UNIVERSITY OF EDUCATION, WINNEBA

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DESIGN MODIFICATION AND SIMULATION OF FOUR POSTS LIFTING DEVICE FOR LIGHT DUTY VEHICLES

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THESIS SUBMITTED TO THE SCHOOL OF GRADUATE AND RESEARCH STUDIES AT THE DEPARTMENT OF MECHANICAL AND AUTOMOBILE ENGINEERING TECHNOLOGY, FACULTY OF TECHNICAL EDUCATION, UNIVERSITY OF EDUCATION WINNEBA. COLLEGE OF TECHNOLOGY EDUCATION KUMASI, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MPHIL IN AUTOMOBILE ENGINEERING TECHNOLOGY

SEPTEMBER 2021

DECLARATION

STUDENT'S DECLARATION

I sincerely, hereby declare that this thesis is the true work of my own original research, first of its kind, never existed anywhere and that no part of it has been presented for another MPhil in this university or elsewhere.

Candidate's Name: Arthur David

Signature: ……………………..

Date: ……………………..

SUPERVISOR'S DECLARATION

I declare that the preparation and presentation of this thesis was supervised in accordance with the guidance on thesis work laid down by Akentene Appiah Minka University of Skills Training and Entrepreneurial Development.

Supervisor Name: Kwabena Offeh Gyimah (PhD)

Signature: ………………………………………

Date: ………………………………………

DEDICATION

I dedicate this work to my wife: Mrs Agnes Arthur Aggrey, my mother: Helena Arthur, my late father: Mr. Justice Keanbarty Arthur, my siblings: James Arthur Aggrey, Joyce Arthur, Frederick Arthur and Franlina Arthur Takyi and my children Festus Arthur, Empress Arthur.

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I would like to extend special thanks to all the lectures in the department for their immense contribution throughout my study. Their valuable advice and constructive suggestions have greatly improved the present work.

ABSTRACT

The value of human life and equipment cannot be under estimated as far as growth and development of every establishment is concern. In many institutions, workshops, garages and companies, there are safety protocols and precautions governing the movement of the workers and equipment. Once most of our repairs and preventive maintenance inspections (PMI) cannot be done without the assistance of vehicle lift, there is the need to re-engineer and re-packaged the trend in which some of this lift is designed so that it will provide the needed safety and reduce financial burden on its users. This research has come as a result of the challenges and concerns some researchers and users of these lifts had encountered; this has called for improving on the existing four poles lifts so that it can contribute in finding a lasting solution to the practical problems regarding the use of the said lifts. Also, this study is not to condemn the work of previous inventors but to display innovative ideas, ameliorate and redesign the unit so that it will perform the desired functions and become useful to others. The new design is focused on improving on lift frames and other components. It comes with four specific functions as follows; capable of lifting the entire vehicle, lifting the front end of the vehicle alone, tittered from the front end, lifting the rear end alone or tittered from rear end, a lift with a simple/physical/exclusive mechanical lock at each pole and finally a lift which is movable. Other accessories such as wheel chocks and stop switches have been incorporated. All the analysis and results under static structural analysis, have been discussed. The required load capacity and preferable material selection have been determined. Several tests were carried out to determine the effectiveness of the device in lifting loads of 1 ton, 2 tons, 3 tons, 4 tons up to 7 tons respectively. This study will help to overcome drudgery, injuries, increase timeliness and efficiency in the work places while carrying out maintenance works, would also help in reducing size, space occupied, cost employed in maintenance operations.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Over the past decade, different kinds of lifts, have been brought into an existence and this has been one of the key contributors in automobile industries. Lift apparatus was developed to meet the needs of vehicle mechanics and others users but some still rely on unapproved supports due to fear, failures and functions. Therefore, there is the need to design a lift that would be accepted by all in terms of its functions and safety.

However, although the existing lifts had served a wide range of purposes in various capacities but there are major concerns, problems and issues which have been raised by some users and researchers. McCann (2003) the study weighs up or assesses the deaths of construction workers due to personnel lifts. Deaths of construction workers for 1992–1999 were examined using data from the Census of Fatal Occupational Injuries, a Bureau of Labuor Statistics database. The study identified 339 deaths: 42% from boom-supported lifts; 26% from suspended scaffolds; 19% from scissor lifts; 5% from crane platforms; and 7% from unapproved lifts (e. g, forklift platforms). Burlet-Vienney, Galy & Bertrand (2016) analyzed a vehicle stability using two-post above-ground automotive lifts; Distribution of forces in arms. This study gets the measure that the rate of vehicles falling off two-post above-ground (2PAG) lifts in garages is a fairly frequent. Conforming to the above contemplates; OSU (2005) studied risk of vehicles falling from two-post vehicle lifts in motor vehicle repair ponders on the aforesaid issue. Lin & Cohen (1997) carrying out study on accidents in the trucking industry, it is believed to be the largest database of its kind, three thousand and fifty-three (3,053) accidents were reported by a cross-section of over two dozen trucking companies throughout the United States during the three-year period of program implementation. Data analyses indicate that ‘slips and falls’, followed by ‘struck by’ and ‘overexertion’ injuries were the accident types most frequently reported. In addition, detailed accident scenarios were identified, including the four most critical accident problems in the industry, namely those involving vehicle ingress and egress, overexertion's, motor vehicle collisions, as well as those occurring during vehicle repair and maintenance activities. Recommendations emphasizing ergonomic solutions are proposed bearing on issues of improved equipment design, use of personal protective devices, employee safety training programs, and facility/vehicle maintenance programming. Additionally, there are other pioneers and writers who were also concerned about the safety of lift equipment for vehicle lift, some are as follows; first, User's Guide to the world of vehicle lifts which emphasize using pistons to raise the vehicle for repairs it's also talks about safety features such as self-locking mechanisms, maintenance and preservation; public transportation; vehicles and equipment (Chu, 2004). Secondly, Kelley & Elliott (2011) opined that vehicle guidance system for automotive lifts brought a lift system comprises one or more lifting members that are operable to selectively raise and lower a vehicle.

Note that all the stated pathfinders particularly did their investigations based on the safety of the lift due to unforeseen failures. By the same token, after conscientious reading of the problems noted by many explorations on the existing vehicle lifts (the inground lift, scissor lifts, four post lift, two post lift and single post lift) and concerns raised, it was observed that the four-pole lift is more preferable in terms of voltage and usage although it has some difficulties in doing certain maintenance.

According to Lee & Cho (2015) and (Lift F.P., n.d) the four-post lift is the most preferred type in many workshops but has difficulties in doing certain maintenance. Hence this study is focus on improving on the four-post lift so that it can perform the necessary task, enhance it safety and acceptable in all workshops.

1.2 STATEMENT OF THE PROBLEM

The demand for mechanics and lift users. After critical analysis and inquiries on problems and issues relating to vehicle lift falls and failures from researchers,

a. Accidents and sense of fear associated with use of lifts: it was observed that some peoples feel panic when working under lift. OSU (2005) outlines the risk in using the two-post lift. Lin & Cohen (1997) reported an occurrence of accidents during vehicle repair and maintenance activities. McCann (2003) noted that from the report in construction related personal lifts identified 339 deaths. Thompson et al. (2018) noted that many of the failures of these lift are caused by component.

b. The preference of reliable, multi-functional lifts with aesthetic sense: Rawahi & Sudhir (2014) outlined three key factors as requirement for lift as: Reliability, Availability and Maintainability that will be accepted in all automobile industries.

   The developments of automobile lifts started with In-ground lifts, Scissors-Type Lift, Four Post, Two posts lifts, and finally Single post lift (Lifts, n.d.). The in-ground lifts was faded out due to its dirt trapping into the underground system (Fletcher & Felpel, 1996). Granata (2004) developed scissors-type lift but certain repairs cannot be done on it due to its nature of design, there leads to the introduction of a four-post as one of the most popular lifts in automobile workshops for now. However, maintenance on a four-post lift is not as convenient as on a two post because you are forced to work around the ramps and in some instances will have to use a jacking tray to elevate the car off the ramps to perform maintenance, listed these has necessitated the need to re-design this four-post lift and simulate it.

1.3 THE PURPOSE OF THE STUDY

The main purpose of the study is to design, modify and simulate four posts lifting device for light duty vehicles

This purpose can be achieved through these specific objectives:

a. To design a multi-function four-post lift

b. To enhance its safety

c. To simulate and conduct analysis on the four-post lift design

1.4 SIGNIFICANCE OF THE STUDY

The significance are as follows;

i. It will save time for Auto mechanics, Welders, Auto body repair works and the likes when working on vehicles

ii. It will also boost technological advancement in automobile field as far as servicing, repairs and maintenance of motor vehicle are concerned.

iii. It will serve as a guide for other researchers to emulate.

1.5 ORGANIZATION OF THE STUDY

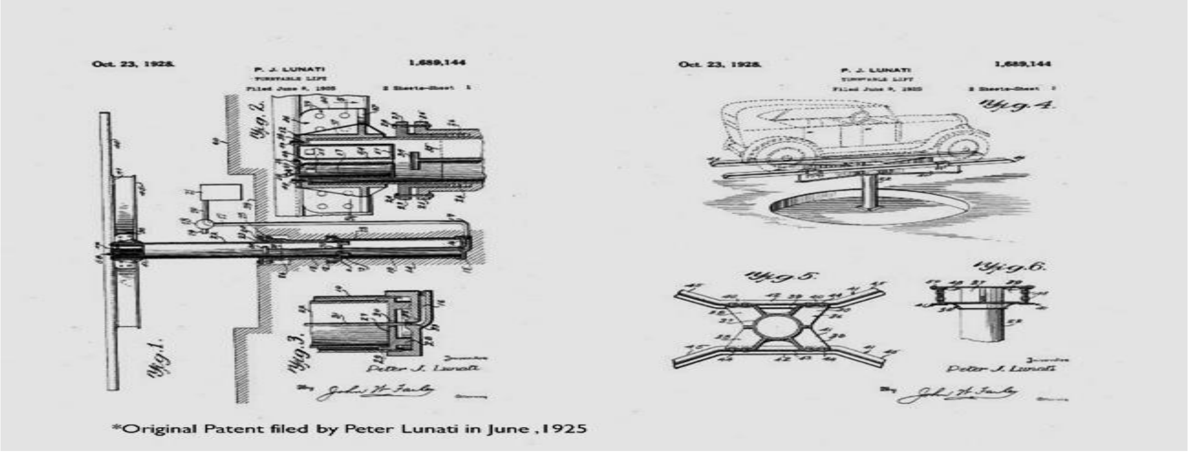
This thesis comprises five chapters. The first chapter have five components, namely background study, statement of the problem, purpose of the study, significance of the study, and organization of the thesis. Chapter two is the literature review of the existing research work and other research works related to the study, both theoretical and practical works relevant to the study. The third chapter highlights on the materials and methods used for modelling, detail drawings, assembly of the unit, analysis and simulation of the geometry. Chapter four is the results and discussion, also with supporting tables, graphs and histograms. Chapter five is the conclusion and summary, with recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Trend of Lifting Device for Motor Vehicles

Lunati (1925) designed the first rotary vehicle lift shown in Figure. 2.1, it was explained that while in the business as a mechanic, he quickly realized his dislike for crawling in and out of a pit, to fix automobiles. An idea hit him one day while getting a haircut. The barber's chair went up-and-down with such ease. Lunati thought to himself why couldn't this same idea be used for vehicles. And so, the journey began to invent the world's first hydraulic vehicle lift. He filed his first patent in June 1925 and Rotary Lift was born. Peter Lunati designed, built and patented the first fully hydraulic automotive lift and gave rise to a new industry. The first Rotary Lift was installed in Liversiege Service Station, Memphis, Tennessee. The name "Rotary" came from the fact the lift would rotate 360 degrees with vehicle raised. Today, Peter Lunati's vision lives on, more than likely, in ways he never imagined. We are proud to carry on his legacy and know that we strive to keep the same simple idea that make the lives of technicians better each day. As explained in in page 3, the developments of automobile lifts begun with In-ground lifts (Fletcher & Felpel, 1996), Scissors-Type Lift (Granata, 2004), Four Post, two posts lifts, and finally Single post lift (Lifts, n.d.) but the four-post or column lift is one of the most popular lifts in automobile workshops, often referred to as a drive-on lift.



*Original Patent filed by Peter Lunati in June ,1925

Figure. 2.1, layout of the first rotary lift (Lunati, 1925)

2.2 POWER SYSTEMS

Power systems are used to transmit and control power (Rabi, 2009).

2.2.1 CLASSIFICATION OF POWER SYSTEMS

As maintained by Rabi (2009), there exist different types of power systems; these are as follows; mechanical, electrical, pneumatic, and fluid.

2.2.1.1 The mechanical power systems

The mechanical power systems use mechanical elements to transmit and control the mechanical power. The drive train of a small car is a typical example of a mechanical power system (Rabi, 2009).

2.2.1.2 Electrical Power Systems

Electrical power systems solve the problems of power transmission distance and flexibility, and improve controllability. Electrical power systems offer advantages such as high flexibility and a very long power transmission distance, but they produce mainly rotary motion (Rabi, 2009).

2.2.1.3 Pneumatic Power Systems

Pneumatic systems are power systems using compressed air as a working medium for the power transmission. Their principle of operation is similar to that of electric power systems. The air compressor converts the mechanical energy of the prime mover into mainly pressure energy of compressed air (Rabi, 2009).

2.2.1.4 Hydraulic Power Systems

According to Rabi (2009), the hydraulic power systems transmit mechanical power by increasing the energy of hydraulic liquids. Two types of hydraulic power systems are used: hydrodynamic and hydrostatic. Hydrodynamic (also called hydrokinetic) power systems transmit power by increasing mainly the kinetic energy of liquid. Generally, these systems include a rotor dynamic pump, a turbine, and additional control elements. The applications of hydrodynamic power systems are limited to rotary motion. There are two main types of hydrodynamic power systems: hydraulic coupling and torque converter. In the hydrostatic power systems, the power is transmitted by increasing mainly the pressure energy of liquid. These systems are widely used in industry, mobile equipment, aircrafts, ship control, and others. The hydrostatic power systems are commonly called hydraulic power systems (Rabi, 2009).

Totten (2011) handbook of hydraulic engineering, maintained that, from a general perspective: a hydraulic system is an arrangement of interconnected components that use a liquid under pressure to provide energy transmission and control. As Rabi (2009) said God created the first and most wonderful hydraulic system:). Murty & Thandaveswara (2014) using hydraulics or the use of fluid power to run machinery has been around for quite a while for over 2000 years

2.2.1.4.1 Basic Hydraulic Power Systems

As Rabi (2009) outlined the following basic hydraulic power systems as;

a) The prime mover that supplies the system with the required mechanical power. The pump converts the input mechanical power to hydraulic power.

b) The energy-carrying liquid which is transmitted through the hydraulic transmission lines: pipes and hoses. The controlled hydraulic power is communicated to the hydraulic cylinder, which converts it to the required mechanical power. Generally, the hydraulic power systems provide both rotary and linear motion.

2.3 COMPARISON OF POWER SYSTEMS

Table 2.1 shows, a brief comparison of the different power systems, by Rabi (2009),

Table. 2.1: Comparison of Power Systems

Comparison of Power Systems				
SYSTEM PROPERTY	**MECHANICAL**	**ELECTRICAL**	**PNEUMATIC**	**HYDRAULIC**
Input energy source	ICE and electric motor	ICE and hydraulic, air or steam turbines	ICE, electric motor, and pressure tank	ICE, electric motor, and air turbine
Energy transfer element	Mechanical parts, levers, shafts, gears	Electrical cables and magnetic field	Pipes and hoses	Pipes and hoses
Energy carrier	Rigid and elastic objects.	Flow of electrons	Air	Hydraulic liquids
Power to weight ratio	Poor	Fair	Best	Best
Torque/inertia	Poor	Fair	Good	Best
Stiffness	Good	Poor	Fair	Best
Response speed	Fair	Best	Fair	Good
Dirt sensitivity	Best	Best	Fair	Fair
Relative cost	Best	Best	Good	Fair
Control	fair	Best	Good	Good
Motion type	Mainly rotary	Mainly rotary	Linearly or rotary	Linearly or rotary

2.4 MEANING OF HYDRAULICS

The word hydraulics' originate from the Greek word hydaulikos which in turn originates which means water in Greek and aulos which means pipe. In the opinion of Das, Saikia & Das (2013) the simplest definition of hydraulics is the study of liquids at rest and in motion, Also Mobley (1999) explained that the word hydraulics means "Liquid in motion": in the operation of fluid power systems, there must be flow of fluid**.** According to the Pascal's law, any force applied to a confined fluid is transmitted uniformly in all direction throughout the fluid regardless of the shape of the container (Mobley, 1999). In addition to this, Hydrostatics means: liquid at rest (Mobley, 1999).

2.4.1 COMPONENTS OF HYDRAULIC SYSTEM

To control and transmit power through pressurized fluids, an arrangement of interconnected components is required. Such arrangement is commonly referred to as system (Mobley, 1999). Some of the components which may be in every hydraulic system which include the following;

2.4.1.1 Reservoir

This is the tank that holds the hydraulic fluid or stores the fluid to support the system. The reservoir is also designed to aid in separation of air from the fluid (Asonye et al., 2015)

2.4.1.2 Hydraulic Pump or, motor:

This is the energy source for hydraulic system. It converts electrical energy into dynamic pressure. The pump helps to speed up the circulation of the hydraulic fluid. As described by Asonye et al. (2015).

2.4.1.3 Relief Valve

This is always installed downstream of the hydraulic. When this is opened, the fluid is ported back into the reservoir (Asonye et al., 2015)

2.4.1.4 Lines (pipe, tubing, or flexible hoses)

The hydraulic hoses or pipes are used to transmit fluid from one place to another. According to Hyvarinen et al, (2020), the hydraulic hoses with various dimensions are used as energy feeding systems in wall or drill systems, all systems require some means to transmit hydraulic fluid from one component to another.

2.4.2 Advantages of hydraulic system

Asonye et al., (2015) outlined the following as advantages and disadvantages of hydraulic system:

a. Hydraulic systems have large load carrying capacity

b. High efficiency with minimum friction loss keeps the cost of a power transmission at a minimum.

c. Hydraulic systems are smooth and quiet in operation,

d. vibration is kept to a minimum control.

e. Handling, control of a wide range of speed and forces is easy.

f. Repairing and replacement of parts is easy.

2.4.3 Disadvantages of hydraulic system:

a. The main disadvantage of a hydraulic system is maintaining the precision parts when they are exposed to bad climates and dirty atmospheres (Asony et al., 2015).

2.4.4 Applications of Hydraulics

Hydraulics is used for the generation, control, and transmission of power by the use of pressurized liquids. According Yang & Pan (2015), hydraulic topics ranges through some parts of science and most of engineering modules, and cover concepts such as pipe flow, dam design, fluidics and fluid control circuitry. Common hydraulic fluids are based on mineral oil or water as reported by Hydraulics (Murty & Thandaveswara, 2014).

One place you'll find plenty of hydraulic machinery is on a construction site. Cranes, bulldozers and all sorts of heavy equipment are run using hydraulic drives. Another area that has seen significant advantages from hydraulic systems is agriculture.

Aerospace applications are also heavily invested in the use of hydraulics. Hydraulic systems power many parts of a plane, including things like brakes, cargo doors, steering, propeller control and wing flaps. Aside from vehicle and industrial usage, you can find hydraulic systems everywhere. Office chairs and dishwashers are two household objects that often use hydraulics.

2.5 HYDRAULIC FLUID

The fluid provides the vehicle that transmits input power, such as from a hydraulic pump to the actuator device or devices that perform work. Yannopoulos et al. (2015) opined that, the original hydraulic fluid dating back to the time of ancient Egypt was water. Modern hydraulic system uses petroleum-based oils, with additives to inhibit foaming and corrosion. Petroleum oils are inexpensive, provide good lubricity and, with additives, have long life. The brake and automatic transmission fluids in your car are examples (Durfee, Sun & Van de Ven, 2009) and (Colarelli et al., 2001) even though the composition of hydraulic fluid consists of 99% base stock with about 1% additives.

