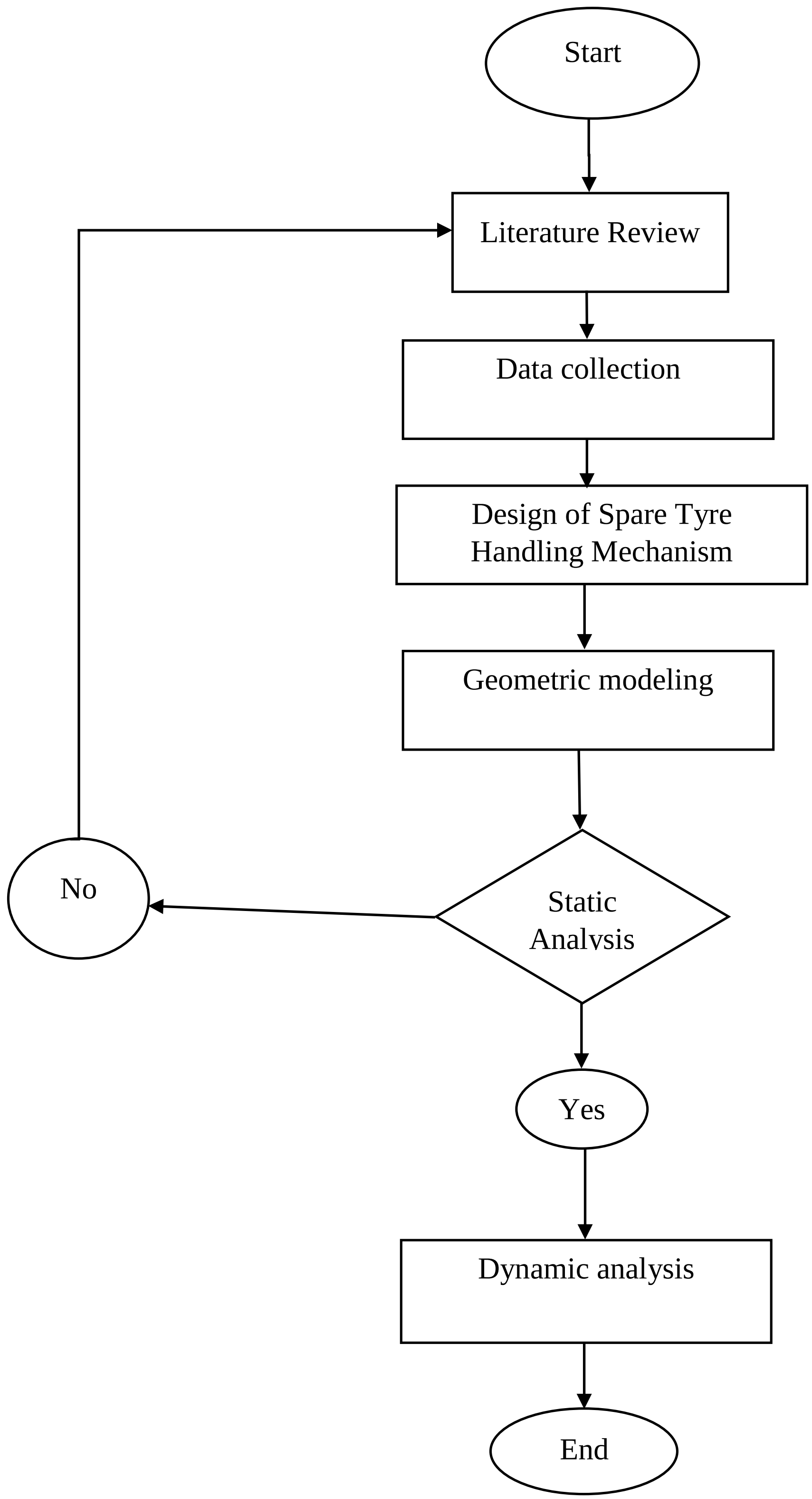


Figure 3.1 Block diagram of research methodology

3.3 Materials

To review the related literature; internet and computer have been used. Microsoft Word is used to compile the document. Also, SOLIDWORKS software is used to model the spare tyre handling mechanism, and ANSYS workbench is used to carry out both static and dynamic analysis. Hydraulic circuit is designed using FluidSIM.

3.3.1 Material Selection

The materials used to construct the structure of the spare tyre handling mechanism are: For all structural materials like RHS, L-steel, U-channel- channel and Pin, ASTM A36 carbon steel which has 250 MPa yield strength is used. These materials are used to make parts of base frame, vertical and horizontal structure in spare tyre handling mechanism for Howo 336 Dump Truck.

a) L-steel which is commonly called angle steel is used in welded frames, columns and beams providing various benefits to a range of construction and mechanical applications. For this thesis work angle steel which has a 50×50×3 mm specification is used.
b) Rectangular hollow sections (RHS) are a good option for mechanical, structural, and construction purposes (Tirfe, 2021). For this thesis work Rectangular hollow section (RHS) which has a 50×50×3 mm specification is used.
c) U-channel is used for its strength and its specification is 50×50×3 mm
d) A hydraulic cylinder which has a 32 mm diameter and 500 mm piston stroke is used. It is selected to meet quick lowering and lifting of the spare tyre. Stainless steel is used.
e) Plates with thicknesses 3mm,5mm and 10 mm are used.
f) Bolt M20 with nut and washer is used. ASTM A193 Grade B7 steel is used
g) Pin 30 mm diameter

CHAPTER FOUR

MODELING AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM

4.1 Introduction

To do geometrical modelling and numerical analysis, all the necessary data about the existing dump truck have been collected. The data is collected from the Construction Machinery Production Industry and the Metals Fabrication Industry (MFI). Then, based on the collected data the geometry of a dump truck and spare tyre handling mechanism has been modeled. This is done by using SOLIDWORKS, and the entire analysis is performed in ANSYS Workbench. The hydraulic circuit is designed using FluidSIM. The detailed process involved in geometry creation, analysis and the strategy used for optimization are explained in the subsequent sections.

4.2 Design of Spare Tyre Handling Mechanism

The main aim of this thesis is to design and analyze a spare tyre handling mechanism for a Howo 336 Dump Truck. Designing a spare tyre handling mechanism for a Howo 336 Dump Truck involves creating a system that allows for easy access and replacement of the spare tyre in case of a flat or damaged tyre. The mechanism should be robust, user-friendly, easy to assemble, maintainable, coastwise, and efficient (Dieter and Schmidt , 2009). This is to ensure that the downtime of the truck is minimized.

Here are the key Considerations that have been made in designing the spare tyre handling mechanism

i. Functionality: The design should meet the functional requirements ensuring that it can perform the necessary tasks effectively and efficiently.

ii. Location: Determining the optimal location for storing the spare tyre on the truck. It should be easily accessible but not obstructive to other truck components or cargo space.

iii. Mounting: Choosing a secure mounting method for the spare tyre to ensure it stays in place during the truck's operation, even on rough terrains.

iv. Lifting Mechanism: This is designing a lifting mechanism that can safely lower and raise the spare tyre from its storage location. It should be easy to operate and capable of handling the weight of the spare tyre.

v. Locking Mechanism: Incorporating a locking mechanism to secure the spare tyre in place when not in use, preventing theft or accidental dislodging.

vi. Accessibility: Ensure that the spare tyre handling mechanism is easily accessible to the truck driver or maintenance personnel without the need for specialized tools.

vii. Durability: Use better materials and components that can withstand expected load.

viii. Integration: Integrate the spare tyre handling mechanism seamlessly with the existing truck design to maintain the overall aesthetics and functionality of the vehicle.

ix. Safety: The mechanism has been designed to securely hold the spare tyre in place without risk of falling off while the vehicle is in motion.

x. Cost-effectiveness: The mechanism is designed to be cost-efficient in terms of materials, manufacturing, and installation costs.

xi. Operation: The piston in a hydraulic cylinder is typically pushed by hydraulic fluid under pressure. When the hydraulic fluid is forced into one side of the cylinder, it creates pressure on the piston, causing it to move in the desired direction.

4.2.1 Dimensional Considerations of Spare Tyre Handling Mechanism

To determine the dimension of the spare tyre handling mechanism, the following requirements have been considered.

i. Size and weight of the spare tyre: The dimensions of the spare tyre, including its diameter, width, and weight, will influence the design of the handling mechanism. The mechanism should be able to accommodate the size and weight of the spare tyre effectively.

ii. Mounting location: The available space within the dump truck for mounting the spare tyre and the handling mechanism should be considered. The dimensions of the mechanism should fit within the allocated space without interfering with other truck components.

iii. Reach and accessibility: The dimensions of the handling mechanism should allow for easy access to the spare tyre for installation and removal.

iv. Compatibility with dump truck specifications: The dimensions of the mechanism should be compatible with the specifications of the Howo 336 Dump Truck to ensure seamless integration and functionality.

v. Clearance and space constraints: Consider the available space within the dump truck for the spare tyre handling mechanism. Ensure that the dimensions of the mechanism do not interfere with other components or operations of the truck.

4.3 Geometry Creation

The spare tyre mechanism has four basic sub-assembles:

I. Base frame sub-assembly

   Framework that serves as the foundation or support for other components and is used to securely hold the Vertical structure of the mechanism.

II. Hydraulic cylinder

   The hydraulic cylinder extends the piston to lower the spare tyre from its stowed position and retracts its piston to keep the spare tyre in an upright position back into its storage location, allowing it to be easily accessed for replacement.

III. Vertical structure

   This is structure or support system that is oriented vertically to facilitate the storage, and stowage of the spare tyre.

IV. Horizontal structure

   Support system that is oriented horizontally to facilitate the movement or positioning.

4.4 Fastening Mechanism

A weld joint is used to join the structure of the mechanism. Welding is one type of permanent joining process by which two or more solid parts are joined together. Since the strength of the welded joint is similar to that of the parent parts, the load-carrying capacity of welded components remains unchanged before and after joining (Rammohan., 2019). Additionally, bolts and nuts are used to join the base frame with the chassis structure of the dump truck. The three sub-assembles are also joined together by a pin which allows both rotational and translational motion of components of the spare tyre handling mechanism.

4.5 Geometrical Modeling of Parts and Assembly

The following are geometric modelling of spare tyre handling mechanisms which have been designed.

I. Hydraulic cylinder: It is the double double-acting type of cylinder used to raise and lower the spare tyre. It uses pressurized fluid to move in both directions. Figure 4.1 depicts the hydraulic cylinder.

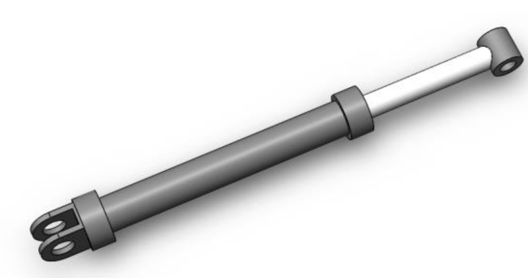


Figure 4.1: Hydraulic cylinder

II. Vertical member: Vertical member is a structural component that is oriented vertically or upright in spare tyre handling to keep the spare tyre in the desired height. Figure 4.2 shows RHS used as vertical structure.

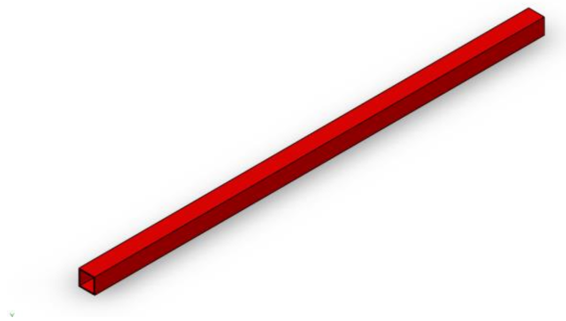


Figure 4.2: Vertical member

I. Horizontal member: The horizontal member is a structural component that is oriented horizontally in spare tyre handling to keep the spare tyre for touching the ground. Figure 4.3 shows RHS used as a horizontal component.

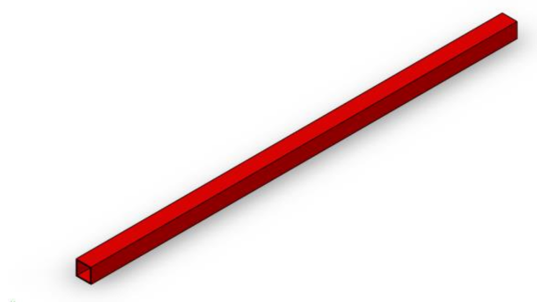


Figure 4.3: Horizontal member

II. Rib: Figure 4.4 shows ribs which are structural elements that are used to provide additional stiffness and strength to horizontal and vertical components or members.

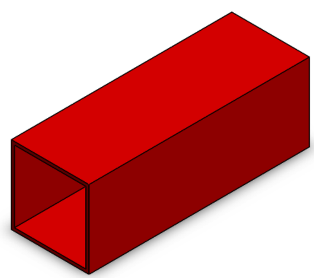


Figure 4.4: Rib

III. Pin: Figure 4.5 shows a pin fastener that is used to join two or more components together in the mechanism.

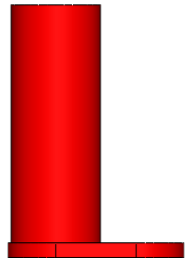


Figure 4.5: Pin

IV. Brace: Figure 4.6 shows a brace which is the diagonal member that is used to prevent buckling or deformation.

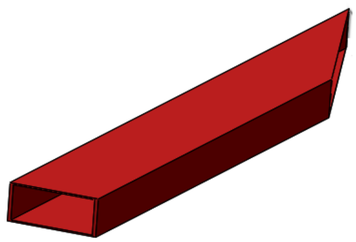


Figure 4.6: Brace

V. Angle steel: Figure 4.7 shows angle steel, it provides support, stability, and a secure foundation for the components of the spare tyre handling mechanism that are mounted or attached to it.

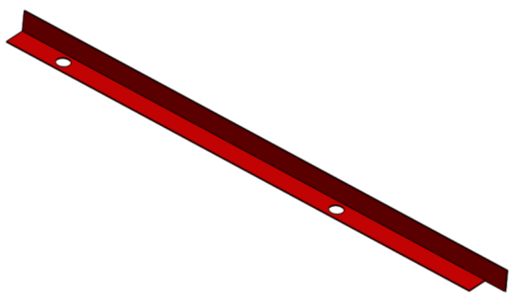


Figure 4.7: Angle steel

VI. Rib plate: Figure 4.8 shows a rib plate which is a thin plate which provides additional strength to the base frame assembly.

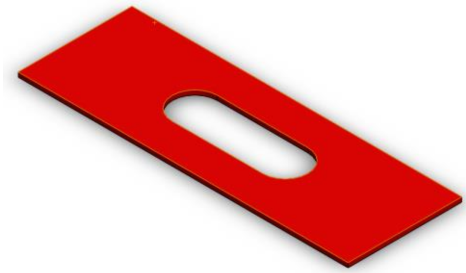


Figure 4.8: Rib plate

VII. Hydraulic cylinder support: Figure 4.9 indicates hydraulic cylinder support or carrier that is used to hold and securely mount the cylinder to a frame in place within the assembly of the mechanism. This is to ensure that it remains in the correct position and orientation during operation.

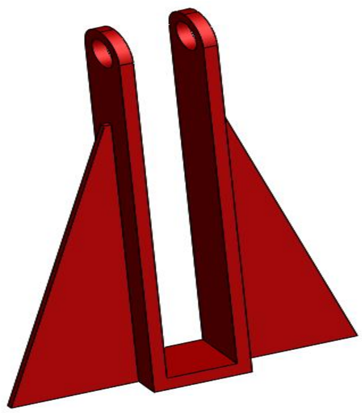


Figure 4.9: Hydraulic cylinder support

VIII. Vertical support: Figure 4.10 shows vertical support carrier that carries vertical structure and allows rotational motion of it.

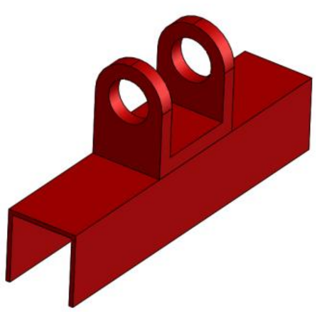


Figure 4.10: Vertical support

IX. A spare tyre carrier plate: Figure 4.11 shows a spare tyre carrier plate which is helpful to securely fasten the tyre to the mechanism, even during rough off-road conditions or bumpy roads. Ensuring that it remains in place and does not shift or fall off while the vehicle is in motion.

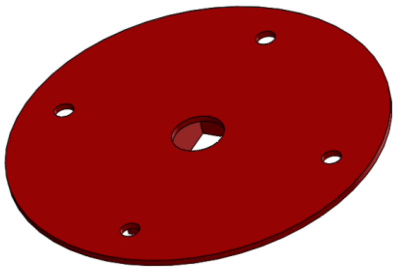


Figure 4.11: Spare tyre carrier plate

X. A spare tyre support structure: Figure 4.12 shows a spare tyre support structure that is used to support spare tyres.

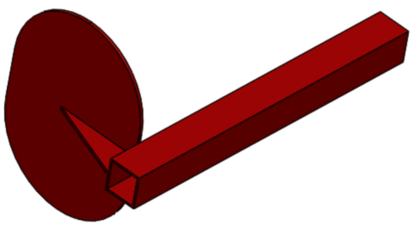


Figure 4.12: Spare tyre support structure

XI. Bearing: Figure 4.13 shows the bearing that is used to enable rotational movement between two parts of the mechanism during raising and lowering of spare tyre.

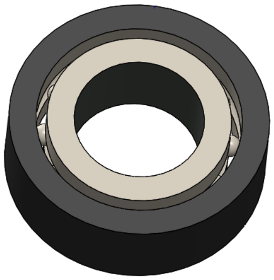


Figure 4.13: Bearing

XII. Connector: This part is used to connect piston with vertical structure. Figure 4.14 shows connector.

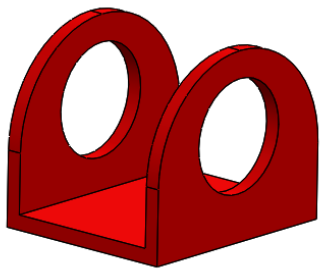


Figure 4.14: Connector

XIII. Sub-assembly of base frame. This is a structure which carries the vertical and horizontal frame. Figure 4.15 shows sub-assembly of base frame.

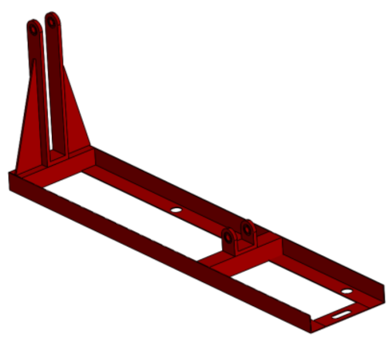


Figure 4.15: Sub-assembly of the base frame

XIV. Sub-assembly of vertical and horizontal structure. Figure 4.16 shows the sub-assembly of vertical and horizontal structure.

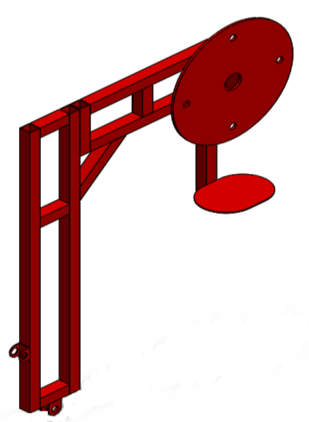


Figure 4.16: Sub-assembly of vertical and horizontal structure

XV. Whole assembly in an upright position: The figure 4.17 shows the whole assembly of the mechanism in an upright position.

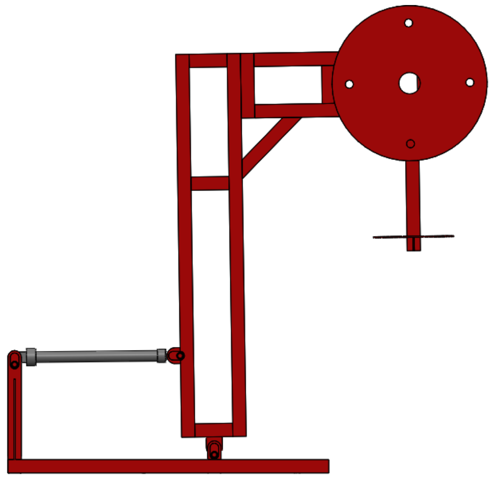


Figure 4.17: The whole assembly in an upright position

XVI. Assembly: Figure 4.18 shows the whole assembly model loaded with spare tyre.

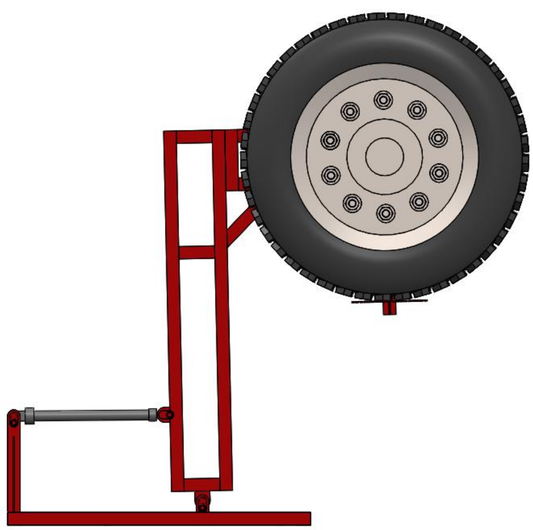


Figure 4.18: The whole assembly model loaded with spare tyre

XVII. Assembly: Figure 4.19 shows the spare tyre handling mechanism model during lowering.

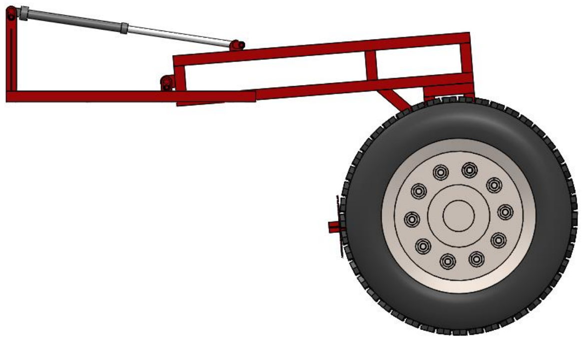


Figure 4.19: Mechanism model during lowering

XVIII. Dump truck model: Figure 4.20 shows Howo Dump Truck model with spare tyre handling mechanism in an upright position

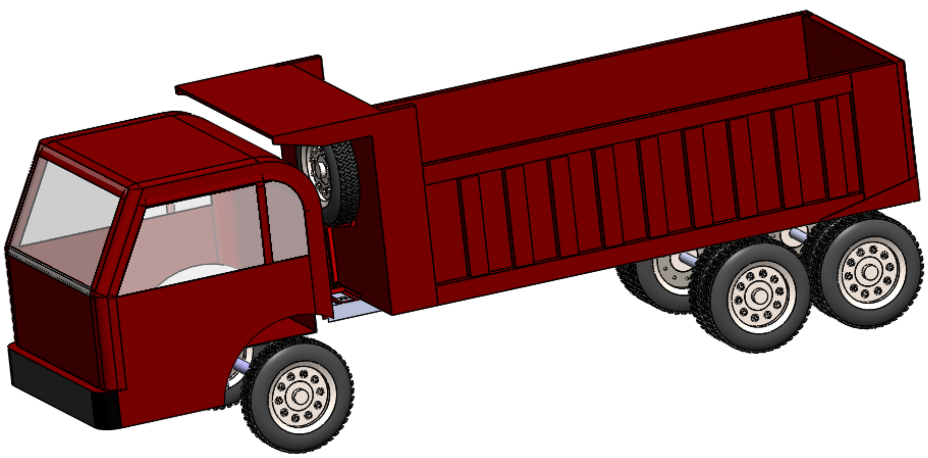


Figure 4.20: Dump truck model

XIX. Dump truck model: Figure 4.21 shows Howo Dump truck model with spare tyre handling mechanism during lowering.

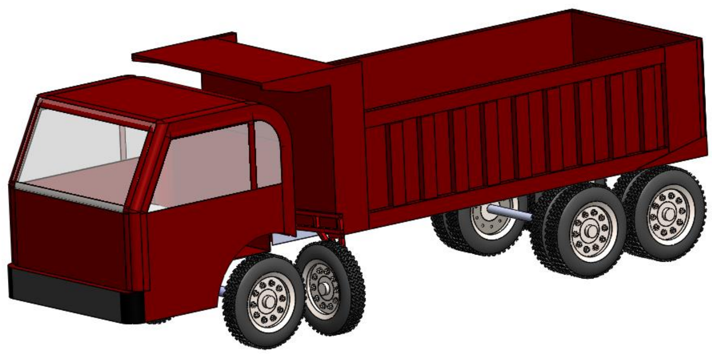


Figure 4.21: Dump truck model with spare tyre handling mechanism during lowering

4.6 Force Analysis

For this analysis, the summation of two categories of loads has been considered.

i. Spare tyre load = 1471.5 N

ii. Live load dictated by the conditions involved (Chairman, 1989).

This is assumed to be = 98.1 N

The total load on the spare tyre handling mechanism is 1569.6 N

4.6.1 Force Analysis During the upright position

In figure 4.22, by considering the entire spare tyre handling structure in an upright manner, mathematical modelling can be made. That is from the spare tyre handling mechanism that carries a 1569.6 N load of the spare tyre during the upright position, the action of force goes to member BC which means along the hydraulic cylinder. Thus, the reaction force at a fixed support B and the reaction forces acting at E can be solved.

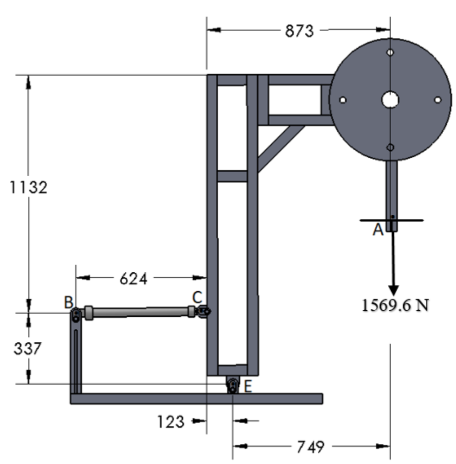


Figure 4.22: Spare tyre handling mechanism

Based on the principle of static equilibrium (equation of equilibrium condition), the sum of forces in the vertical or horizontal direction and the sum of moments about any point must be equal to zero.

To draw FBD of the mechanism the correspondence of the frame with defined illustration has been taken. It is known that a rigid system of interconnected body analyzed as a single unit (Meriam and Kraige, 2002).

All dimensions are in millimeter (mm), but during calculation conversion into meter (m) has been done.

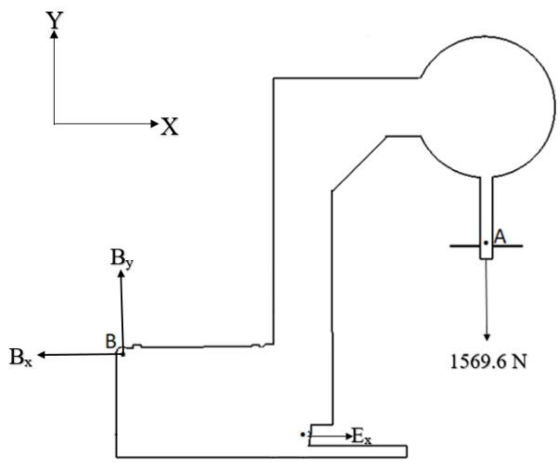


Figure 4.23: Free body diagram of the mechanism

Figure 4.23 shows FBD and reaction forces. From FBD reaction forces can be determined.

Thus, the summation of moment at a point B is equal to zero.

$[\sum_{MB} = 0]$ -1569.6 N×1.497 m+E_x×0.337 m=0 ………. Equ (4.1)

Where E_x is the reaction force at a point E

E_x =69723.4 N

$[\sum_{Fy} = 0]$ B_y-1569.6 N =0………………………………. Equ (4.2)

B_y =1569.6 N

$[\sum_{Fx} = 0]$ B_x + E_x =0……………………………………Equ (4.3)

$B_{x} + 69723.4\ N=0$

$B_x= -69723.4\ N$

Now the force in the hydraulic cylinder BC can be calculated

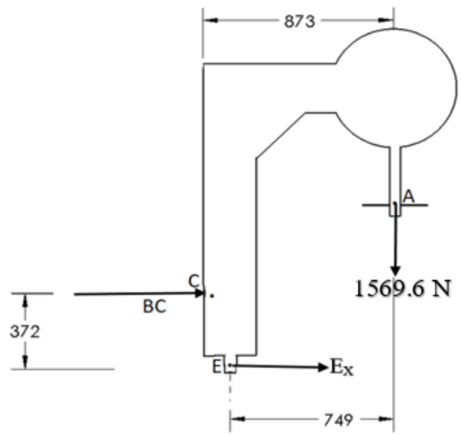


Figure 4.24: Free body diagram vertical structure

Figure 4.24 depicts the FBD of the vertical structure, this helps to find force along the hydraulic cylinder.

Thus, the force along the hydraulic cylinder at the upright position will be:

$[\sum_{ME} =0]$ BC×0.372 m-1569.6 N×0.749 m=0…………. Equ (4.4)

0.372 m×BC-1175.6 Nm=0

BC=3160.3 N or

F_{BC} = 3160.3 N

4.6.2 Force Analysis During Lowering

By considering the entire spare tyre handling structure during the lowering of the spare tyre, mathematical modelling can be made. That is from the spare tyre handling mechanism that carries a 1569.6 N load of spare tyre during lowering, the applied force acting along BC which means along hydraulic cylinder, the reaction force at a fixed support B and the reaction forces acting at a point can be solved.

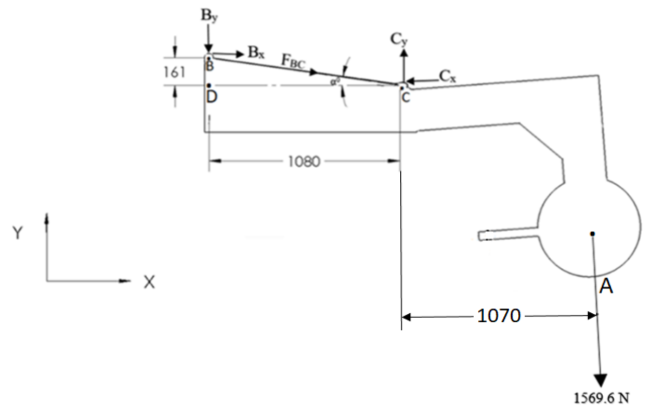
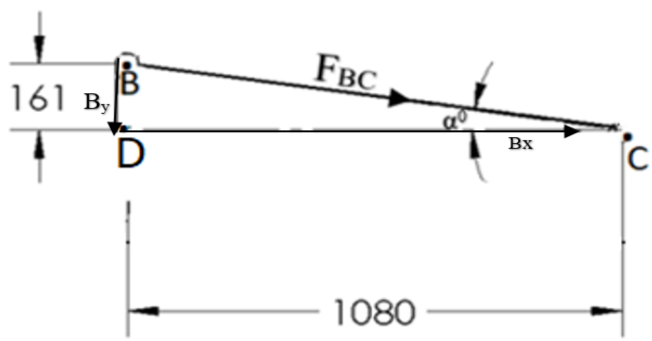


Figure 4.25:Free body diagram of the mechanism during lowering

From the free body diagram (FBD) of figure 4.25 of the entire mechanism, reaction force can be determined.

Now the FBD force along the hydraulic cylinder has been considered.



$\alpha = \tan^{-1}\left(\frac{161}{1080}\right)$……………………..Equ (4.5)

$= 8.4^{\circ}$

Then,

After angle alpha (α) has been calculated from the entire FBD of the mechanism during lowering, the moment at C is considered according to the following.

Again based on the principle of static equilibrium, the sum of forces in the vertical or horizontal direction and the sum of moments about any point must be equal to zero.

$[\sum_{MC} = 0]$ $-1569.6\ N \times AC + F_{BC} \times \cos\alpha \times BD + F_{BC} \times \sin\alpha \times DC = 0$…… Equ (4.6)

Where,

BD and DC are moment arms

F_{BC}=is Force along BC or force along hydraulic cylinder

α= is the tilting angle of the hydraulic cylinder during the lowering of the spare tyre

$$= \quad -1569.6\ N\times1.07\ m+F_{BC}\times\cos8.4^{\circ}\times0.161m+F_{BC}\times\sin8.4^{\circ}\times1.080\ m=0$$

$$= \quad 0.32\ m\times F_{BC}=1679.5\ N$$

F_{BC} = 5.2 kN, this is force along hydraulic cylinder during lowering of spare tyre

Now, the reaction forces B_y and B_x at a fixed point B will be;

$B_y = F_{BC}\times\sin\alpha$………………………………. Equ (4.7)

$B_y = 5.2\ kN\times\sin8.4^{\circ}$

B_y = 759.6 N downward

$B_X = F_{BC}\times\cos\alpha$…………………………………. Equ (4.8)

$B_X = 5.2\ kN\times\cos8.4^{\circ}$

B_X = 5.1 kN

Then the summation of forces along the Y-direction will be

$[\sum_{Fy} = 0]$ C_y-1569.6 N-By=0……………………. Equ (4.9)

Where,

B_y is reaction force along Y-direction at a fixed point B, and

C_y is reaction force along the Y-direction at a fixed point C

C_y-1569.6 +759.6 N =0

C_y =810 N

The summation of forces along the X-direction will be

$[\sum_{Fx} = 0]$ $C_X + B_X = 0$……………………………… Equ (4.10)

Where,

C_X is the reaction force along the X-direction at a fixed point B, and

$C_X + 5.1$ kN =0

$C_X = - 5.1$ kN

4.7 Material Selection

The selection of materials for the intended design took into account factors such as the strength of the materials, cost-effectiveness, and the ease of creating a functional product. The most commonly utilized structural steel in construction due to its highly cost-effective nature is the mild steel angle bar especially when compared to High-strength low-alloy (HSLA) steels. Angle steel and rectangular hollow section (RHS) which are made from ASTM A-36 mild steel are selected for design due to their unique properties and characteristics.