2.5.1 Types of Hydraulic Fluid

a. biodegradable hydraulic fluids: Environmentally sensitive applications (e.g. farm tractors and marine dredging).Typically, these oils are available as ISO 32, ISO 46, and ISO 68 specification oils (Sharma et al., 2006). Others include Synthetics Oils, Mineral Oils, and Bio-Based Lubricants: Chemistry and Technology (Rudnick, 2020) Synthetics, mineral oils, and bio- based lubricants.

b. Brake fluid: This is a type of hydraulic fluid used in hydraulic brake and hydraulic clutch applications in vehicles. It is responsible for transferring force into pressure and to amplify braking force.

2.5.2 Using Hydraulic Fluid in a Closed System

A closed-circuit hydraulic system is one where the fluid flows continuously through the system from pump to motor and back with only case drain oil returning to the reservoir. One of the major advantages in using hydraulic fluids in a closed system is that the pressure exerted throughout the system is the same at any point. The effort to operate the component is determined by the area of which the pressure is applied. Fluid is not compressible; any effort applied at one place will be transmitted without loss of pressure or movement anywhere in the system (Manring & Fales, 2019).

2.5.3 Equipment that use Hydraulic fluids

a. Hydraulic Lifts. Hydraulic lifts are used for moving goods or people vertically. See Appendix C for hydraulic circuit of the new design.

b. Hydraulic Brakes. Braking system of the vehicle is an important example of hydraulics.

c. Hydraulic Steering. For vehicle power steering systems

d. Hydraulic Jacks. Hydraulic fluid for jacking vehicles

e. Heavy Equipment. For garbage trucks, industrial machineries.

f. Airplanes. Hydraulic fluid for aircraft flight control systems and doors

g. Hydraulic Shock Absorbers. Hydraulic fluid, for vehicle suspension and steering dampers (Totten, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 INTRODUCTION

This section talks about materials selected for the design and the methods used in designing the unit. It also consists of the design tools used and how the individual components were designed.

3.2 MATERIALS

Structural Steel, Cast Iron GJL 100 and Carbon Steel 1020 Annealed were selected to run the test and their solution results have detailed the best ones for the design. The solution results from the analysis based on yield strength of the materials were compared to that of the original material in table 3.1, 3.2, and 3.3 to determines the best materials to be selected for the unit.

3.2.1 MECHANICAL PROPERTIES OF SAMPLED MATERIALS

The tables 3.1, 32 and 3.3 displays the materials presented under consideration and their properties were taken from the ANSYS 2021 R2 Software standard material library.

Table 3.1: Mechanical properties of Structural Steel

STRUCTURAL STEEL	
Density	7.85e-06 kg/mm³
Young's Modulus	2e+05 MPa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+05 MPa
Shear Modulus	76923 MPa
Isentropic Secant Coefficient of Thermal Expansion	1.2-05 1/˚C 1/
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength.	50 MPa

Table 3.2: Mechanical properties of Cast Iron

CAST IRON EN GJL 100	
Density	6.999e-0.6 kg/mm^3
Young's Modulus	89440 MPa
Poisson's Ratio	0.26
Bulk Modulus	62111 MPa
Shear Modulus	34592 MPa
Isentropic Secant Coefficient of Thermal Expansion	1.196e-05 1/˚C
Ultimate Tensile Strength	141.4MPa
Ultimate Yield Strength.	78.81 MPa

Table 3.3: Mechanical properties of Carbon Steel Annealed

CARBON STEEL 1020 ANNEALED	
Density	7.85e-06 kg/mm^3
Young's Modulus	2.124E+05 MPa
Poisson's Ratio	0.29
Bulk Modulus	1.6857e+05 MPa
Shear Modulus	82326 MPa
Isentropic Secant Coefficient of Thermal Expansion	1.143e-05 1/˚C
Ultimate Tensile Strength	393 MPa
Ultimate Yield Strength.	293 MPa

3.3 METHODS USED FOR MODIFYING THE UNIT

- Solid modeling of the components (Formation of three-dimensional Computer Aided Design models by considering the standard base dimensions of 2800kg located at Kumasi Technical Institute Workshop and 4000kg lifts at Akenten Appiah - Minka University of Skills Training and Entrepreneurial Development (AAMUSTED) Automobile Engineering Laboratory) using Autodesk Inventor professional 2017, Product of Computer Aided Design software.

- Detail drawing of components using Autodesk Inventor professional 2017. See Appendix A for the detail drawings/Parts List.

- Assembly of individual components using Autodesk Inventor professional 2017**.** See Appendix B for the assembly drawings in five stages
- Saving the assembled unit in STEP File formats using Autodesk inventor.
- Importing the STEP Files using ANSYS 2021 R2 software.
- Meshing of the geometry using ANSYS 2021 R2 software
- Selection of the type of material using ANSYS 2021 R2 software.
- Selection of fixed constraint (fixed support) using ANSYS 2021 R2 software.
- Applying of the forces, or load using ANSYS 2021 R2 software
- Selecting the stresses using ANSYS 2021 R2 software
- Solution: using ANSYS 2021 R2 software.

Figure 3.1 and 3.2 shows the assembly of the entire unit at low level and high level with a model car placed on it.

ASSEMBLY OF NEWLY MODIFIED VEHICLE LIFT

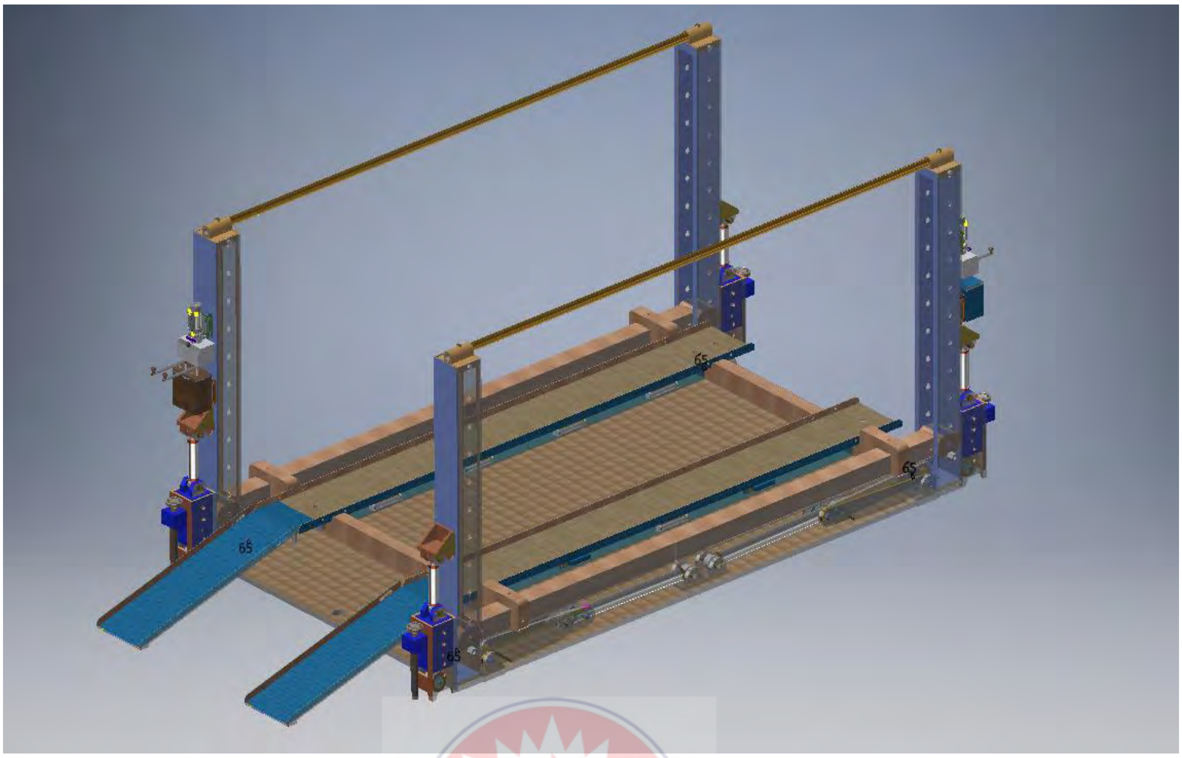


Figure 3.1, Assembly of Newly modified Vehicle Lift at Low Level

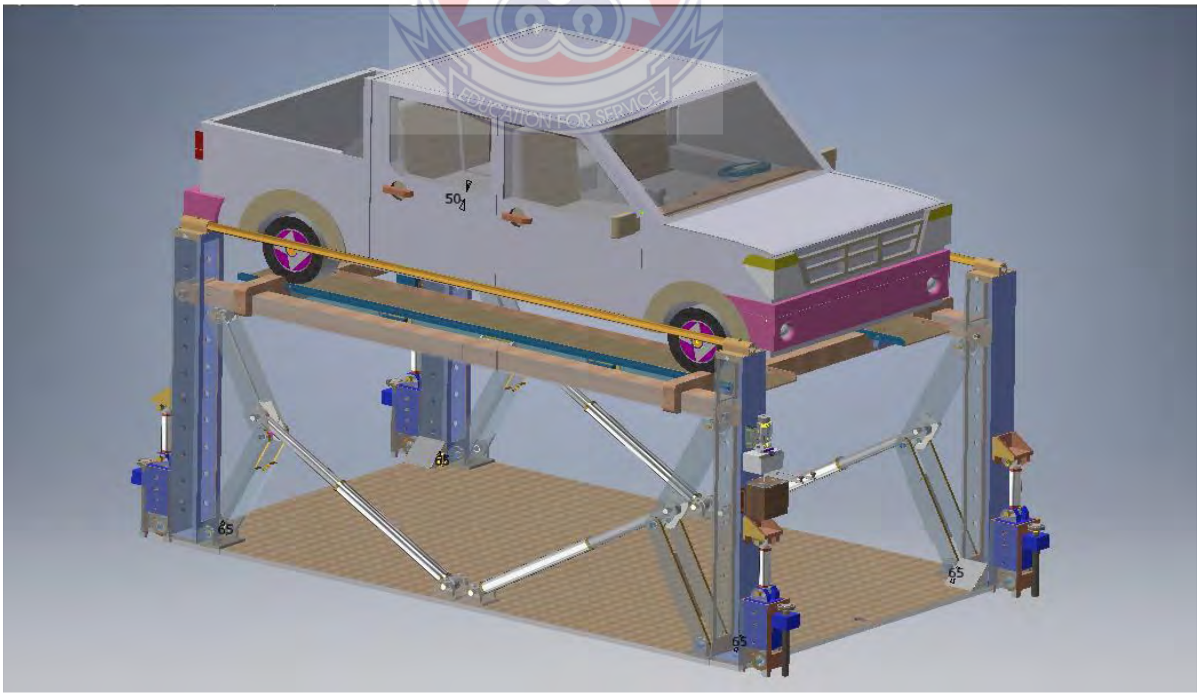


Figure 3.2, Model pick-up on new modified Lift at High Level

3.4 THE DESIGN CONCEPTS AND CALCULATIONS

The first thing to consider is the weight of the vehicle acting on the hydraulic cylinder/ram. Amedorme & Fiagbe (2016) outlined the following theory of hydraulic lift system and failure prediction of components using the Pascal principle as follows;

i. Consider a ram and plunger as in Fig. 3.3a or b,

ii. Operating in two cylinders of different diameters, which are interconnected at the bottom, through a chamber filled with some liquid or fluid.

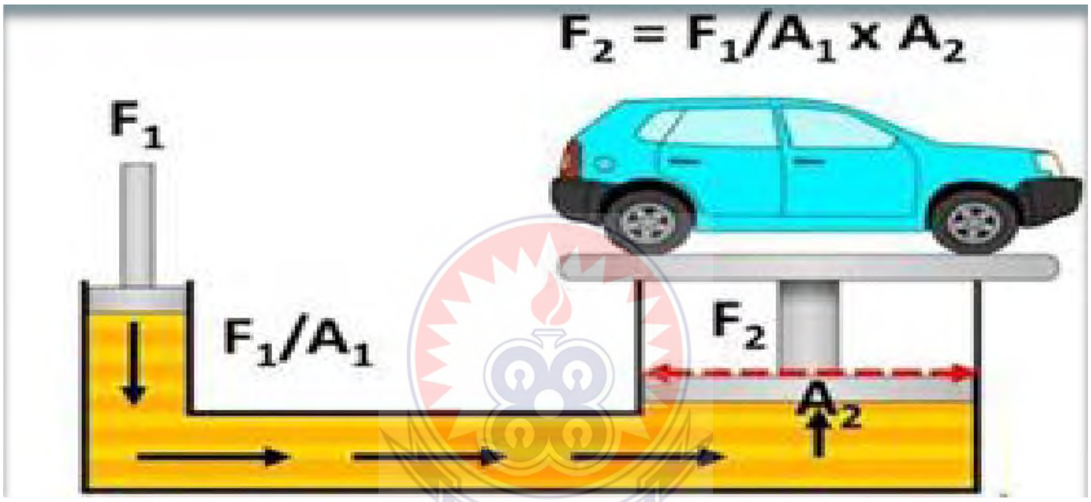


Figure. 3.3a, Pascal Principle

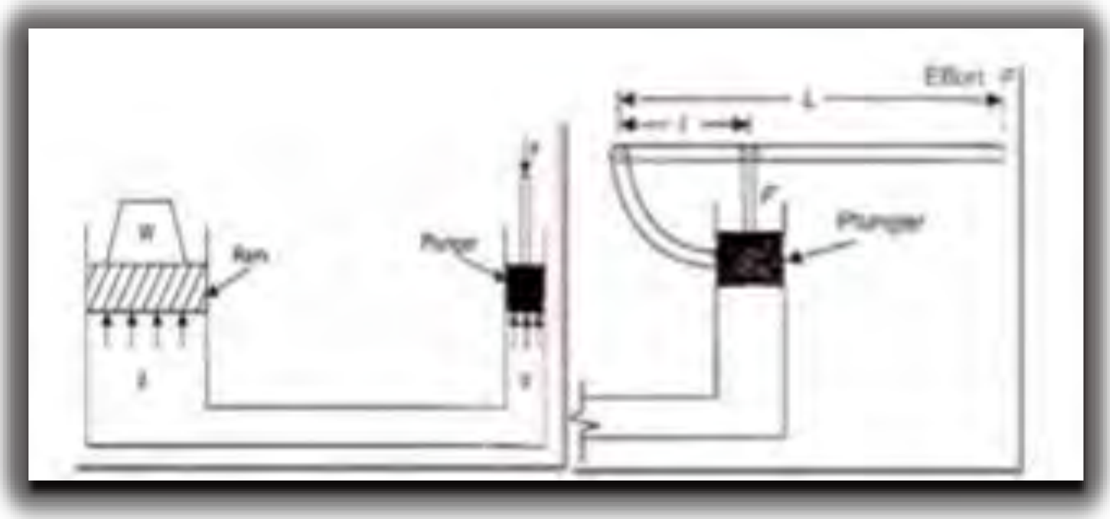


Figure. 3.3b, Pascal Principle

Let's W = Weight to be lifted = $F2$

F = Force applied to the plunger = $F1$

A = Area of the ram and = $A2$

a = Area of the plunger = $A1$

Hence; Pressure intensity produced by the force F = Force/Area of plunger

$$P = F/a = F1/a1 \tag{1}$$

From the Pascal's law, the intensity pressure (P) will be equally transmitted in all directions.

Therefore, the pressure intensity on the ram will be

$$P = F/a = W/A \text{ or } W = F(A/a) \tag{2}$$

The above equation clearly explains that by applying a small force on the plungers from the ports on either the main or movable wheel pushing ports/pumps (manual pump) through the hoses/pipes to the ram/pistons the main and movable wheels pushing pistons/rams, a large force "W" on the said rams will be developed.

The mechanical advantage of unit above unit will be = A/a in fig. 3.3 b; If the force (F) in the plunger is applied by a lever which has a mechanical advantage (L/I), then the total mechanical advantage of the unit = (L/I) (A/a). The ratio (L/I) is known as leverage of the unit (Amedorme & Fiagbe, 2016).

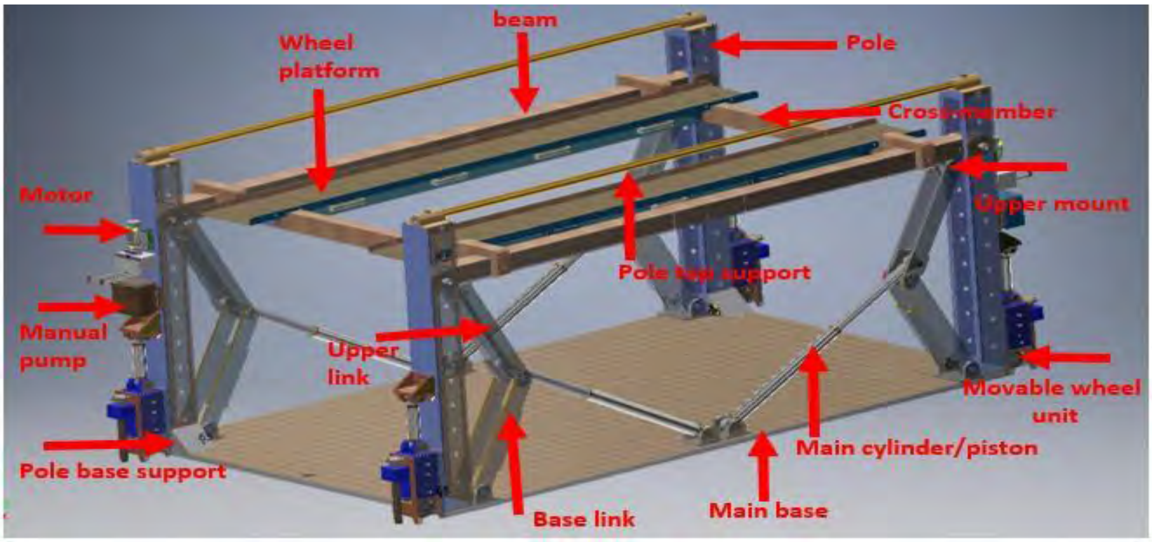


Figure. 3.4, Sample of the new designed lift

Considering a load (W) of 1500kg of a vehicle in Figure. 3.3a is placed on the lifting device in Figure 3.4, and the main hydraulic cylinders (4 cylinders) are mounted in inclined position as shown (Momin, Hatti, Dalvi, Bargi & Devare, 2015), the total load acting on the cylinder would be as follows;

Mass to be put on lift: 1500 kg

Taking FOS (factor of safety) = 1.5 for mass

1500 x 1.5 = 2250 kg rounding the mass to 3750kg (3)

Mass of top frames= 120 kg (main beam, inner beam, cross members, wheel platforms)

Mass of each link: 5kg (8 x 8) = 64kg (upper 4, and lower 4)

Mass of links of cylinder mounting = 8 kg

Mass of cylinders = 8 x 4kg = 32kg

Total Mass: 120 + 64 + 8 + 32 + 3750 = 3974kg (4)

i. Total load = 3974 x 9.81 = 38984N approximately 40000N (5)

If the load of 3000kg is placed on the lift, then the total load would be 77968N considering factor of safety.

In doing calculations on the design, the existing dimensions has to be considered due to international standards, and also the required wheel base and track length of vehicles which are going to be placed on the lift in order to work within the said standards.

In addition to this, **Von Mises Criterion** (Maximum Distortion Energy Criterion) this is based on determination of the distortion energy in a given material (Amedorme, & Fiagbe, 2016) two criteria are used to predict the likelihood of failure in a ductile material. These are maximum shear stress theory (MSST) and distortion energy theory (DET). The maximum shear stress theory (MSST) states that a component will fail when the shear stress exceeds a critical value. This critical stress is determined from standard uniaxial tensile tests. On the other hand, the distortion energy theory (DET) which is also called von Mises yield criterion and predicts failure with greater accuracy than MSST states that failure is caused by the elastic energy associated with shear deformation. a given material is safe as long as the maximum value of the distortion per unit volume in the material remains smaller than the distortion energy per unit volume required to cause yield in a tensile test specified of the same material.