Some reasons why angle steel and rectangular hollow section and L-angle have been chosen as a material selection include:

1. Structural Strength: Angle steel is known for its high strength-to-weight ratio, making it suitable for structural applications where strength is essential.

2. Versatility: Angle steel can be easily cut, welded, and formed into various shapes, making it versatile for a wide range of applications.

3. Cost-effective: Angle steel is relatively inexpensive compared to some other materials, making it a cost-effective choice for many projects.

4. Ease of installation: Angle steel is easy to work with and install, which can help reduce labour costs and construction time.

5. Durability: Angle steel is durable and resistant to corrosion, making it suitable for outdoor or harsh environments.

6. Availability: Angle steel is readily available in various sizes and thicknesses, making it easy to source for different projects.

4.7.1 ASTM A36 Mild Steel

The typical carbon content of mild steel ranges from 0.05% to 0.35 (Wyndham, 2007). Mild steel is an incredibly versatile and valuable material that can be easily machined and shaped into forms. It is cost-effective and exhibits favorable mechanical properties. Mild steel is commonly used in a wide range of applications, including general structural fabrication and sheet metal work (Sultana and Ferdus, 2014). The density of mild steel is 7900 kg/m^3 (Chemical Rubber Co, 1994). This is taken for this study.

4.8 Static Analysis

The static analysis of the mechanism is carried out in ANSYS. The spare tyre handling mechanism is made from 50×50×3 square hollow section (RHS) and 50×50×3 angle steel.

I. Load applied on the mechanism

The loads which are applied on the mechanism are the load due to the weight of the spare tyre and live load (load due to different tools and accessories). These tools and accessories can include items such as a jack, canvas, lug wrench, tyre iron, tyre repair kit, tyre pressure gauge, torque extension bar or torque stick, and any other tools or equipment needed for changing a tyre or performing maintenance on the vehicle.

- The weight of the spare tyre

  The mass of the spare tyre is 150 kg

  $W = mg$……………………………Equ (4.11)

  $W = 150 \text{ kg} \times 9.81 \text{ m/s}^2$

  $W = 1471.5 \text{ N}$

  Where is weight, m is mass and g is gravity

- Live load (load due to different accessories)

  This is assumed to be 10 kg

  $W = mg$

  $W=10 \text{ kg} \times 9.81 \text{ m/s}^2$

  $W= 98.1 \text{ N}$

  And total load is 1471.5 N +98.1 N = 1569.6 N

4.8.1 Conceptual Design Model

It helps to quickly iterate on design concepts and make informed decisions about the final design. It was modelled using SOLIDWORKS. Figure 4.26 shows geometric modelling.

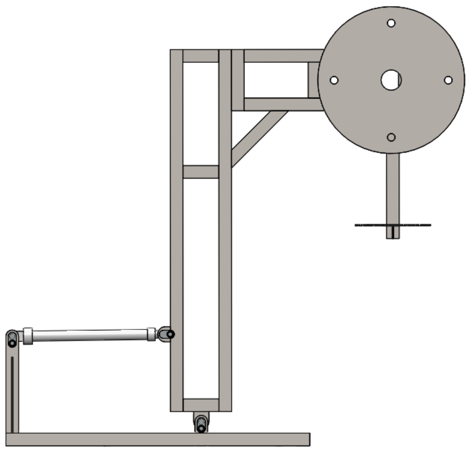


Figure 4.26:Conceptual design

4.8.2 Mesh Generation

This is used to discretize the geometry into smaller elements to facilitate numerical analysis and simulation. Figure 4.27 shows mesh generation.

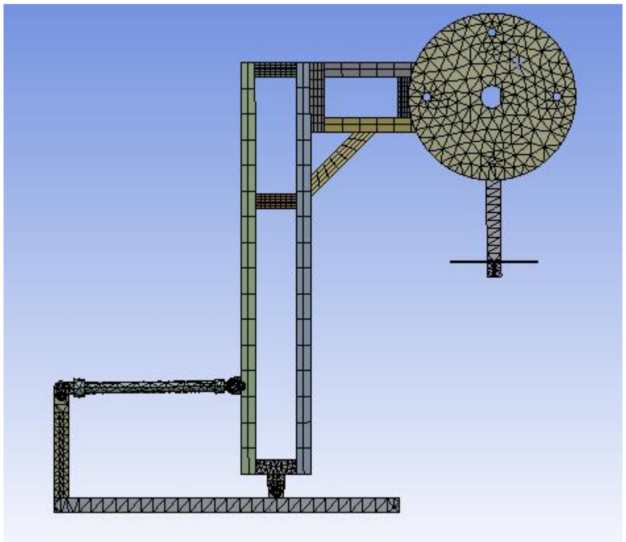


Figure 4.27:Mesh generation

4.8.3 Applying Boundary Condition

This section deals with applying boundary conditions. The base of the spare tyre handling mechanism is secured or fixed to implement stress analysis. These conditions are used to constrain the movement of the model.

4.8.4 Stress Analysis

I. Equivalent (Von-Mises) Stress

Von Mises stress is a value used to determine if a given material will yield or fracture. The yield point is the point on a stress-strain curve that indicates the limit of elastic behavior and the beginning of plastic behavior. A material is said to start yielding when the von Mises stress reaches a value known as yield strength. According to the figure 4.28 the maximum equivalent stress of the structure is 128.69 MPa is less compared to the yield strength of the material which is 250 MPa.

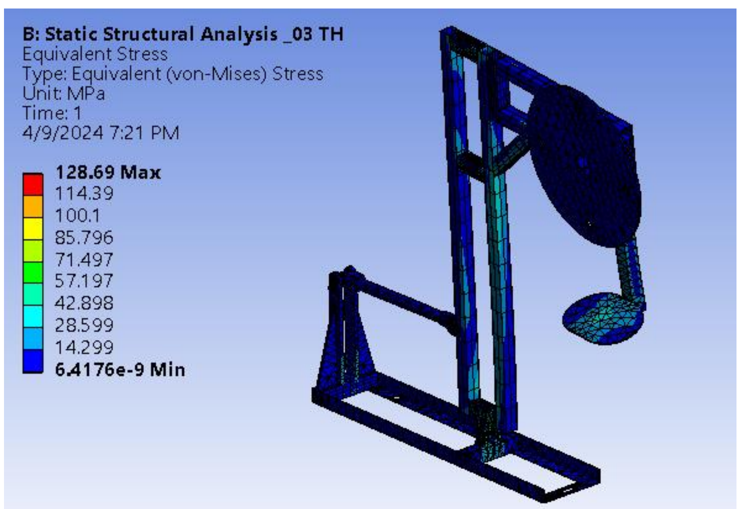


Figure 4.28:Equivalent (Von-Mises) Stress of the structure

Thus, Safe stress or working stress (σ_w); is determined by the material's yield strength and is expressed as the yield strength (σ_y) divided by a safety factor (N) (D. Callister, 2000).

$$\sigma_w = \frac{\sigma_y}{N} \text{.....................Equ (4.12)}$$

Hence,

$$N = \frac{\sigma_y}{\sigma_w} \quad ,$$

$$N = \frac{250 \text{ MPa}}{128.69\ MPa}$$

$$N \quad = 1.9$$

This confirms that the design is considered to be safe according to engineering standards and practices.

II. Total deformation

Deformation is the alteration in the dimensions or configuration of an object. ANSYS workbench categorizes deformation into two forms: total deformation and directional deformation. Both types of deformation are employed to determine displacement due to stress. Directional deformation occurs along specific directions such as X, Y, and Z. Total deformation is calculated as the square root of the sum of the squares of the X, Y, and Z directions. According to the figure 4.29 the maximum total deformation is 5.6 mm.

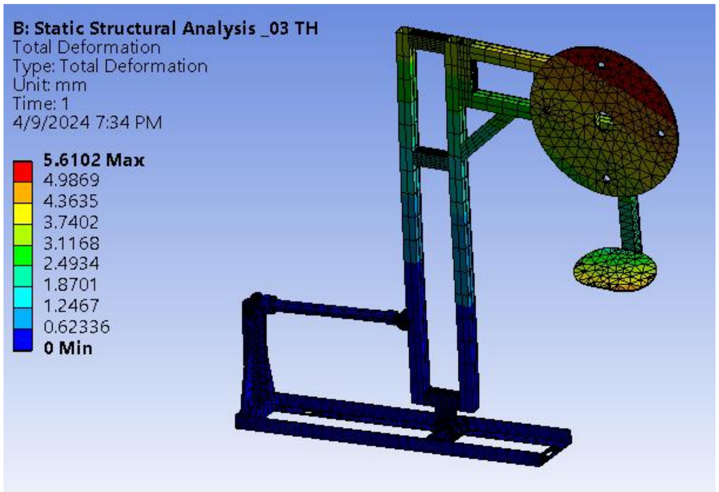


Figure 4.29: Total deformation of the structure

III. Maximum shear stress

The maximum shear stress occurs when there is a concentrated shear force in a small area. For this analysis, according to the figure 4.30 the maximum shear stress corresponds to 66.657 MPa.

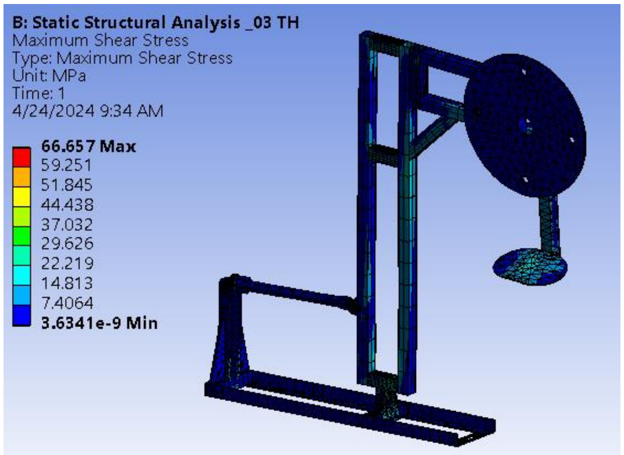


Figure 4.30:Total deformation of the structure

4.9 Hydraulic System

Hydraulic systems are enclosed fluid-based systems that use pressured incompressible liquids as their transmission medium. The hydraulic system operates based on Pascal's law, which states that a fluid confined in a container experiences uniform pressure in all directions (Osman.M., 2017).

Actuators, pumps, pressure control valves, direction control valves, and storage vessels make up the majority of the hydraulic control system's components (Kong et al., 2024). It has benefits, which include a high power-to-weight ratio, quick reaction times, and excellent control precision (Liu et al., 2024).The major components of hydraulic system are:

a) Pumps - A hydraulic pump is a mechanical device that transforms mechanical power into hydraulic energy.
b) Valves are a crucial element of the hydraulic control system utilized to manage the direction, flow rate, and pressure of the hydraulic fluid throughout the hydraulic system.
c) Hydraulic tank/reservoir: These components are integral to the hydraulic system as they store hydraulic fluid.
d) Filters: Filters are employed to maintain the cleanliness of the fluid before it enters the entire hydraulic system through the pump.

4.9.1 Cylinder and Pump Selection

By considering the above analytical results of force acting on the cylinder, the selection of the hydraulic cylinder for the design is determined. For this study, a double-acting hydraulic cylinder is selected. In a double-acting cylinder, hydraulic pressure is applied to one side of the piston to extend it, and then pressure is applied to the other side to retract it. It uses hydraulic fluid to power the forward stroke. From the numerical analysis, forces acting on the cylinder both in its upright position and during the lowering of the spare tyre are:

a. Hydraulic cylinder force (F_{BC}) = 5.2 kN during lowering spare tyre
b. Hydraulic cylinder force (F_{BC}) = 3160.3 N when the mechanism is in an upright manner

By considering the maximum result acting on the cylinder that is 5.2 kN during the lowering of the spare tyre, the appropriate cylinder for the spare tyre handling mechanism is selected from the catalogue. For this study, operating pressure P that corresponds with 5.2 kN is 6.5 MPa from the catalogue of hydraulic cylinders.

Therefore,

The hydraulic cylinder pressure will be:

$P = F_{BC}/A$………………………………… Equ (4.13)

Where,

F_{BC} is hydraulic cylinder force during the lowering of spare tyres, and

A is an area of hydraulic cylinder

$A = F_{BC}/P$

$\pi D^2/4 = \frac{5.2 \text{ kN}}{6.5 \text{ MPa}}$

$D^2 = \frac{20.8\ N}{20410\ Pa}$

$D = \sqrt{1.019 \times 10^{-3}} m^2$

D = 0.032 m by converting it to millimeter (mm) it will be:

D = 32 mm, is bore diameter of cylinder this value conforms to ISO 3320 standard

The rod diameter of the piston is selected to be 30 mm; this also conforms to ISO 3320 standard value. The stroke has been selected as 500 mm which conforms to ISO 4393 standard value.

Pump pressure is 6.5 MPa. From the corresponding outflow of hydraulic cylinder, the flow rate of pump is 0.000365 m^3/min. Mechanical and volumetric efficiency is assumed to be 85 and 87 respectively. The speed of the pump is 1450 RPM. Thus, the power which will run this pump is 0.0535 kW from pump catalogue.

4.9.2 Hydraulic Circuit Design

Data to design hydraulic circuits for spare tyre handling mechanisms has been listed in table 4.1.

Table 4. 1: Hydraulic circuit specification:

No	Parameter	Specification	
1	Force	Max	5200 N
		Min	3160.3 N
2	Pump Pressure	6.5 MPa	
3	Stroke	500 mm	
4	Road diameter	30 mm	
5	Bore diameter	32 mm	
6	Velocity	365.2 mm/sec	

The maximum pump lift can be determined by atmospheric pressure and is given by pressure head as given:

$P = \rho gh$……………………………………Equ (4.14)

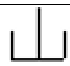
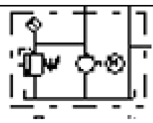
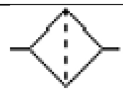
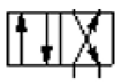
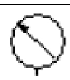
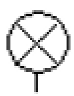
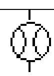
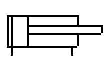
Where, ρ is the density of hydraulic oil 780.50 kg/m^3 (Azmi.R., 2016) , g is the gravitational force, and h is height.

Thus,

$P = 780.50\ kg/m^3 \times 9.81\ m/s^2 \times 1.43\ m$

$P = 10949\ Pa$

Table 4.2: Designation of hydraulic components

	Symbol	Designation	Explanation
1		Tank	Used to store hydraulic fluid
2		Pump Unit	The pump unit supplies a constant volumetric flow. The operating pressure is limited by the internal pressure of the relief valve.
3		Filter	The filter limits the contamination of the fluid respecting a certain tolerance value to reduce the risk of damage to the components.
4		Configurable 4/n way valve	The configurable 4/n way valve is a way valve with four connections, where both its body elements and its operation modes are user-definable.
5		Manometer	The manometer measures the pressure at its connection
6		Pressure indicator	An optical signal is activated when the pressure at the connection to the pressure display exceeds the preset switching pressure.
7		Flow meter	Measures the flow rate.
8		Double acting cylinder	Double-acting cylinder with piston rod on one side.

Source FluidSIM-H (Demo version)

I. Hydraulic circuit design during retracting stroke or upright position of spare tyre handling mechanism

The circuit diagram to control the double-acting cylinder is shown in figure 4.31. When the configurable 4/n way valve is actuated into the right envelope configuration, the cylinder retracts as oil flows from port P through port B. Oil in the blank end is returned to the tank via the flow path from port A to port T.

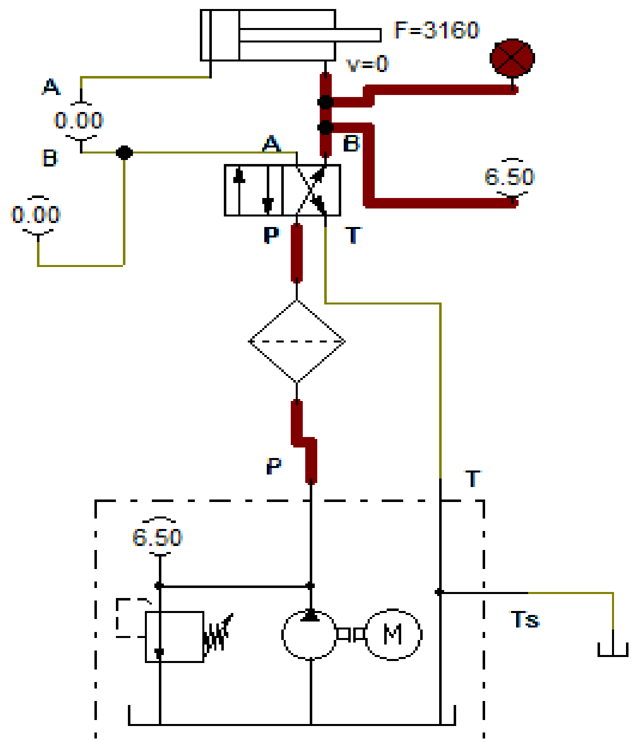


Figure 4.31: Hydraulic circuit during upright position

Figure 4.32 shows motion parameters that is position is reduced from 500 mm to zero, while both velocity and acceleration declined and then return to zero. Force is reduced from 5200 N to 3160 N.

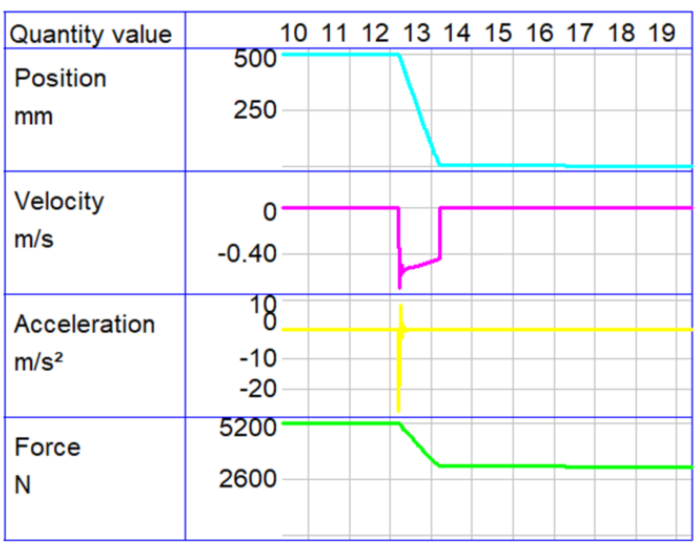


Figure 4.32:Motion parameters during retracting stroke

II. Hydraulic circuit design during extending stroke or during lowering spare tyre

When the configurable 4/n way valve is actuated into the flow path as it is shown in figure 4.33, the cylinder is extended against its load as oil flows from port P through port A. Oil in the rod end of the cylinder is free to flow back to the tank through the four-way valve from port B through port T.

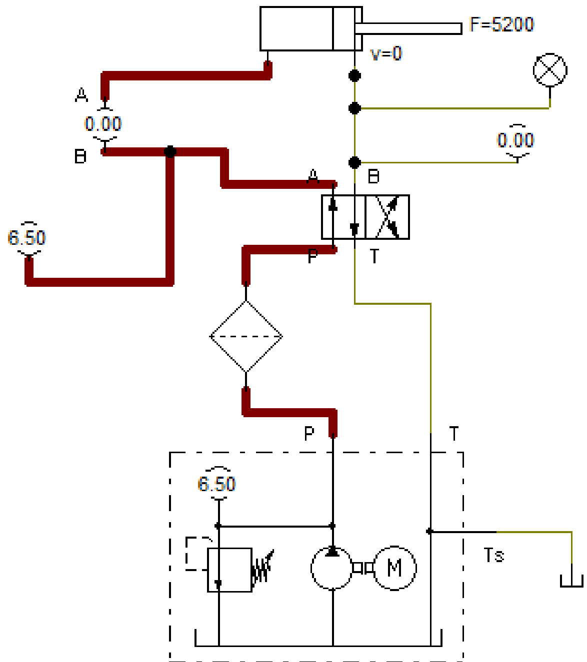


Figure 4.33: Hydraulic circuit during extracting stroke

Figure 4.34 shows motion parameters that is position is increased from zero to 500 mm. Force is increased linearly from 3160 N to 5200 N.

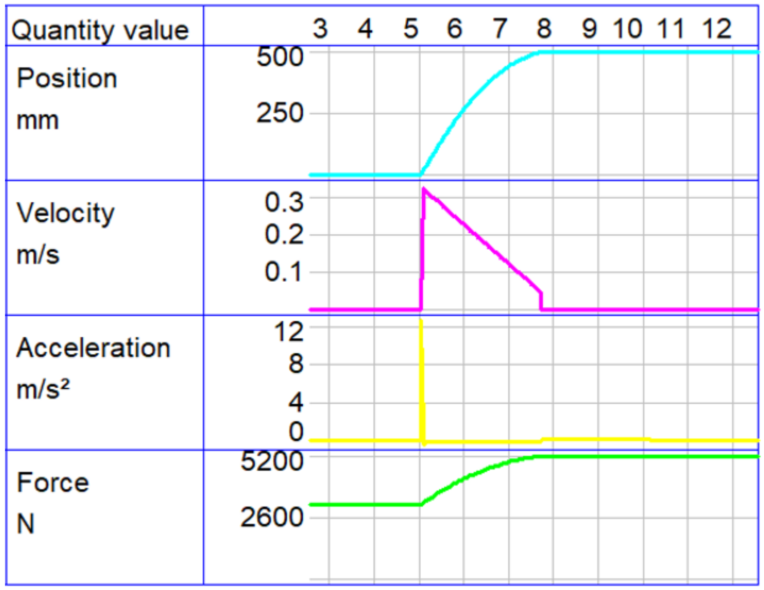


Figure 4.34: Motion Parameters during extracting stroke

4.10 Dynamic Analysis

During handling operations, spare tyre positioning is considered. This includes tracking the vertical position (height) and horizontal position (alignment) of the tyre within the mechanism.

Overall mechanism undergoes three types of motions which are:

I. Rotational motion of the vertical structure of the mechanism
II. Rotational motion of the hydraulic cylinder
III. Translational motion or stroke of the piston

Figure 4.35 shows the three types of motion during lowering and lifting of spare tyre handling mechanism. During the lowering or extension of the piston, each component acquires 86° and 8.4° rotational angle and 500 mm stroke respectively.

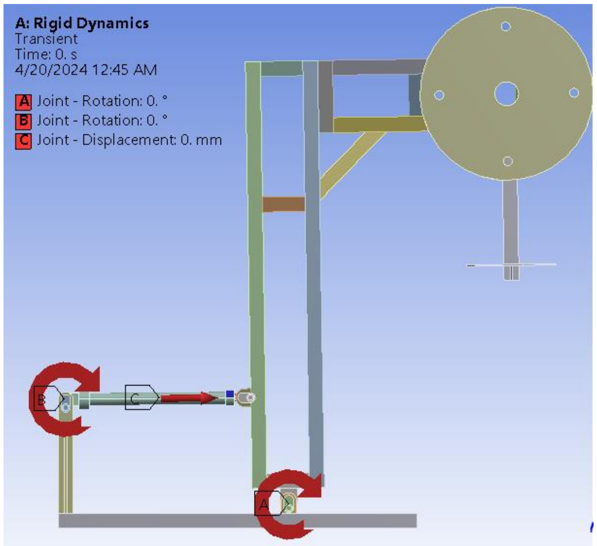


Figure 4.35: Types of motion

I. Rotational motion of vertical structure of the mechanism

Vertical structure is a very crucial component of the mechanism and it undergoes rotational motion. Figure 4.36 shows motion of vertical structure.

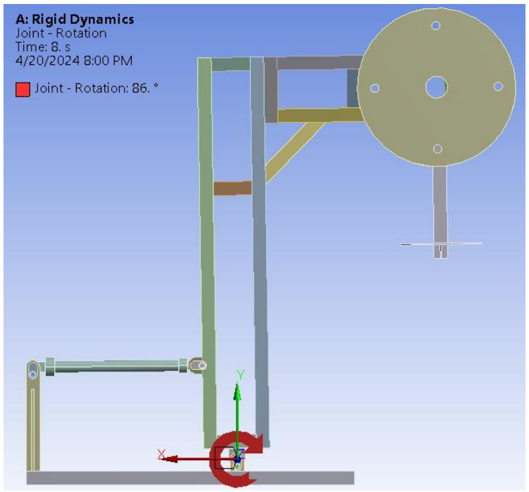


Figure 4.36: Rotational motion of vertical structure

To rotate 86 degrees or 1.5 radians around a pin, 8 seconds is assumed that to lower the spare tyre, the angular velocity of vertical structure (ω_{vs}) will be:

$\omega_{vs} = \Delta\theta_{vs}/\Delta t$……………………………………...Equ (4.15)

Where,

$\Delta\theta_{vs}$ is the change of an angle,

Δt =change in time

$\omega_{vs} = \frac{1.5\ rad}{8\ sec}$

$\omega_{vs} = 0.188\ \frac{rad}{sec}$

Linear velocity (v)

$V_{vs} = \omega_{vs} \times R_{vs}$..Equ (4.16)

Where,

R_{vs} is structural length considered as rotational radius which is 1811.4 mm

$V_{vs} = 0.188\ \frac{rad}{sec} \times 1811.4$ mm

$V_{vs} = 340.54\ \frac{mm}{sec}$

II. Rotational motion of hydraulic cylinder

The hydraulic cylinder which is involved in the spare tyre handling process undergoes rotational motion. Figure 4.37 shows rotational motion of hydraulic cylinder.

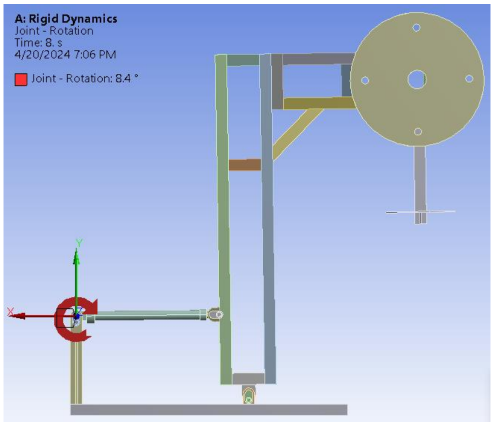


Figure 4.37: Hydraulic cylinder rotation

To rotate the hydraulic cylinder, 8.4 degrees or 0.146 radians rotation is needed concerning the horizontal plane during lowering. The angular velocity of the hydraulic cylinder (ω_{hc}) will be:

$\omega_{hc} = \Delta\theta hc/\Delta t$……………………………………………. Equ (4.17)

$$\omega hc = \frac{0.146\ rad}{8\ sec}$$

$$\omega hc = 0.01825\ \frac{rad}{sec}$$

Linear velocity (V_{hc}) ……………………………………...Equ (4.18)

$V_{hc} = \omega_{hc} \times R_{hc}$

Where,

R_{hc} is the hydraulic cylinder length or rotational radius which is 500 mm

$$V_{hc} = 0.01825\ \frac{rad}{sec} \times 500\ mm$$

$$V_{hc} = 9.1\ \frac{mm}{sec}$$

III. Translational motion: During this motion, the piston moves along the X and Y-axis. It paves the lowering and lifting of spare tyres. The figure 4.38 shows the translational motion of the mechanism.

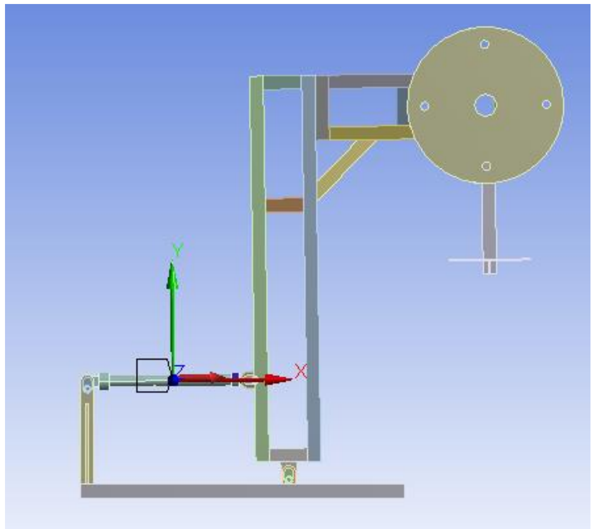


Figure 4.38: Piston motion

$V_t = \frac{S}{t}$ ………………………………Equ(4.19)

Where,

V_t is the Velocity during the translational motion of the piston

S is the piston stroke, and

t is time

Then,

$V_t = \frac{500\ mm}{8\ sec}$

V_t = 62.5 mm/sec

4.11 Working Principle

In this research work, a spare tyre handling mechanism is designed to lower, raise and store a spare tyre for easy access and storage in a Howo 336 Dump Truck. The mechanism typically consists of a piston or actuator to lower and raise the spare tyre. The spare tyres are locked by bolt and nut. Here is the working principle of the spare tyre handling mechanism:

I. Lowering the spare tyre:

When the piston moves in the right direction, it exerts a force that is transmitted to the spare tyre mounting structure. As the piston moves to the right, it causes the spare tyre mounting structure to lower, allowing the spare tyre to descend from its storage position. The spare tyre is lowered gradually and smoothly as the piston continues to move in the right direction to the desired position.

II. Raising the spare tyre:

When it is time to raise the spare tyre back into its storage position, the piston is activated to move in the left direction. As the piston moves to the left, it exerts an upward force on the spare tyre mounting structure, causing the spare tyre to be lifted back into its storage location. The spare tyre is raised smoothly and securely by the spare tyre handling mechanism until it reaches its fully stored position.

III. Storing the spare tyre:

Once the spare tyre has been lifted to the upright position, the piston stops moving. Since it's locked by bolt and nut, the spare tyre remains in its place until needed. The spare tyre handling mechanism securely holds the spare tyre in position, ensuring that it does not move or shift during vehicle operation.

Overall, the spare tyre handling mechanism provides a convenient and efficient way to lower and raise a spare tyre for maintenance, replacement, or emergency use in a Howo 336 Dump Truck.

IV. Power transfer

Here is an overview of how energy is transmitted in a dump truck hydraulic system:

1. Engine: The dump truck is equipped with an engine. The engine generates power through the combustion of fuel, which is then converted into rotational motion.

2. Power Take-Offs (PTOs): Power take-offs (PTOs) are mechanical gearboxes that are attached to apertures provided on truck transmissions and are used to transfer the power of the vehicle engine to auxiliary components, most commonly a hydraulic pump.

The transmissions commonly found in larger vehicles will have provisions for the mounting of a PTO. Generally, there are two apertures, one on each side of the transmission (Muncie Power Products, 2015).

The PTO unit is engaged when the driver activates a control inside the cab, sending power from the engine to the hydraulic pump.

3. Hydraulic Pump: The hydraulic pump is connected to the PTO and driven by the power generated by the engine. The pump pressurizes hydraulic fluid, which is then used to actuate the hydraulic cylinders that lift and lower the spare tyre.

4. Hydraulic System: The pressurized hydraulic fluid from the pump is distributed to the hydraulic cylinders through hydraulic hoses. The cylinders extend and retract, allowing spare tyre to be raised and lowered.

Oil tank, pump and PTO unit is kept on the right side of truck and assembled upon the chassis. Figure 4.39 shows how power is transferred from engine to hydraulic cylinder.

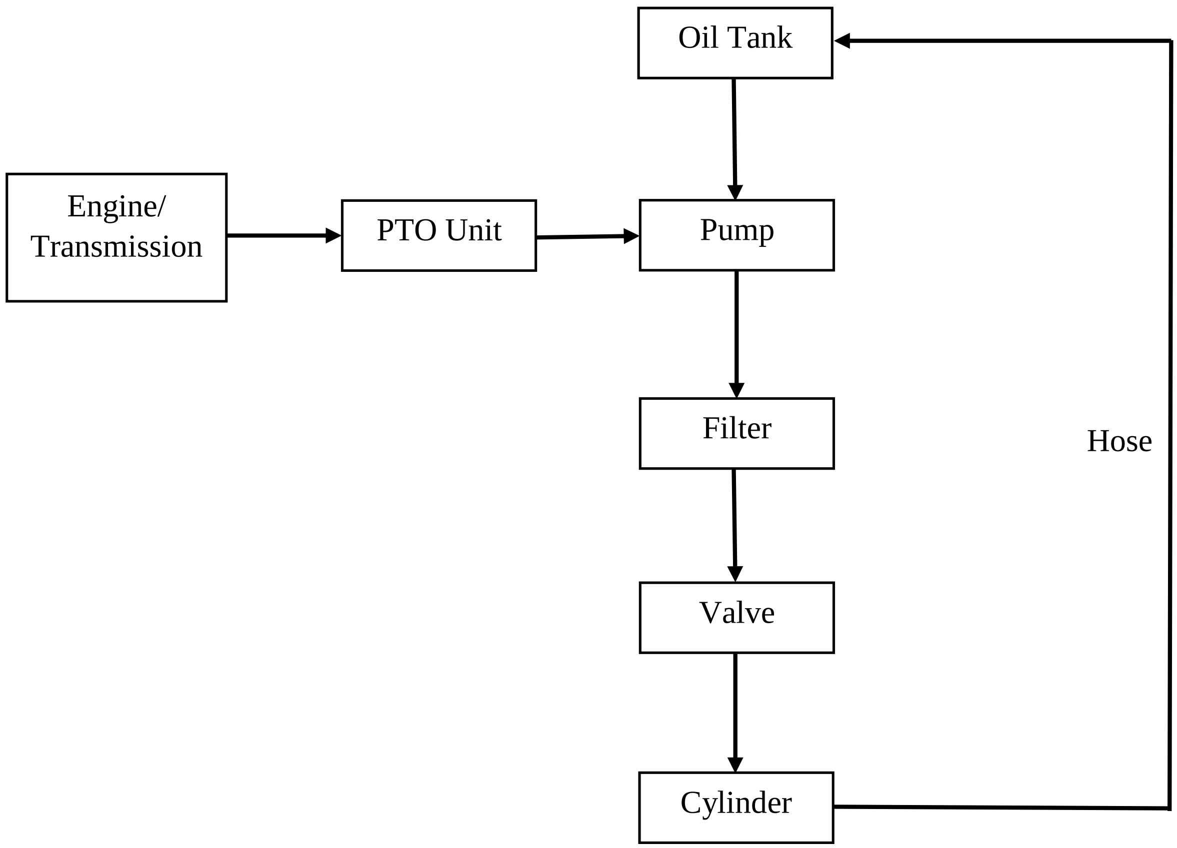


Figure 4.39: Power transfer diagram for spare tyre handling mechanism

CHAPTER FIVE
RESULTS AND DISCUSSIONS

5.1 Results of Static Analysis

Static analysis of the mechanism was conducted using ANSYS Workbench. This is crucial in understanding the structural integrity and performance of components and systems. Through this analysis, stress distribution, deformation patterns, and potential failure points have been identified providing a comprehensive understanding of the system's behavior under specified loading scenarios and ensuring that the system can withstand the expected loads while maintaining structural integrity. The insights gained from the static analysis of stress and deformation in the system will contribute to the overall quality, safety, and performance of the system, ultimately enhancing its functionality and longevity in real-world applications.