The von Mises stress σe for triaxial stress state:

$$\sigma e = \frac{1}{\sqrt{2}} [([(\sigma_2 - \sigma_1)^2 + (\sigma_3 - \sigma_1))^2 + (\sigma_3 - \sigma_2)^2]^{½} \qquad (1)$$

For the biaxial stress state, the von Mises stress reduces

$$\sigma e = (\sigma_1^2 - \sigma_2^2 - \sigma_1\sigma_2)^{½} \qquad (2)$$

Failure occurs if

$$\sigma e \geq \frac{Sy}{ns} \qquad (3)$$

where Sy = Yield stress of material, ns = Factor of safety

Factor of safety =Ultimate Load (Strength)/Allowable Load (Stress). The allowable load is always less than the ultimate failure stress. Hence, the factor of safety is always greater than one (1).

The factor of safety increases the safety of the people and reduces the risk of a failure of a project or artifact. When it comes to safety of an equipment and fall protection. The factor of safety is extremely important.

The above explanations will help determine the parameters for the software in doing analysis.

3.5 PARAMETERS APPLIED TO ANSYS SOFTWARE

Mackrory (2018) forces conversion factors; the deprecated unit kilogram-force (kgf) or kilopond (kp) is the force exerted by one kilogram of mass in standard earth gravity (defined as exactly 9.80665 m/s^2)

One kilogram-force is equal to exactly 9.80665 newton. This implies that, 1 kilogram or kilogram force (kg or kgf) = 9.80665 newton's (N) = 1000 grams (g) = 1000000 milligrams (mg)

If the force of 1 kg on the earth or an object with a mass of 1kg will experience a force of 9.80665 which is approximately10N due to gravity, i.e., the weight of a 1kg mass is 10N.

Since:

a. the unit symbol is for newton is N

b. and the symbol of the force is F (force)

Then: weight = m × g

Where, Mass = m and gravity g = 9.80665 m/s^2,

Hence; the forces or loads in kilogram on my load conversion table or chart on my new design will be outlined as follows:

In choosing the rated capacity of 3000kg and considering factor of safety of 5000kg and 7000kg loads on the unit. The loads in newton will be as follows:

1kg = 10N due to gravitational force.

Hence; weight of,

A. 1500 kg = 9.80665 or 10 x 1500 = 15000N

B. 3000 kg = 9.80665 or 10 x 3000 =30000N

C. 4000 kg = 9.80665 or 10 x 4000 =40000N

D. 5000 kg = 9.80665 or 10 x 5000 = 50000N

E. 7000kg = 9. 80665 or 10 x 7000 = 70000N

The materials selected were analyzed according to the rated loads. Although the rated load is 3000kg but it was tested up to 7000kg due to factor of safety. Also, all the results were arranged and compared with rated loads of (30000N, 40000N, 50000N and 70000N) in three stages as follows,

1) High Levels: Structural steel, Cast Iron, carbon Steel 1020 Annealed
2) Inclined Levels: Structural steel, Cast Iron, carbon Steel 1020 Annealed
3) Low Levels: Structural steel, Cast Iron, carbon Steel 1020 Annealed

Followed by discussions on:

a. Von-Mises

b. Total Deformations

c. Shear Stress

d. Equivalent Strain

With supporting:

(a) Tables

(b) Graphs and

(c) Histograms

The numerical procedure in Figure 3.5 – 3.16 display the Mesh, material assignment, load applied (N), and fixed support being the boundary conditions applied.

Nine (9) out of thirty-six (36) results have been displayed (only the results of 30000N are shown in Figure 4.1 – 4.36). The rest (40000N, 50000N and 70000N) are demonstrated in table 4.1 - 4, graph 4.1 – 4.3, and histogram 4.1 – 4.7, in the results discussion.

3.6 NUMERICAL PROCEDURE

First of all, from the methods, analysis have been carried out by ANSYS 2021 R2 Workbench software for that assembly has been imported to ANSYS in STEP file format by Autodesk Inventor professional. The material properties have been defined as table 3.1, 3.2 and 3.3.

After meshing of model 236161 nodes & 100455 elements were generated. Constraints & loads have been defined for static analysis. Fixed constraints have been defined to the main base of the support as shown in figures 3.5 – 3.16 respectively.

Loads have been defined as 30000N, 40000N, 50000N, and 70000N respectively (See Appendix D for solution report on 40000N load applied to the lift). The stresses include, Von-Mises stress, Total deformation, shear stress, and Equivalent strain.

The materials selected were simulated in all three stages (High Level, Inclined Level and Low Level) under four different rated loads (30000N, 40000N, 50000N and 70000N).

All the corresponding results according to the chosen stresses and selected materials under consideration have been displayed orderly in Levels with respect to stresses in chapter four. The following Figures (3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11 ,3.12, 3.13, 3.14, 3.15 and 3.16) display the mesh, fixed support, force applied, and material selection of the parts used for the analysis.

The Figures 3.5 – 3.8 shows the mesh, material assignment, load applied (N), and fixed support in Static Structural Analysis of the modified Lift at high Level using **Structural Steel** at 30000N.

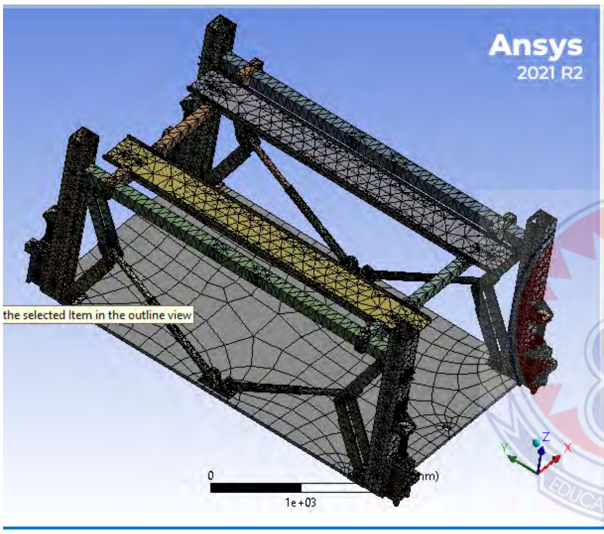


Figure. 3.5, Mesh

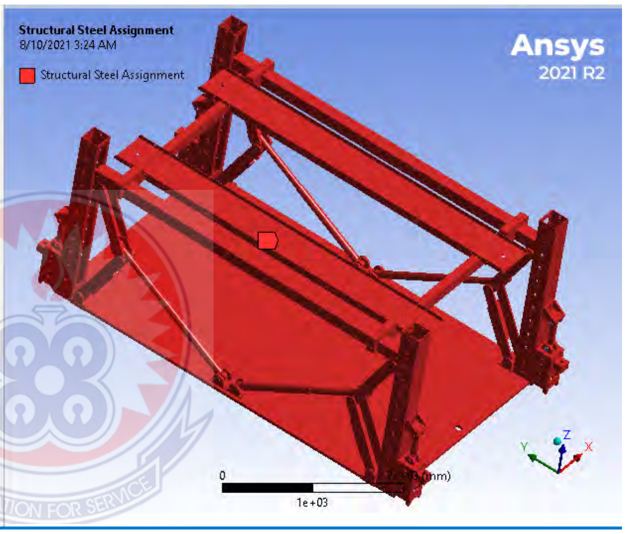


Figure. 3.6, Material Assignment

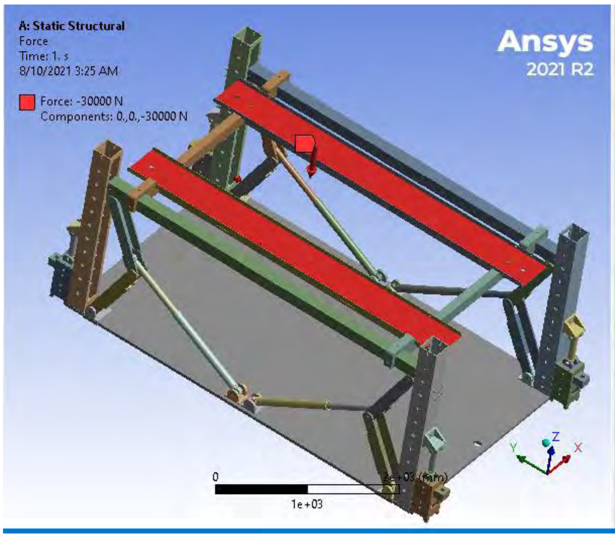


Figure. 3.7, force Applied

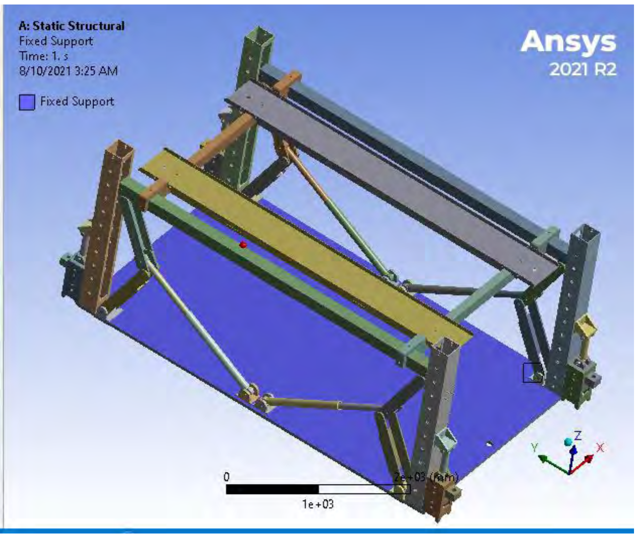


Figure. 3.8, Fixed Support

Figures shown 3.9 – 3.12 display the geometry of the load apply (N), fixed support, material assignment, and mesh in Static Structural Analysis of the New Lift at Inclined Level using Cast Iron at 30000N.

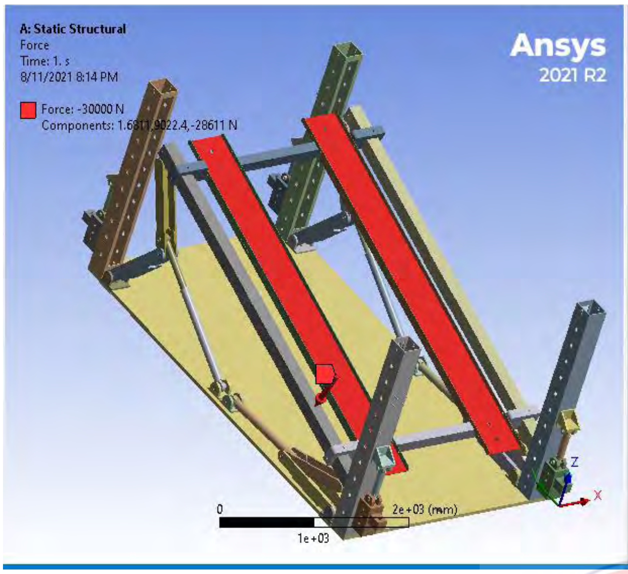


Figure. 3.9, force Applied

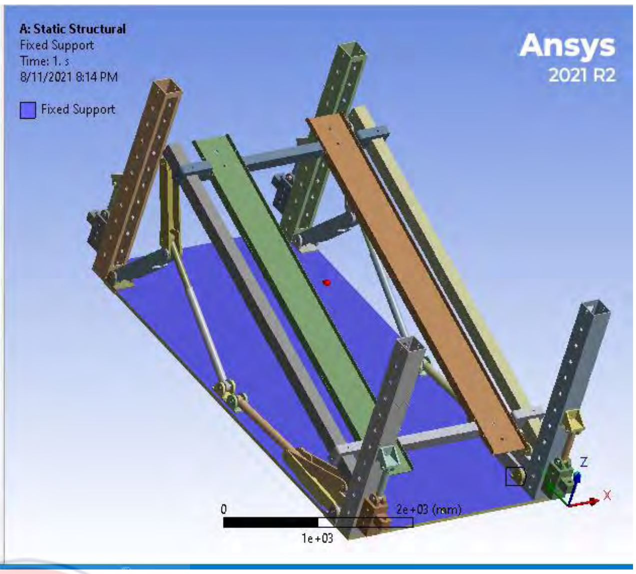


Figure. 3.10, Fixed Support

Figure. 3.11, Material Assignment

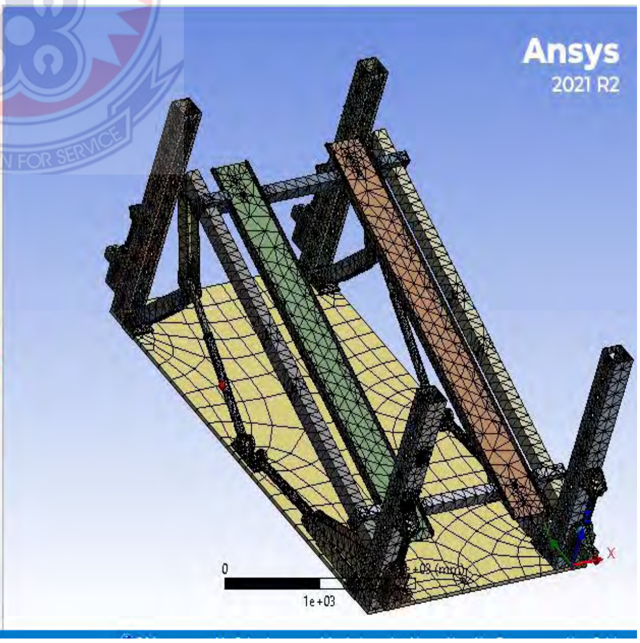


Figure. 3.12, Mesh

The Figures 3.13 – 3.16 display the geometry of the load apply (N), fixed support, material assignment, and mesh in Static Structural Analysis of the New Lift at Inclined Level using **Carbon steel 1020 Annealed** at 30000N.

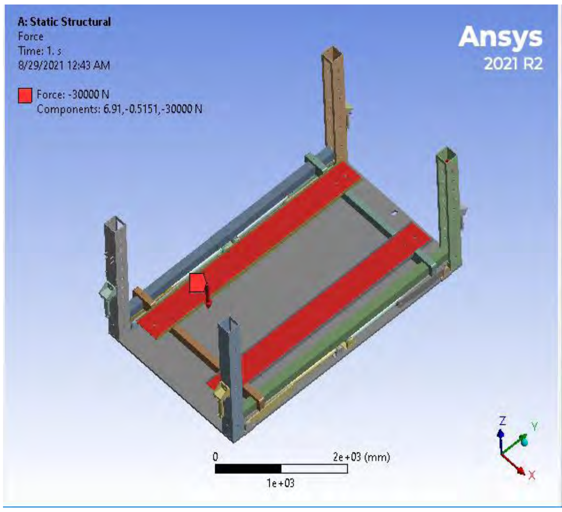


Figure. 3.13, force Applied

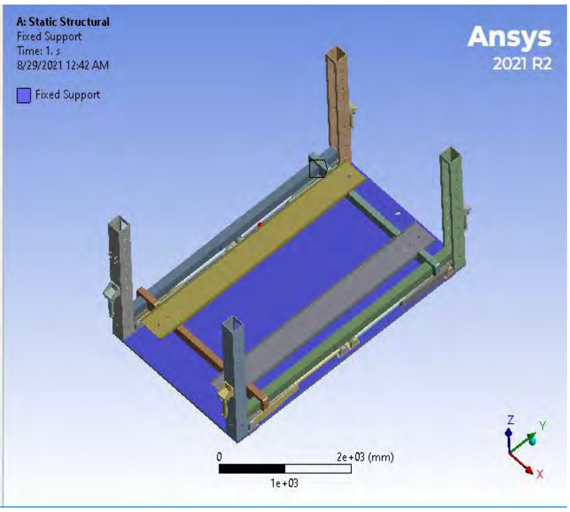


Figure.3.14, Fixed Support

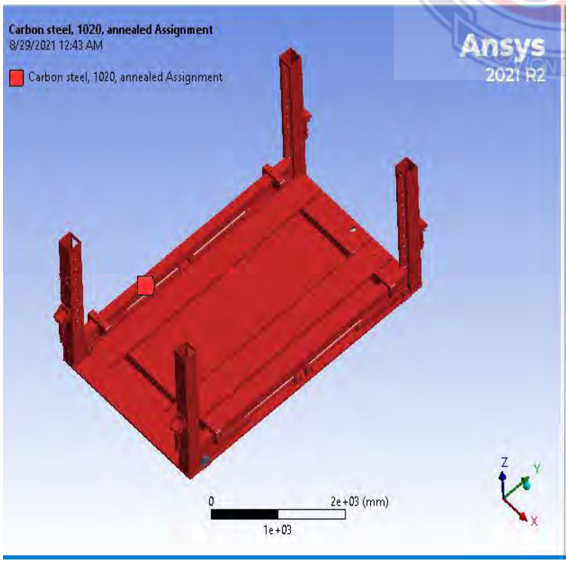


Figure. 3.15, force Applied

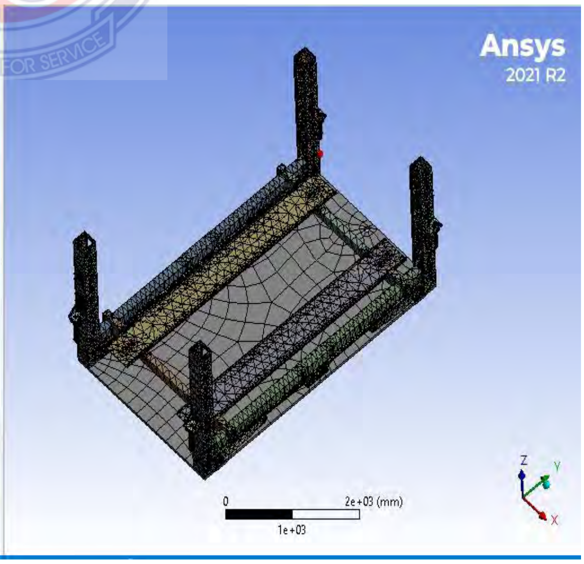


Figure.3.16, Fixed Support

CHAPTER FOUR

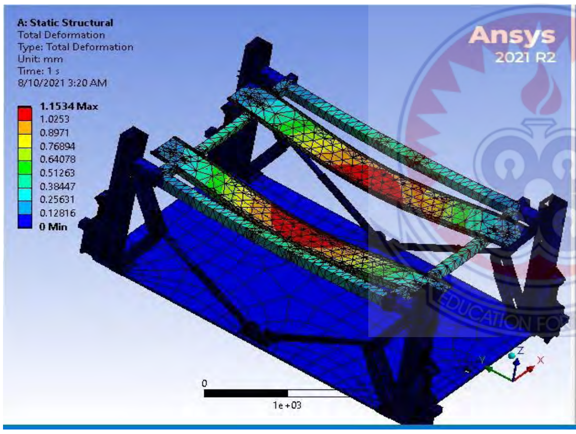
RESULTS AND DISCUSSIONS

4.1 INTRODUCTION.

This chapter present the static results and discussions of selected martials in three stages (High level, Inclined Level and Low Level) under 30000N – 70000N with Figures, Tables, Graphs and Histograms.

4.2 STATIC RESULTS OF STRUCTURAL STEEL AT HIGH LEVEL 30000N

Figures 4.1 – 4.4 shows the design of four post lift at high level and load of 30000N imposed on it. The result outlines the Total deformation of 1.1534, Von-Mises stress of 50.393, the Shear stress of 13.491 and equivalent strain 0.00028045 of Static Structural Analysis.