The input parameters of the mechanism at the upright position and during lowering or at a maximum extension of the piston are given in Table 5.1.

Table 5.1: Input parameters

No	Parameters	At upright Position	At a maximum extension of the piston
1	Total applied load(F)	1569.6 N	1569.6 N
2	Force in the hydraulic cylinder (F_{BC})	3160.3 N	5.2 kN
3	The angle of the cylinder with the horizontal plane	0°	$\alpha = 8.4^{\circ}$
4	Maximum height	1735 mm	1297 mm
6	Maximum length	1811 mm	2465 mm
7	Stroke	0	500 mm
8	Angle Vertical structure to vertical plane	0°	-86°

I. Equivalent Stress

According to the figure 5.1, the maximum equivalent stress of the structure is 128.69 MPa which is less compared to the yield strength of the material which is 250 MPa. Therefore, the spare tyre handling mechanism can withstand the load of the spare tyre and accessories that is applied to it.

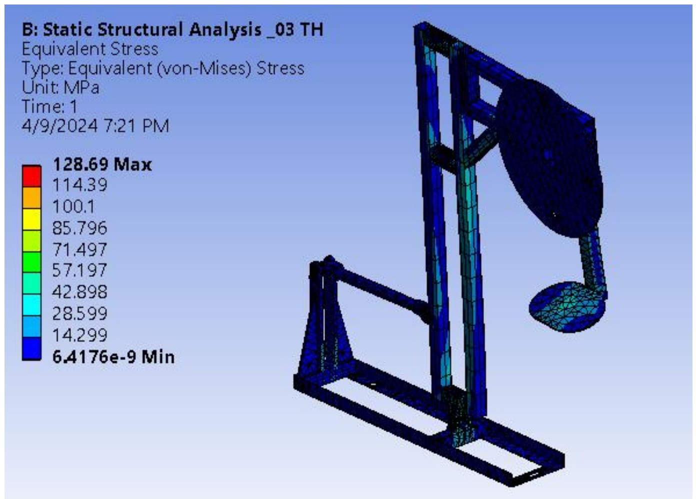


Figure 5.1: Equivalent (Von Mises) stress

Table 5.2:Equivalent (Von Mises) stress

Time [s]	[A] Equivalent Stress (Min) [MPa]	[B] Equivalent Stress (Max) [MPa]
0.1	6.42E-10	12.869
0.2	1.30E-09	25.739
0.3	1.92E-09	38.609
0.4	2.57E-09	51.478
0.5	3.22E-09	64.348
0.6	3.84E-09	77.219
0.7	4.50E-09	90.089
0.8	5.15E-09	102.96
0.9	5.78E-09	115.83
1	6.42E-09	128.7

As it is given in figure 5.2 single plot on the graph represented by a green line, which extends in a straight, diagonal line from the bottom left corner towards the upper right corner, showing a linear relationship between time and equivalent stress. This suggests that as time increases, the equivalent stress also increases proportionally. The linear increase in equivalent stress over time suggests that the material is experiencing a gradual increase in applied stress until it reaches its maximum point which is 128.69 MPa.

There are two labelled points on the graph, marked as "A" near the origin and "B" near the top right corner, indicating specific points of interest or measurements taken at those time intervals.

Overall, the graph provides a visual depiction of how equivalent stress increases linearly with time for the particular scenario of the mechanism.

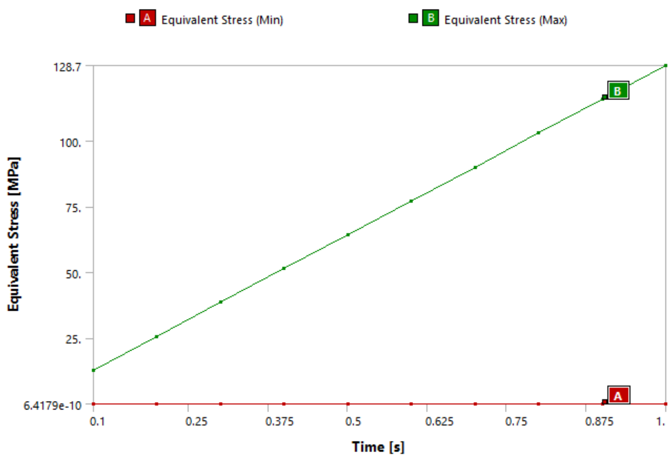


Figure 5.2: Graphical Representation of equivalent stress

II. Total Deformation

Figure 5.3 shows a maximum deformation of 5.6 mm in the structure for the given loading conditions. This deformation is within the allowable limits as specified by the structural standards L/100 which is 600/100=6mm (Smith, 2017).

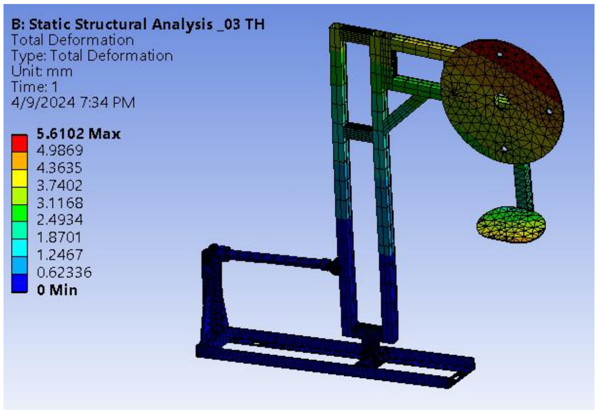


Figure 5.3:Total deformation

Table 5.3: Total deformation

Time [s]	[A] Total Deformation (Min) [mm]	[B] Total Deformation (Max) [mm]
0.1	0	0.56102
0.2	0	1.122
0.3	0	1.683
0.4	0	2.2441
0.5	0	2.8051
0.6	0	3.3661
0.7	0	3.9271
0.8	0	4.4881
0.9	0	5.0491
1	0	5.6101

The graph displays a linear relationship between time and total deformation, suggesting that as time increases, the total deformation also increases proportionately. The data points for both the minimum and maximum total deformation seem to align along a straight line, indicating a consistent rate of deformation over time.

There are also two labels, "A" and "B," corresponding with the minimum and maximum deformation points at the beginning and the end of the observed time frame, respectively.

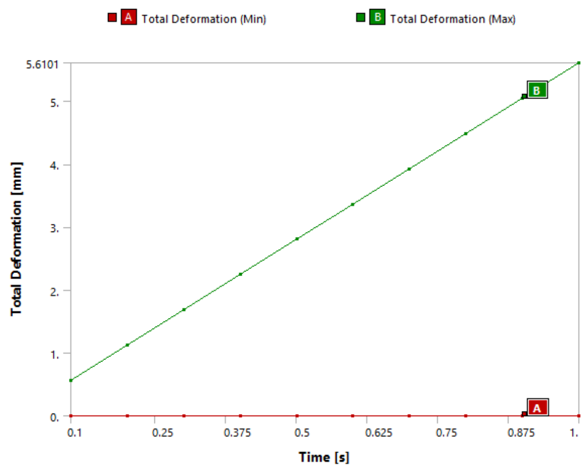


Figure 5.4: Graphical representation of total deformation

III. Shear stress

According to Figure 5.5, the structure's maximum shear stress is 66.657 MPa, which is lower than the material's yield strength of 250 MPa. This conforms with engineering standard.

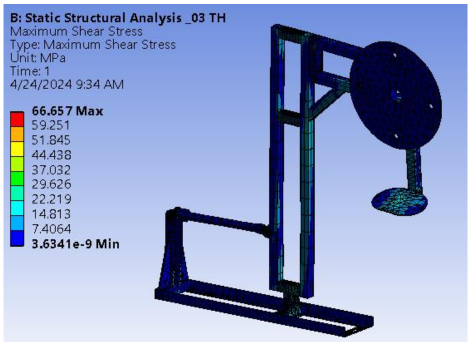


Figure 5.5: Maximum shear stress

Table 5.4: Maximum shear stress

Time [s]	[A] Maximum Shear Stress (Min) [MPa]	[B] Maximum Shear Stress (Max) [MPa]
0.1	3.63E-10	6.6654
0.2	7.36E-10	13.331
0.3	1.09E-09	19.996
0.4	1.46E-09	26.662
0.5	1.82E-09	33.328
0.6	2.18E-09	39.993
0.7	2.54E-09	46.659
0.8	2.91E-09	53.325
0.9	3.27E-09	59.991
1	3.63E-09	66.657

Figure 5.6 shows a graph plotting shear stress in Mega Pascal (MPa) against time in seconds (s). There are two data points highlighted on the graph: one at the beginning of the shear axis and one at the end of the time axis. The graph features a green line that starts at the lower left-hand corner (near the origin) and rises linearly toward the upper right-hand corner, indicating a direct proportional relationship between shear stress and time.

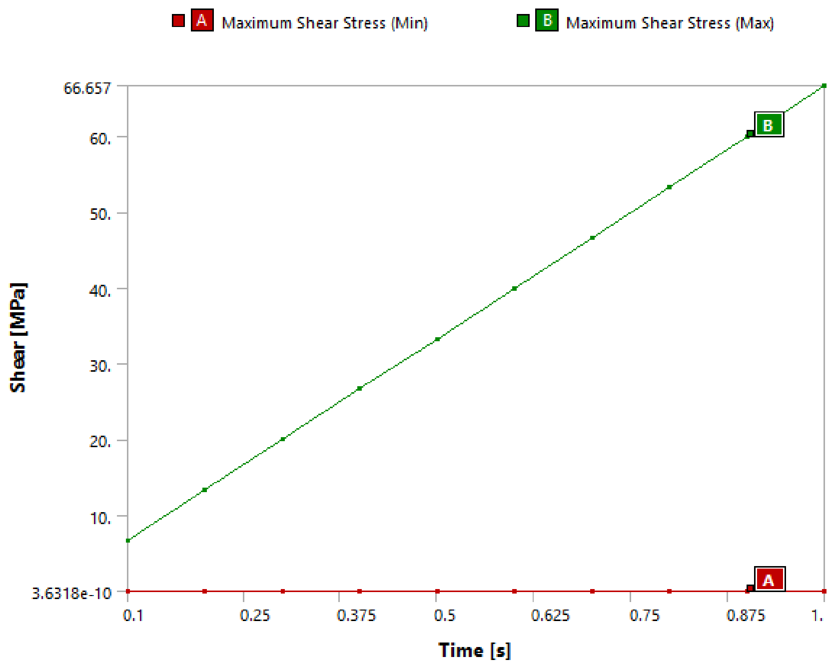


Figure 5.6: Graphical representation of maximum shear stress

5.2 Results of Dynamic Analysis

The ANSYS rigid dynamics solver is intended to be used for the study of the relative motion of parts within an assembly. The analysis focuses on how the spare tyre moves and is positioned within the handling mechanism. This includes studying the displacement of key components, such as the lifting structure and mounting structure over, time.

I. Rotational motion of vertical structure of the mechanism

When the vertical structure rotates 86 degrees in the clockwise direction, lowering of spare tyres takes place to the desired limit within eight seconds. Figure 5.7 shows the rotation of vertical structure.

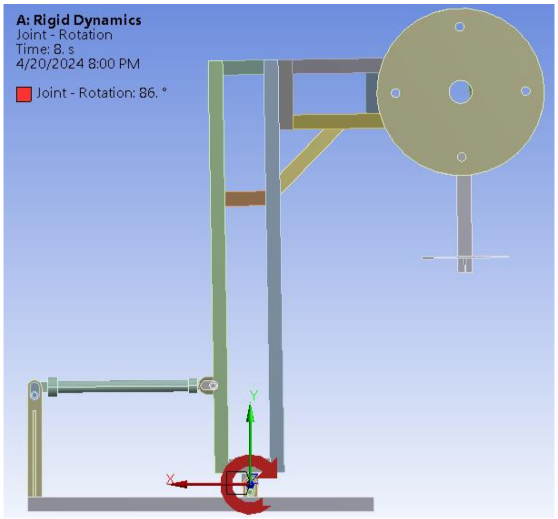


Figure 5.7: Rotation of vertical structure

Table 5.5: Rotation for vertical structure

Time [s]	Rotation (Rotation) [°]
0	0
1	-10.75
2	-21.5
3	-32.25
4	-43
5	-53.75
6	-64.5
7	-75.25
8	-86

The figure 5.8 displays a red line with a negative slope, indicating that the rotational angle of vertical structure of mechanism is decreasing as time progresses. Also provides a visual representation of how the rotational reaction of the spare tyre handling mechanism changes over time, offering insights into its performance and behavior.

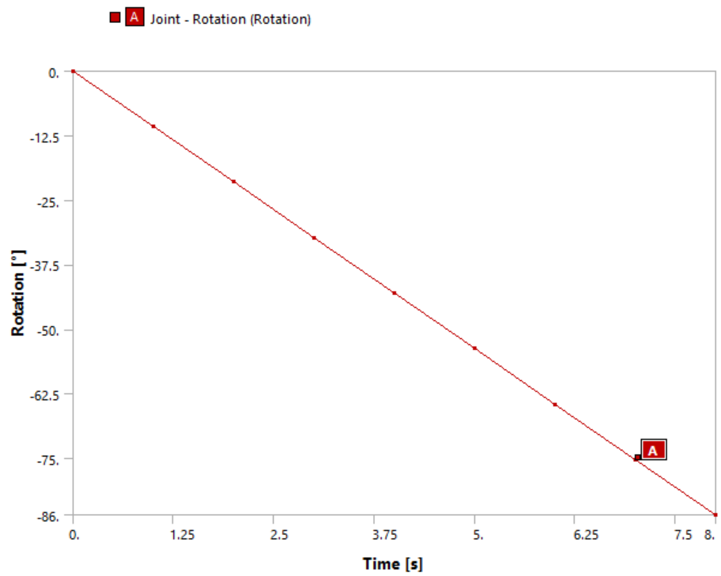


Figure 5.8: Graphical representation of rotation

II. Rotational motion of the hydraulic cylinder

Analyzing the rotation of this component helps in assessing its functionality, alignment, and interaction with the spare tyre. Figure 5.9 shows the rotation of the hydraulic cylinder.

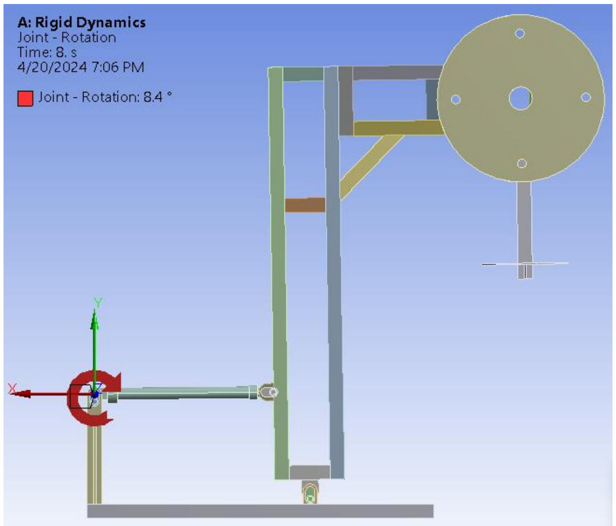


Figure 5.9: Rotation of Hydraulic cylinder

Table 5.6: Rotation of hydraulic cylinder

Time [s]	Joint B Rotation [°]
0	0
1	1.05
2	2.1
3	3.15
4	4.2
5	5.25
6	6.3
7	7.35
8	8.4

Figure 5.10 shows a single red line that represents the data, showing a steady increase in position as time progresses. This suggests that the mechanism moves at a constant speed.

The graph represents the position of the hydraulic cylinder over time, showing how it rotates within its maximum range of 8.4 degrees. The data points on the graph indicate the cylinder's position at specific time intervals, demonstrating its movement within the specified angle. The precise control and movement of the hydraulic cylinder as it rotates within the 8.4-degree range. The smooth and consistent increase in position over time could indicate the accurate control of the cylinder's rotation, highlighting the system's ability to maintain precision.

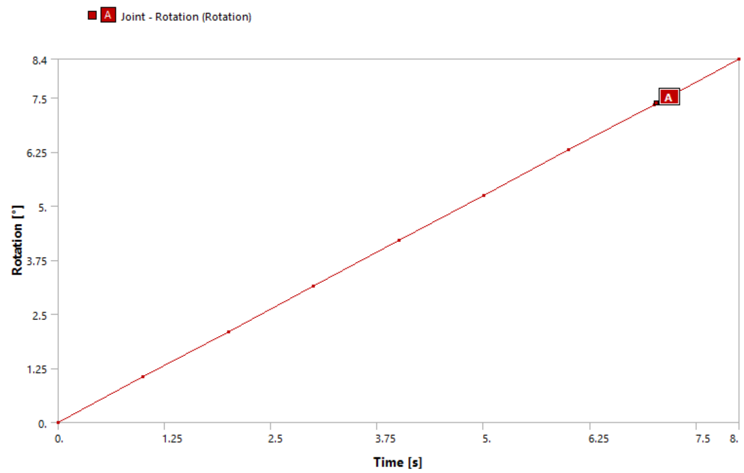


Figure 5.10: Graphical representation for rotation of Hydraulic cylinder

III. Position of spare tyre carrier

Figure 5.11 depicts a spare tyre handling mechanism. The green circular object represents the mounting point for the spare tyre. The structure appears horizontal and is connected to the green circle or mounting structure for the spare tyre suggesting a mechanism that allows the spare tyre to move. The shorter vertical structure attached at the other end of the horizontal structure forms an L-shaped structure, indicating a possible lifting or lowering motion for the spare tyre providing a smooth and controlled movement for the spare tyre and making the tyre touch the ground.

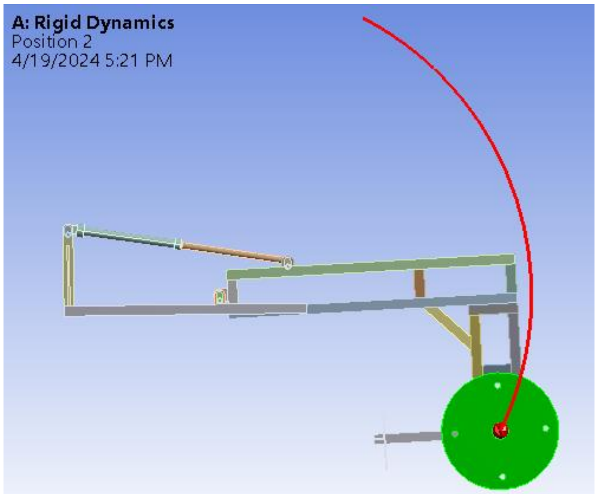


Figure 5.11: Position of spare tyre carrier

Table 5.7: Position of spare tyre carrier

Steps	Time [s]	Position 2 (X) [mm]	Position 2 (Y) [mm]	Position 2 (Z) [mm]
1	0	-435.04	1956.2	718.08
2	1.00E-02	-471.84	1935.9	718.08
3	2.29E-02	-518.53	1908.1	718.08
4	3.88E-02	-574.6	1871.6	718.08
5	5.76E-02	-638.49	1825.7	718.08
6	7.93E-02	-708.18	1769.6	718.08
7	0.10373	-781.54	1702.8	718.08
8	0.13109	-856.45	1624.7	718.08
9	0.16162	-930.84	1535	718.08
10	0.1957	-1002.7	1433	718.08
11	0.23392	-1069.8	1318.5	718.08
12	0.27707	-1130.1	1191.1	718.08
13	0.32619	-1180.9	1050.8	718.08
14	0.37619	-1216.2	915.05	718.08
15	0.42619	-1237.6	787.82	718.08
16	0.47619	-1247.8	669.85	718.08
17	0.52619	-1249.2	561.51	718.08
18	0.57619	-1243.9	462.84	718.08
19	0.62619	-1233.6	373.68	718.08
20	0.67619	-1219.8	293.69	718.08
21	0.72619	-1203.9	222.46	718.08
22	0.77619	-1186.8	159.49	718.08
23	0.82619	-1169.4	104.25	718.08
24	0.87619	-1152.4	56.212	718.08
25	0.92619	-1136.3	14.84	718.08
26	0.97619	-1121.5	-20.381	718.08
27	1.0262	-1108.3	-49.944	718.08
28	1.0762	-1096.8	-74.317	718.08
29	1.1262	-1087.2	-93.939	718.08
30	1.1762	-1079.4	-109.22	718.08
31	1.2262	-1073.6	-120.55	718.08
32	1.2762	-1069.5	-128.3	718.08

In figure 5.12 The horizontal axis (X-axis) represents time in seconds, indicated as "Time [s]," while the vertical axis (Y-axis) represents some form of position or displacement in millimeters, labelled as the position of spare tyre carrier [mm]. Each position's curve starts at a different value of displacement at time zero and changes over time.

It means that at the very beginning of the time interval (time zero), each position (represented by the curves) has a specific initial displacement to the XYZ coordinate. Position in the X-direction showing a steep decline, Position Y-direction showing very little change, and Position Y-direction showing a moderate decline over the 1-second interval displayed. In the Z-direction, it does not change.

As time progresses, the changes in the curves reflect how positions in different directions move relative to each other and evolve dynamically over the specified time. The generated model or simulation of the mechanism in the figure helps to understand how the spare tyre would be manipulated and positioned using this mechanism.

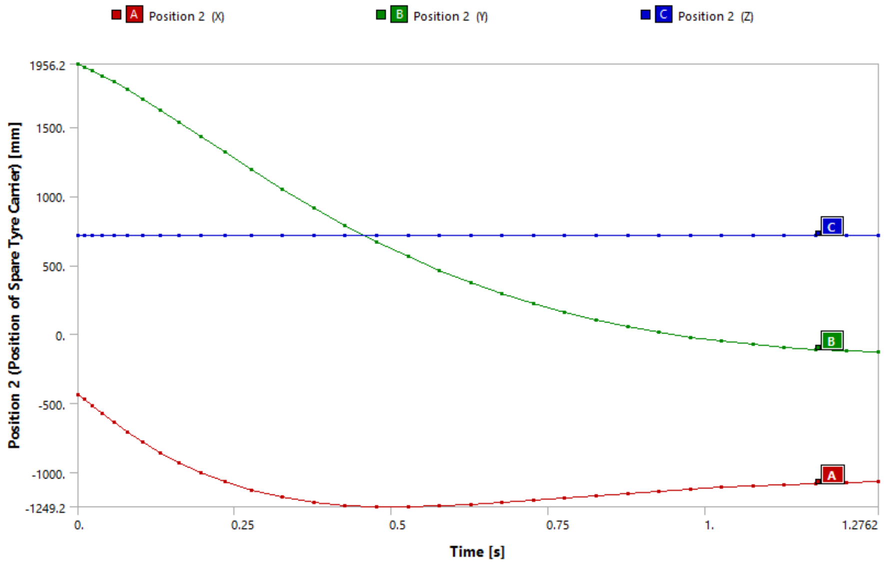


Figure 5.12: Graphical representation of the position of the spare tyre carrier

IV. Velocity of spare tyre carrier: This helps to understand how it behaves during the dynamic analysis.

Table 5.8: Velocity

Steps	Time [s]	Velocity Probe 2 (X) [mm/s]	Velocity Probe 2 (Y) [mm/s]	Velocity Probe 2 (Z) [mm/s]	Velocity Probe 2 (Total) [mm/s]
1	0	-1788.4	-958.56	-2.37E-11	2029.1
2	1.00E-02	-1748.9	-966.87	-2.35E-11	1998.4
3	2.52E-02	-1690.7	-977.56	-2.32E-11	1953
4	4.63E-02	-1613	-988.95	-2.27E-11	1892
5	7.36E-02	-1517.5	-998.38	-2.20E-11	1816.5
6	0.10728	-1407.5	-1002.9	-2.12E-11	1728.2
7	0.14725	-1286.6	-999.61	-2.03E-11	1629.3
8	0.19357	-1158.3	-986.15	-1.91E-11	1521.2
9	0.24357	-1032.5	-962.1	-1.79E-11	1411.2
10	0.29357	-918.51	-930.03	-1.67E-11	1307.1
11	0.34357	-815.23	-891.5	-1.55E-11	1208
12	0.39357	-721.66	-847.77	-1.43E-11	1113.3
13	0.44357	-636.96	-799.95	-1.32E-11	1022.6
14	0.49357	-560.36	-748.97	-1.21E-11	935.4
15	0.54357	-491.18	-695.68	-1.10E-11	851.61
16	0.59357	-428.78	-640.81	-9.93E-12	771.04
17	0.64357	-372.56	-585.03	-8.92E-12	693.59
18	0.69357	-321.96	-528.93	-7.95E-12	619.21
19	0.74357	-276.42	-473.05	-7.02E-12	547.89
20	0.79357	-235.45	-417.85	-6.13E-12	479.62
21	0.84357	-198.56	-363.78	-5.29E-12	414.44
22	0.89357	-165.3	-311.2	-4.49E-12	352.38
23	0.94357	-135.25	-260.46	-3.74E-12	293.48
24	0.99357	-108.04	-211.83	-3.02E-12	237.79
25	1.0436	-83.316	-165.58	-2.35E-12	185.36
26	1.0936	-60.786	-121.91	-1.73E-12	136.22
27	1.1436	-40.191	-81.002	-1.15E-12	90.424

The graph in figure 5.13 illustrates the velocity profiles over time for velocity probe 2 in the three spatial dimensions X, Y, and Z, as well as the total velocity. The data is now shown for a slightly extended time interval up to approximately 1.1436 seconds. velocity components.

X-Component (A - Red): Starts at approximately -1788.4 mm/s and increases non-linearly.

Y-Component (B - Green): Begins from a negative value around -1000 mm/s and increases steadily in a nearly linear manner, leveling off just below 0 mm/s at the end of the observed interval.

Z-Component (C - Blue): Remains constant throughout the time interval, maintaining a velocity of 0 mm/s. This indicates no movement in the Z-direction.

Total Velocity (D - Purple): The total velocity is calculated as the vector sum of the individual components (X, Y, and Z). It starts from a high value of about 2029.1 mm/s and decreases non-linearly, converging towards a steady value of around 100 mm/s by the end of the interval.

Initial Conditions: At time t = 0, the X and Y components both have significant negative values, indicating initial velocities in the negative directions of the respective axes. The Z-component is zero, indicating no initial movement along the Z-axis.

Generally, the graph shows dynamic changes in the velocities along the X and Y axes, with the Z-axis remaining stationary. This behavior suggests forces or influences acting primarily in the X and Y directions, leading to acceleration and deceleration phases. The total velocity graph captures the combined effect, showing an overall trend of deceleration.

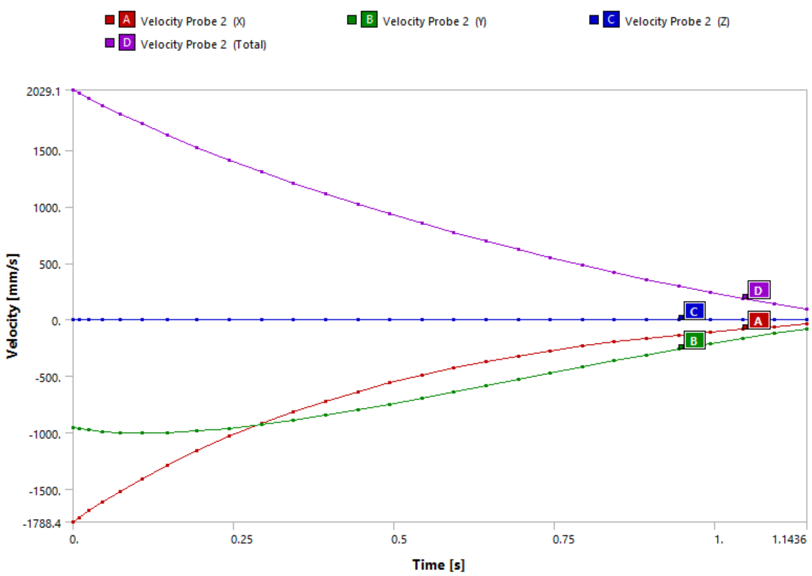


Figure 5.13: Velocity probe

5.3 Time Analysis to Lift and Lower Spare Tyre

The time it takes to lift and lower a spare tyre is an important factor to be considered in emergencies when a flat tyre needs to be replaced quickly. Assessments have been conducted on the same activities for all of the three methods supposed to be used to handle spare tyres or Howo dump trucks.

I. Time efficiency assessment for new spare tyre handling mechanism

When a new spare tyre handling mechanism is used, the time taken to lift and lower the spare tyre is summarized in table 5.9. Here only activities related to lifting and lowering are included.

Table 5.9: Time for new spare tyre handling mechanism

No	Activities	Time (s) it takes	
1	Lifting spare tyre	8	
2	Lowering spare tyre	8	
3	Tilting the cabin	null	
4	Seeking road side assistance	null	
5	climbing up into the space between cabin and dump box of the truck	null	
6	Stepping down from the dump truck	null	
7	Pulling a chain up and down	null	
		Total time (s)	16

The table 5.9 provides a comprehensive comparison of various lifting and lowering activities in a structured table format. It effectively distinguishes between tasks that demand substantial time, specifically the lifting and lowering of the spare tyre, and those that are instantaneous or require no time investment, such as tilting the cabin, seeking roadside assistance, climbing into the space between the cabin and dump box, pulling a chain up and down and stepping down from the dump truck.

The absence of time allocated to the latter activities indicates that they are not part of the process when utilizing a new spare tyre handling mechanism. However, these actions are integral components of the manual and chain block methods. This distinction shows the efficiency and time-saving benefits of the new spare tyre handling mechanism compared to traditional methods, highlighting the streamlined and optimized approach it offers in comparison to more time-consuming alternatives.

II. Time efficiency assessment of the manual method of lifting and lowering spare tyre

When the manual method of lifting and lowering a spare tyre is used, the time taken to lift and lower a spare tyre is summarized in table 5.10. Here only activities related to lifting and lowering are included.

Table 5.10: Manual method

No	Activities	Time (s) it takes	
1	Lifting spare tyre	120	
2	Lowering spare tyre	120	
3	Tilting cabin	10	
4	Seeking roadside assistance	1320	
5	climbing up into the space between the cabin and the dump box	20	
6	Stepping down from the dump truck	25	
7	Pulling a chain up and down	null	
		Total time (s)	1615

III. Time efficiency assessment of the chain block (chain hoist) method of lifting and lowering the spare tyre

When the chain block method of lifting and lowering the spare tyre is used, the time taken to lift and lower the spare tyre is summarized in the table 5.11. Here only activities related to lifting and lowering are included.

Table 5.11: Time for chain block method

No	Activities	Time (s) it takes	
1	Lifting spare tyre	null	
2	Lowering spare tyre	null	
3	Tilting cabin	10	
4	Seeking road side assistance	null	
5	climbing up into the space between cabin and dump box	20	
6	Stepping down from the dump truck	25	
7	Pulling a chain up and down	480	
		Total time (s)	535

5.4 Comparison Between Methods

Figure 5.14 shows a comparison of the total time taken by three different methods new spare tyre handling mechanism, manual, and chain block. It provides valuable insights into their time efficiency. The new spare tyre handling mechanism is the quickest, taking only 0.28 minutes. This indicates a significant speed improvement compared to the manual method, which is the most time-consuming that is 26.92 minutes. This means when a new spare tyre handling mechanism is used the time to lift and lower the spare tyre is decreased by 98.9% compared to the manual method.

The chain block method falls in between the other two, taking 8.92 minutes. This means when a new spare tyre handling mechanism is used, the time to lift and lower the spare tyre is decreased by 66.9% compared to the chain block method. While it is not as fast as the new spare tyre handling mechanism, it still outperforms the manual method by a considerable margin. This data suggests that implementing the new spare tyre handling mechanism could lead to substantial time savings and increased efficiency in handling tasks related to spare tyres.

By considering the data presented in figure 5.14, it becomes evident to choose an efficient method for handling roadside situations. Implementing faster and more effective techniques can not only save time but also enhance productivity, safety, and convenience for drivers in need of assistance on the road. Another benefit that can be gained when using the new spare tyre handling mechanism is improved safety and reduced physical strain on individuals involved in the tyre-changing process.

Traditional manual methods of changing a spare tyre often require significant physical effort and can pose safety risks, especially if proper lifting techniques are not followed. The new spare tyre handling mechanism, with its efficient and potentially automated features, can help minimize the physical strain on individuals by simplifying the tyre-changing process and reducing the need for manual lifting and handling of heavy tyre.

By utilizing the new spare tyre handling mechanism, organizations can enhance workplace safety by reducing the risk of injuries related to manual handling tasks. This can lead to a healthier and safer work environment for employees involved in tyre-changing operations, ultimately contributing to improved overall productivity and employee well-being.