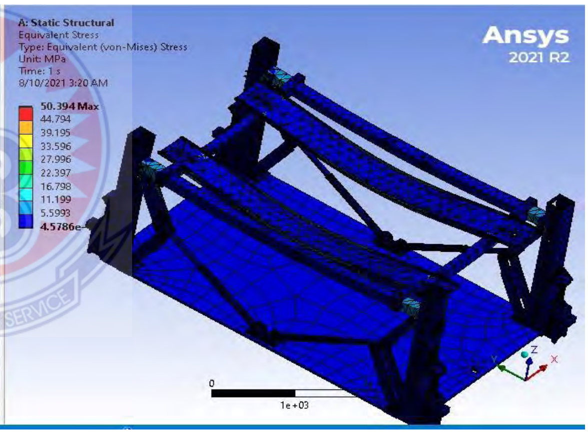
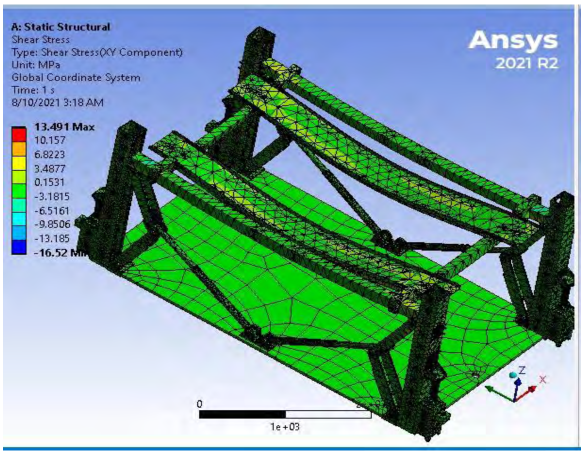


Fig. 4.1: Total deformation; 1.1534, **Fig. 4.2: Von-Mises stress; 50.394**



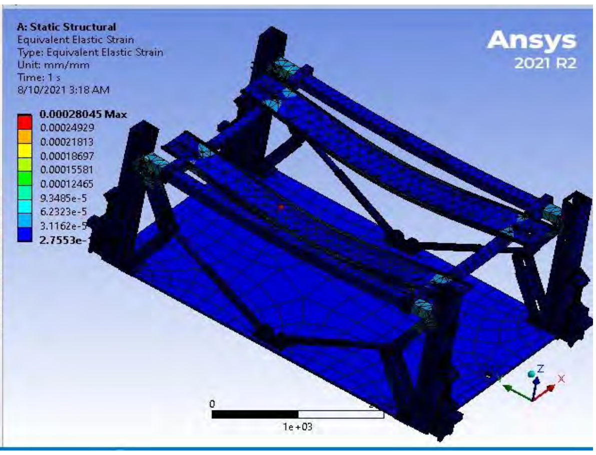
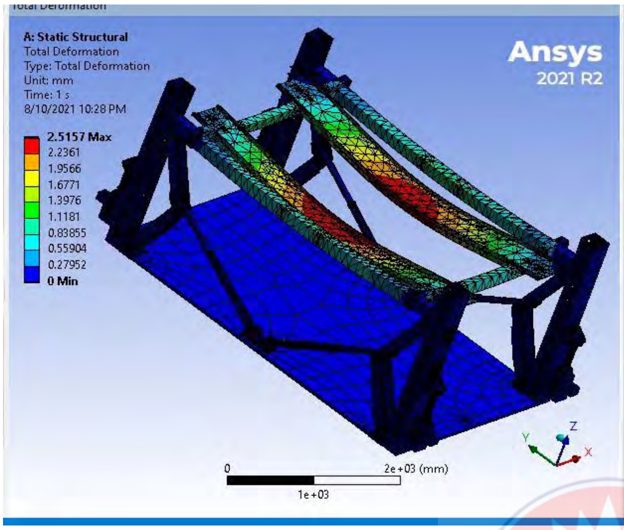


Fig. 4.3: Shear stress; 13.491 **Fig. 4.4: Equivalent strain; 0.00028045**

4.3 STATIC RESULTS OF CAST IRON AT HIGH LEVEL 30000N

Figure 4.5 - 4.8, shows the design of four post lift at high level and load of 30000N imposed on it. The results display the Total deformation of 2.5157, Von-Mises stress of 66.866, the Shear stress of 21.732 and equivalent strain 0.00065505 of Static Structural Analysis.



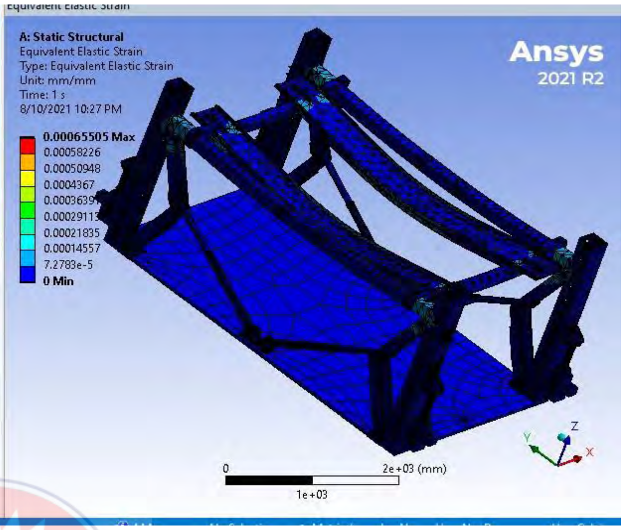
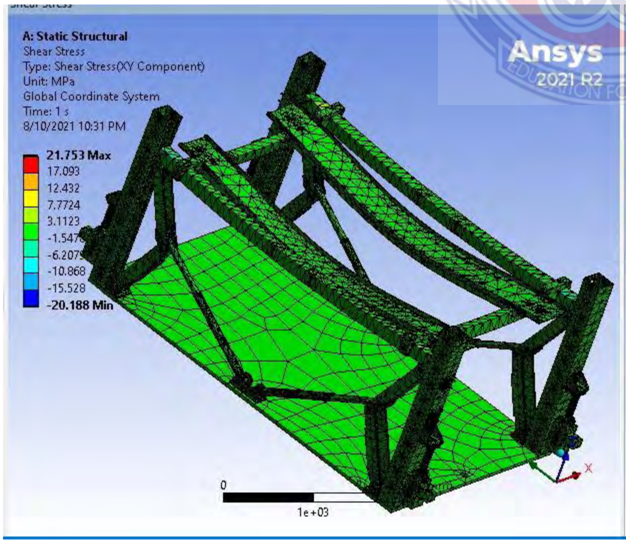


Fig. 4.5: Total deformation of 2.5157 **Fig. 4.6: Von-Mises stress; 66.866,**



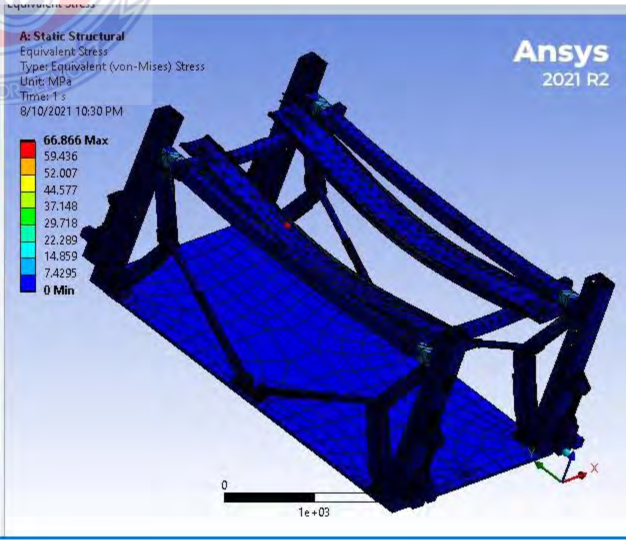


Fig. 4.7: Shear stress of 21.732 **Fig. 4.8: Equivalent strain; 0.00065505**

4.4 STATIC RESULTS OF CARBON STEEL ANNEALED AT HIGH LEVEL 30000N

Figures 4.9 – 4.12 show the design of four post lift at high level and load of 30000N imposed on it. The result shows the Total deformation of 1.0879, Von-Mises stress of 51.433, the Shear stress of 13.017 and Equivalent strain 0.00026958 of Static Structural Analysis.

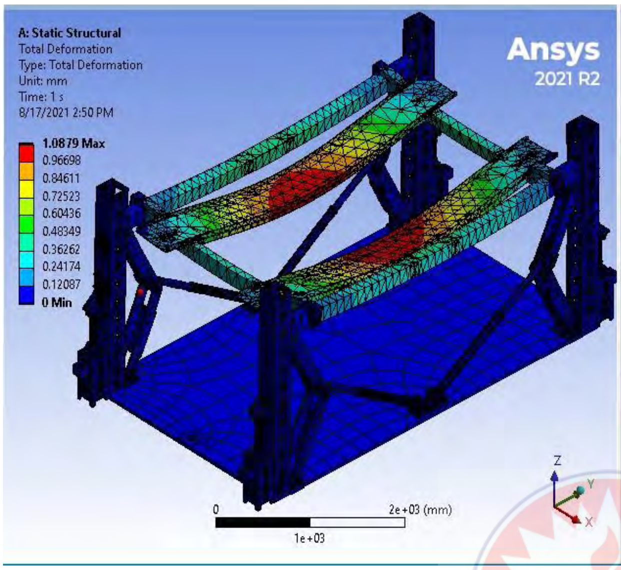


Fig. 4.9: Total deformation; 1.0879

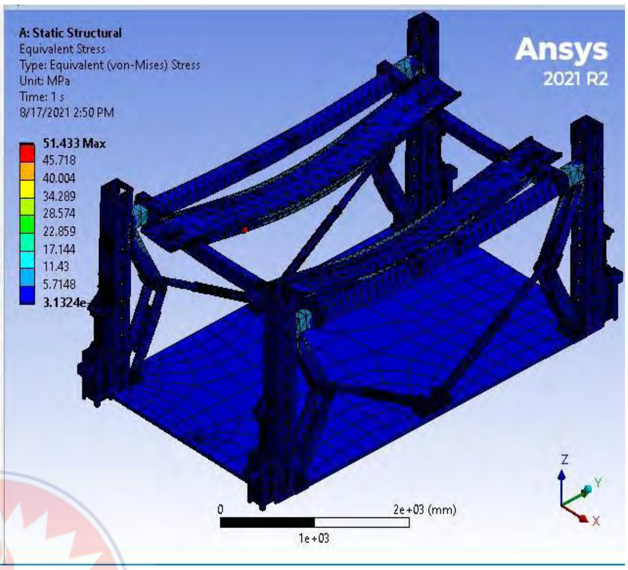


Fig. 4.10: Von-Mises stress; 51.433

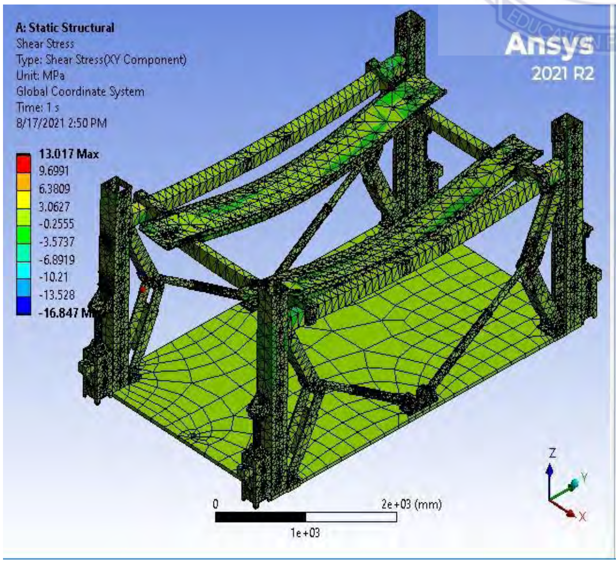


Fig. 4.11: Shear stress; 13.017

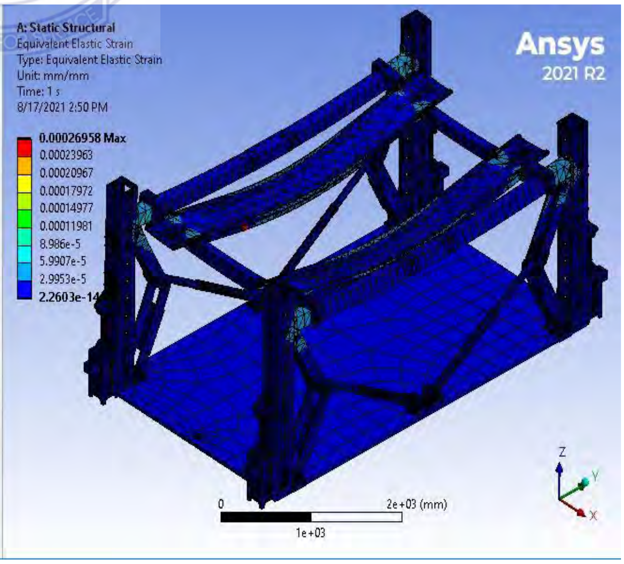


Fig. 4.12: Equivalent strain; 0.00026958

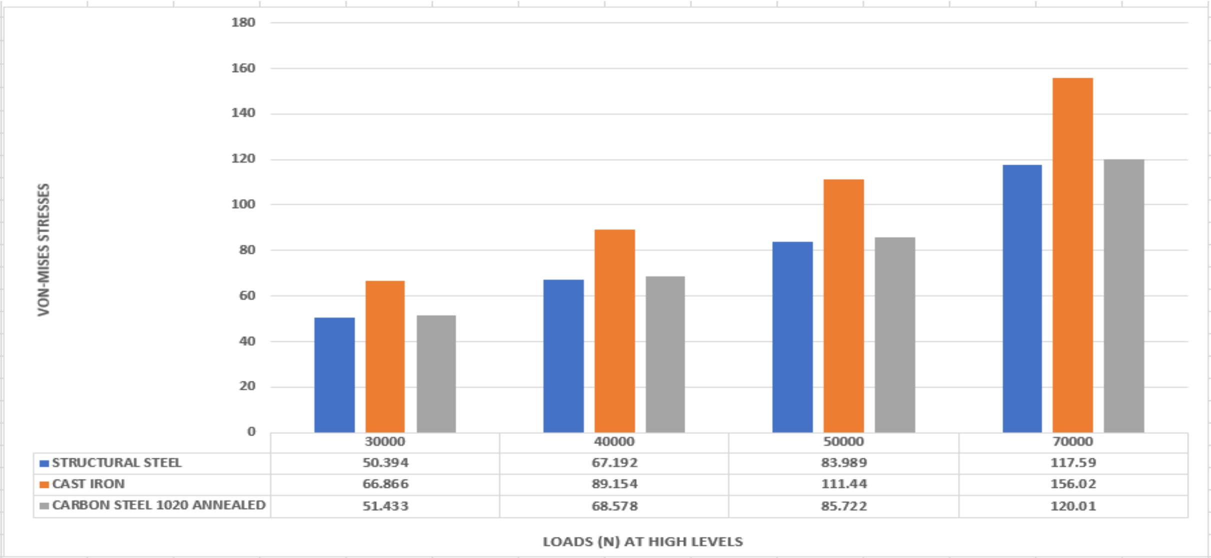
4.5 COMPARATIVE ANALYSIS OF MATERIALS

a. **Von Mises Stresses, lift at high levels:** The results of this static structural analysis in Figures, 4.2, 4.6, 4.10 under 30000N and further results in 40000N, 50000N, 70000N shows that the equivalent (Von-Misses) stress of the structural steel at high levels are the smallest one followed by carbon steel annealed under the same load and boundary conditions where as compared to cast iron the difference is higher. This implies that structural steel and carbon steel annealed have less stressed and better performance as shown in table 4.1 and histogram 4.1.

Table 4.1: High Levels: Von – Mises Stresses

VON-MISES STRESES AT HIGH LEVELS				
LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
		Von-MISES	Von- MISES	Von- MISES
30000	HIGH	50.394	66.866.	51.433.
40000	HIGH	67.192	89.154	68.578
50000	HIGH	83.989	111.44	85.722
70000	HIGH	117.59	156.02	120.01

Histogram. 4.1: Showing Von-Mises Stresses at High Level

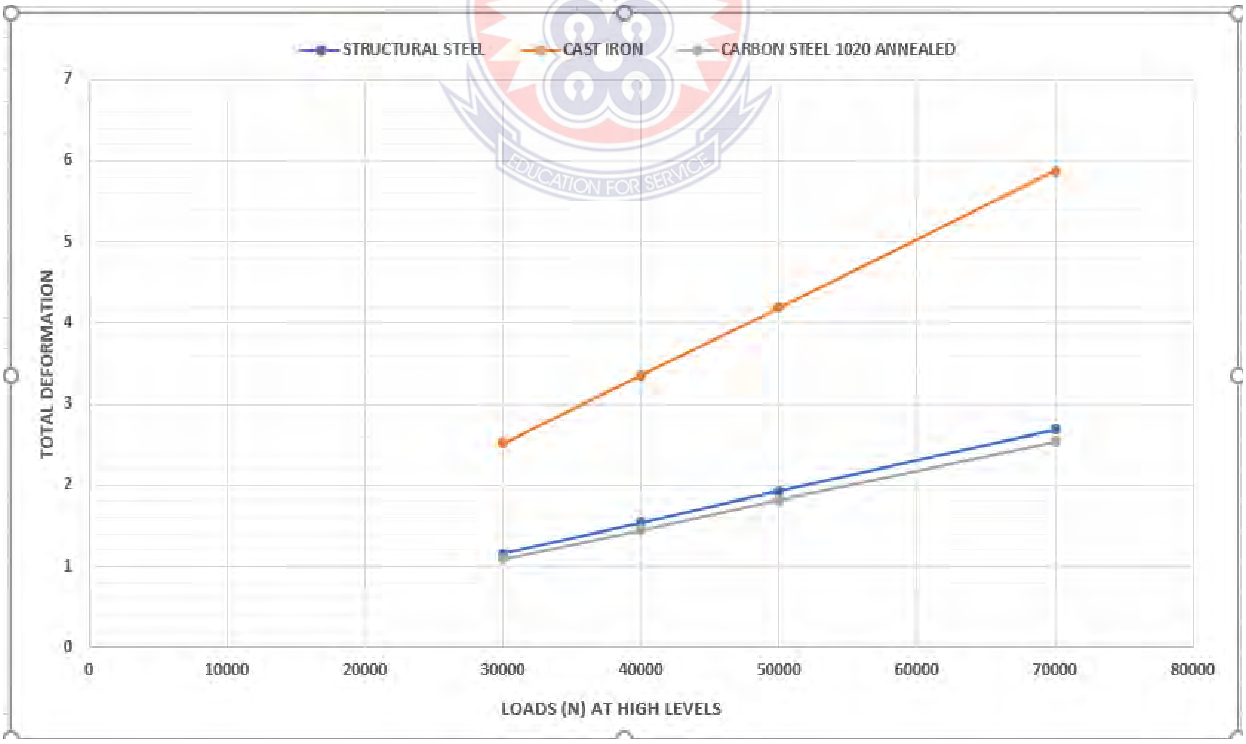


b. **Total Deformations: lift at high level.** The results of this static structural analysis in Figures, 4.1, 4.5, 4.9 under 30000N and further results in 40000N, 50000N, 70000N, and the graph 4.1 displayed clearly explain that, the maximum displacements of carbon steel 1020 annealed and structural steel have the lowest deformation value compare with that of the cast iron. When external loads applied to the unit or the structure, it may deform or elongate according to the nature of the applied load.

In other words, since the total deformations are higher in the middle of the wheel platforms and less at the front and rear ends of the lift where the wheels will be, it is safe.

Also, the deformation is just 1.1534 at maximum (under the rated load of the unit) which is less than 2mm, so it will not have any effect on the unit because, the solution/unit was in millimeters (an effect which is difficult to be seen).