In addition to time savings and efficiency, the new spare tyre handling mechanism's focus on safety and ergonomics can be a valuable benefit for businesses looking to optimize their operations while prioritizing the well-being of their workforce.

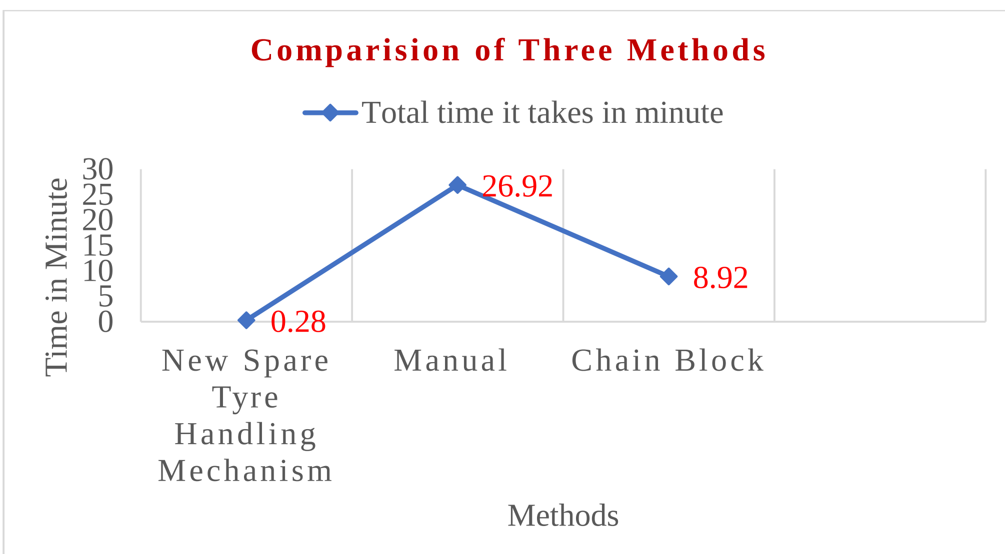


Figure 5.14: Comparison of three methods

5.5 Performance of Spare Tyre Handling Mechanism

Performance optimization is crucial for improving the functionality, efficiency, and reliability of spare tyre handling in dump trucks. Spare tyre handling pertains to how efficiently and effectively a driver can store, access, and utilize the spare tyre when needed. Here are some key performance optimizations that have been performed in the spare tyre handling mechanism for the Howo 336 dump truck.

I. Accessibility and ease of use: As the newly designed mechanism does not require climbing up and down, and working in a narrow place the accessibility of the spare tyre is quick and simple during tyre changing. This easy-to-access and user-friendly spare tyre mechanism can enhance the usability and accessibility of the spare tyre. Because it uses a hydraulic system where only a single person can lift and lower spare tyres by using a hand pedal.

II. Durability and reliability**:** As can be seen from the stress analysis and safety factor, the spare tyre handling mechanism which has been designed is durable and reliable. Since its working strength is less than yield strength it has a 1.97 safety factor which confirms that the design is safe as per engineering standards.

III. Quick deployment: This is the process of implementing, installing, and integrating systems. Thus, efficient deployment mechanisms, such as quick-release systems or hydraulic cylinders which are used in this mechanism can speed up the tyre-changing process during emergencies. This ensures that the spare tyre can be quickly deployed and installed when needed.

By focusing on these aspects, the functionality, efficiency, and reliability of spare tyre handling in dump trucks is improved, ensuring that drivers can effectively manage tyre-related issues and emergencies with confidence and ease.

5.6 Aerodynamic Analysis of the Howo 336 Dump truck

This analysis is carried out to see the aerodynamic effect of new spare tyre handling mechanism that is addressed in this thesis work. The geometry of the truck is created using CATIA V5 and imported to ANSYS workbench in IGS format. The numerical computation is conducted with second order discretization.

5.6.1 Mesh Generation

In order to capture the flow physics near the dump truck, a fine mesh of unstructured triangles was put on the boundary of the dump truck. Figure 5.15 shows mesh generated for Howo 336 Dump Truck before attachment of new spare tyre handling mechanism or without spare tyre handling mechanism. For existing dump truck 63766 nodes and 329536 elements are used.

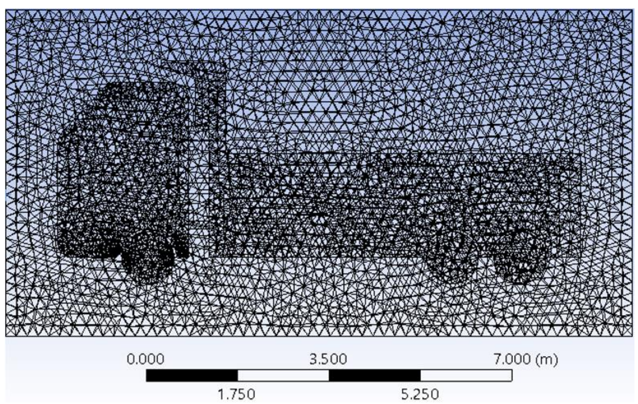


Figure 5. 15: Mesh generated on Dump truck without spare tyre handling mechanism.

Figure 5.16 shows mesh generated when new spare tyre handling mechanism is mounted between cab and dump box. For new spare tyre handling mechanism 80296 nodes and 416272 are used.

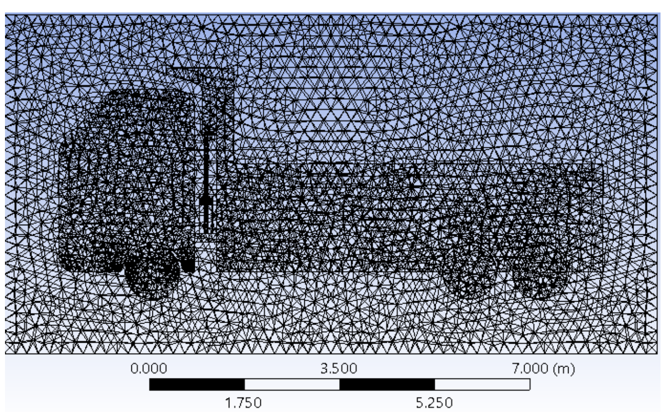


Figure 5. 16: Mesh generated on Dump truck with spare tyre handling mechanism

5.6.2 Boundary Conditions

All the boundary conditions used in the analysis are listed in the table 5.12

Table 5. 12: Boundary conditions

Surface/Part	Type	Condition
Enclosure-Inlet	Velocity Inlet	Constant velocity: 78 km/hr Turbulent intensity: 5% Viscosity ratio: 1
Enclosure-Outlet	Pressure Outlet	Gauge pressure=0 Pa Turbulent intensity: 5% Viscosity ratio: 10
Road	Roughness	Shear condition: no slip condition Roughness height = 0 Roughness constant = 0.5
Enclosure-Sides	Symmetry	-
Dump truck	Walls (Stationary)	No-slip

5.7 Results and Discussions of CFD Analysis

Aerodynamic evaluation of airflow over a dump truck is performed using analytical method or Computational Fluid Dynamics (CFD) approach. The computational results of existing dump truck model and dump truck model with new spare tyre handling mechanism are presented and discussed. The solution was performed using ANSYS FLUENT; k-w (K-Omega) viscous modeling is used to perform the analysis. Since the maximum speed of the Howo 336 Dump Truck is 78 km/hr, its considered for both dump truck without spare tyre handling mechanism and dump truck with new spare tyre handling mechanism.

5.7.1 Results for Dump Truck Without Spare Tyre Handling Mechanism

I. Residual History

The numerical computation is conducted with second order discretization for 600 iterations. Figure 5.17 shows residual history of dump truck without spare tyre handling mechanism at the speed of 78 km/hr.

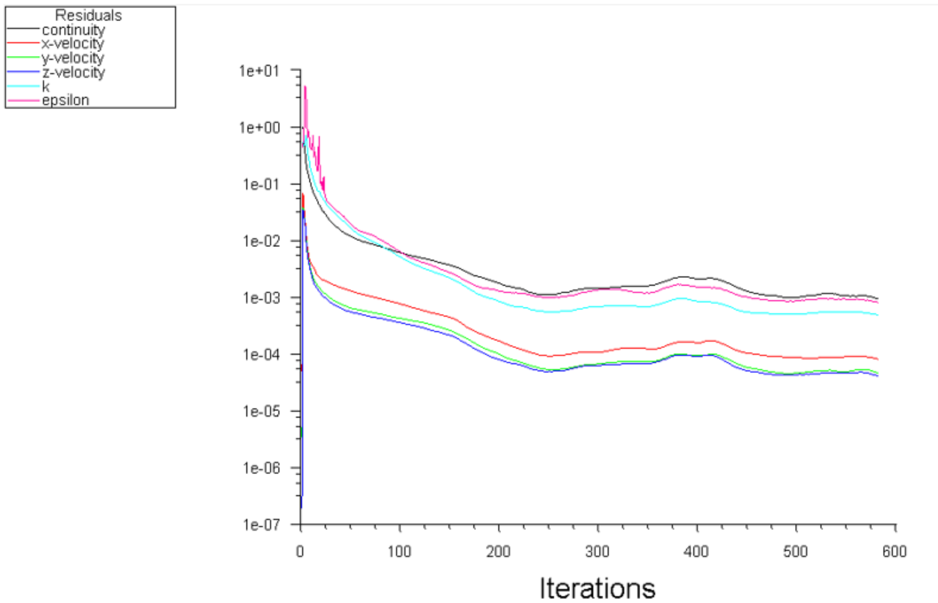


Figure 5. 17: Residual history of dump truck without spare tyre handling mechanism

II. Drag Coefficient

As it is shown in Figure 5.18 the drag coefficient converges after 50th iteration. Total iteration is 600. This iteration is selected because there was no change in the value of the drag coefficient after this iteration. The drag coefficient of the dump truck without spare tyre handling mechanism is 0.7046 at the speed of 78 km/hr.

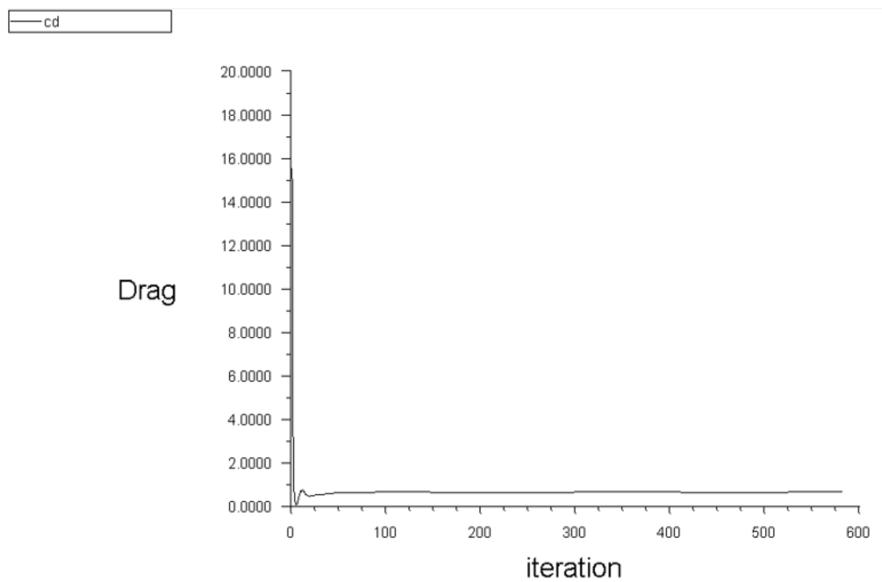


Figure 5. 18: Drag coefficient of dump truck without spare tyre handling mechanism

III. Lift Coefficient

As it is shown in Figure 5.19 the lift coefficient converges after 75th iteration. lift coefficient of the dump truck without spare tyre handling mechanism is 0.1987 at the speed of 78 km/hr.

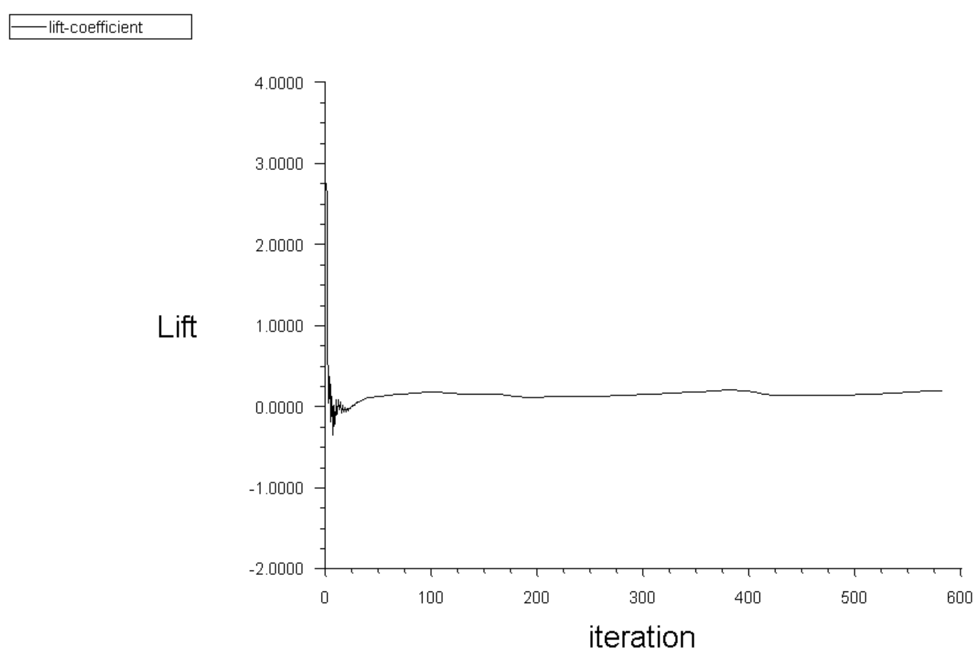


Figure 5. 19: Lift Coefficient of dump truck without spare tyre handling mechanism

IV. Pressure Contour

As it is seen in Figure 5.20 the pressure at the front face of the dump truck is high. The high pressure in the front part of the dump truck indicates that the velocity is low at that point. The pressure distribution over the dump truck is similar. The colors on the pressure contour indicate the intensity of the pressure. The red color indicates the maximum pressure and the blue color shows the minimum pressure.

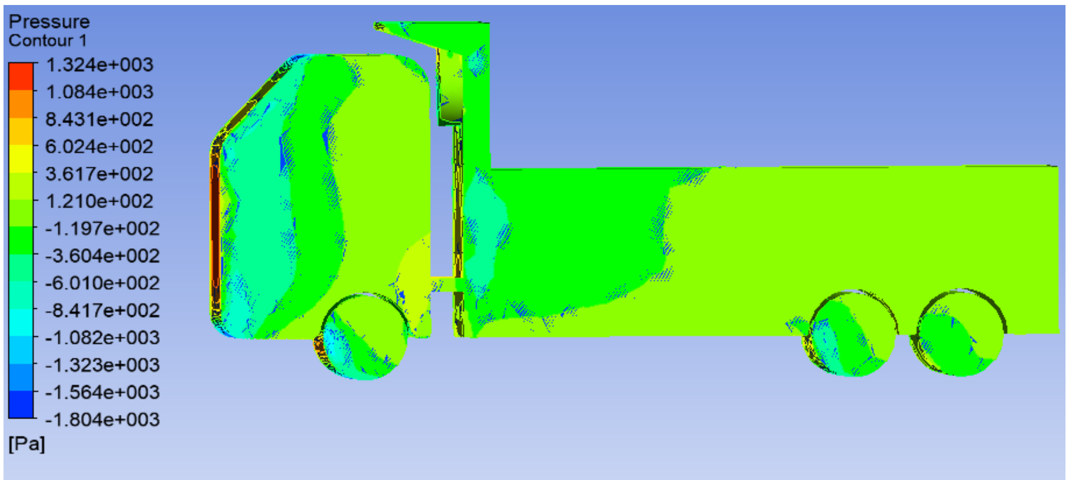


Figure 5. 20: Pressure contour of the dump truck without spare tyre handling mechanism

V. Velocity Contour

As it is given in Figure 5.21, when viscous air flows over the dump truck, vortices are created at the rear causing the flow to deviate from the smooth streamline flow. Under these conditions the air flow pressure in front of the dump truck is higher than atmospheric pressure while the pressure behind is lower than that of the atmosphere, consequently the dump truck will be sucked in the direction of air movement.

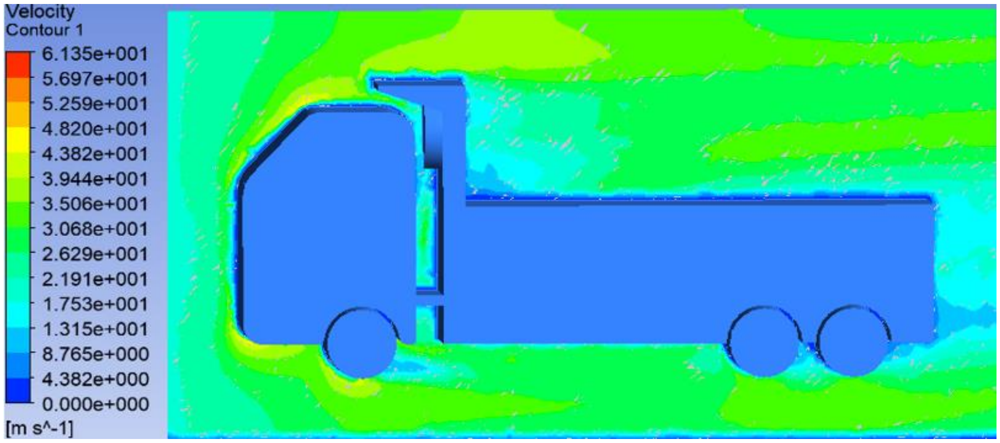


Figure 5. 21: Velocity Contour of the dump truck without spare tyre handling mechanism

5.7.2 Results for Dump Truck with New Spare Tyre Handling Mechanism

I. Residual History

The simulation is carried out for 350 iterations. Figure 5.22 shows residual history of dump truck with new spare tyre handling mechanism at the speed of 78 km/hr.

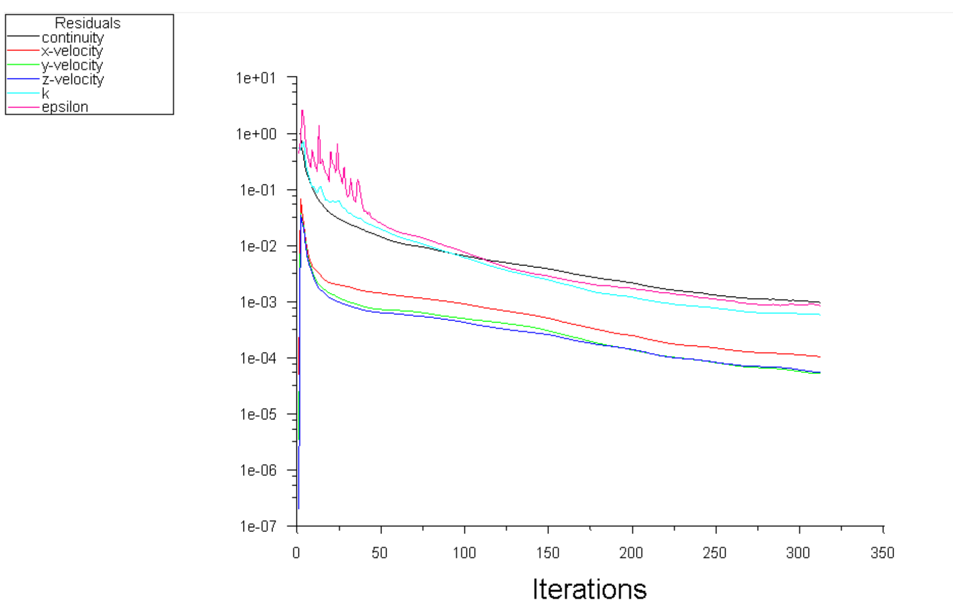


Figure 5. 22: Residual history of dump truck with new spare tyre handling mechanism

II. Drag Coefficient

As it is shown in Figure 5.23 the drag coefficient converges after 25th iteration. Total iteration is 350. This iteration is selected because there was no change in the value of the drag coefficient after this iteration. The drag coefficient of the dump truck with new spare tyre handling mechanism is 0.6549 at the speed of 78 km/hr.

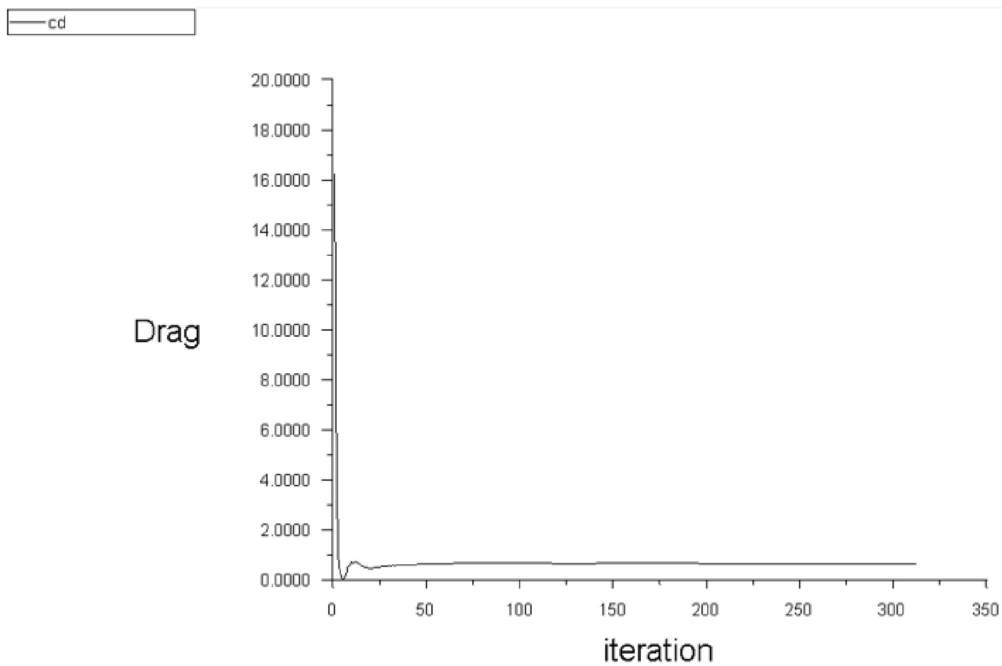


Figure 5. 23: Drag coefficient of dump truck with new spare tyre handling mechanism

III. Lift Coefficient

As it is shown in Figure 5.24 the lift coefficient converges after 25th iteration. lift coefficient of the dump truck with new spare tyre handling mechanism is 0.1118 at the speed of 78 km/hr.

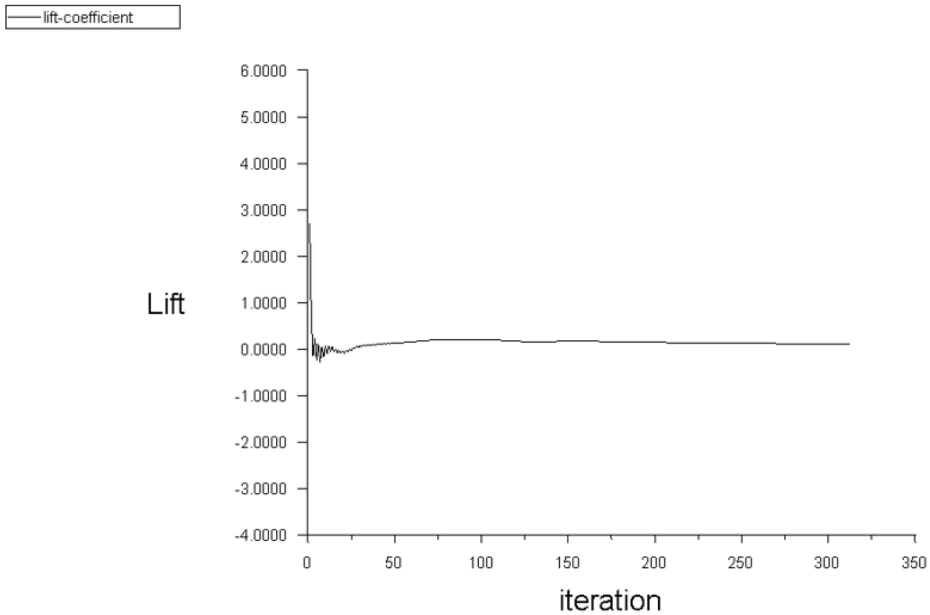


Figure 5. 24: Lift coefficient of dump truck with new spare tyre handling mechanism

VI. Pressure Contour

As it is seen in Figure 5.25 the pressure at the front face of the dump truck is high. The high pressure in the front part of the dump truck. The red color indicates the maximum pressure and the blue color shows the minimum pressure.

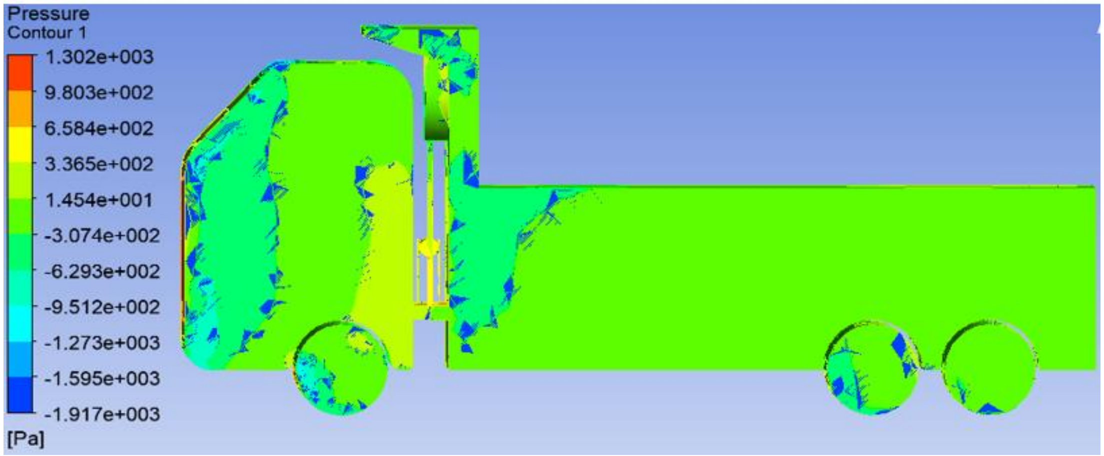


Figure 5. 25: Pressure contour of dump truck with new spare tyre handling mechanism

VII. Velocity Contour

As it is seen in Figure 5.26 low velocity is observed at the back side of cabin and rear part of dump truck.

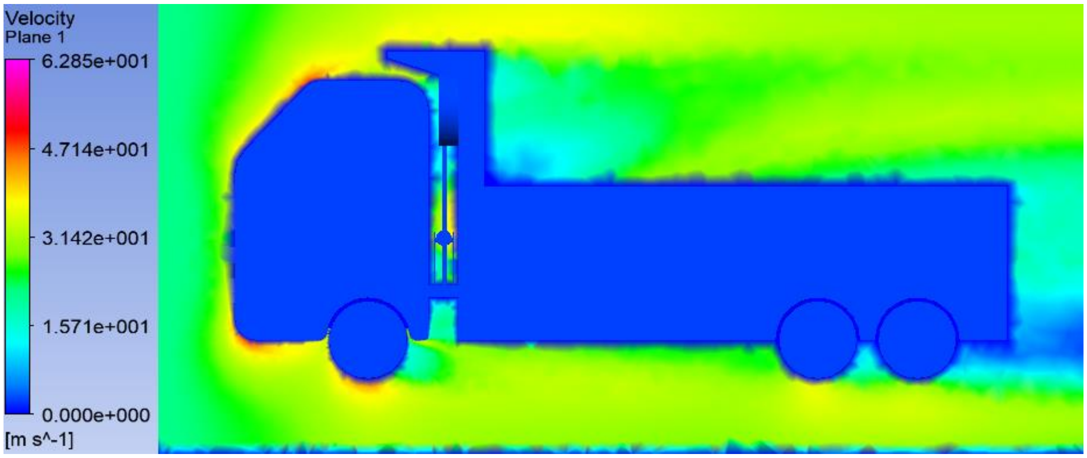


Figure 5. 26: Velocity Contour of dump truck with new spare tyre handling mechanism

5.8 Comparison Between Models

The two models of dump truck are similar, but new spare tyre handling mechanism is added to one model. The comparison in terms of drag coefficient and lift coefficient has been made in Table 5.13.

Table 5. 13: Comparison of two models

Model	Speed (Km/hr)	Drag Coefficient (Cd)	Lift Coefficient	Percentage of Cd Reduction (%)	Percentage of Lift Coefficient (%)
Dump Truck with New Spare Tyre Handling Mechanism	78 km/hr	0.6549	0.1118	7	43.7
Dump Truck without Spare Tyre Handling Mechanism	78 km/hr	0.7046	0.1987	–	–

Drag coefficient is due to friction, pressure, and induced drag. From the table 5.13 Drag coefficient is reduced means the spare tyre handling mechanism that inserted between cabin and cargo box is positively affecting the wake that is formed behind the cabin by making smooth flow of air. The wake behind a cabin of dump truck is the disturbed airflow pattern created as it moves forward.

The lift coefficient indicates that the spare tyre handling mechanism inserted between the cabin and cargo box is not only affecting the drag coefficient but also impacting the dump truck's lift characteristics. The lift coefficient is a measure of the lift force generated by an object, such as a vehicle. The lift coefficient is crucial for determining the vehicle's stability, handling, and overall aerodynamic performance.

If we consider Howo 336 Dump Truck, around 150 kg mass of spare tyre and fuel tank are mounted on the left side of this truck. Whereas, on the right side, there is no such kind of attachment. In the broader context of the drag coefficient being reduced and the lift coefficient also decreased, it suggests that the spare tyre handling mechanism is positively influencing the aerodynamic behavior of the dump truck. Of course, this vehicle has the problem of losing its stability, and this may help to reduce accident that is happened due to instability.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the time analysis, the existing methods both manual and chain block methods take a long time, are tiresome, and increase fatigue for the driver. To improve this, a new spare tyre handling mechanism has been fitted on the chassis between the cabin and dump box. As a result, the new spare tyre handling mechanism which is reliable, durable, easy-to-access, user-friendly, reduces turnaround times increases productivity, and minimizes the risk of injuries has been designed. Additionally, the spare tyre mounted on the dump box increases a certain amount of fuel consumption as the dump box is lifted for daily loading and unloading purposes. As it is removed from the dump box fuel is saved.

The main findings are:

- When a new spare tyre handling mechanism is used the time to lift and lower the spare tyre is decreased by 98.9% and 66.9% compared to manual and chain block methods respectively.
- New spare tyre handling mechanism is easy-to-access and user-friendly
- The process of implementing, installing, and integrating systems is quick when a new spare tyre handling mechanism is used.
- When a new spare tyre handling mechanism is used 0.4905 L/Hr fuel is saved.
- The maximum equivalent stress of the structure is 128.69 MPa which is less compared to the yield strength of the material. Therefore, the spare tyre handling mechanism can withstand the load of the tyre and accessories applied to it.
- The maximum deformation is 5.6 mm in the structure for the given loading conditions. This deformation is within the allowable limits as specified by the structural standards.
- The maximum shear stress of the structure is 66.657 MPa which is less compared to the yield strength of the material and its acceptable.

- When the vertical structure and hydraulic cylinder of the spare tyre handling mechanism rotate 86 degrees within 8 (eight) seconds, the spare tyre touches the ground for tyre replacement purposes.
- This work proves the possibility of designing a spare tyre handling mechanism for the Howo 336 dump truck to minimize the time for lifting and lowering spare tyres, increase productivity, and reduce driver fatigue during tyre changing.
- Drag coefficient of the truck is reduced by 7%.

6.2 Recommendations

- Dump truck manufacturing companies have to check their spare tyre handling mechanism and give more emphasis as there is significant time minimizing and performance increasing by changing spare tyre handling mechanism as discussed in this study.
- It can be observed from the result that, the spare tyre handling mechanism is improved due to the new design. Therefore, dump truck manufacturers should use this mechanism instead of chain block or manual methods.

6.3 Recommendations for Future Work

The following recommendations can be taken into consideration for future work.

- It is recommended to design automated locking tools because bolt and nuts increase the tyre-changing cycle.

- Vibration Loads caused by road irregularities, bumps, and potholes that the vehicle encounters during operation may cause failure to the mechanism. Therefore, it is recommended to analyze these loads and take the right measures if it has to be improved.

REFERENCES

Meriam and Kraige. (2002). *Engineering Mechanics Statics* (Fifth ed., Vol. 1). New york, Albany, United States of America: Jhon Wiley and Sons,Inc.

Andersson, F. E. (2018). Compact lifting mechanism of autonomous vehicle.

Blafoss et al. (2021). Effects of load mass and position on the dynamic loading of the knees, shoulders and lumbar spine during lifting: a musculoskeletal modelling approach. *ScienceDirect*.

Cheah et al. (2015). Design and Development Of The Mechanism For Run Flat Tyre, Part 3. *2nd Integrated Design Project Conference (IDPC) 2015* (p. 2). Pahang: Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 9 Jan 201.6.

Chemical Rubber Co. (1994). *CRC Handbook of Chemistry and Physics* (75th edition ed.). Florida.

D. Callister, J. (2000). *Fundamentals of Materials Science and Engineering.* (W. Anderson, Ed.) Salt Lake City, Utah, America: John Wiley & Sons, Inc., 605 Third Avenue,. Retrieved 2001

Falcioni, R. (2018). *Ethiopia's Construction Industry:Transforming a Nation.*

Gupta et al. (2004). *Encyclopedia of Physical Science and Technology* (Third Edition • 2001 ed.). Maryland: ScienceDirect.