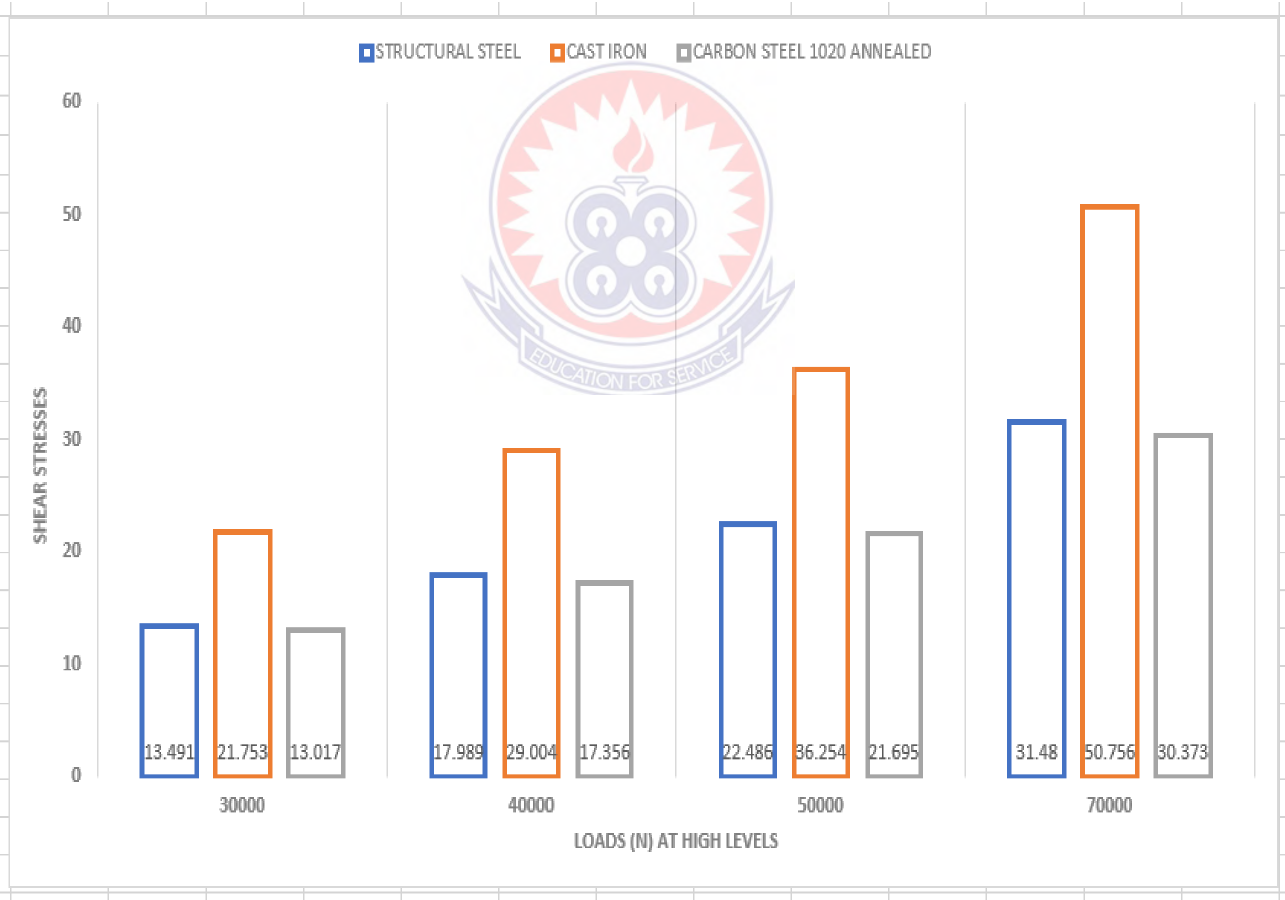
Graph. 4.1: Showing Total Deformations at high level



c. **Sear Stresses, lift at high levels.** The results of this static structural analysis in Figures, 4.3, 4.7, 4.11 under 30000N further results in 40000N, 50000N, 70000N as displayed in the various loading and boundary condition results indicates clearly that the shear stresses of carbon steel annealed and structural steel performed creditably as compared to cast iron, as demonstrated by histogram 4.2. This also authenticate that the unit will be safer to be made by the said materials as the have proven to be better than cast iron.

Also, the colour of the results under 30000N which was 0.1531also shows that the unit is save and better in the analysis.

Histogram. 4.2: Showing Shear Stresses at high level.



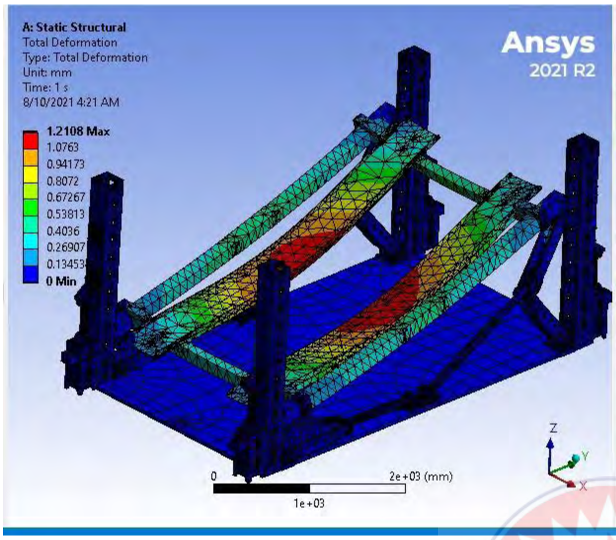
d. **Equivalent Elastic Strains, lift at high levels.** The results of this static structural analysis in Figures, 4.4, 4.8, 4.12 under 30000N and further results in 40000N, 50000N, 70000N and all the indications from the various solutions have proven that the equivalent stresses of structural steel and carbon steel annealed have proven in producing good results which are very close and certified as compared to cast iron at high levels under consideration. The table 4.2, outline the performance of structural steel and carbon steel annealed as compared to cast iron. Also, the colour of the results under 30000N which is 2.7553 shows the unit is safe to be used.

Table. 4.2: High Levels, Equivalent Elastic Strains

EQUIVALENT ELASTIC STRAINS AT HIGH LEVELS				
LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
		Equivalent Strain	Equivalent Strain	Equivalent Strain
30000	HIGH	0.00028045	0.00065505	0.000269958
40000	HIGH	0.00037394	0.0008734	0.00035944
50000	HIGH	0.00046742	0.0010917	0.0004493
70000	HIGH	0.00065439	0.0015284	0.00062902

4.6 STATIC RESULTS OF STRUCTURAL STEEL AT INCLINED LEVEL 30000N

Figures 4.13 - 4.16 show the design of four post lift at high level and load of 30000N imposed on it. The results display the Total deformation of 1.2108, Von-Mises stress of 53.072, the Shear stress of 20.928 and Equivalent strain 0.00028989 of Static Structural Analysis.



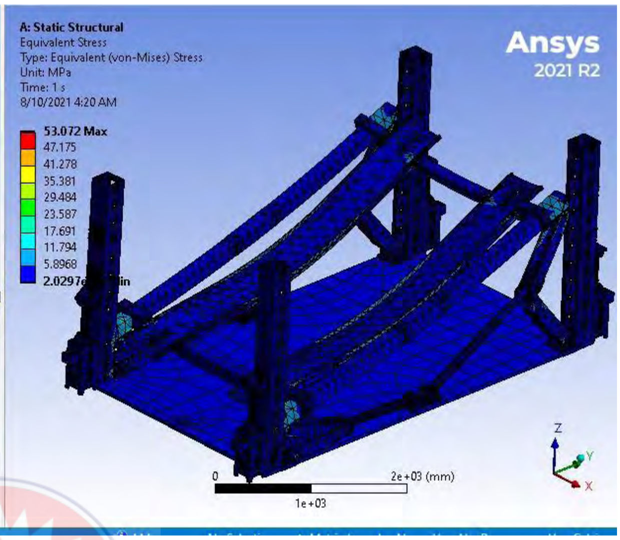
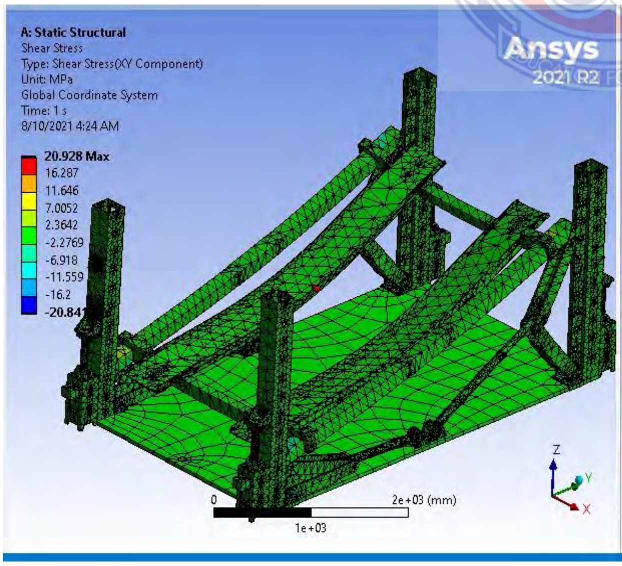


Fig. 4.13: Total deformation; 1.2108 **Fig. 4.14: Von-Mises stress; 53.072**



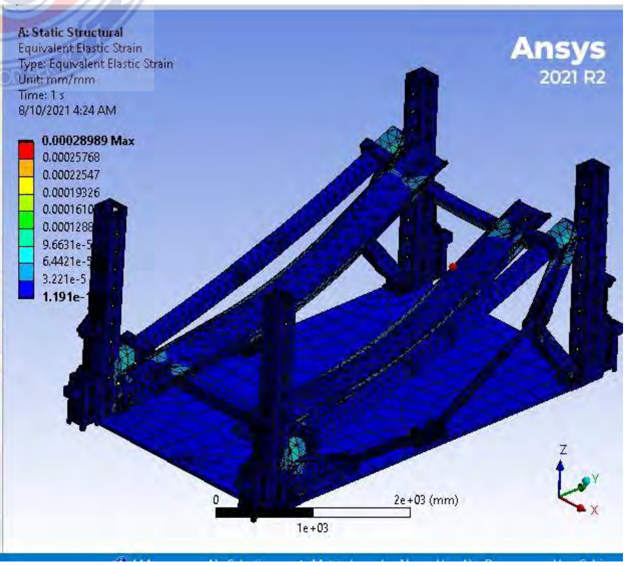
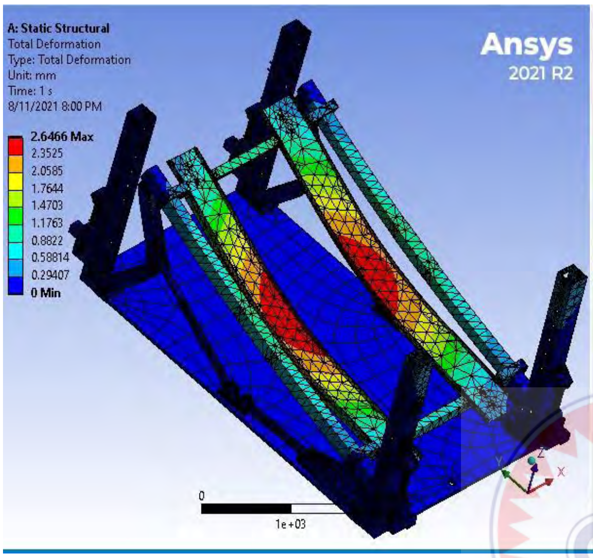


Fig. 4.15: Shear stress; 20.928 **Fig. 4.16: Equivalent strain; 0.00028989**

4.7 STATIC RESULTS OF CAST IRON AT INCLINED LEVEL 30000N

Figures 4.17 – 4.20 show the design of four post lift at high level and load of 30000N imposed on it. The result outlines the Total deformation of 2.6466, Von-Mises stress of 83.73, the Shear stress of 39.592 and Equivalent strain 0.00067547 of Static Structural Analysis.



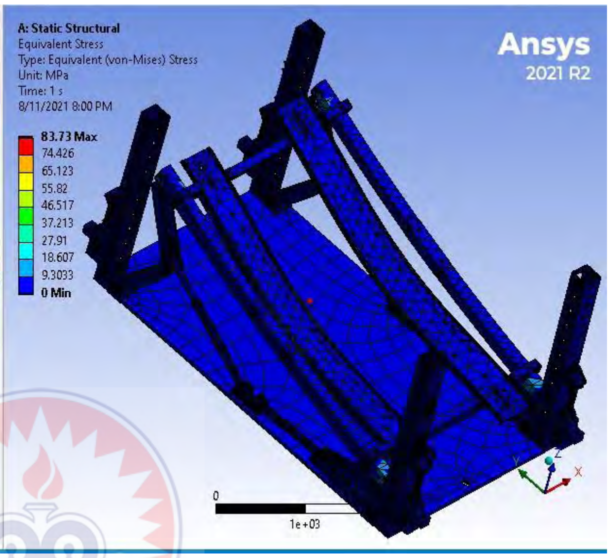
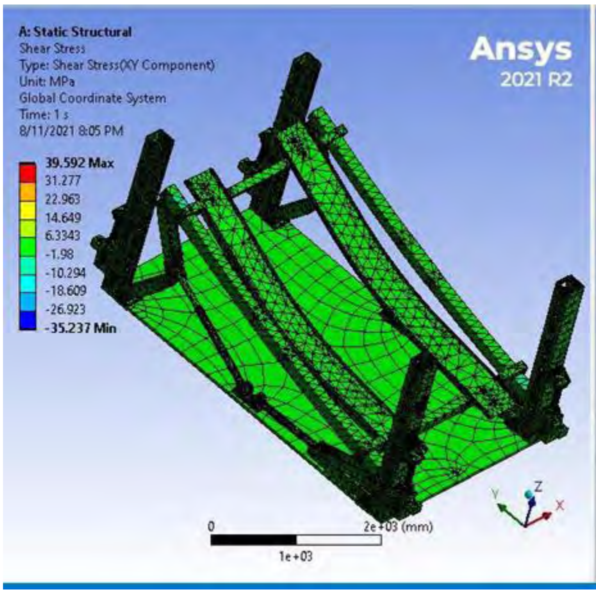


Fig. 4.17: Total deformation; 2.6466 **Fig. 4.18: Von-Mises stress; 83.73,**



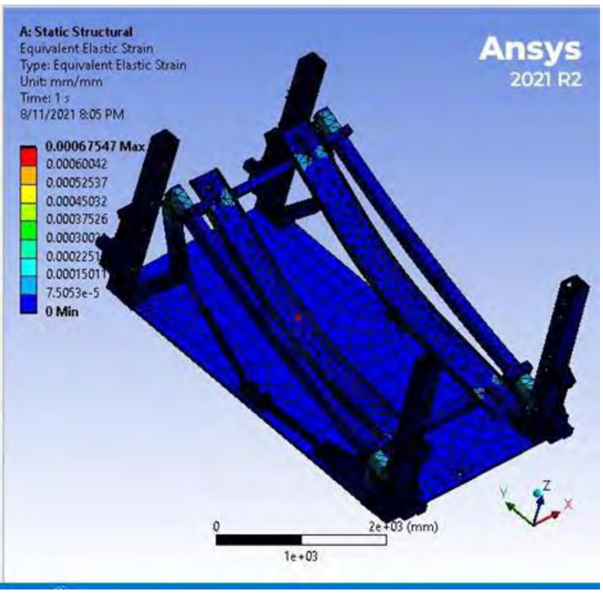
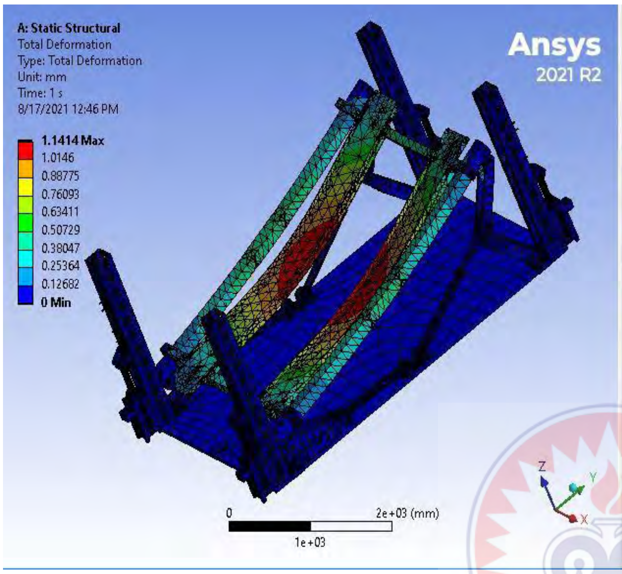


Fig. 4.19: Shear stress; 39.592 **Fig. 4.20: Equivalent strain; 0.00067547**

4.8 RESULTS OF CARBON STEEL ANNEALED AT INCLINED LEVEL 30000N

Figures 4.21 – 4.24 show the design of four post lift at high level and load of 30000N imposed on it. The results demonstrate the Total deformation of 1.1414, Von-Mises stress of 52.196, the Shear stress of 20.212 and Equivalent strain 0.00027859 of Static Structural Analysis.



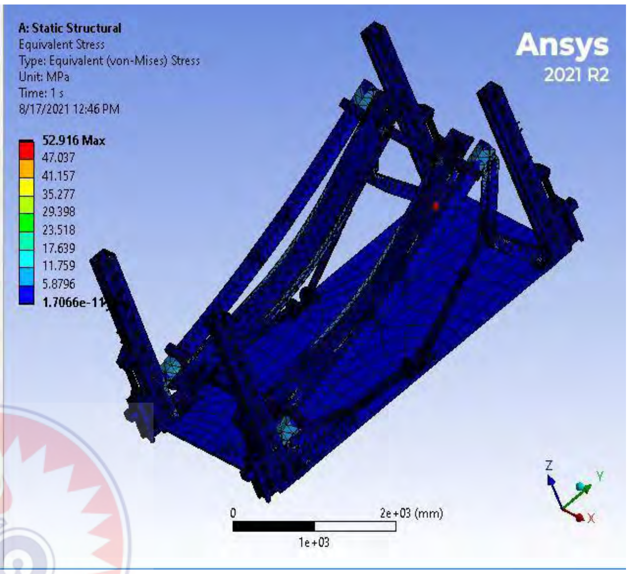
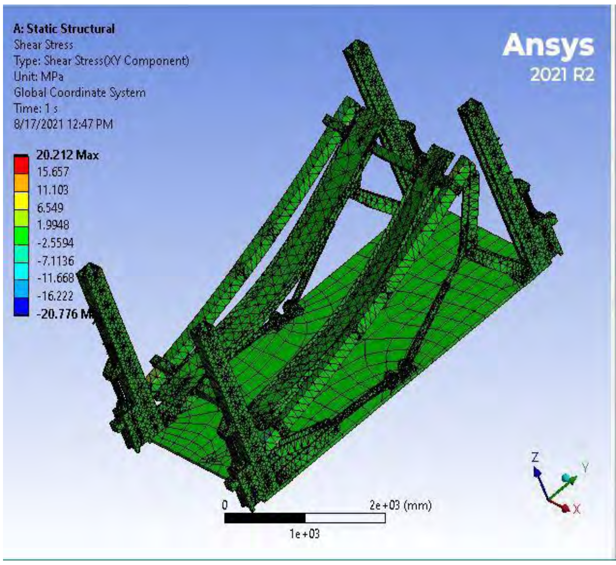


Fig. 4.21: Total deformation; 1.1414

Fig. 4.22: Von-Mises stress; 52.196



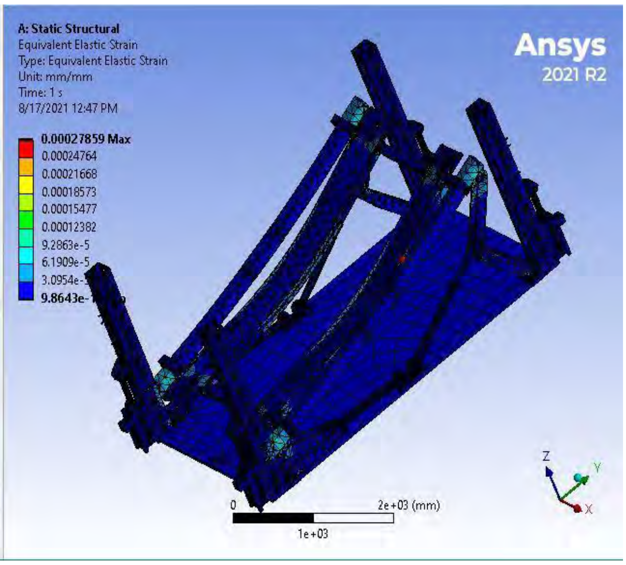


Fig. 4.23: Shear stress; 20.212

Fig. 4.24: Equivalent strain; 0.00027859

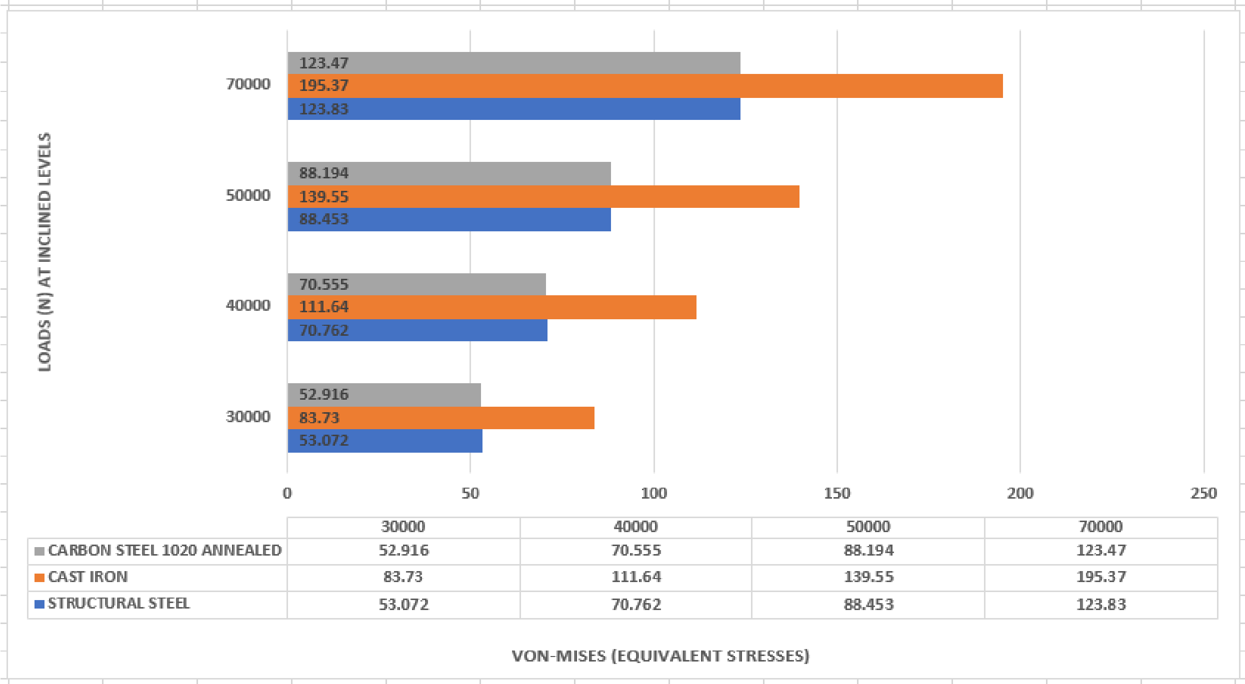
4.9 COMPARATIVE ANALYSIS OF MATERIALS

a. **Von Mises Stresses, lift at inclined levels:** The results of this static structural analysis in Figures, 4.14, 4.18, 4.22 under 30000N further results in 40000N, 50000N, 70000N shows that the equivalent (Von-Misses) stress of carbon steel annealed and structural steel at inclined levels are the smallest as compared to cast iron.

Also, subtracting (50.394 from 51.433 at high level = 1.039), as compared to that of inclined level of (53.072 from 52.916, will be 0.156), this show that the gap at high level is higher than that of inclined level which makes the structural steel always proven to be good under all test solutions. Cast iron still remains the weakest.

In addition to this, using the ANSYS 2021 R2 Workbench software, the values of equivalent (Von-Misses) stress found along with the given boundary conditions and applied loads of 30000N as the rated capacity shows that structural steel and carbon steel 1020 annealed can withstand the load perfectly according to the yield strength of the material (250 MPa). The histogram 4.3, shown demonstrate the performance of three materials with respect to Von-Mises stress at inclined levels.

Histogram. 4.3: Showing Von-Mises Stresses at high levels



	30000	40000	50000	70000
▨ CARBON STEEL 1020 ANNEALED	52.916	70.555	88.194	123.47
▨ CAST IRON	83.73	111.64	139.55	195.37
▨ STRUCTURAL STEEL	53.072	70.762	88.453	123.83

b. **Total deformation at inclined level.** The results of this static structural analysis in Figures, 4.13, 4.17, 4.21 under 30000N further results in 40000N, 50000N, 70000N and graph 4.2, demonstrates clearly, or attest that the maximum displacement of carbon steel annealed and structural steel have the smallest deformation values compared to cast iron and that the external loads may elongate according to the nature of the applied load.

Graph. 4.2: Showing Total deformation at inclined levels

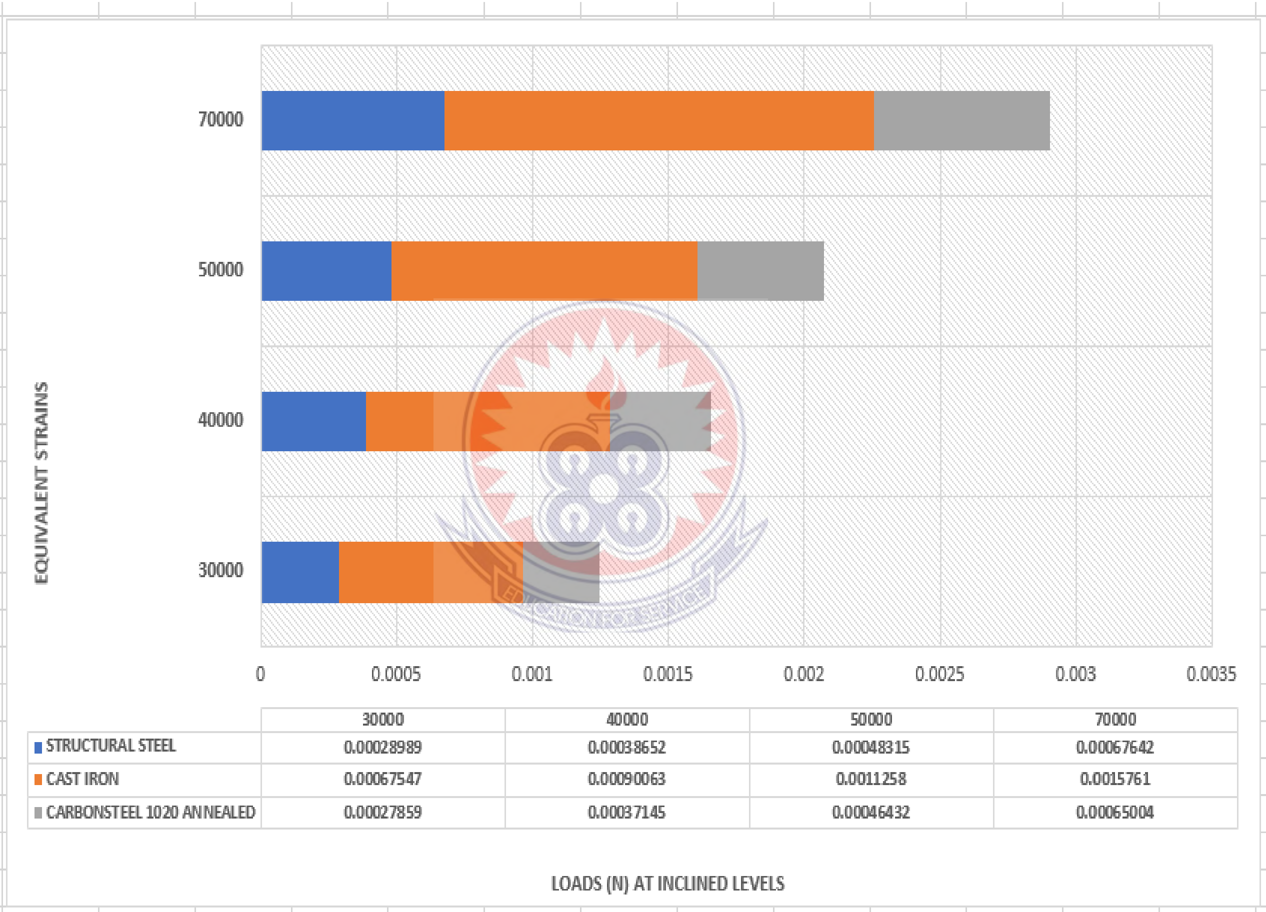
c. **Shear stress at inclined levels.** The results of this static structural analysis in Figures, 4.15, 4.19, 4.23 under 30000N further results in 40000N, 50000N, 70000N, and the table 4.3 shown indicates that the shear stresses of carbon steel annealed and structural steel shows almost an equal value as compared to Cast Iron which is higher. This indicates that the lift will have a good shear stress for structural steel and carbon steel annealed than cast iron under the same boundary condition.

Table. 4.3: **Inclined Levels: Shear Stresses**

SHEAR STRESSES AT INCLINED LEVELS				
LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
		Shear Stress	Shear Stress	Shear Stress
3000	INCLINED	20.928	39.592	20.212
40000	INCLINED	27.905	52.788	26.949
50000	INCLINED	34.881	65.985	33.686
70000	INCLINED	48.833	92.379	47.16

d. **Equivalent Elastic Strain at inclined level.** The results of this static structural analysis in Figures, 4.16, 4.20, 4.24 under 30000N further results in 40000N, 50000N, 70000N and the histogram 4.4, shown and all the indications from the graph shows that the equivalent stresses of structural steel and carbon steelannealed have good test than cast iron considering equivalent strains of the results.

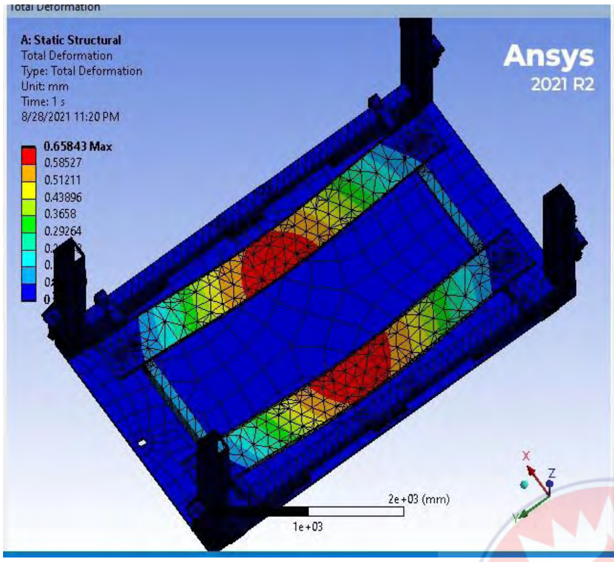
Histogram. 4.4: Equivalent Elastic Strain at inclined level



	30000	40000	50000	70000
■ STRUCTURAL STEEL	0.00028989	0.00038652	0.00048315	0.00067642
■ CAST IRON	0.00067547	0.00090063	0.0011258	0.0015761
■ CARBONSTEEL 1020 ANNEALED	0.00027859	0.00037145	0.00046432	0.00065004

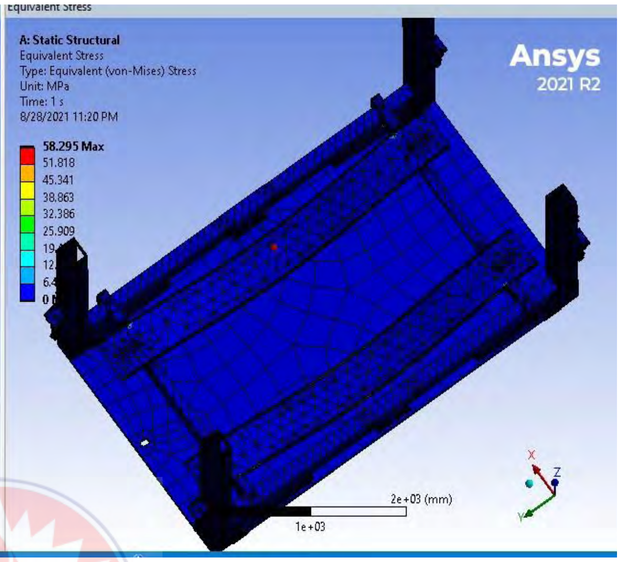
4.10 STATIC RESULST OF STRUCTURAL STEEL AT LOW LEVEL 30000N

Figures 4.25 – 4.28 show the design of four post lift at high level and load of 30000N imposed on it. The result outlines the Total deformation of 0.65843, Von-Mises stress of 58.295, the Shear stress of 6.1036 and equivalent strain 0.00032175 of Static Structural Analysis.



Total Deformation

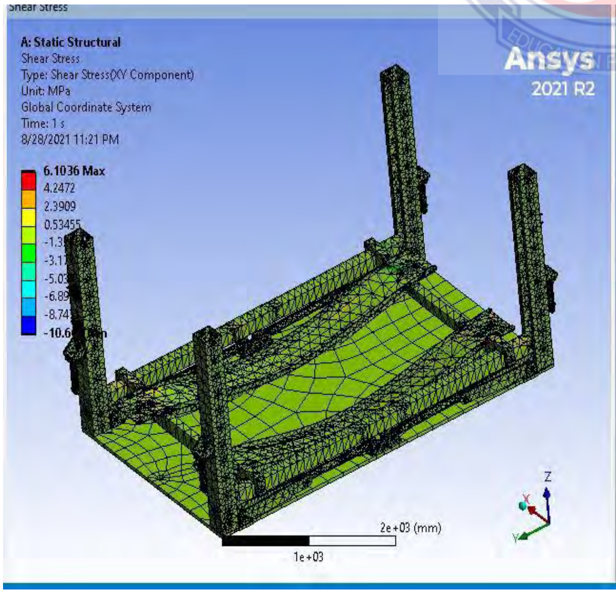
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
8/28/2021 11:20 PM



Equivalent Stress

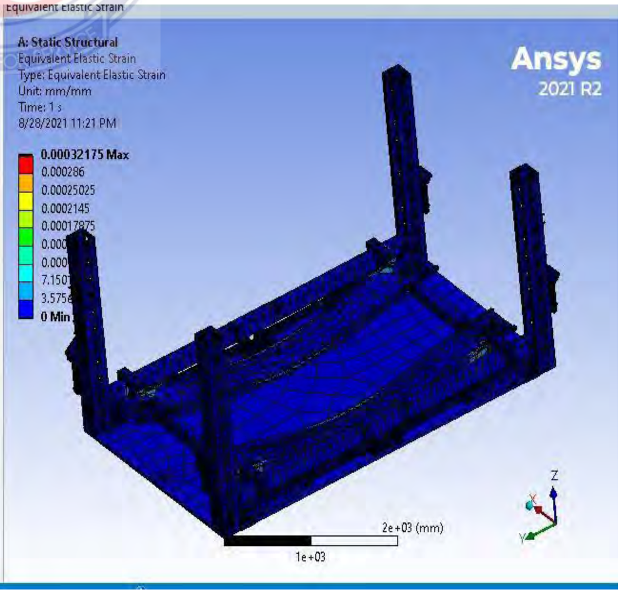
A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
8/28/2021 11:20 PM

Fig. 4.25: Total deformation; 0.65843 **Fig. 4.26: Von-Mises stress; 58.295**



Shear Stress

A: Static Structural
Shear Stress
Type: Shear Stress(XY Component)
Unit: MPa
Global Coordinate System
Time: 1 s
8/28/2021 11:21 PM



Equivalent Elastic Strain

A: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain
Unit: mm/mm
Time: 1 s
8/28/2021 11:21 PM

Fig. 4.27, Shear stress; 6.1036 **Fig. 4.28, equivalent strain; 0.00032175**

4.11 STATIC RESULST OF CAST IRON AT LOW LEVEL 30000N

Figures 4.29 – 4.32 show the design of four post lift at high level and load of 30000N imposed on it. The results display the Total deformation of 1.4693, Von-Mises stress of 58.457, the Shear stress of 6.5201 and Equivalent strain 0.00071952 of Static Structural Analysis.

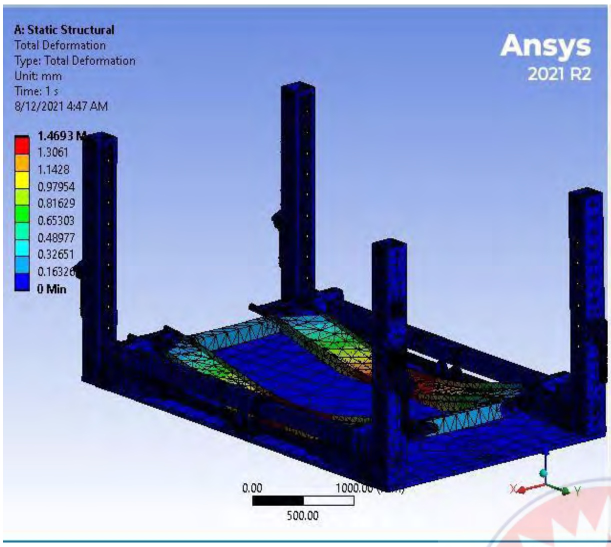


Fig. 4.29: Total deformation; 1.4693,

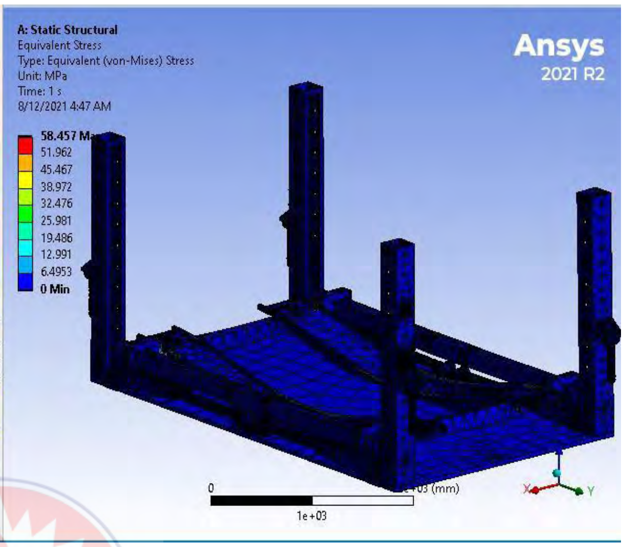


Fig. 4.30: Von-Mises stress; 58.457

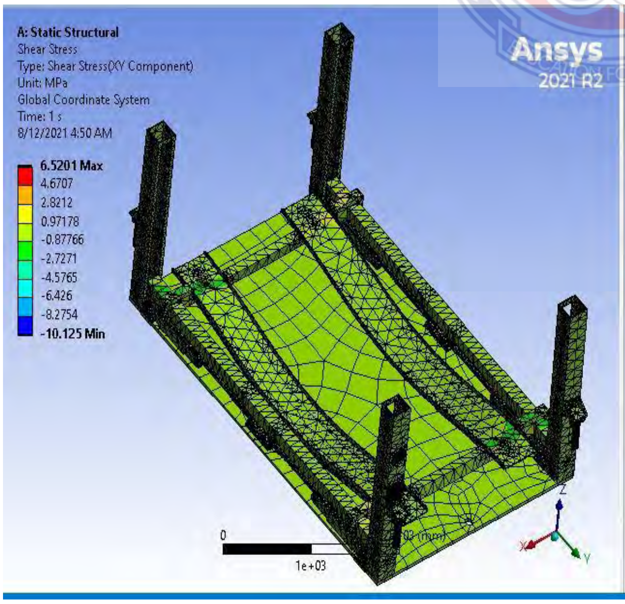


Fig. 4.31: Shear stress; 6.5201

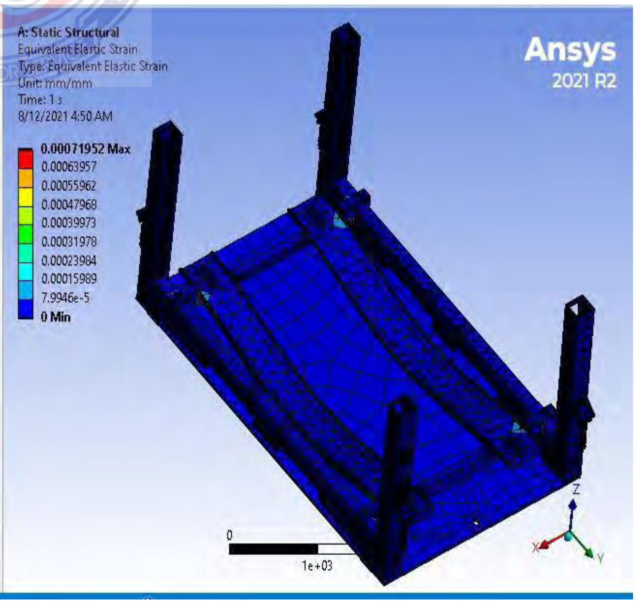


Fig. 4.32: Equivalent strain; 0.00071952

1.12 RESULST OF CARBON STEEL 1020 ANNEALED AT LOW LEVEL 30000N Figures 4.33 – 4.36 show the design of four post lift at high level and load of 30000N imposed on it. The results demonstrate the Total deformation of 0.61989, Von-Mises stress of 58.339, the Shear stress of 6.1674 and Equivalent strain 0.00030295 of Static Structural Analysis.