Harsh. (2023). Development of mobile smart material-handling system. *Sciencedirect*, 2.

Jahirul et al. (2022). Automobile fuels (diesel and petrol) from plastic pyrolysis oil—Production and characterisation. *7th International Conference on Advances on Clean Energy Research, ICACER 2022 April.* Barcelona: http://www.elsevier.com/locate/egyr. Retrieved Noveember 7, 2022

Jasmin et al. (2023). The influence of transfer distance and pace of work on foot positioning strategies and low back loading in a manual material handling task. *ScienceDirect*.

Jiang et al. (2022). Kinematic analysis and energy saving optimization design of parallel lifting mechanism for stereoscopic parking robot. *ScienceDirect*.

John.et al. (2016). *Theory of Machines* (fifth ed.). New York, Michigan: OXFORD UNIVERSITY PRESS.

K.Pushphanathan et al. (2018). DESIGN AND ANALYSIS OF SOLAR. *International Journal of Emerging Technology in Computer Science & Electronics*.

Kaustubh, S. (2015). Advanced Spare Wheel Carrier. *International Journal of Scientific & Engineering Research*.

Kong et al. (2024, January Qingdao). Three-model-driven fault diagnosis method for complex hydraulic control system: Subsea blowout preventer system as a case study. *ScienceDirect, 247*, 1. Retrieved January 2024

Kumar et al. (2017). Design and Fabrication of Dump Truck Tilting System. *Scincedirect*, 327-334.

Kumar.N. (2022). *Advancement in Oxygenated Fuels for Sustainable Development Feedstocks and Precursors for Catalysts Synthesi.*

Liu et al. (2024, January 3). Adaptive self-structuring neural network control for full-state constrained hydraulic systems with disturbance compensation. *ScienceDirect, 129*, 1. Retrieved Febrauary 5, 2024

Marrs, C. J. (2016). Jeep WJ Multipurpose Oversize Spare Tire Carrier. *ScholarWorks@CWU*.

Matus et al. (2021). Engineering design of lifting device weighing up to 3.5 tons. *ScienceDirect*.

Mohammadi.F. (2017). Design, Analysis, and Electrification of a Solar-Powered.

Murrenhoff et al. (2017). Reducing Fuel Consumption in Hydraulic Excavators—A Comprehensive Analysis.

Osman.M. (2017). Introduction to Hydraulic Systems. *Researchgate*, 1.

Pavlenko et al. (2022). *Analysis of the stress state of the 4-axle dump truck lifting.*

Philips, F. (2019). Original Equipment Manufacturers'Replacement Tires Limited Warrenty.

Rammohan. (2019, September). Compression Performance and Thermal Analysis of Hollow Low Carbon Mild Steel Cylinders with Circumferential Butt-Welded Joints. *Amity Journal of Engineering and Technology (AJET).*

Redi. (2015). Assessment of Road Traffic Crash Data Collection and Management System of .

Samuel et al. (2021). Analytical investigation of hydraulic scissor lift for modular industrial plants in ethiopia. *ScinceDirect*.

Shete, K. (2015). Advanced Spare Wheel Carrier. *International Journal of Scientific & Engineering Research*.

Simaite. (2015). *Analysis and Design of a Truck Spare Wheel Lifting Mechanism.*

Smith, R. J. (2017). Deflection Limits in Tall Buildings. *Deflection Limits in Tall Buildings – Are they useful?* (p. 9). Los Angeles: https://www.researchgate.net/figure/Design-deflections_tbl1_269083259. Retrieved October 13, 2017, from https://www.researchgate.net/figure/deflection-limits-in-international-standards_tbl2_269083259.

Soufi et al. (2023). Generation of material handling system alternatives: A constraints satisfaction problem approach. *ScienceDirect*.

Sultana and Ferdus. (2014, December 25-26). Analysis of Mechanical Properties of mild steel Applying Various Heat treatment. *International Conference on Mechanical, Industrial and Energy Engineering 2014*, 3.

Tanzharikova et al. (2013). Design of New Load lifting Mechanism. *Elsevier sciencedirect*.

Tirfe. (2021, 10). Investigation of Aerodynamically Efficient Rooftop Cargo Compartment for. *ReasearchGate*, 42.

Valdes et al. (2017). Spare Wheel Lift Mechanism for a Motor Vehicle. *United States Patent Publication*.

Venkatesh Babu and K.Sathish kumar. (2017). DESIGN AND FRABRICATION OF DUMP TRUCK TILTING SYSTEM. *International Journal of Pure and Applied Mathematics, Volume 116 No. 14*, 327.

Wang et al. (2010). Innovative design of the lifting mechanisms for forklift trucks. *Sciencedirect*.

Wofuru-Nyenke. (2020, November). Design Analysis of a Portable Manual Tyre Changer. *EJERS, European Journal of Engineering Research and Science, Vol. 5*(11), 1. Retrieved 2020

Wyndham. (2007). *Carbon Steel Handbook.* Electric Power Research Institute, Inc., California.

APPENDIX

Appendix A: Property of Materials

Table A.1: Material properties

A36 carbon steel angle chemical composition						
Steel Grade	Styles	Carbon, max, %	Manganese, %	Phosphorus, max, %	Sulfur, max, %	Silicon, %
A36	Steel Shapes	0.26	--	0.04	0.05	≤0.40
A36 carbon steel angle mechanical property						
Steel Grade	Styles	Tensile Strength, [MPa]	Yield Point, min, [MPa]			
A36	Steel Shapes	[400 - 550]	[250]			
A36 equal angle steel specification						
Item	Leg 1 (mm)	Leg 2 (mm)	Thickness (mm)	Weight (kg/m)		
EA36020	50	50	3	2.332		

Source ASTM A36 Angle Steel for Construction, Machines & Tower

Appendix B: Data Collection

I. Data collection in the Construction Machinery Production Industry

The dimensions of the dump truck may vary depending on the length of the frame, but almost all dump truck bodybuilders use the same dimensions for the same frame.

Table B.1: Cargo box dimension

No	Parameter	Dimension (mm)
1	Length	6812
2	Width	2482
3	Rear height	1273
4	Front height	1560
5	Minimum space between dump box and cabin	400
6	Maximum space between dump box and cabin	650
7	Cargo box tilt angle	45°-60°

Table B.2: Chassis Dimension

No	Parameter	Dimension (mm)
1	Length	5613
2	Width	2300
3	Space between two ends of a horizontal column of the chassis	900
4	Space between the end of the horizontal column and the end of the chassis	1600
5	Space for assembling spare tyre handling mechanism	370
6	From the ground to the end of the chassis (vertical)	1200
7	From the ground to the lower end of the dump body	1400

II. Data collection in the Metals Fabrication Industry (MFI)

The following data is collected at the Metals Fabrication Industry

Table B.3: Tyre specification

No	Parameter	Dimension (mm)
1	Width	260
2	Rim Diameter	600
3	Height	250
4	Outer diameter the Tyre	1100
5	Maximum tyre lifting height	1700
6	Loading capacity of dump truck	12600-25000 kg
		Specification (kg)
7	Weight	142.3

Appendix C: Spare Tyre Specification and Howo 336 Dump Truck Performance Form

Observer Name: Pawlos Barud

Location: Addis Ababa, at Metals Fabrication Industry in the automotive garage

Date: 16/10/2023

Time: 09:00 AM-11:30 AM

---

1. Observation Description:

a) **Spare Tyre Information:**

- Model of the spare tyre: HS801Q
- Size: 1100 mm outer diameter, 600 mm rim diameter, and 260 mm width.
- Mass of tyre: 142.3 ≈150 kg for convenience

b) Load Rating

- Max load single 4000 kg
- Max load dual 3650 kg

2. Dump Truck Information:

a) Truck Information

- Truck model: Howo 336 Dump Truck, ZZ3257N3847A
- Cargo Box Tilt Angle: 45°-60°
- Loading Capacity: 12600-25000 kg
- Times it takes for loading 10 seconds
- Maximum space between cargo box and cabin 670 mm
- Minimum space between cargo box and cabin 350 mm

Observer's Notes:

Some of the data are collected by measuring while others are gained by observing as per their requirement for design.

Appendix D: Operating Manual for Spare Tyre Handling Mechanism

Please read this manual carefully before using the product to ensure safe and proper operation.

1. Installation

- Carefully follow the installation instructions provided with the Spare Tyre Handling Mechanism. Make sure it is securely attached to the designated mounting area in your vehicle.

2. Loading the Spare Tyre

- To load the spare tyre onto the mechanism, lift the tyre and place it onto the wheel mount. Ensure that the tyre is properly secured in place.

3. Storage

- The Spare Tyre Handling Mechanism is designed to securely hold your spare tyre in place, preventing it from moving or coming loose during vehicle operation.

4. Unloading the Spare Tyre

- When you need to use the spare tyre, carefully release the mechanism and lower the tyre to the ground. Be cautious when unloading the tyre to prevent injury or damage to the vehicle.

5. Maintenance

- Regularly inspect the Spare Tyre Handling Mechanism for any signs of wear or damage. Replace any worn or damaged parts immediately to ensure proper functionality.

6. Safety Precautions

- Only use the Spare Tyre Handling Mechanism for its intended purpose of storing and transporting a spare tyre. Do not exceed the maximum weight capacity of the mechanism.

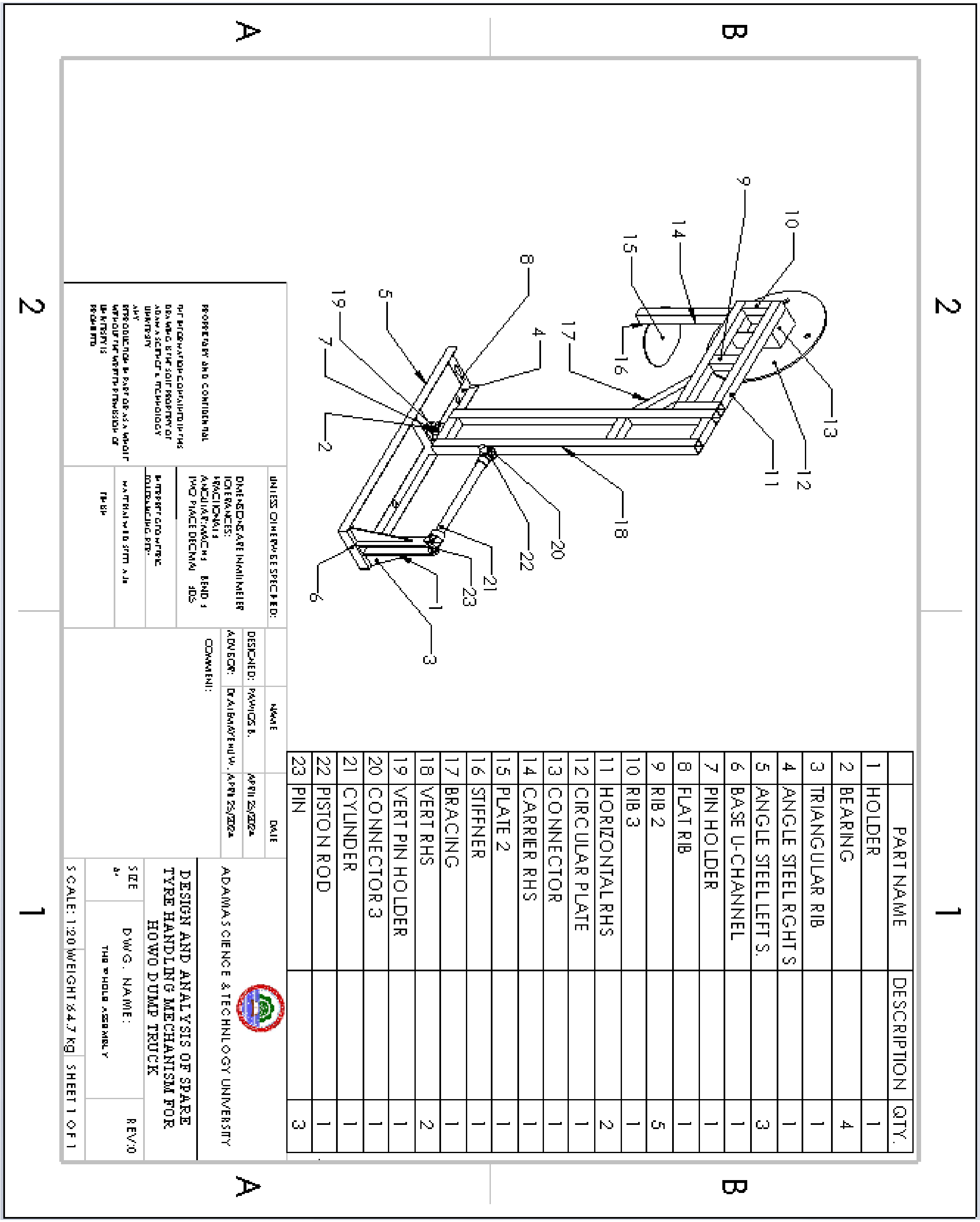
- Always ensure that the spare tyre is securely fastened to the mechanism before driving the vehicle

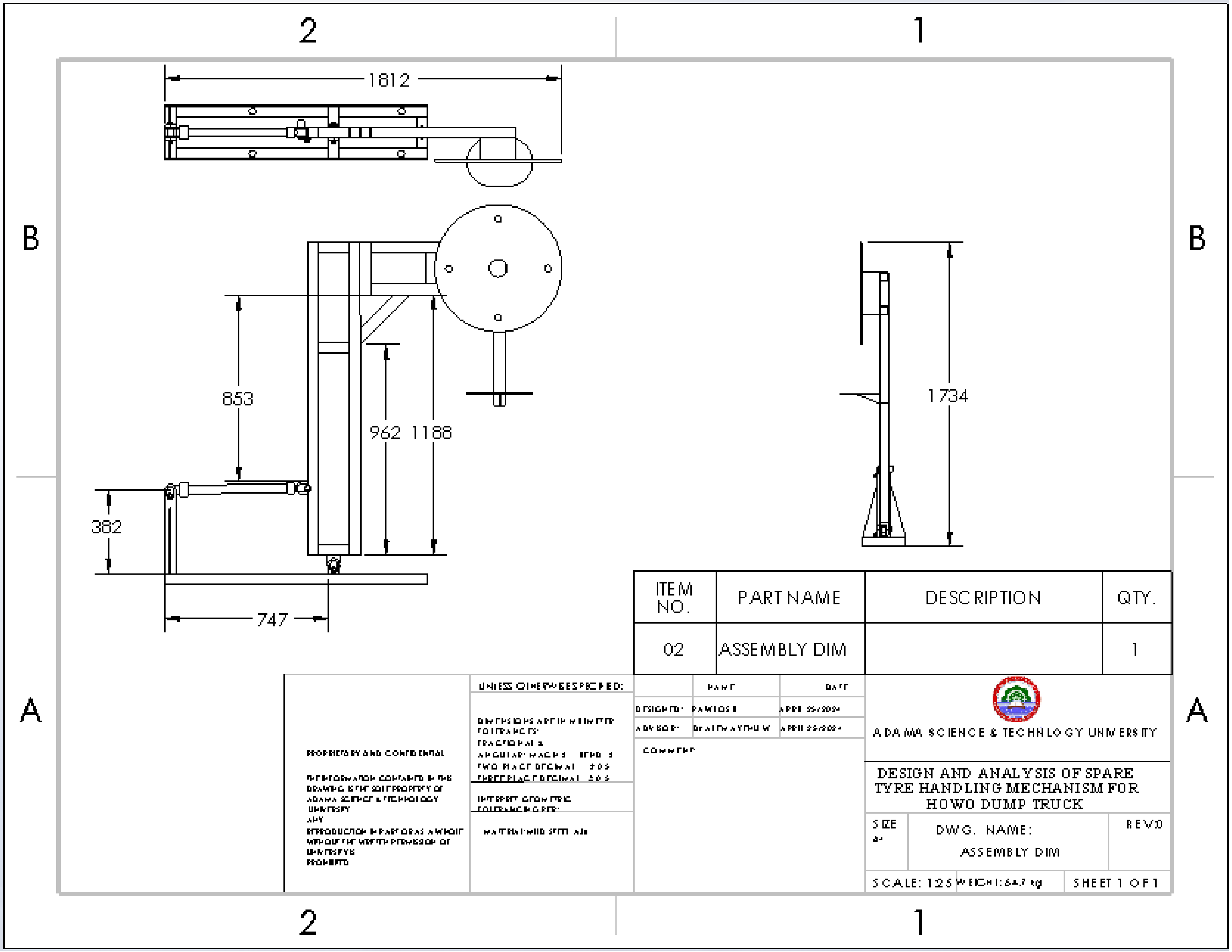
- Avoid any sudden movements or impacts that could cause the spare tyre to dislodge from the mechanism.

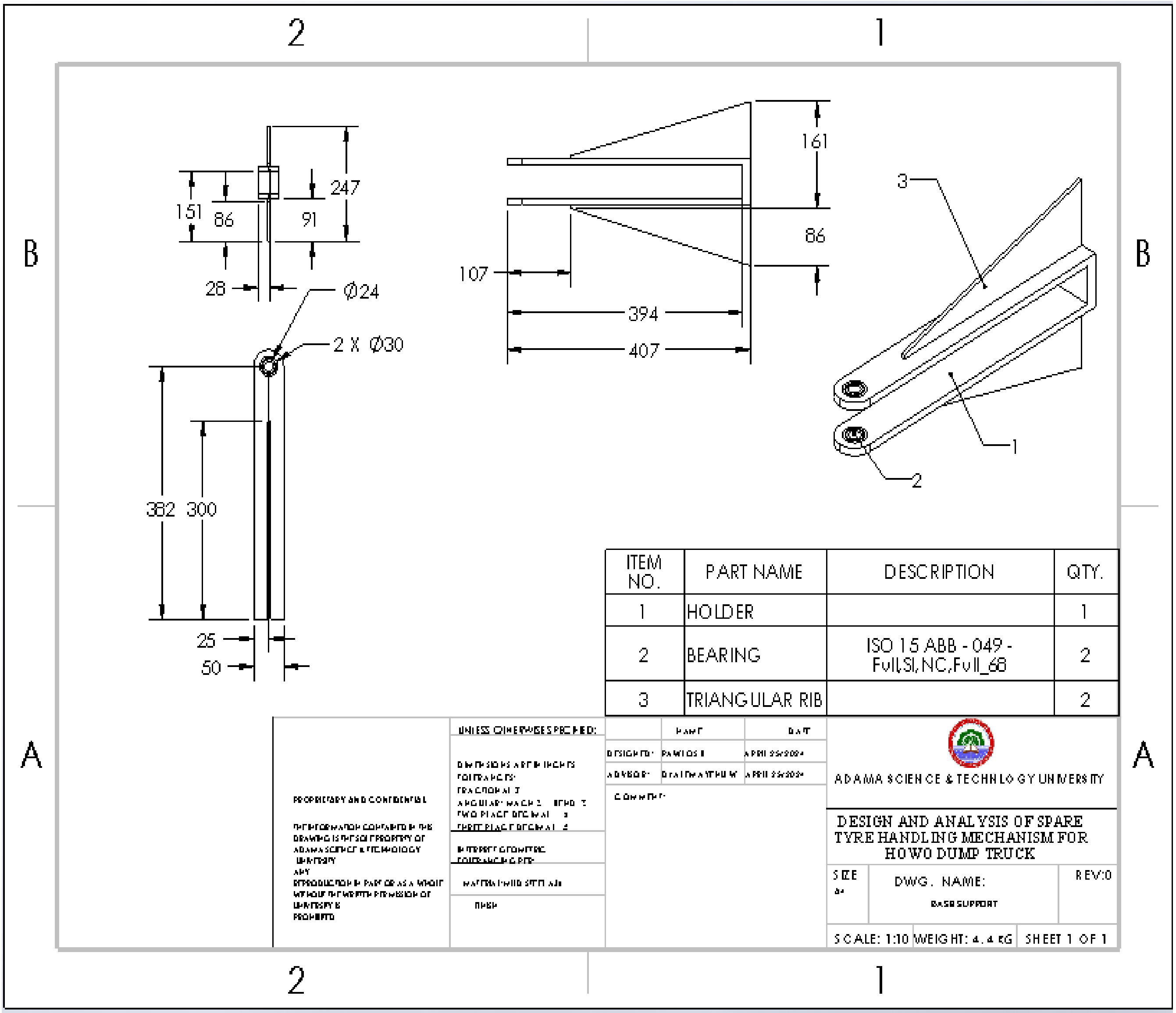
- When lowering the spare tyre, make sure the area is clear of any obstacles or obstructions.

- Keep the mechanism clean and free of debris to prevent any interference with its operation.

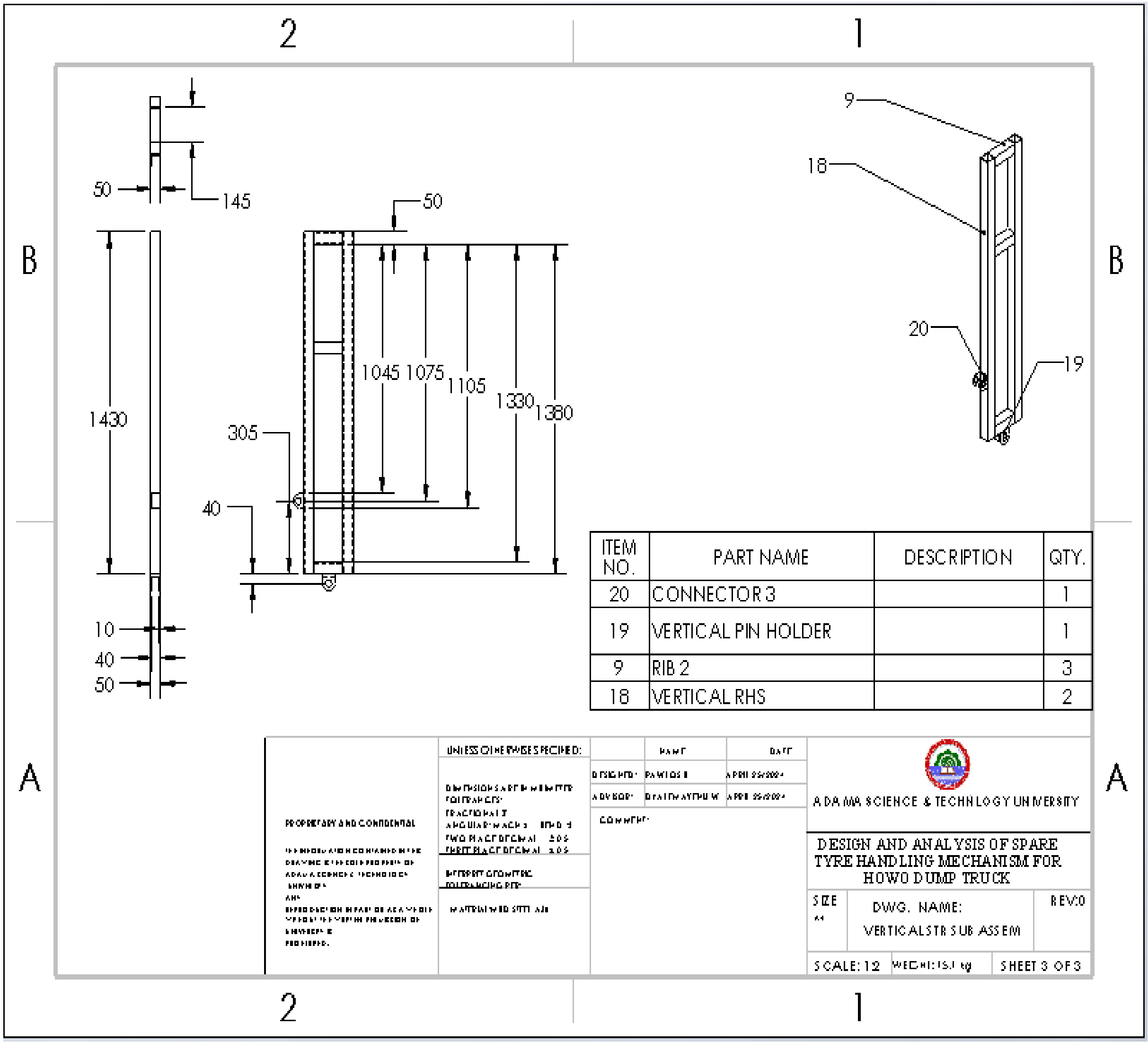
APPENDIX E: Production drawing



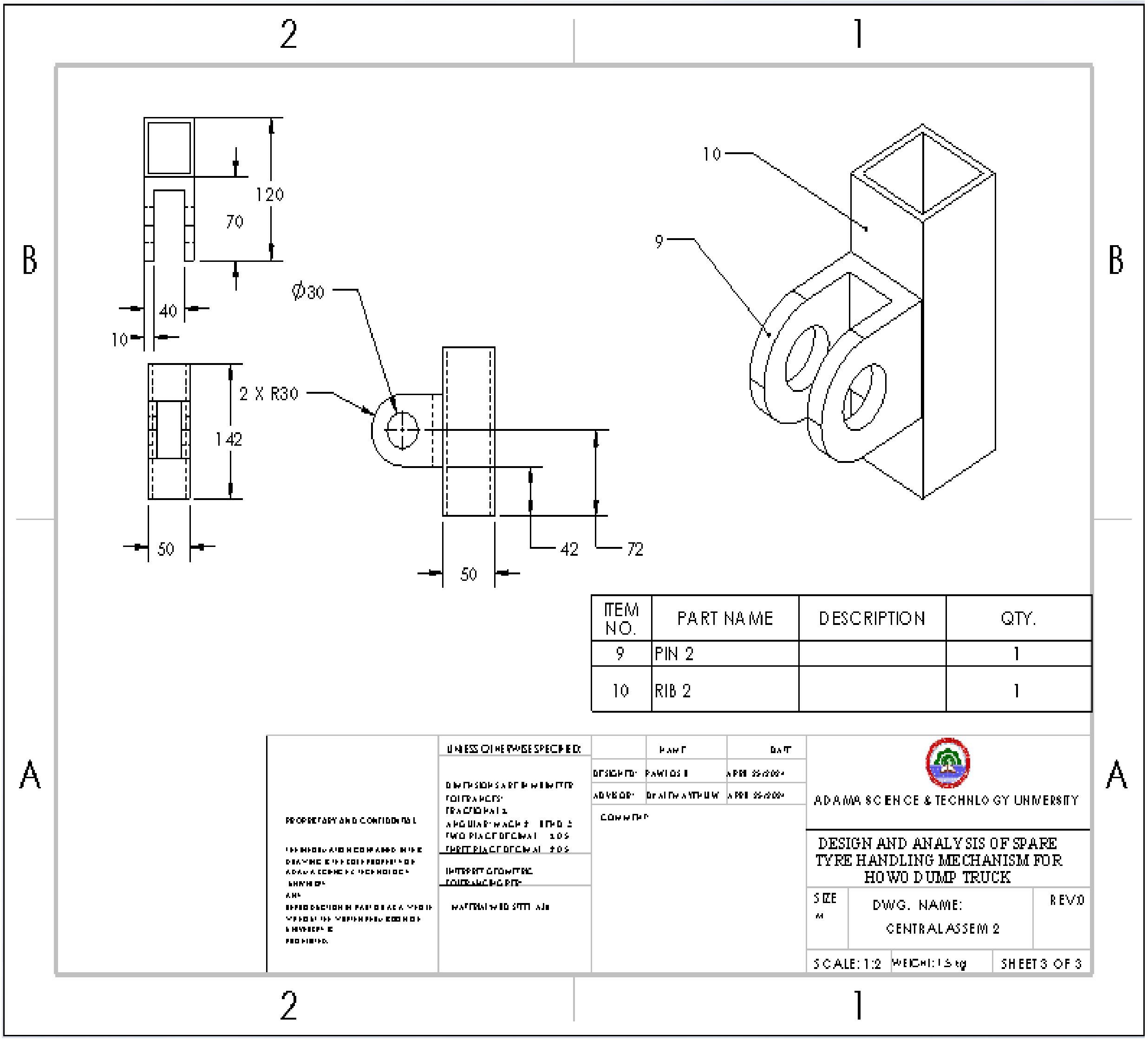

1812
853
962
1188
382
747
1734
ITEM NO.
PART NAME
DESCRIPTION
QTY.
02
ASSEMBLY DIM
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
ASSEMBLY DIM
REV0
SCALE: 1:25
SHEET 1 OF 1



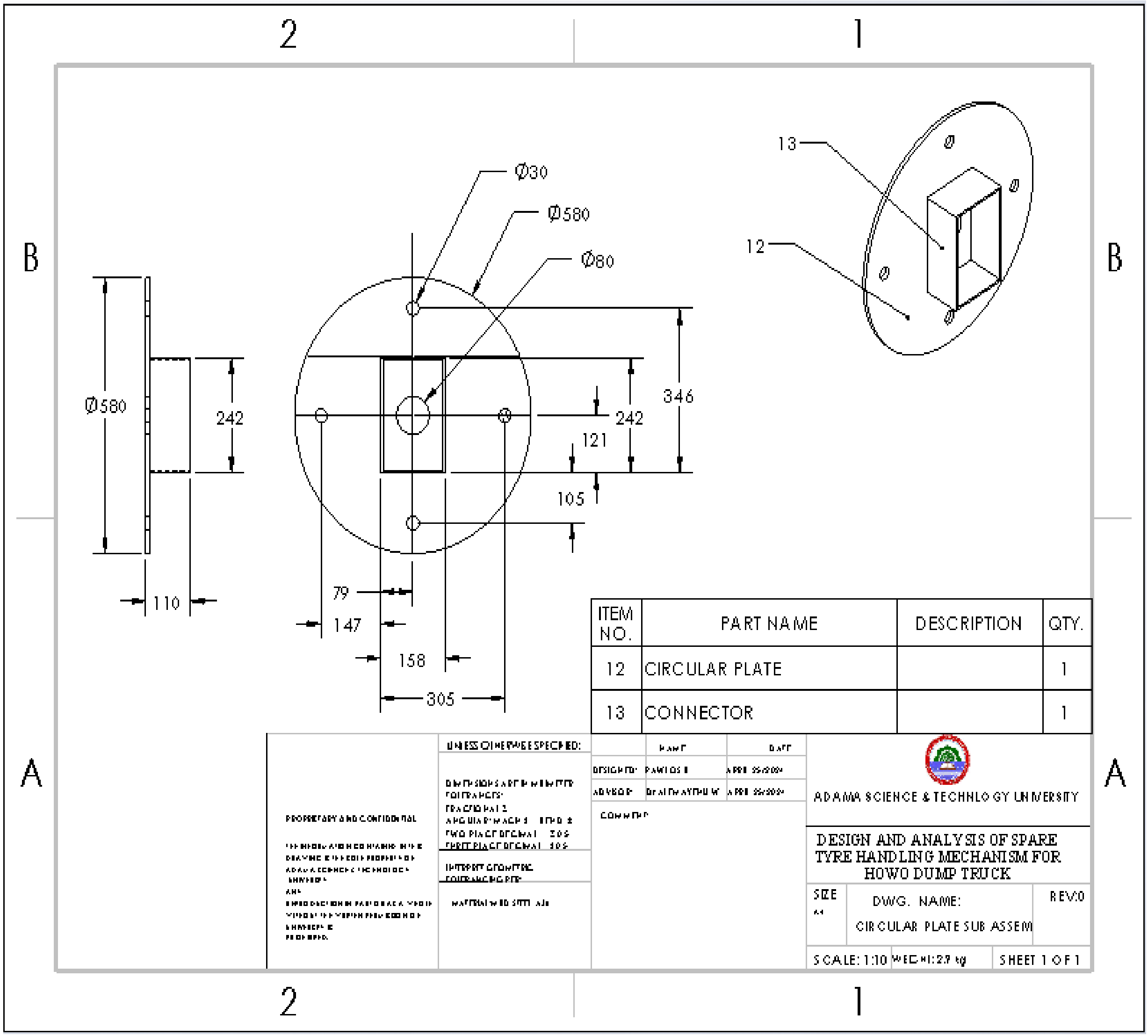
ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	HOLDER		1
2	BEARING	ISO 15 ABB - 049 - Full,SI,NC,Full_68	2
3	TRIANGULAR RIB		2