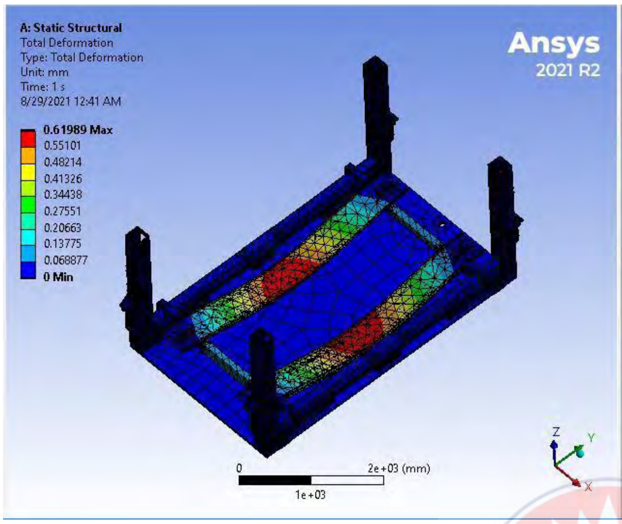


Fig. 4.33: Total deformation; 0.61989

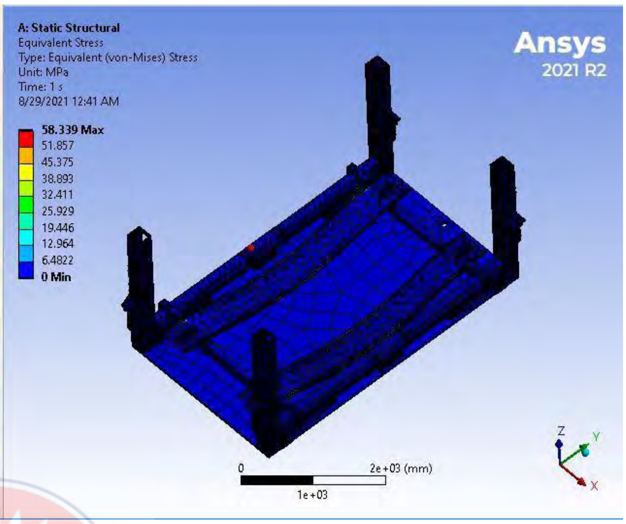


Fig. 4.34: Von-Mises stress; 58.339

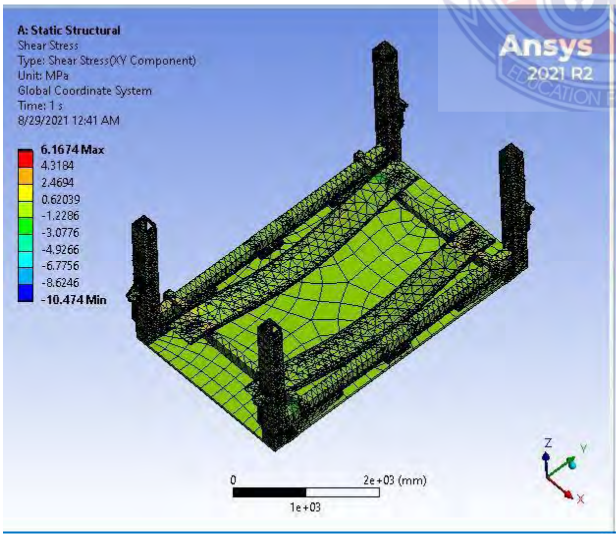


Fig. 4.35: Shear stress; 6.1674

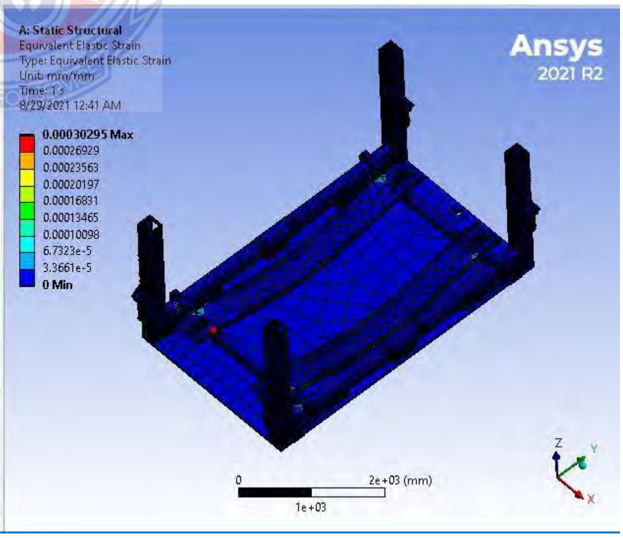


Fig. 4.36: Equivalent strain; 0.00030295

1.13 COMPARATIVE ANALYSIS OF MATERIALS

a. Von Mises Stresses, lift at low levels: The results of this static structural analysis in Figures, 4.26, 4.30, 4.34 under 30000N further results in 40000N, 50000N, 70000N the table 4.4, shown**,** and the histogram 4.5, shows that the equivalent (Von-Misses) stress of the structural steel, carbon steel annealed and cast iron at low levels have smallest values and a little marginal gap over each other as structural steel showing creditably good by leading under the same load and boundary conditions but since cast iron is always at the apex, structural steel and carbon steel annealed have always proven to be the best materials for the unit.

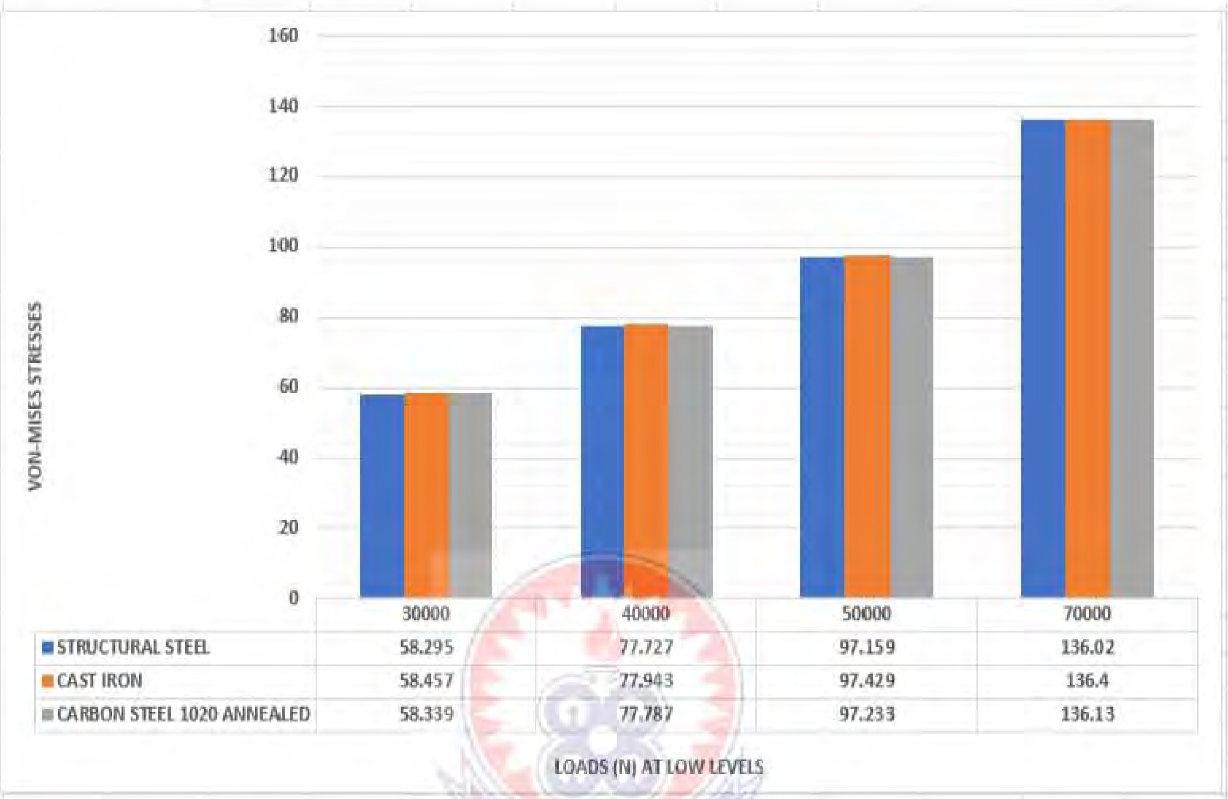
Table. 4.4: Low Levels: Von-Mises Stresses

VON-MISES STRESES AT LOW LEVELS:				
LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
		Von-Mises	Von-Mises	Von-Mises
3000	LOW	58.295	58.457	58.339
40000	LOW	77.727	77.943	77.787
50000	LOW	97.159	97.429	97.233
70000	LOW	136.02	136.4	136.13

The Equivalent (Von Misses) stress, based on distortion energy failure theory, has shown to be particularly effective in the prediction of failure for ductile materials and widely used by designers to check whether their design will withstand a given load condition.

Using the Ansys 2021 R2 Workbench software, the values of equivalent (Von-Misses) stress found along with the given boundary conditions and applied loads of 30000N, 40000N as the rated capacity shows that all the three materials can withstand the load perfectly according to the yield strength of the material as demonstrated below as follows;

Histogram. 4.5: Showing Von Mises Stresses at low levels

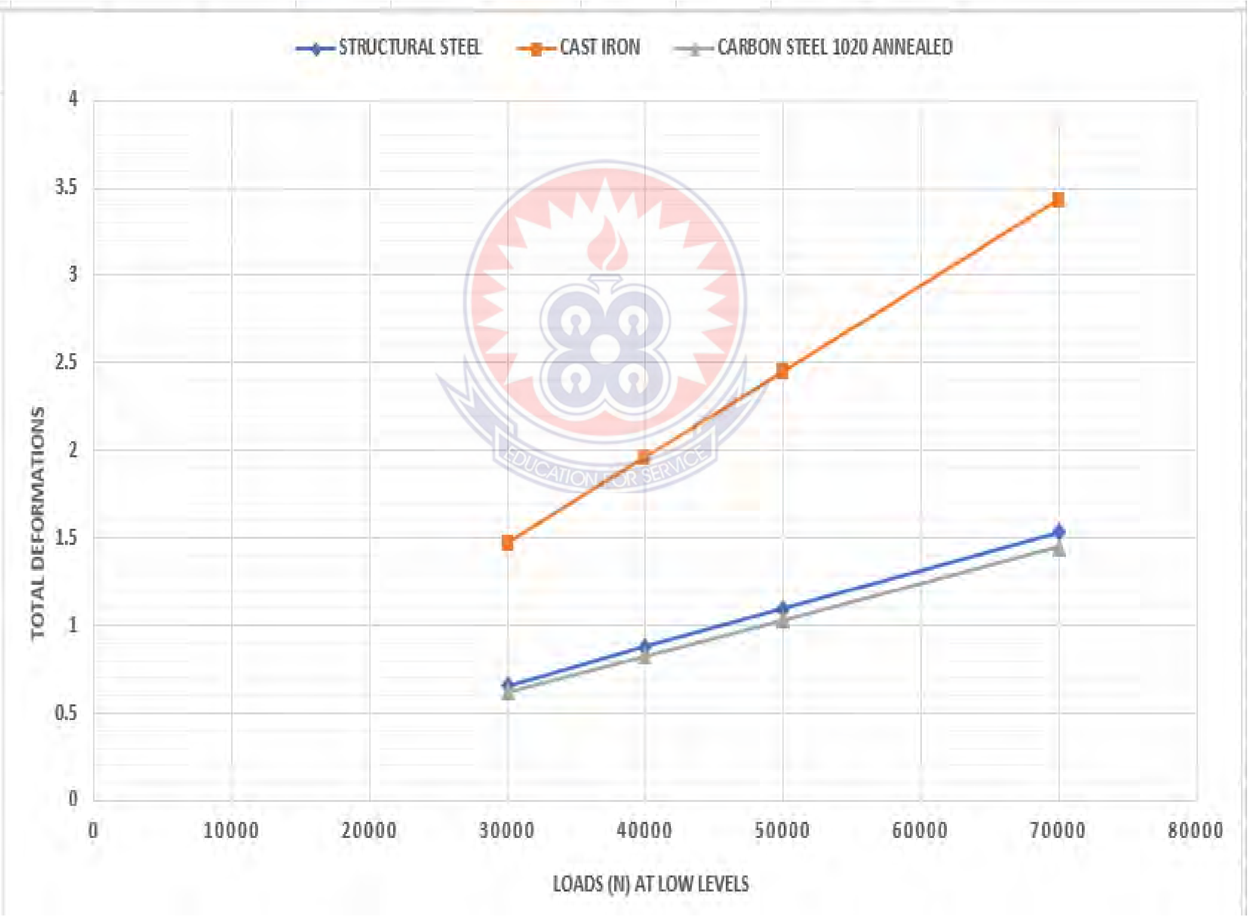


	30000	40000	50000	70000
■ STRUCTURAL STEEL	58.295	77.727	97.159	136.02
■ CAST IRON	58.457	77.943	97.429	136.4
■ CARBON STEEL 1020 ANNEALED	58.339	77.787	97.233	136.13

b. **Total Deformations: lift at low level.** The results of this static structural analysis in Figures, 4.25, 4.29, 4.33 under 30000N further results in 40000N, 50000N, 70000N and graph 4.3 displayed, shows that the maximum displacements of carbon steel 1020 annealed external loads applied to the unit or the structure, it may deform or elongate according to the nature of the applied load.

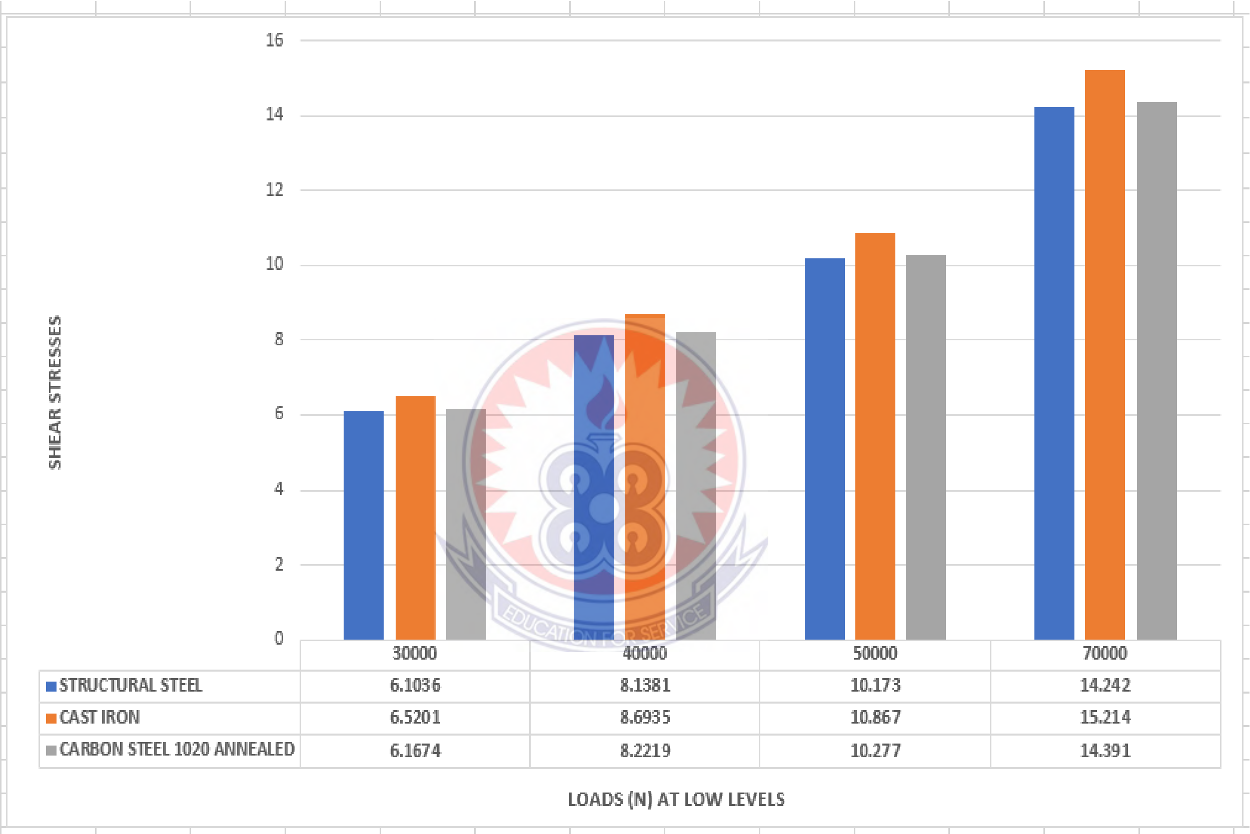
In other words, since the total deformations are higher in the middle of the wheel platforms and less at the front and rear ends of the lift where the wheels will be, it is safe.

Graph. 4.3: Showing Total Deformations at low level.



c. **Sear Stresses, lift at low levels.** The results of this static structural analysis in Figures, 4.27, 4.31, 4.35 under 30000N further results in of 40000N, 50000N and 70000N as displayed in the various loading and boundary condition, it indicates clearly that the shear stresses of structural steel and carbon steel annealed performed creditably with little difference as compared to cast iron, shown in histogram 4.6. This also indicate that the unit will be safer to use.

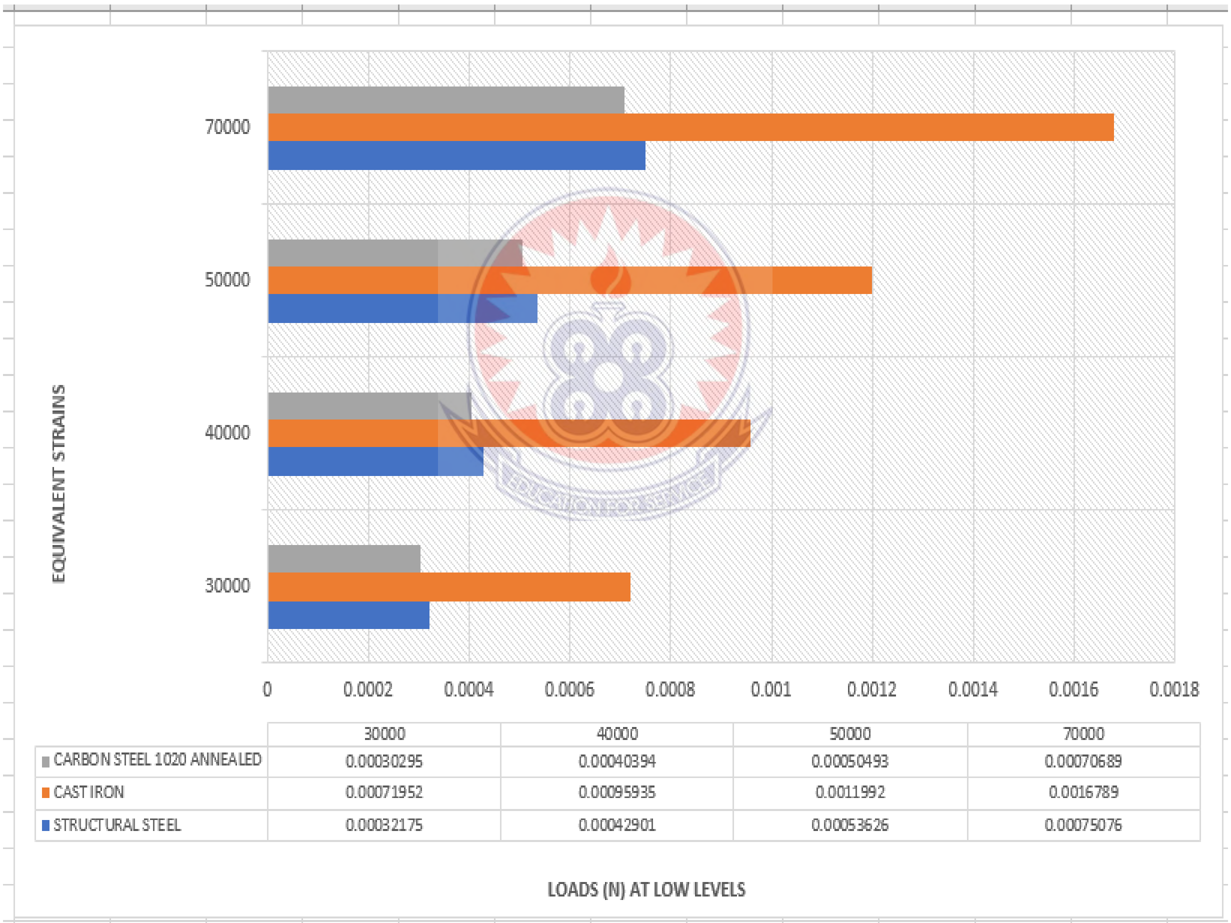
Histogram. 4.6: Sear Stresses at low levels



	30000	40000	50000	70000
■ STRUCTURAL STEEL	6.1036	8.1381	10.173	14.242
■ CAST IRON	6.5201	8.6935	10.867	15.214
■ CARBON STEEL 1020 ANNEALED	6.1674	8.2219	10.277	14.391

d. **Equivalent Elastic Strains, lift at low levels.** all the results from the various solutions in Figures, 4.28, 4.32, 4.36 under 30000N further results in 40000N, 50000N, 70000N have proven that the equivalent stresses of structural steel and carbon steel annealed have proven in producing good results which are very close and certified as compared to cast iron at low levels. The histogram 4.7, outline the performance of carbon steel annealed and structural steel as compared to cast iron.