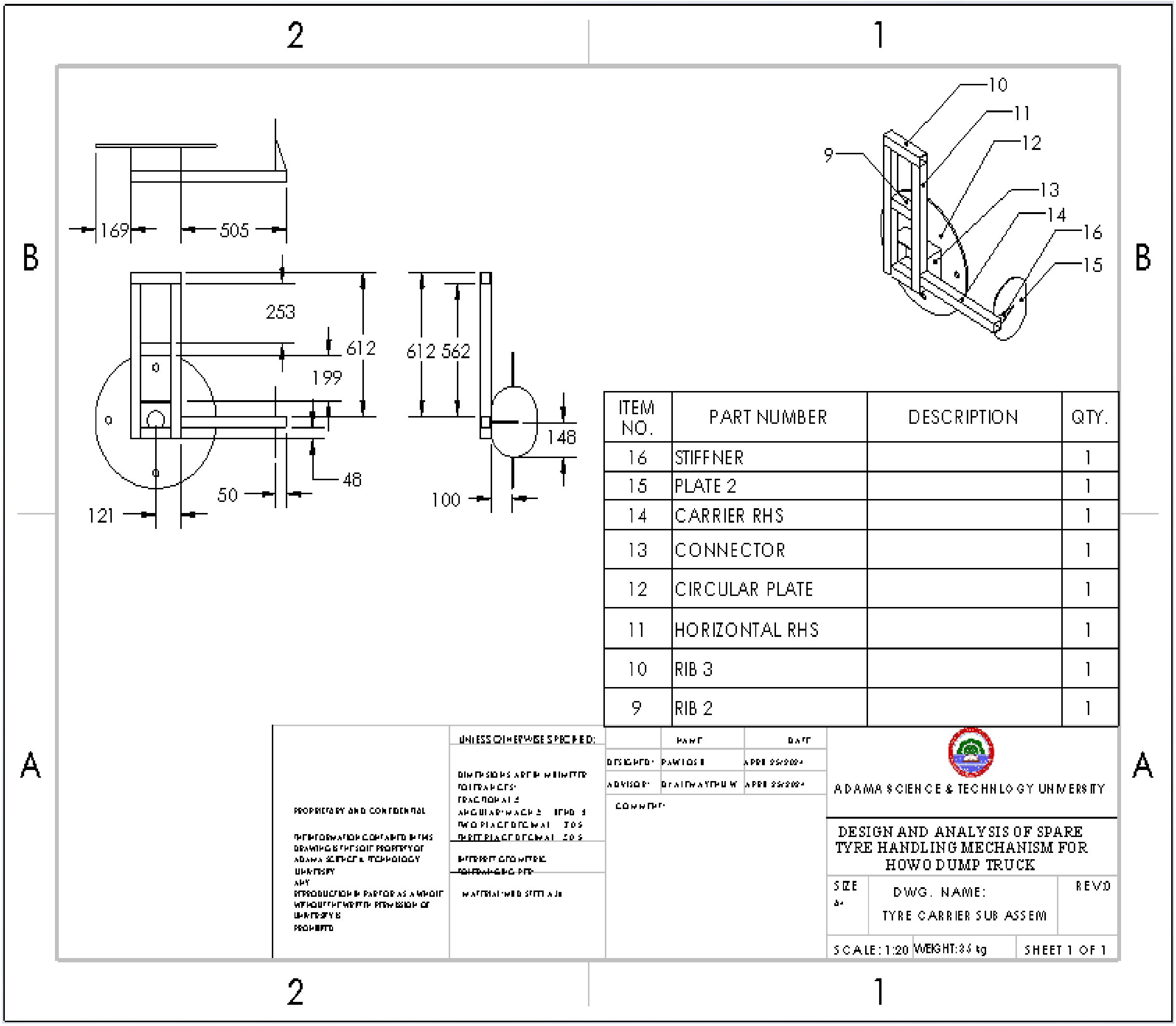
ITEM NO.	PART NAME	DESCRIPTION	QTY.
20	CONNECTOR 3		1
19	VERTICAL PIN HOLDER		1
9	RIB 2		3
18	VERTICAL RHS		2



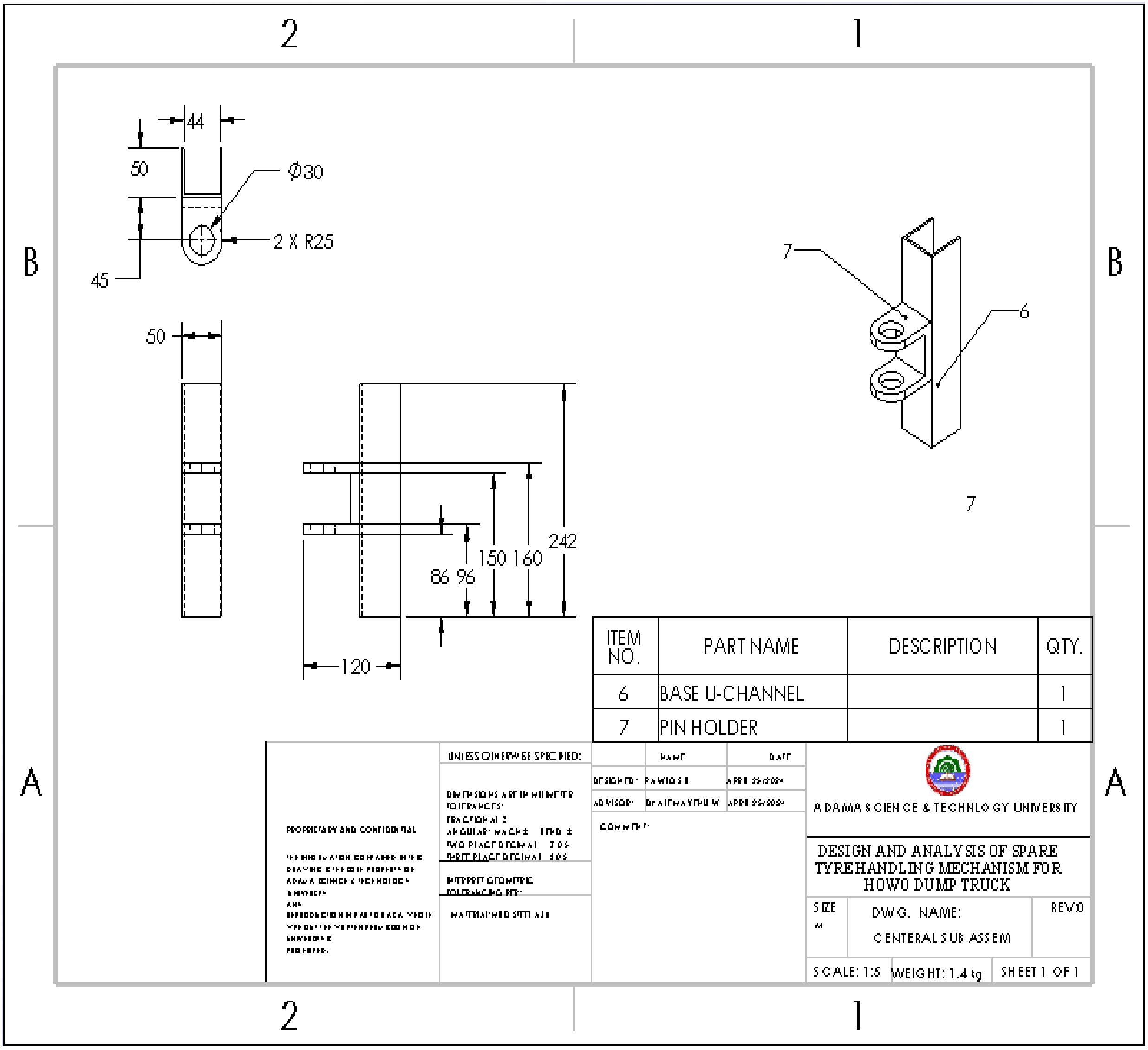
2
1
B
A
120
70
40
10
ϕ30
2 X R30
142
50
42
72
50
10
9
ITEM NO.
PART NAME
DESCRIPTION
QTY.
9
PIN 2
1
10
RIB 2
1
UNLESS OTHERWISE SPECIFIED:
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
CENTRAL ASSEM 2
REV 0
SCALE: 1:2
SHEET 3 OF 3



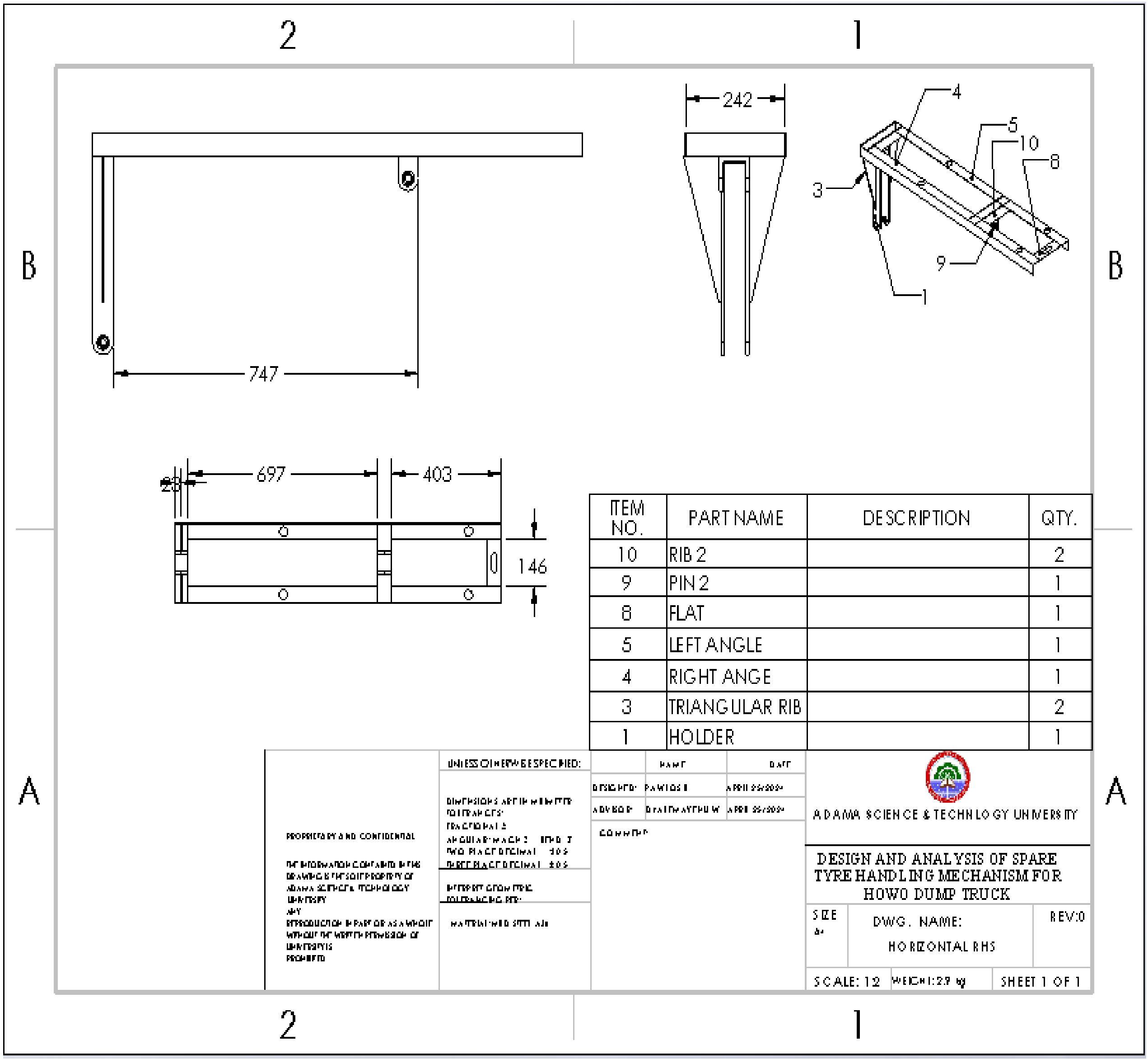
Ø30
Ø580
Ø80
Ø580
242
346
242
121
105
110
79
147
158
305
13
12
ITEM NO. | PART NAME | DESCRIPTION | QTY.
12 | CIRCULAR PLATE | | 1
13 | CONNECTOR | | 1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
CIRCULAR PLATE SUB ASSEM
REV.0
SCALE: 1:10
SHEET 1 OF 1

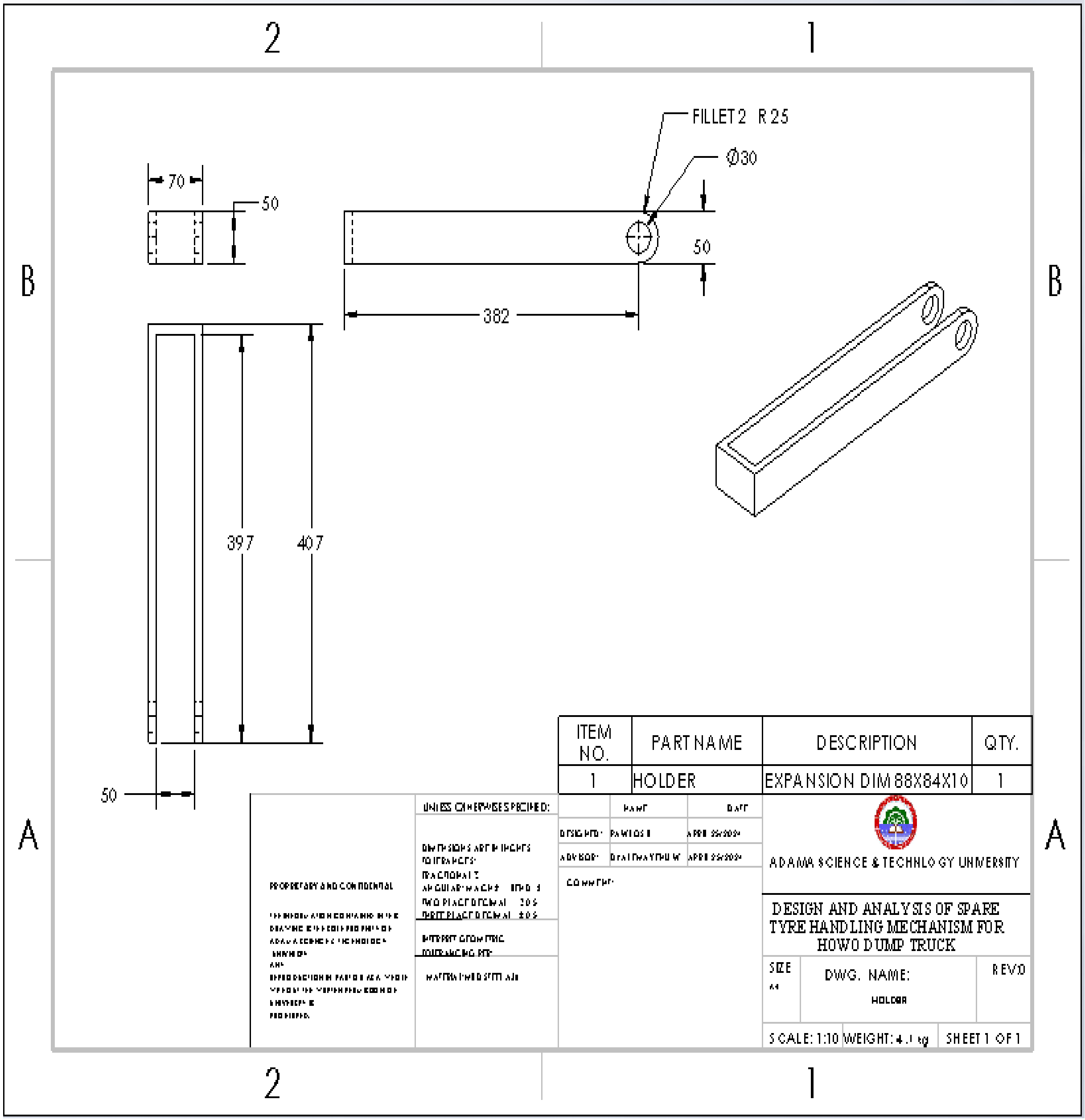


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
16	STIFFNER		1
15	PLATE 2		1
14	CARRIER RHS		1
13	CONNECTOR		1
12	CIRCULAR PLATE		1
11	HORIZONTAL RHS		1
10	RIB 3		1
9	RIB 2		1



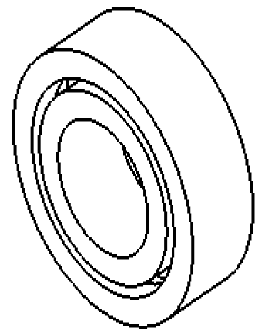
2
1
B
A
44
50
Ø30
2 X R25
45
50
7
6
242
150 160
86 96
120
7
ITEM NO.
PART NAME
DESCRIPTION
QTY.
6
BASE U-CHANNEL
1
7
PIN HOLDER
1
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DESIGNED
ADVISOR
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
CENTERAL SUB ASSEM
REV.0
SCALE: 1:5
WEIGHT: 1.4 kg
SHEET 1 OF 1


2
1
B
A
242
4
5
10
8
3
9
1
747
697
403
28
146
ITEM NO.
PART NAME
DESCRIPTION
QTY.
10 RIB 2 2
9 PIN 2 1
8 FLAT 1
5 LEFT ANGLE 1
4 RIGHT ANGE 1
3 TRIANGULAR RIB 2
1 HOLDER 1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
HORIZONTAL RHS
REV:0
SHEET 1 OF 1



2
1
B
A
FILLET2 R25
Ø30
70
50
50
382
397
407
50
ITEM NO.
PART NAME
DESCRIPTION
QTY.
1
HOLDER
EXPANSION DIM 88X84X10
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
HOLDER
REV.0
SCALE: 1:10
SHEET 1 OF 1

SKF BEARING
OD 47
ID 25
WIDTH (B) 12
BASIC LOAD RATINGS 6.55 kN



ITEM NO.	PART NAME	DESCRIPTION	QTY.
2	SKF BEARING	6005-2Z/VA201	4

PROPRIETARY AND CONFIDENTIAL

UNLESS OTHERWISE SPECIFIED:

	NAME	DATE
DESIGNED		
ADVISOR		

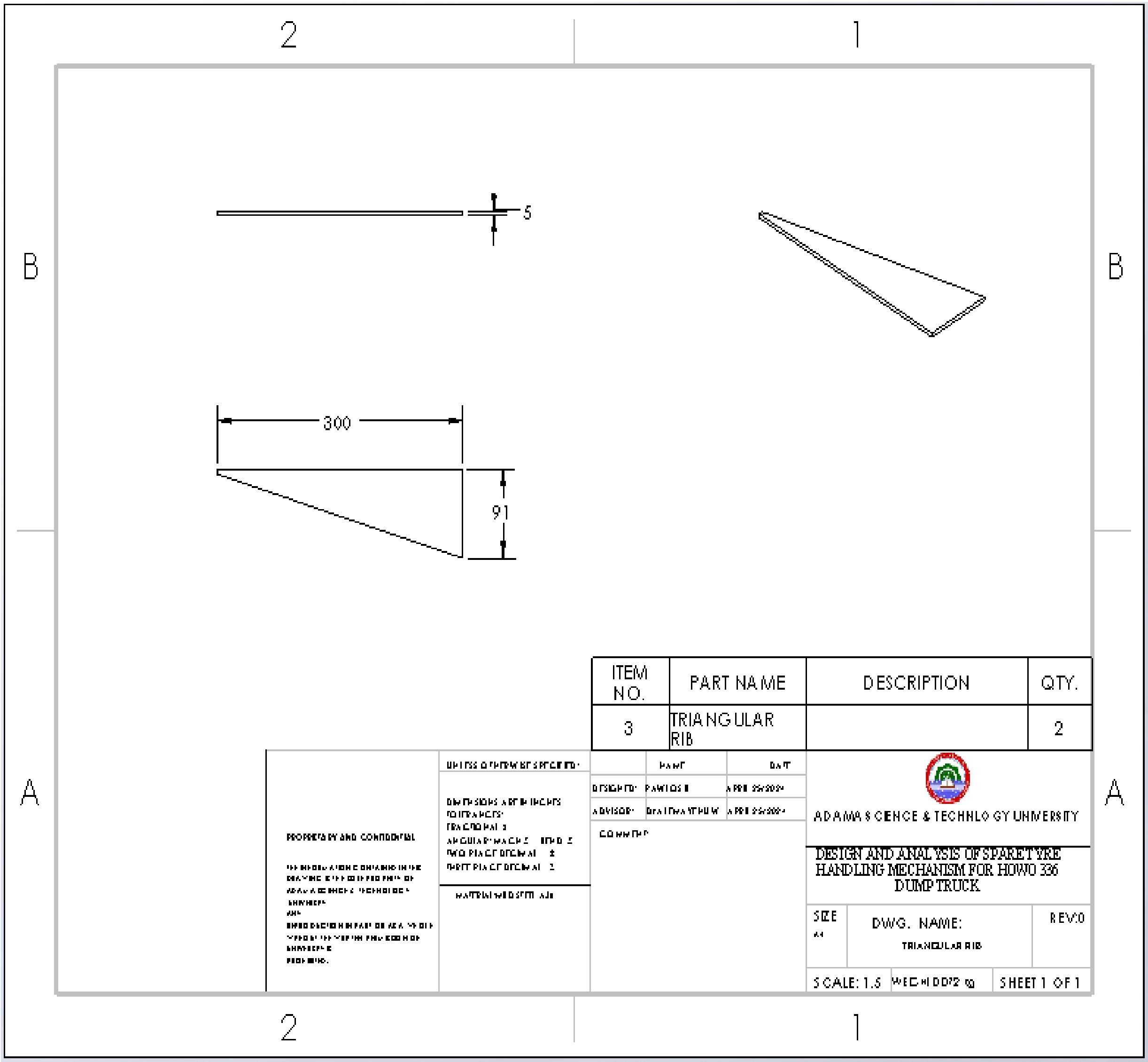
COMMENTS:

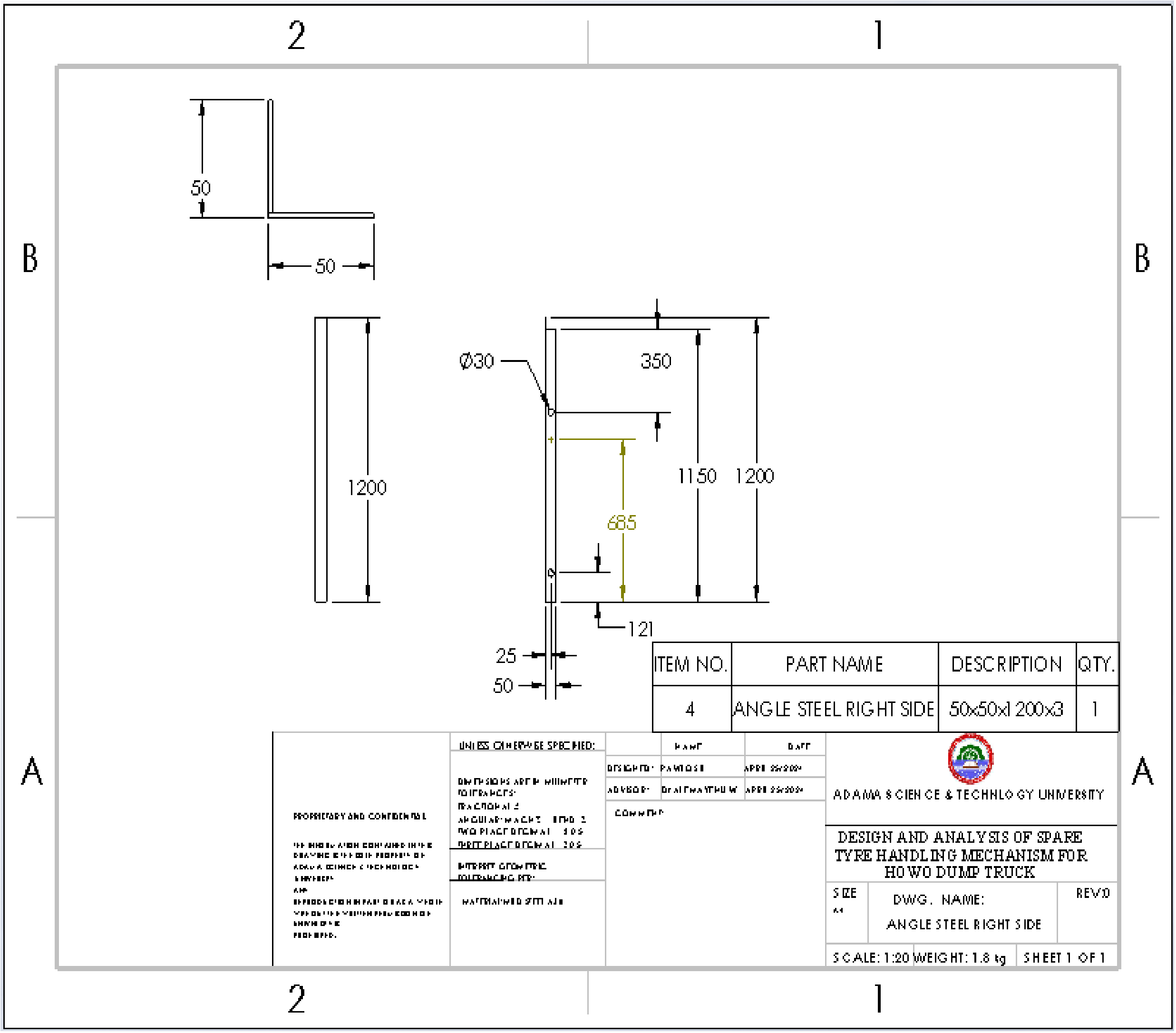
ADAMA SCIENCE & TECHNLOGY UNIVERSITY

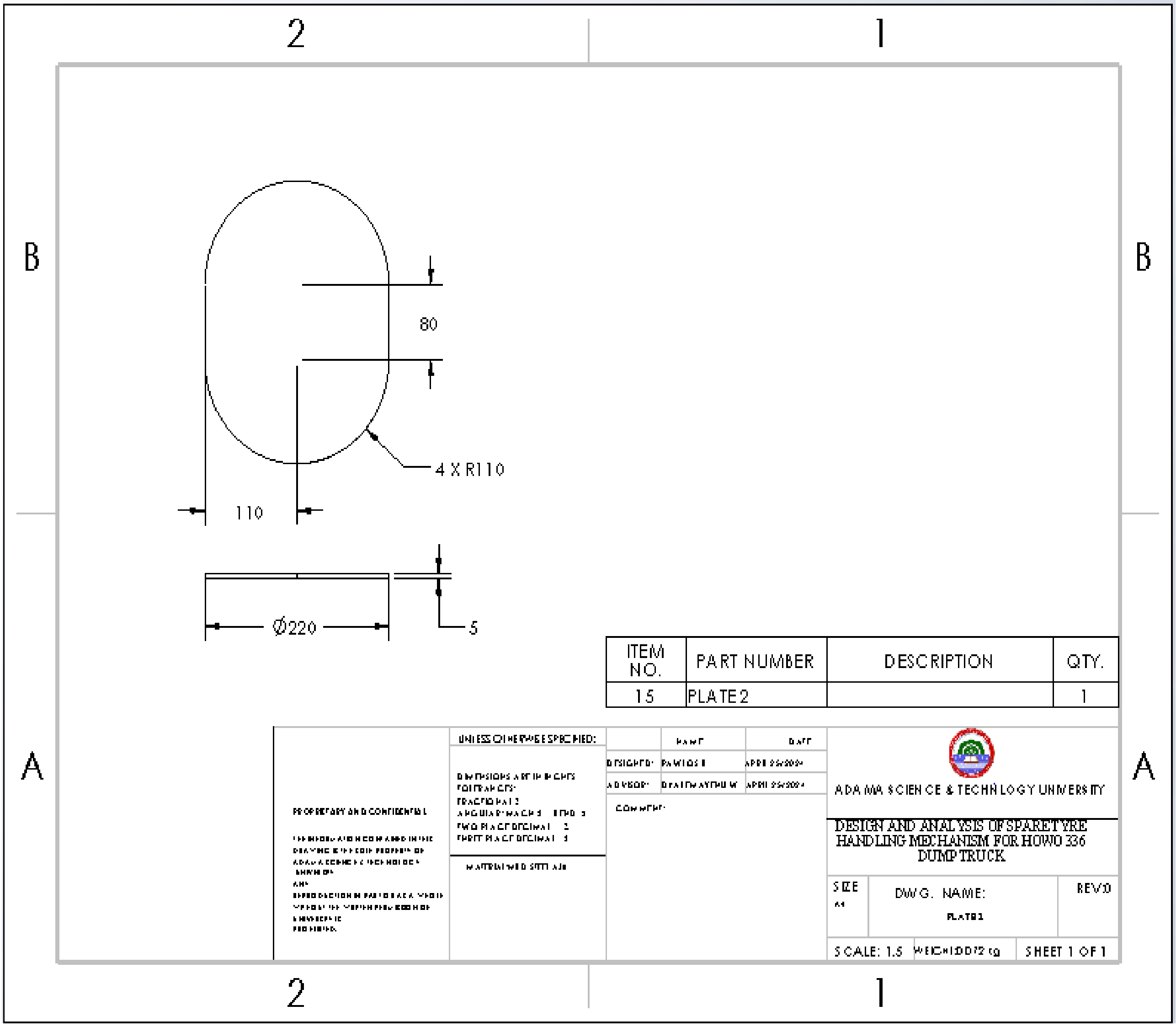
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO 336 DUMP TRUCK

SIZE | DWG. NAME: BEARING | REV:0

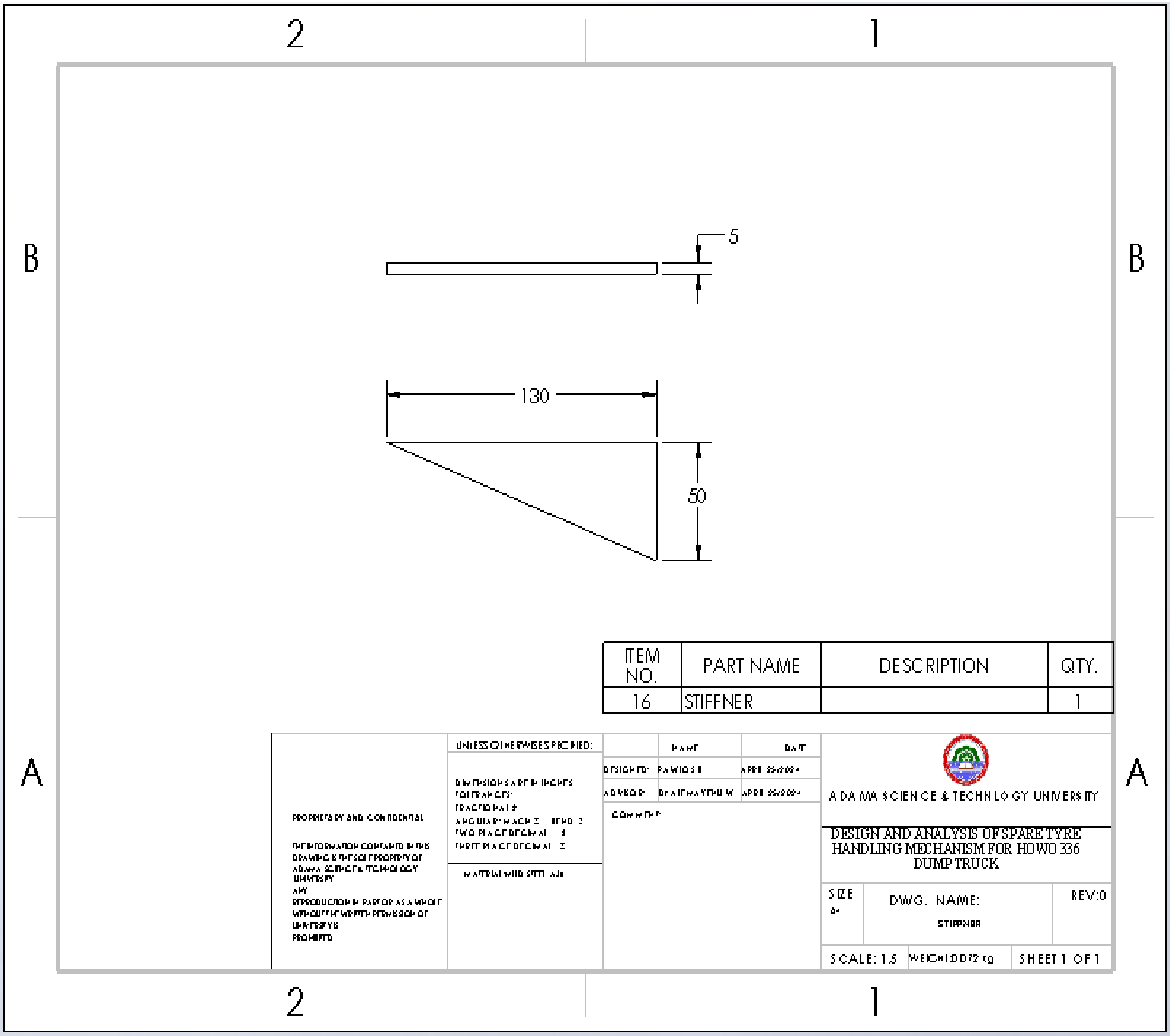
SCALE: 1:5 | SHEET 1 OF 1

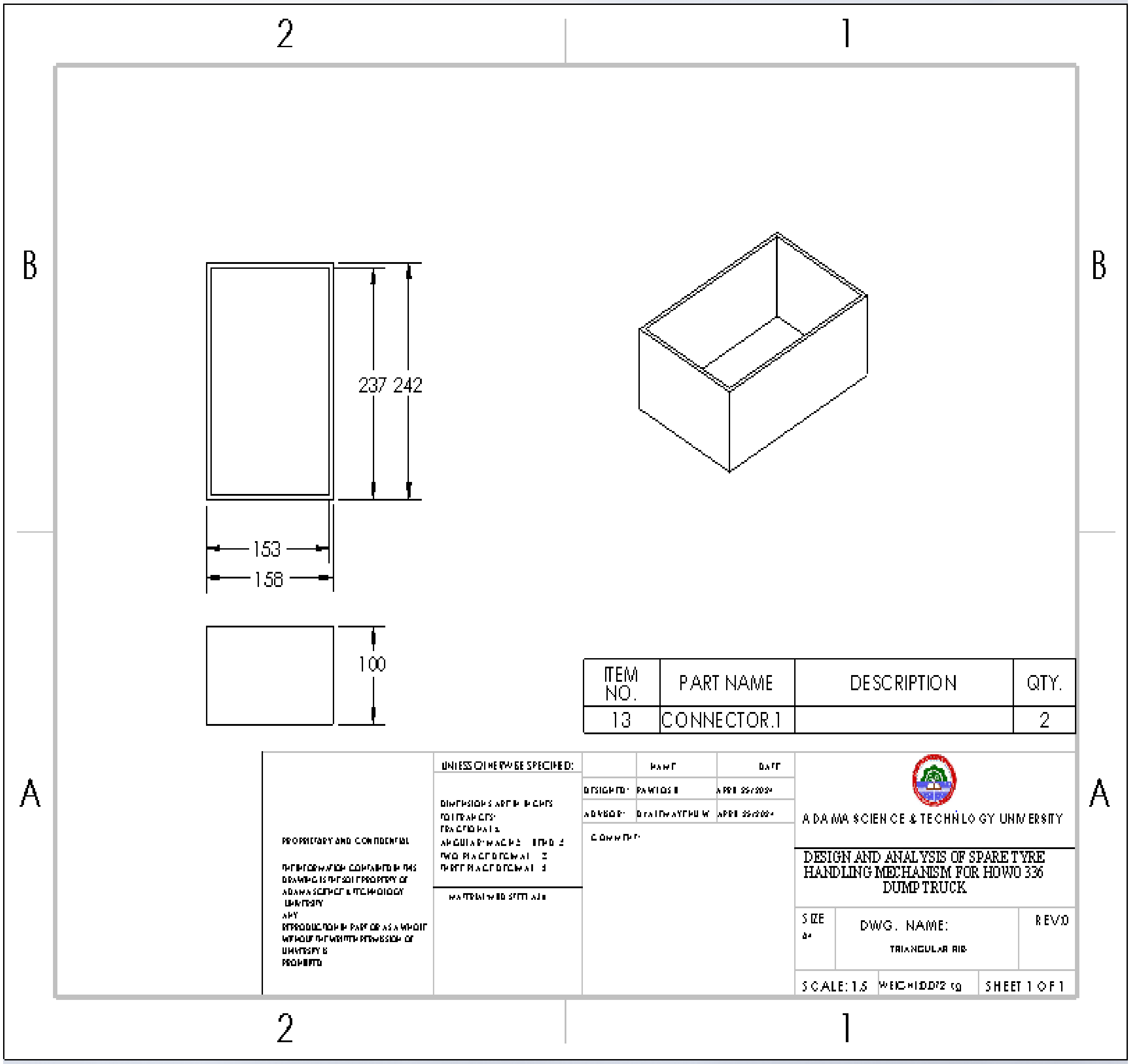

2
1
B
A
5
300
91
ITEM NO.
PART NAME
DESCRIPTION
QTY.
3
TRIANGULAR RIB
2
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARET YRE HANDLING MECHANISM FOR HOWO 336 DUMP TRUCK
SIZE
DWG. NAME:
TRIANGULAR RIB
REV:0
SCALE: 1:5
SHEET 1 OF 1

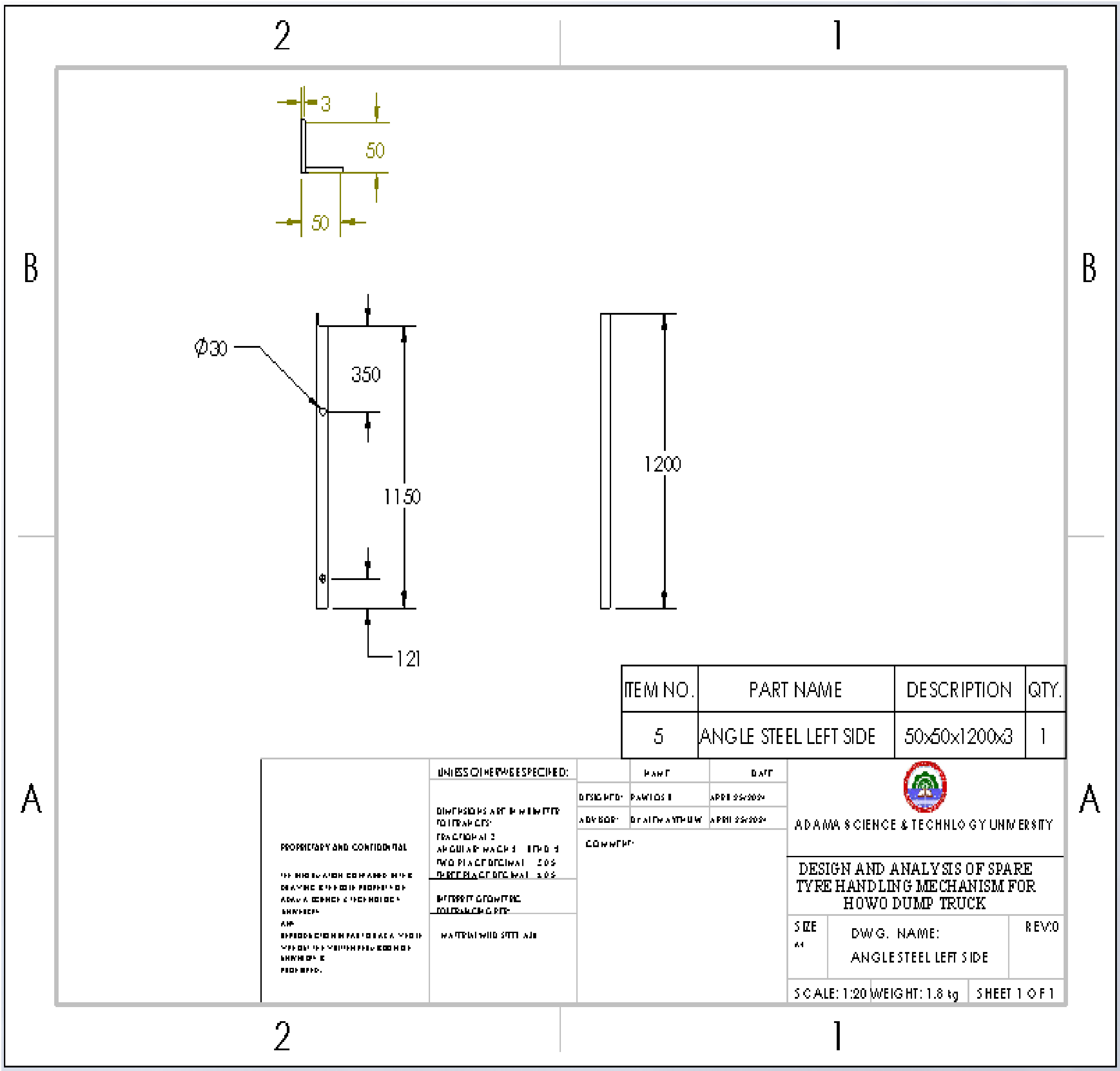

50
50
1200
Ø30
350
1150
1200
685
121
25
50
ITEM NO.
PART NAME
DESCRIPTION
QTY.
4
ANGLE STEEL RIGHT SIDE
50x50x1200x3
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
ANGLE STEEL RIGHT SIDE
REV.0
SCALE: 1:20
WEIGHT: 1.8 kg
SHEET 1 OF 1



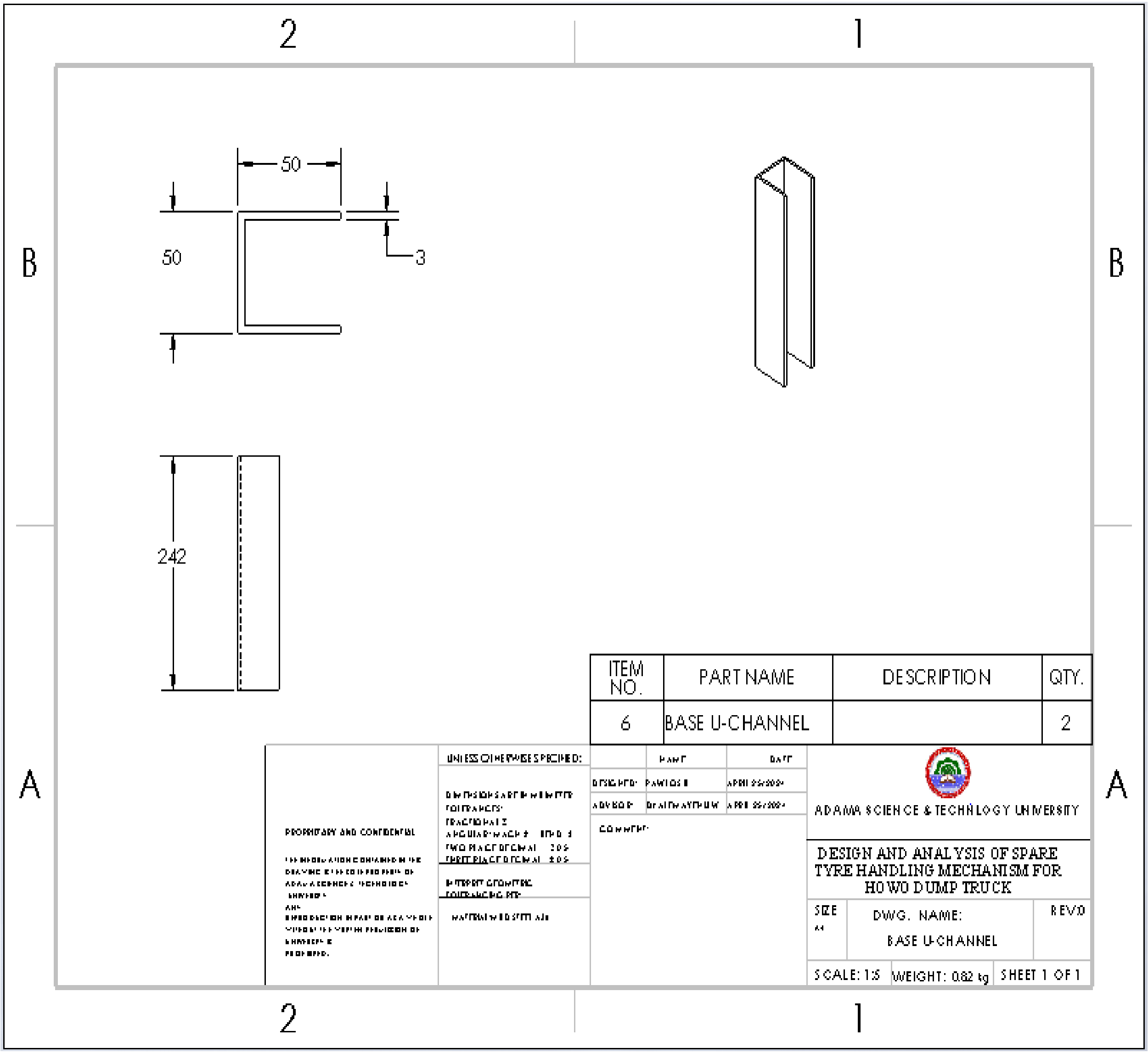
80
4 X R110
110
Ø220
5
ITEM NO.
PART NUMBER
DESCRIPTION
QTY.
15
PLATE 2
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO 336 DUMP TRUCK
SIZE
DWG. NAME:
REV.0
SHEET 1 OF 1

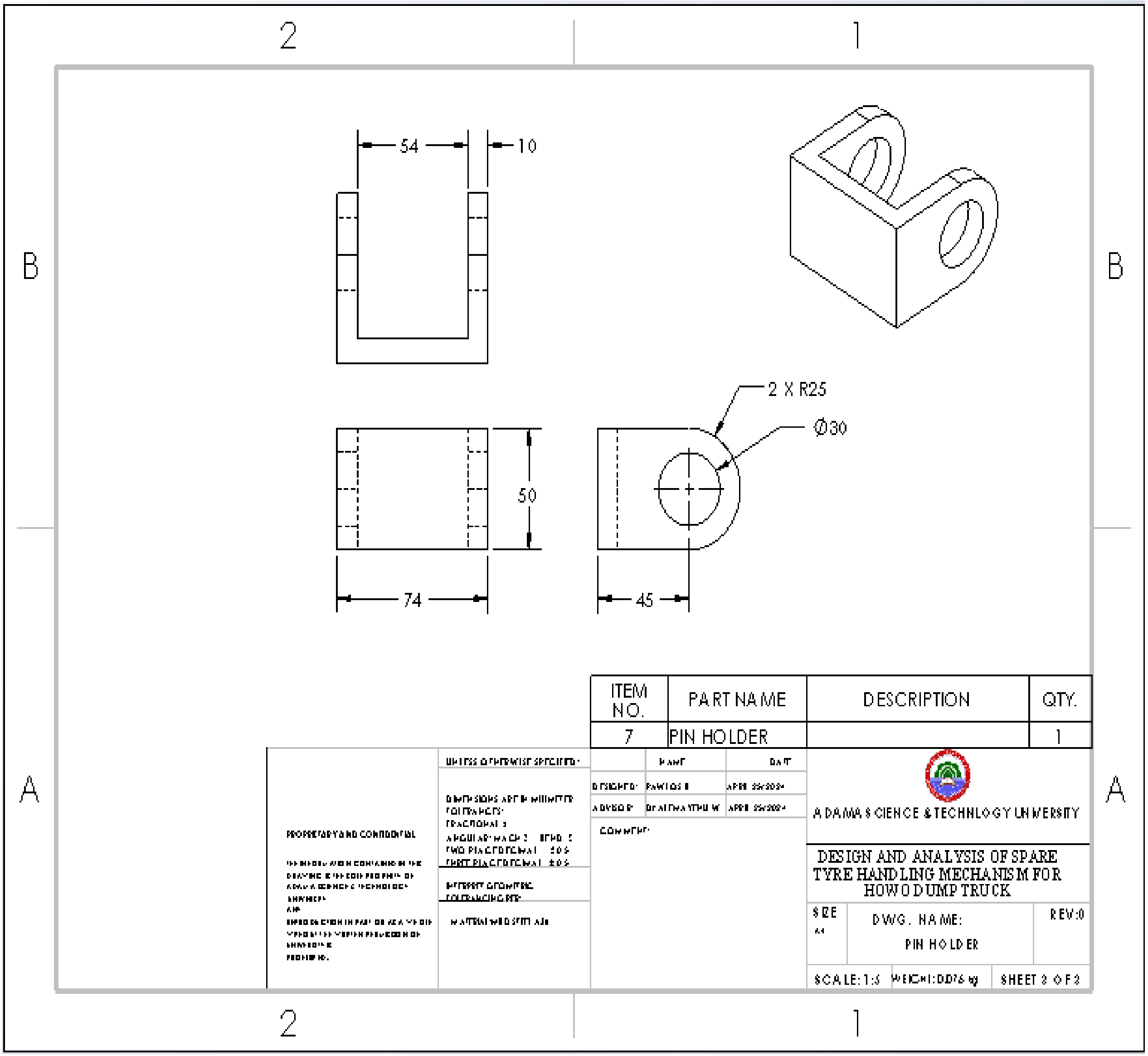

2
1
B
A
5
130
50
ITEM NO.
PART NAME
DESCRIPTION
QTY.
16
STIFFNER
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO 336 DUMP TRUCK
SIZE
DWG. NAME:
STIFFNER
REV:0
SCALE: 1:5
SHEET 1 OF 1

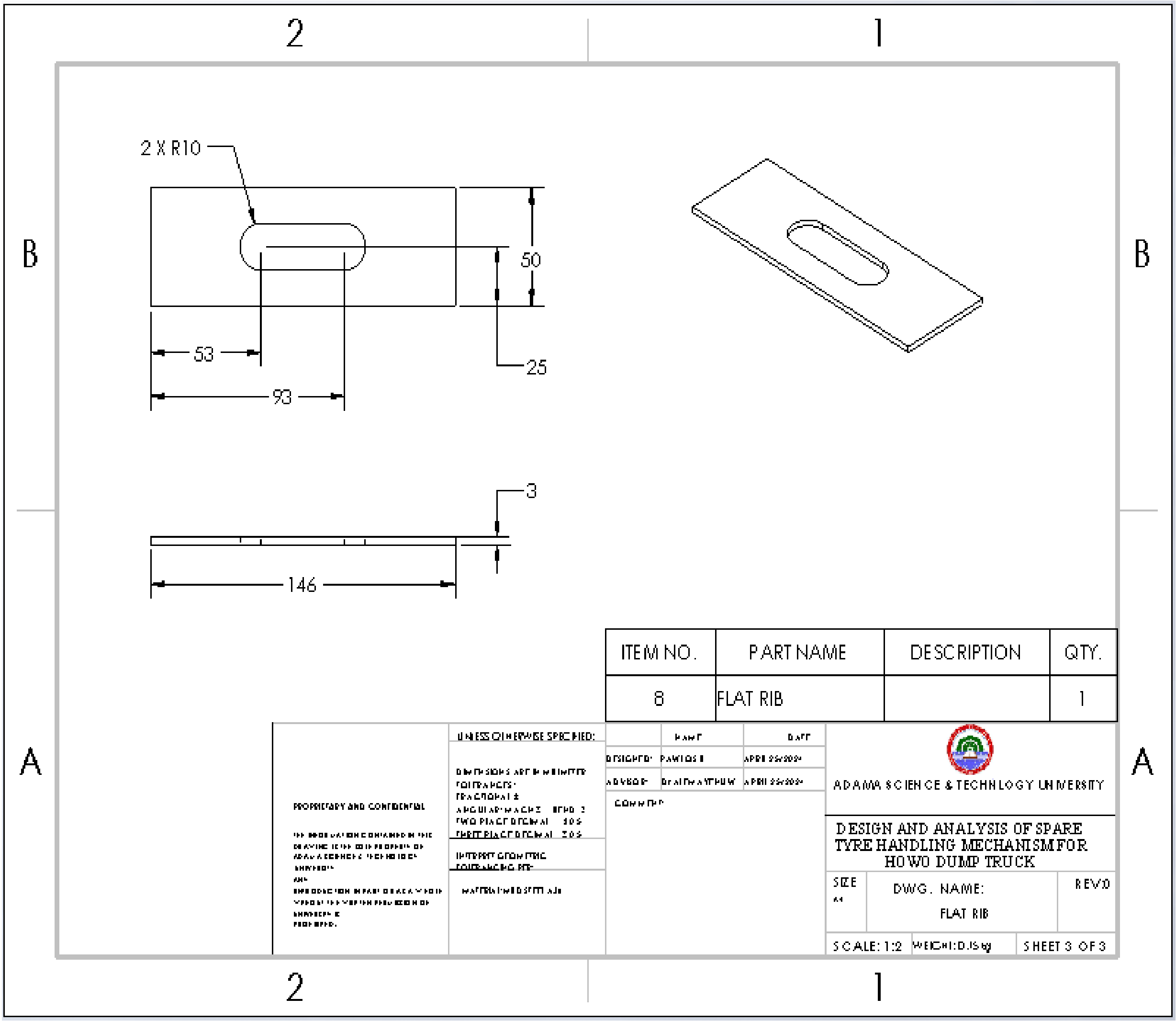

2
1
B
A
237
242
153
158
100
ITEM NO.
PART NAME
DESCRIPTION
QTY.
13
CONNECTOR.1
2
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO 336 DUMP TRUCK
SIZE
DWG. NAME:
TRIANGULAR RIB
REV
SCALE: 1:5
SHEET 1 OF 1

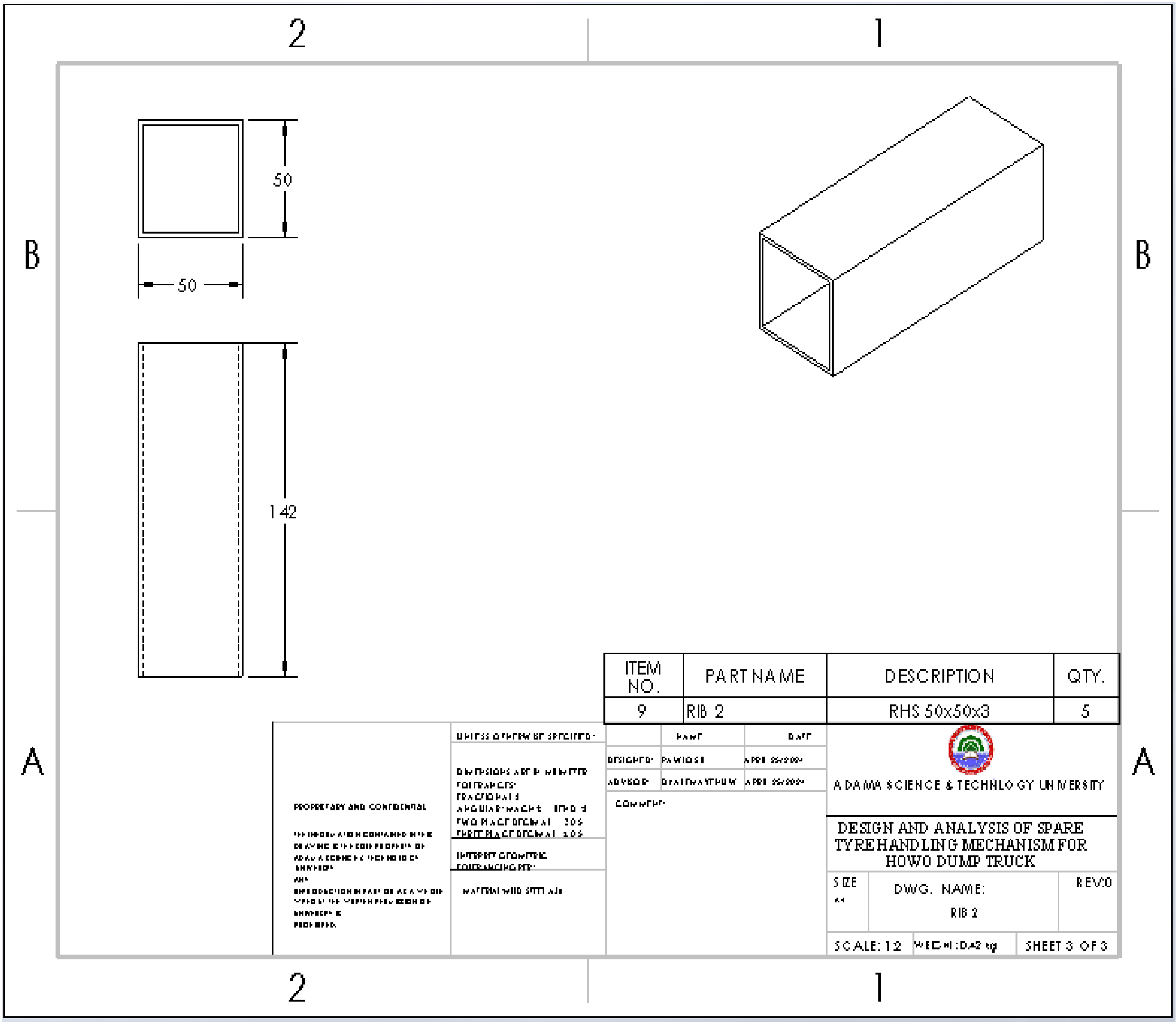


2
1
B
A
3
50
50
Ø30
350
1150
121
1200
ITEM NO.
PART NAME
DESCRIPTION
QTY.
5
ANGLE STEEL LEFT SIDE
50x50x1200x3
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
COMMENTS:
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
ANGLE STEEL LEFT SIDE
REV.0
SCALE: 1:20
WEIGHT: 1.8 kg
SHEET 1 OF 1

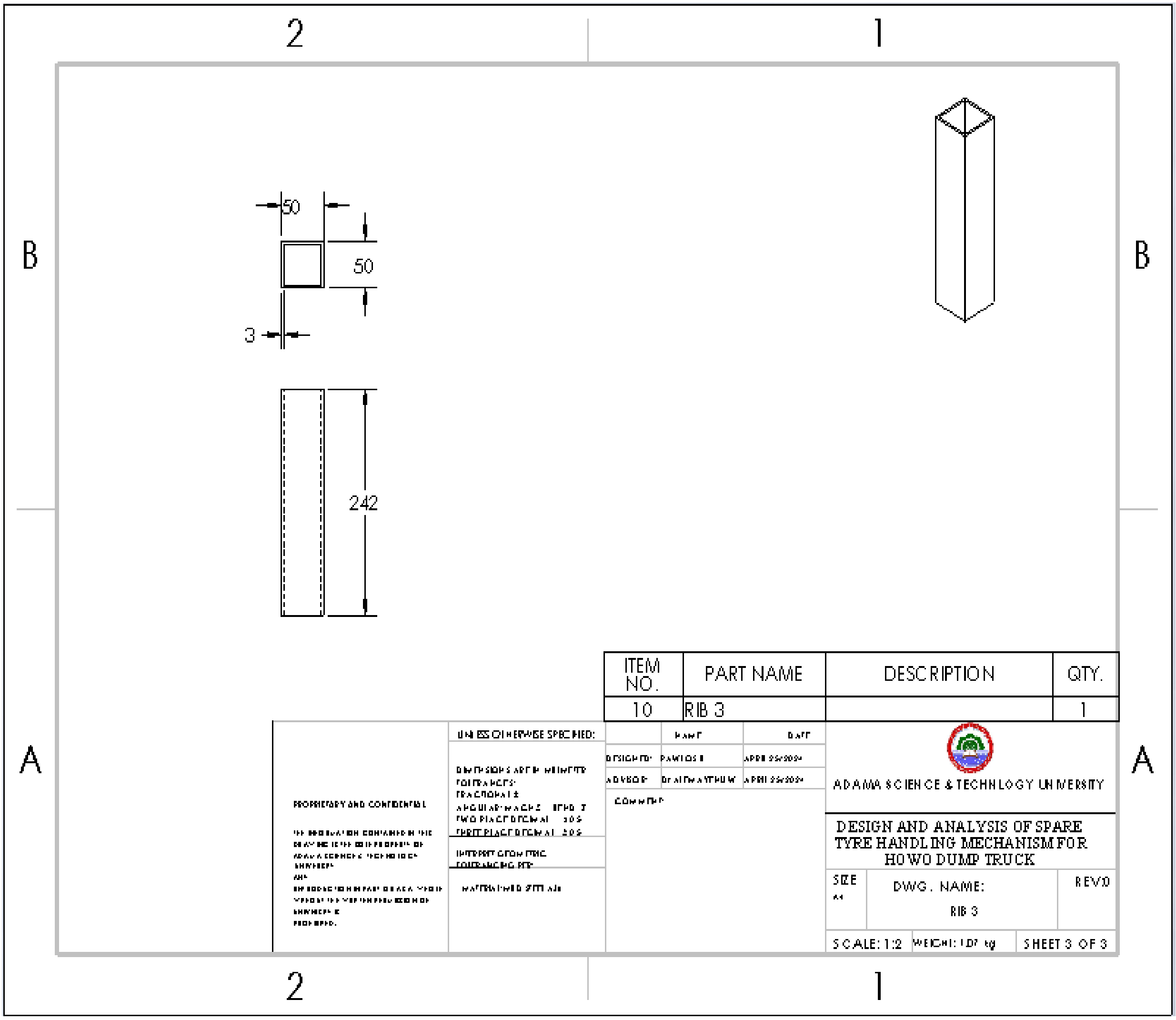

2
1
B
A
50
50
3
242
ITEM NO.
PART NAME
DESCRIPTION
QTY.
6
BASE U-CHANNEL
2
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
COMMENTS:
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
BASE U-CHANNEL
REV.
SCALE: 1:5
WEIGHT: 0.82 kg
SHEET 1 OF 1

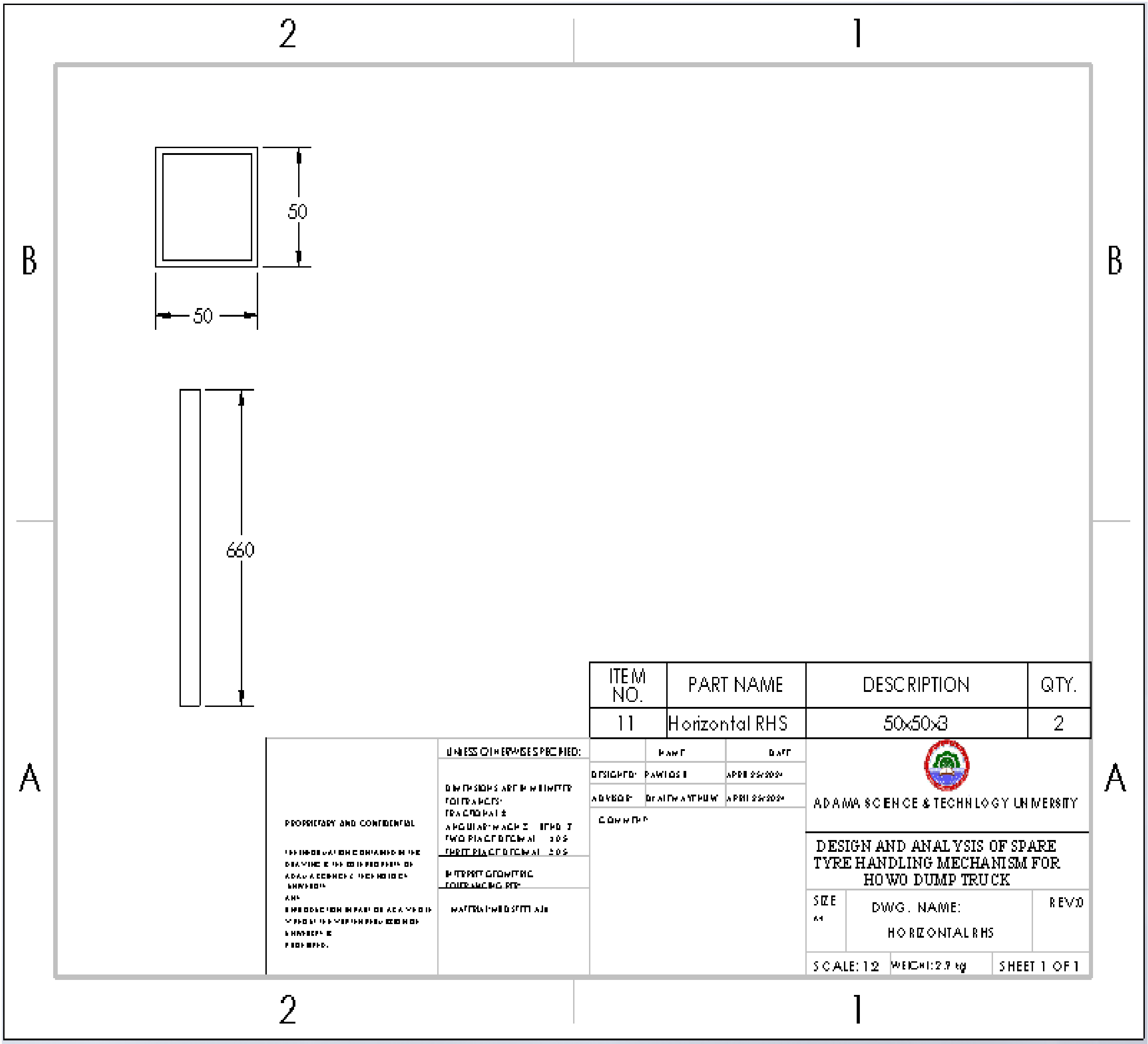

54
10
2 X R25
Ø30
50
74
45
ITEM NO.
PART NAME
DESCRIPTION
QTY.
7
PIN HOLDER
1
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
PIN HOLDER
REV:0
SCALE: 1:5
SHEET 3 OF 3
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
COMMENTS:

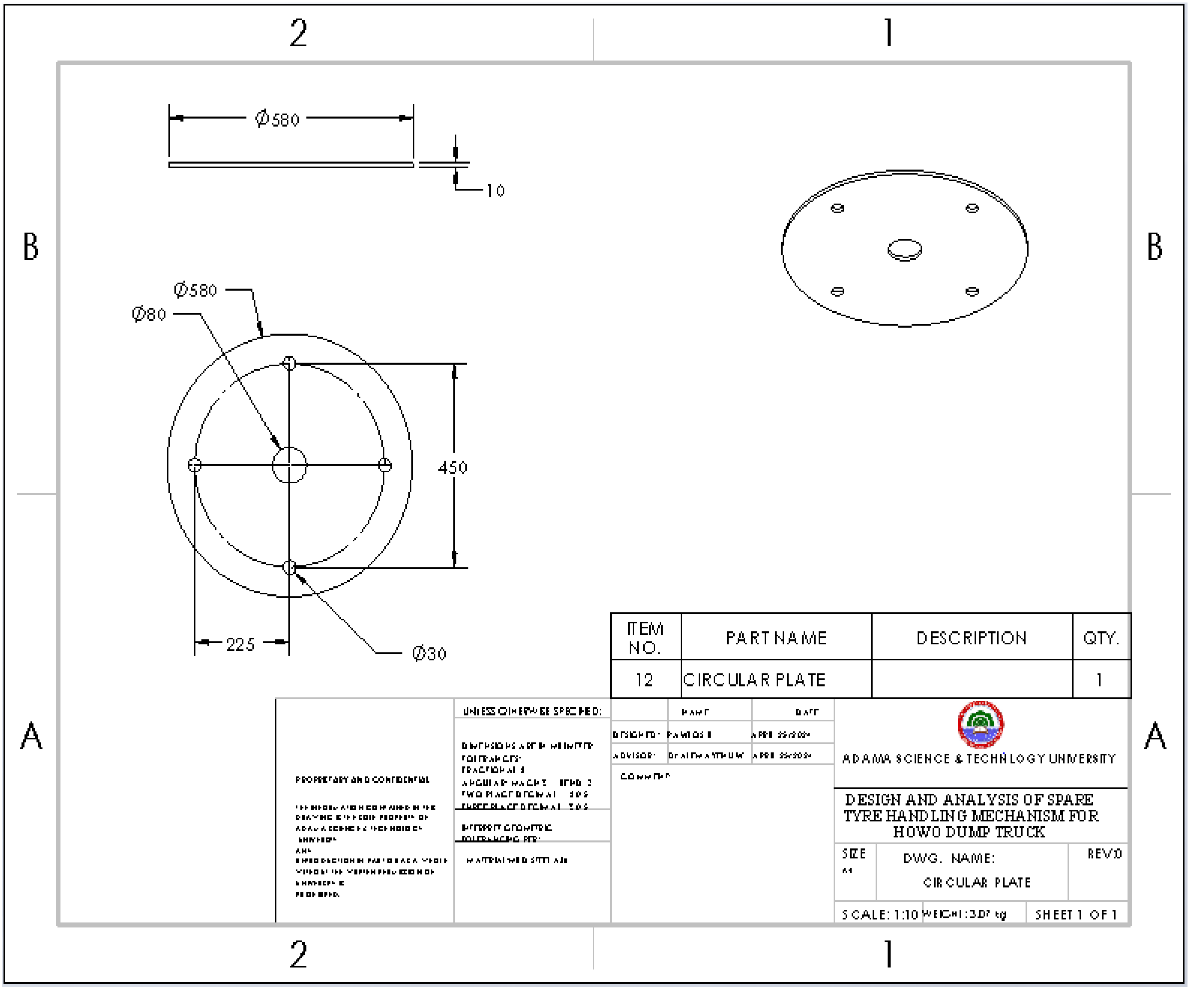

2 X R10
50
25
53
93
3
146
ITEM NO.
PART NAME
DESCRIPTION
QTY.
8
FLAT RIB
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
FLAT RIB
REV.0
SCALE: 1:2
SHEET 3 OF 3



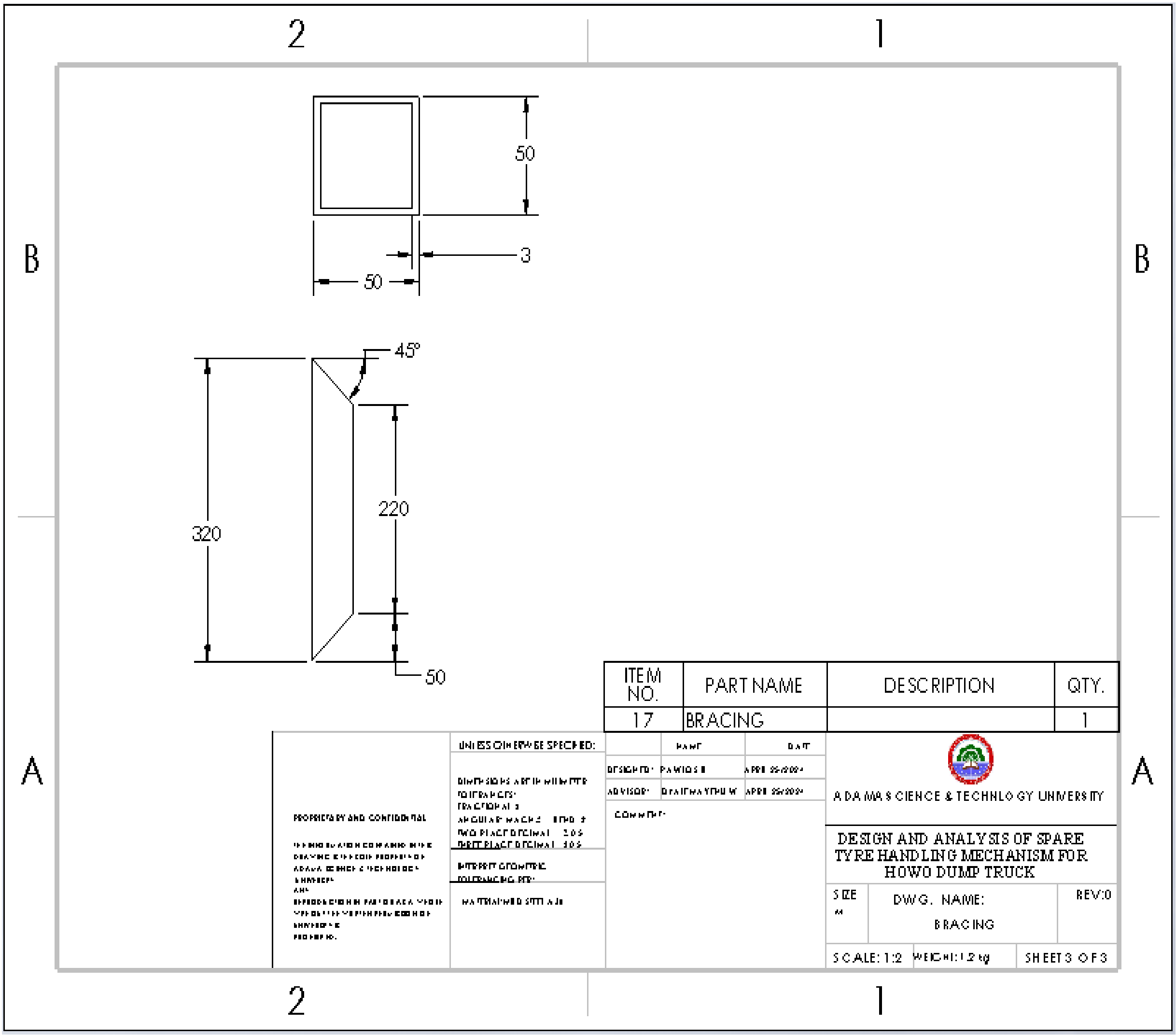
2
1
B
A
50
50
142
ITEM NO.
PART NAME
DESCRIPTION
QTY.
9
RIB 2
RHS 50x50x3
5
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
RIB 2
REV:0
SCALE: 1:2
SHEET 3 OF 3

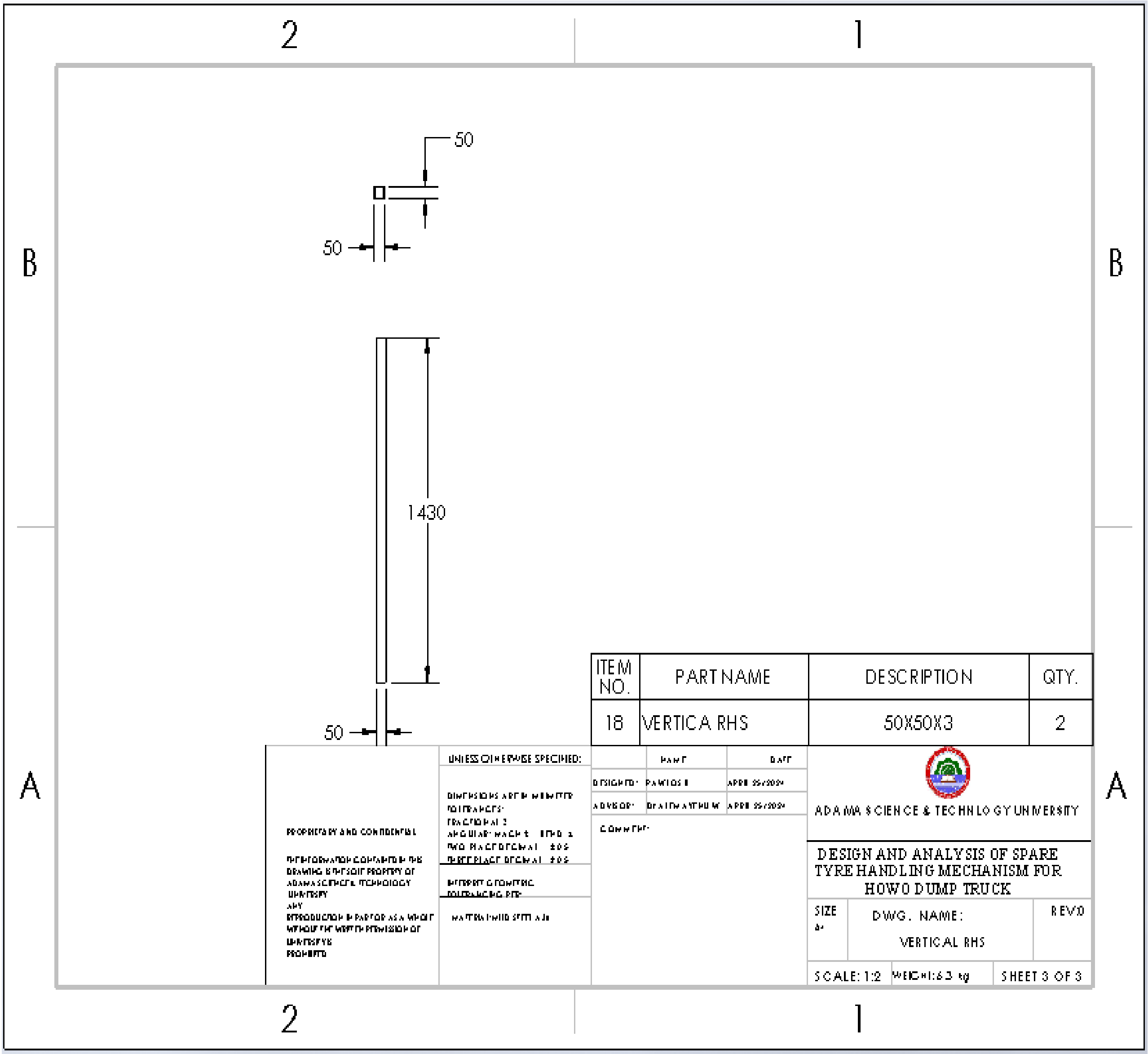

50
50
3
242
ITEM NO.
PART NAME
DESCRIPTION
QTY.
10
RIB 3
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
RIB 3
REV.0
SCALE: 1:2
SHEET 3 OF 3
2
1
B
A

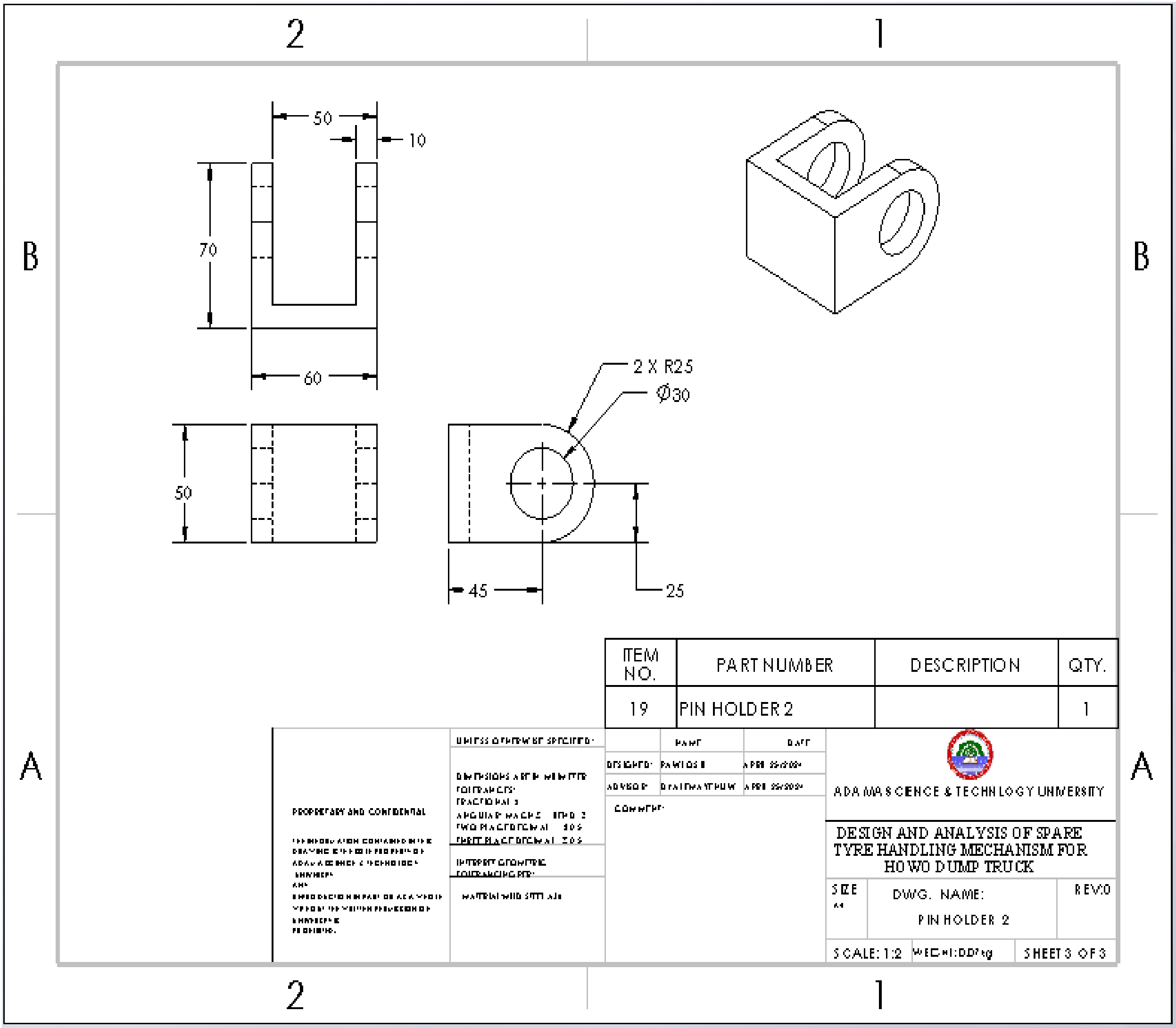

2
1
B
A
50
50
660
ITEM NO.
PART NAME
DESCRIPTION
QTY.
11
Horizontal RHS
50x50x3
2
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
HORIZONTAL RHS
REV
SCALE: 1:2
SHEET 1 OF 1



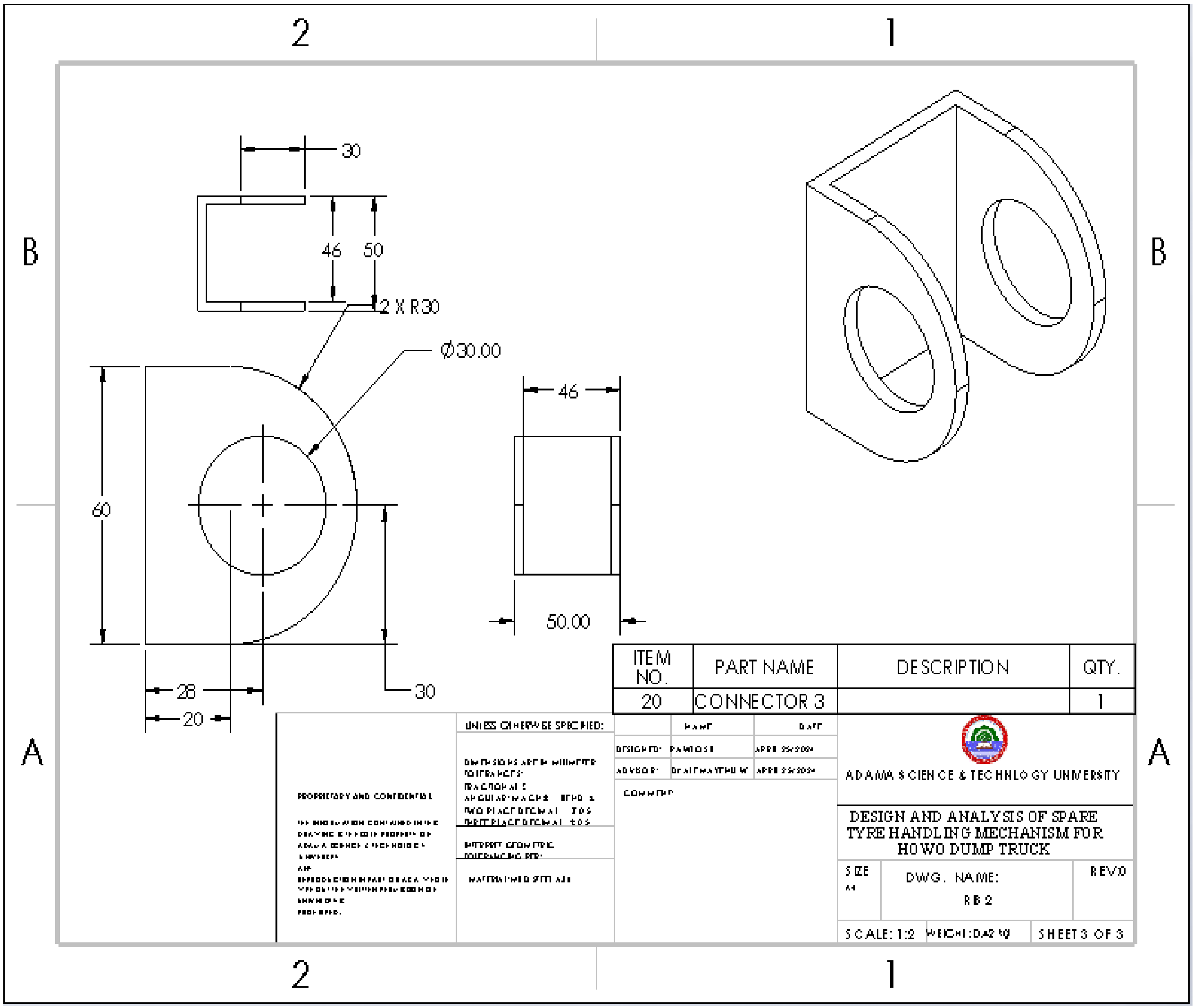
Ø580
10
Ø580
Ø80
450
225
Ø30
ITEM NO.
PART NAME
DESCRIPTION
QTY.
12
CIRCULAR PLATE
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
INTERPRET GEOMETRIC TOLERANCING PER:
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
CIRCULAR PLATE
REV.0
SCALE: 1:10
SHEET 1 OF 1


50
3
50
45°
320
220
50
ITEM NO.
PART NAME
DESCRIPTION
QTY.
17
BRACING
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
BRACING
REV:0
SCALE: 1:2
SHEET 3 OF 3

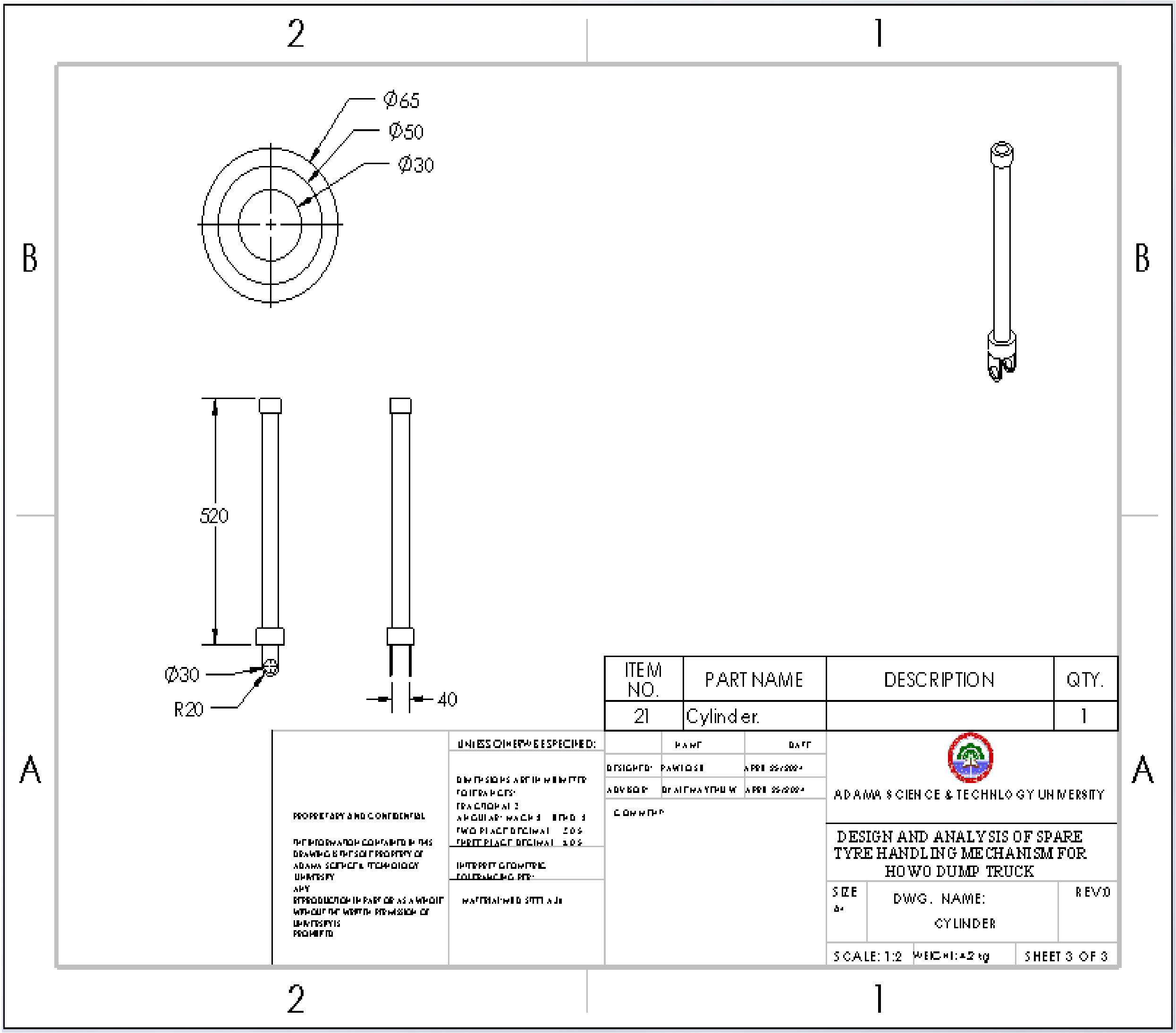

50
50
1430
50
ITEM NO.
PART NAME
DESCRIPTION
QTY.
18
VERTICA RHS
50X50X3
2
UNLESS OTHERWISE SPECIFIED:
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
DWG. NAME:
VERTICAL RHS
SIZE
REV.0
SCALE: 1:2
SHEET 3 OF 3
PROPRIETARY AND CONFIDENTIAL



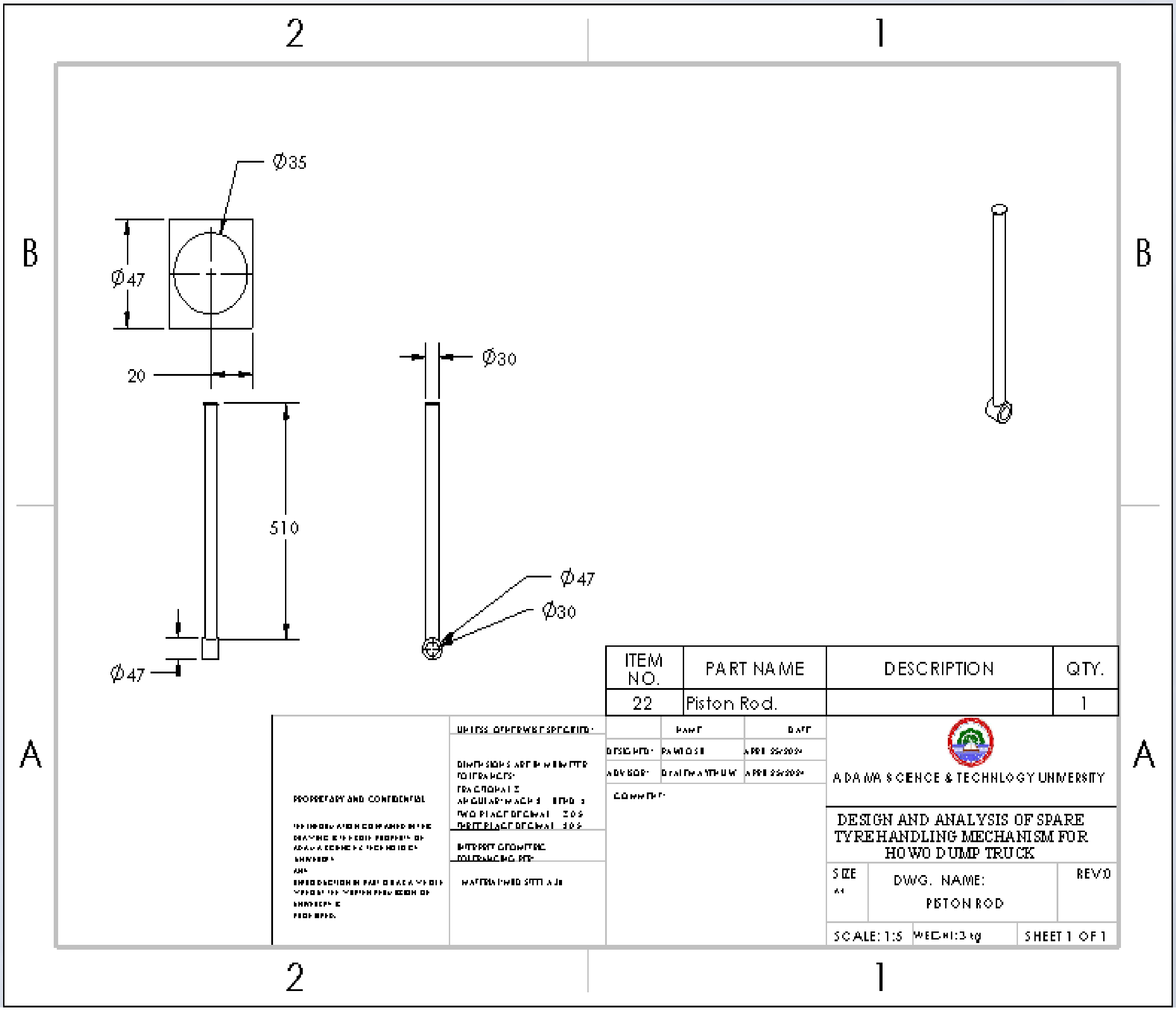
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
19	PIN HOLDER 2		1



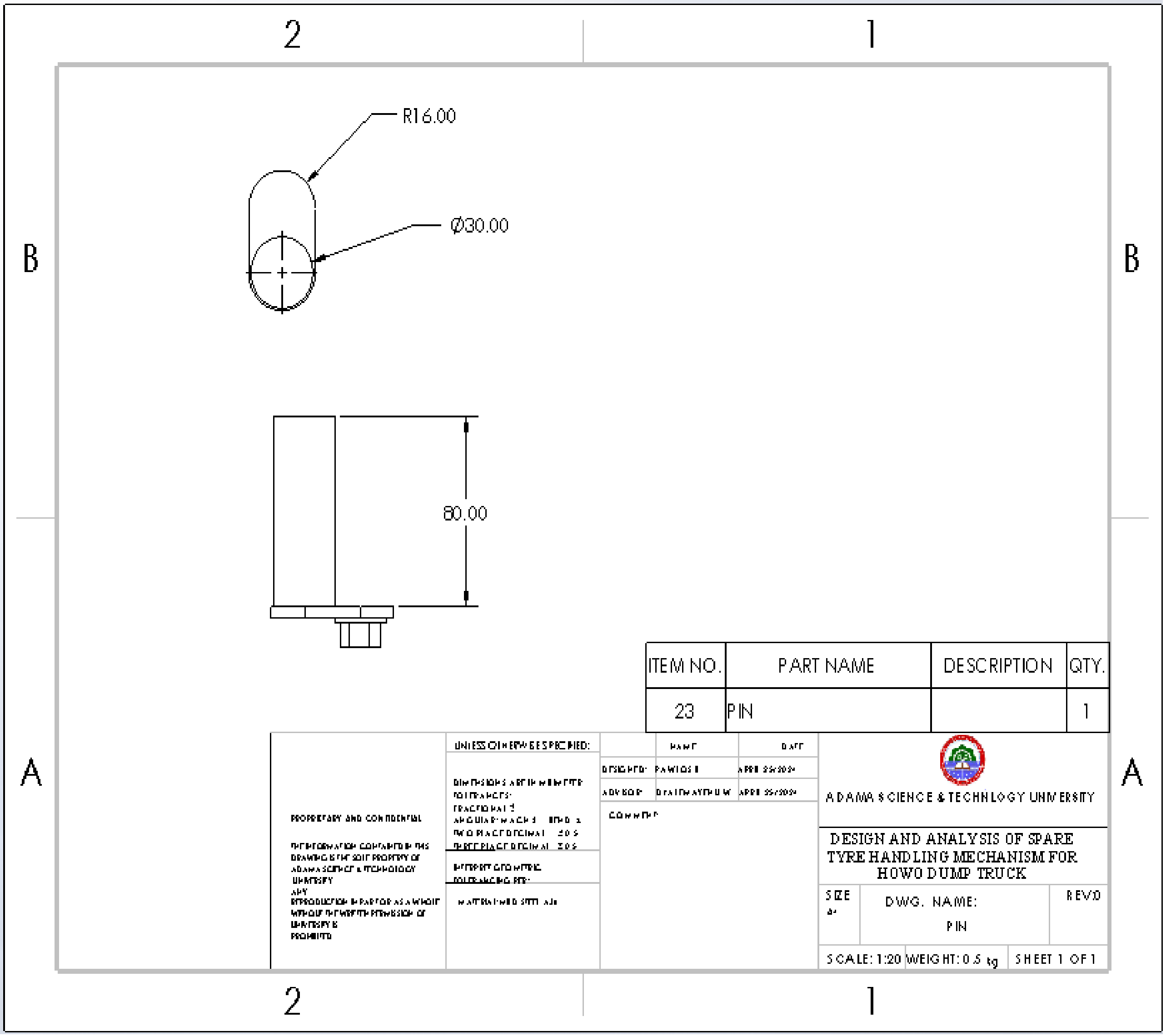
30
46
50
2 X R30
Ø30.00
46
60
50.00
28
20
30
ITEM NO.
PART NAME
DESCRIPTION
QTY.
20
CONNECTOR 3
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
RB 2
REV.0
SCALE: 1:2
SHEET 3 OF 3



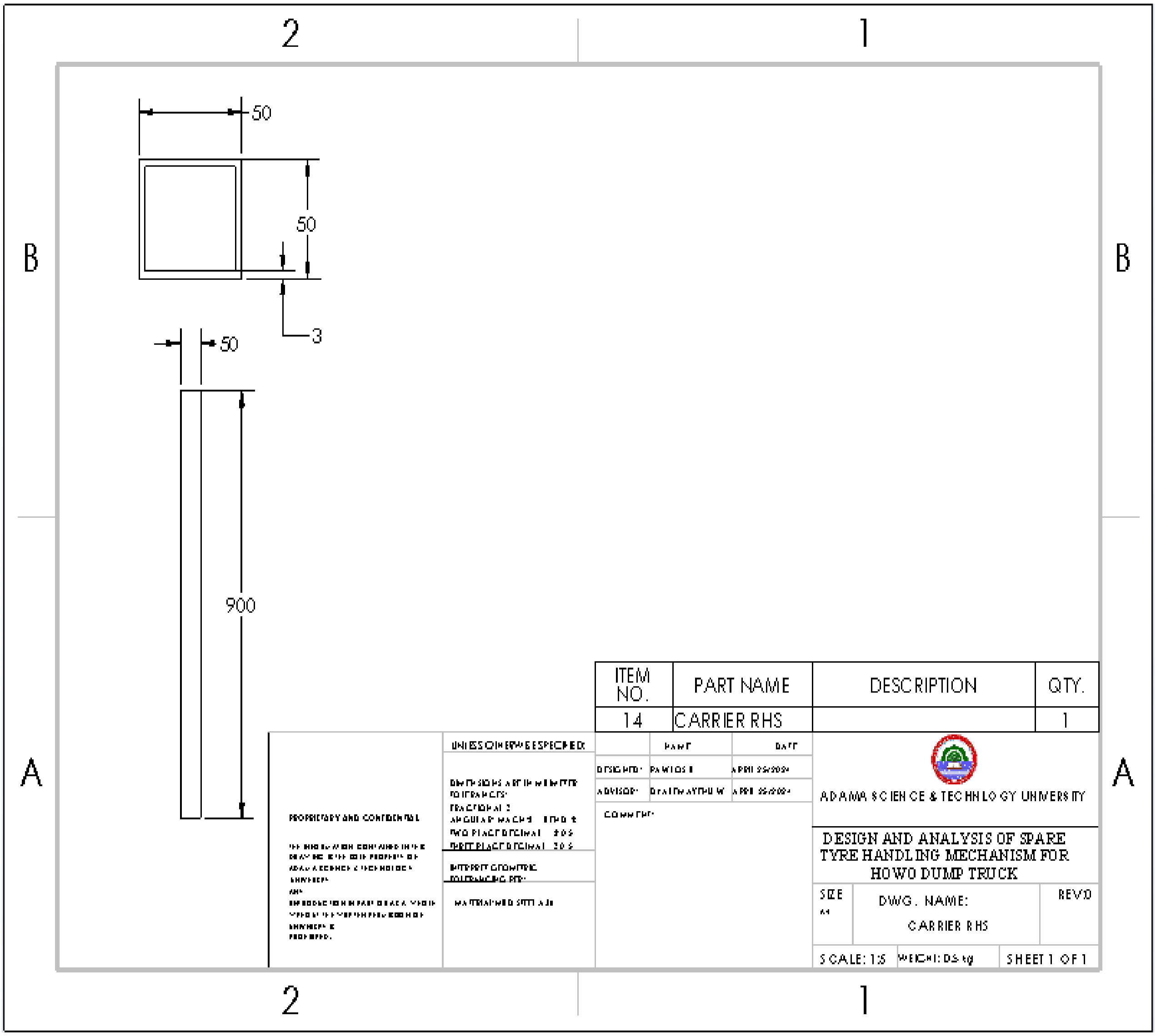
2
1
B
A
Ø65
Ø50
Ø30
520
Ø30
R20
40
ITEM NO.
PART NAME
DESCRIPTION
QTY.
21
Cylinder.
1
UNLESS OTHERWISE SPECIFIED:
ADAMA SCIENCE & TECHNLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
CYLINDER
REV0
SCALE: 1:2
SHEET 3 OF 3



Ø35
Ø47
20
510
Ø30
Ø47
Ø30
Ø47
ITEM NO.
PART NAME
DESCRIPTION
QTY.
22
Piston Rod.
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
NAME
DATE
DESIGNED
ADVISOR
COMMENTS:
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
PISTON ROD
REV.0
SCALE: 1:5
SHEET 1 OF 1



ITEM NO.	PART NAME	DESCRIPTION	QTY.
23	PIN		1


50
50
3
50
900
ITEM NO.
PART NAME
DESCRIPTION
QTY.
14
CARRIER RHS
1
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
ADAMA SCIENCE & TECHNOLOGY UNIVERSITY
DESIGN AND ANALYSIS OF SPARE TYRE HANDLING MECHANISM FOR HOWO DUMP TRUCK
SIZE
DWG. NAME:
CARRIER RHS
REV:0
SCALE: 1:5
SHEET 1 OF 1