Histogram. 4.7. Showing Equivalent Elastic Strains at low levels



	30000	40000	50000	70000
■ CARBON STEEL 1020 ANNEALED	0.00030295	0.00040394	0.00050493	0.00070689
■ CAST IRON	0.00071952	0.00095935	0.0011992	0.0016789
■ STRUCTURAL STEEL	0.00032175	0.00042901	0.00053626	0.00075076

4.14 COMPA RATIVE ANALYSIS OF SOLUTION RESULTS.

Considering the load of 40000N solution report of structural steel in appendix II which produced a mass of 7831.1kg = 78311N in page 174 (under properties), and the load of 3000kg placed on the lift (Figure. 3.4), with result of 77968N and factor of safety (1.5). It was observed that the two results were very close. By adding one-third or two-thirds of the above loads to each other and run a solution, their results (Von-Mises stress) would still be less than that of the original material. E.g., 78311N divided by 3 = 26103.7N, adding 78311 + 26103.7 = 104414.7N, also, 78311N + 52207.4N = 130518.4N.

After imposing the said loads on structural steel, the result produces a Von-Mises stress of 175.39MPa and 219.24MPA which are less than 250MPa and 293.5MPa as shown,

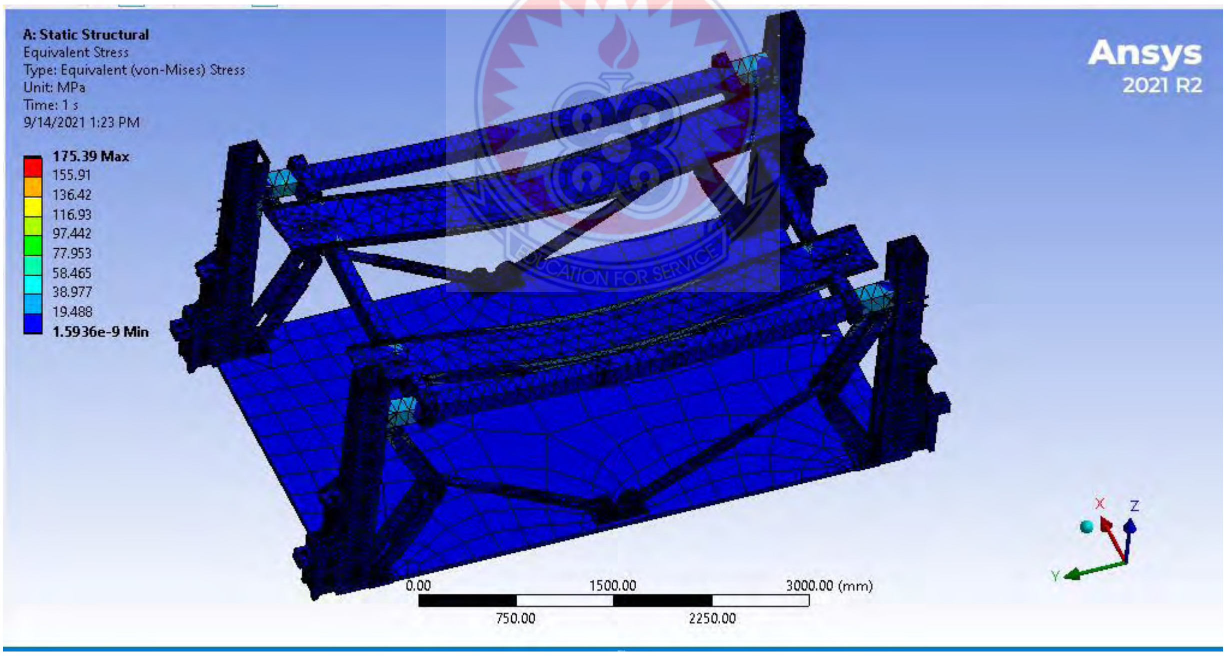


Figure. 4.37: Von-Mises stress; 175.39

The result displayed clearly demonstrates that from the design calculations and solution results, after multiplying three times the rated load of the newly designed lifting device (30000N) and imposed it on the structure using structural steel or carbon steel 1020 annealed, it will have a good test result.

4.15 LOAD VERSE STRESSES FROM THE SOLUTION RESULTS

Table 4.5 - 4.8 display the load verses stresses from the solution results under 30000N, 40000N, 50000N and 70000N in High level, Inclined Level and Low level.

TABLE 4.5 Load Verse Von-Mises (Equivalent Stress)

VOM MISES (EQUIVALENT STRESSES)					
ID NO.	LOAD (N)	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL ANNEALED
A	30, 000	HIGH	50.394	66.866	51.433
		INCLINED	53.072	83.73	52.916
		LOW	58.295	58.457	58.339
B	40, 000	HIGH	67.192	89.154	68.578
		INCLINED	70.762	111.64	70.555
		LOW	77.727	77.943	77.787
C	50, 000	HIGH	83.989	111.44	85.722
		INCLINED	88.453	139.55	88.194
		LOW	97.159	97.429	97.233
D	70, 000	HIGH	117.59	156.02	120.01
		INCLINED	123.83	195.37	123.47
		LOW	136.02	136.4	136.13

TABLE 4.6 Load Verse Total Deformations

TOTAL DEFORMATIONS					
ID NO.	LOAD (N)	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL ANNEALED
A	30, 000	HIGH	1.1534	2.5157	1.0879
		INCLINED	1.2108	2.6466	1.1414
		LOW	0.65843	1.4693	0.61989
B	40, 000	HIGH	1.5379	3.3542	1.4505
		INCLINED	1.6144	3.5288	1.5219
		LOW	0.87791	1.9591	0.82651
C	50, 000	HIGH	1.9223	4.1928	1.8107
		INCLINED	2.018	4.411	1.9023
		LOW	1.0974	2.4489	1.0331
D	70, 000	HIGH	2.6913	5.8699	2.5349
		INCLINED	2.8252	6.1754	2.659
		LOW	1.5363	3.4284	1.4464

TABLE 4.7 Load Verse Shear Stresses

SHEAR STRESSES					
ID NO.	LOAD (N)	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL ANNEALED
A	30, 000	HIGH	13.491	21.753	13.017
		INCLINED	20.928	39.592	20.212
		LOW	6.1036	6.5201	6.1674
B	40, 000	HIGH	17.989	29.004	17.356
		INCLINED	27.905	52.788	26.949
		LOW	8.1381	8.6935	8.2219
C	50, 000	HIGH	22.486	36.254	21.695
		INCLINED	34.881	65.985	33.686
		LOW	10.173	10.867	10.277
D	70, 000	HIGH	31.48	50.756	30.373
		INCLINED	48.833	92.379	47.16
		LOW	14.242	15.214	14.391

TABLE 4.8 Load Verse Equivalent Elastic Strains

EQUIVALENT ELASTIC STRAINS					
ID NO.	LOAD (N)	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL ANNEALED
A	30, 000	HIGH	0.00028045	0.00065505	0.000269958
		INCLINED	0.00028989	0.00067547	0.00027859
		LOW	0.00032175	0.00071952	0.00030295
B	40, 000	HIGH	0.00037394	0.0008734	0.00035944
		INCLINED	0.00038652	0.00090063	0.00037145
		LOW	0.00042901	0.00095935	0.00040394
C	50, 000	HIGH	0.00046742	0.0010917	0.0004493
		INCLINED	0.00048315	0.0011258	0.00046432
		LOW	0.00053626	0.0011992	0.00050493
D	70, 000	HIGH	0.00065439	0.0015284	0.00062902
		INCLINED	0.00067642	0.0015761	0.00065004
		LOW	0.00075076	0.0016789	0.00070689

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

In this thesis, a multi-function lift of an aesthetic sense has been designed. The unit comes with five models' stages (low level, high level, middle level, inclined level and wheels in operation) of which three were used for simulation (high, inclined and low level). All the solid modelling, painting, detail drawing including importing of files in PDF format, saving files in STEP format and assembling of the entire design was done with Autodesk Inventor professional 2017. The analysis and simulation were done with ANSYS R2 2021 software.

In all, 75 components were drawn and shown in detail drawing in Appendix I, some have multiple function e.g., **1)** SN 3A, B & C & 3D, **2)** SN 4B, C, D, E. **3)** SN 13C & 47, **4)** SN 29 & 37, **5)**

SN 30, 32A, 32B, 37A & 46A, **6)** SN 31 & 47, **7)** SN 35A & 38A, are single component which served the same purpose.

The new design includes some improved safety devices such as mechanical locks, stop switches and phone cases which will relief the users of above lift from panicking. The new design also comes with improved lifting mechanisms for lifting or tilting, and pushing pistons with an aesthetic operating system with wheels to move the lift from one location to another serving as multi-function purpose of this design as compared to the existing ones.

The material library as shown in table 3.1, 3.2. & 3.3 displays the mechanical properties of selected materials (the yield strength). A comparative study has been made between the selected materials: static structural analysis was used. From the results, graphs and histograms, it was observed that the Von – Mises's stress of structural steel at all levels shows a less value, e.g., at high levels 30000N; the Von – Mises stresses were as follows: Structural steel 50.394 MPa (Figure. 4.2), Cast iron 66.866 MPa (Figure. 4.6), and Carbon steel annealed 51. 433 MPa (Figure. 4.10). Even at high levels 70000N, Structural was Steel 117.59 MPa, Cast Iron 156.02

MPa, and Carbon Steel Annealed 120.01 MPa, this clearly shows that the best material for the design is structural steel followed by carbon steel annealed. Also, all the comparative solution results on total deformations, shear stresses and equivalent strains including the plotted graphs and histograms have demonstrated that structural steel and carbon steel annealed were the best materials for the design.

In addition to this, both structural steel and carbon steel 1020 annealed demonstrated that they behave differently in different conditions, because at certain stages their results were very close. In all the comparative analysis structural steel has proven to be a little better under yield strength than carbon steel annealed and cast iron. Since these properties plays an important role in designing a lift. Structural steel would be the preferred choice followed by carbon steel 1020 annealed.

Finally, the hydraulic circuit line diagrams for the above design have been provided for easily operation of the main and movable wheels' pistons, shown in Appendix C.

5.2 CONCLUSION

This study is sought to make an acceptable lift for all automobile industries, garages and shops, washing bays, spraying and lube bays.

A multi-functional lift with mechanical lock and guide has been designed to ensure safety

The materials selected are readily available.

Von misses, the Von-mises of Structural Steel at 30000N high level was 50.394MPa.

Total deformation was 1.1534 as compared to 2.5157 of Cast Iron.

Shear stress was 13.491 at maximum as compared to 21.732 of Cast Iron.

Equivalent strain was 0.00028045 as compared to 0.00065505 of Cast Iron.

By comparing all stresses, it shows clearly that Structural steel and Carbon steel Annealed are the beast materials for the design.

5.3 RECOMMENDATIONS

Based on the statement of the problem, objectives and the analysis from the results, the following recommendations are made;

1. Automobile industries should link with institutions to do further research on the said lift and others in order to get the right equipment for the safety of their workers and other users in general since these lifts play a leading role as far as serving, and maintenance of vehicles are concern.
2. Further research should be done on the modeling of the individual components listed in the detail drawing so that the unit can lift vehicle at front, rear or any of the sides
3. In order to ensure that the right materials have been chosen for the design, further analysis should be done on this unit and others to ensure that they are safe.
4. Finally, other designers can do further research on the lifting mechanism to ensure that it can lift easily without any difficulties.

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APPENDICES

APPENDIX A:

DIMENSIONING/DETAIL DRAWINGS OF COMPONENTS/PARTS LIST

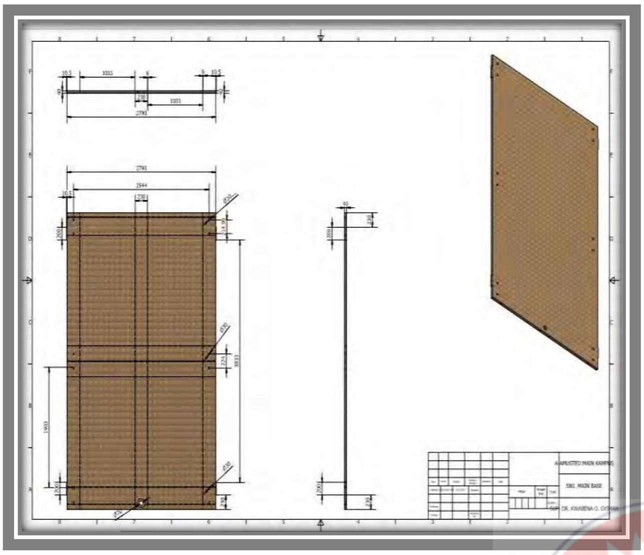

Fig. 1: SN 2; Main Base

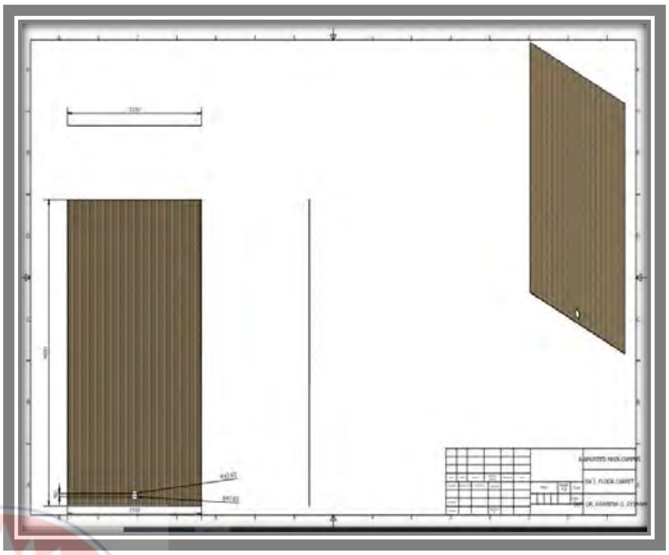

Fig. 2: SN 2. Main Base Floor Carpet

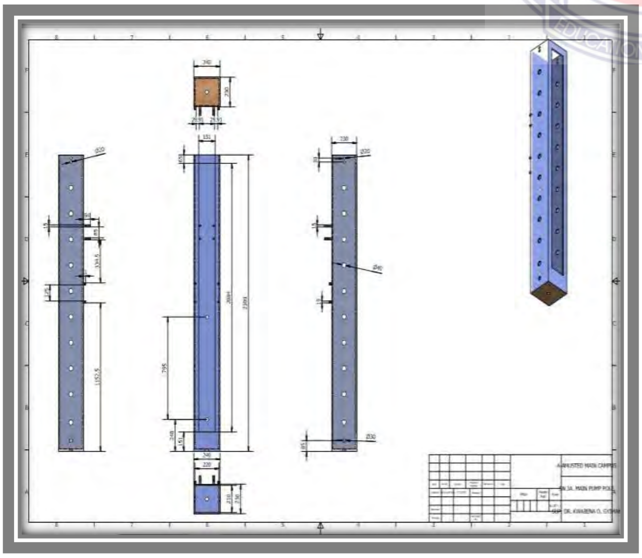

Fig. 3: SN 3A, Pole One (Pole with Main Piston Manual Pump & Motor)

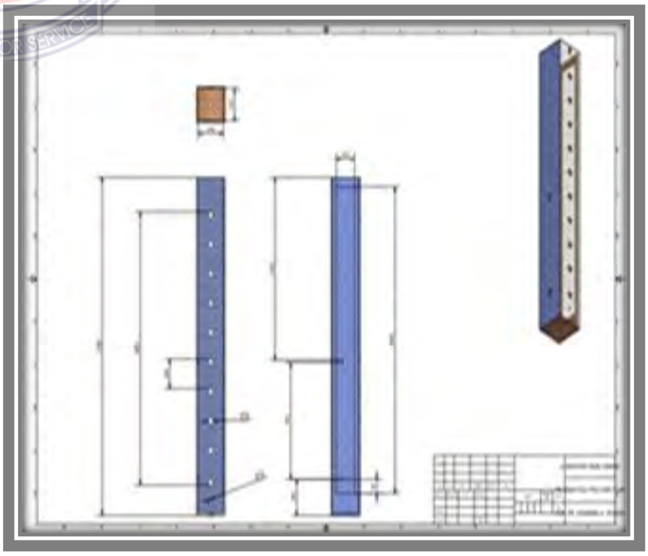

Fig. 4: SN 3B. Pole Two & Four

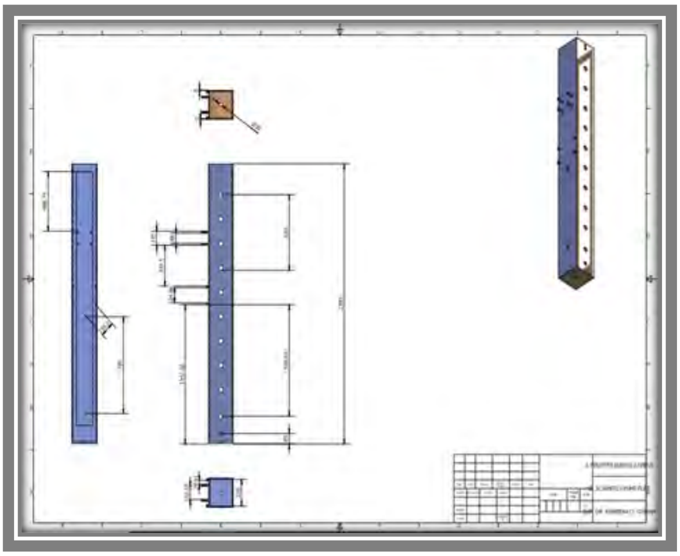

Fig. 5: SN 3C, Pole Three (Pole with Moving Wheels Pump & Motor)

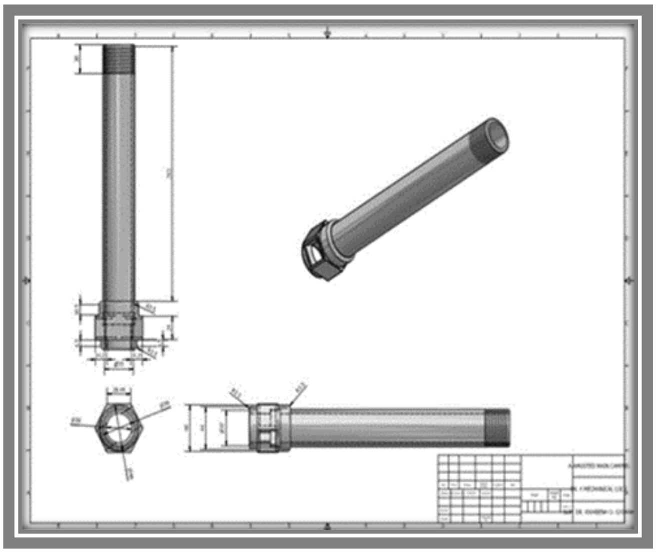

Fig. 6: SN 4. Mechanical Lock

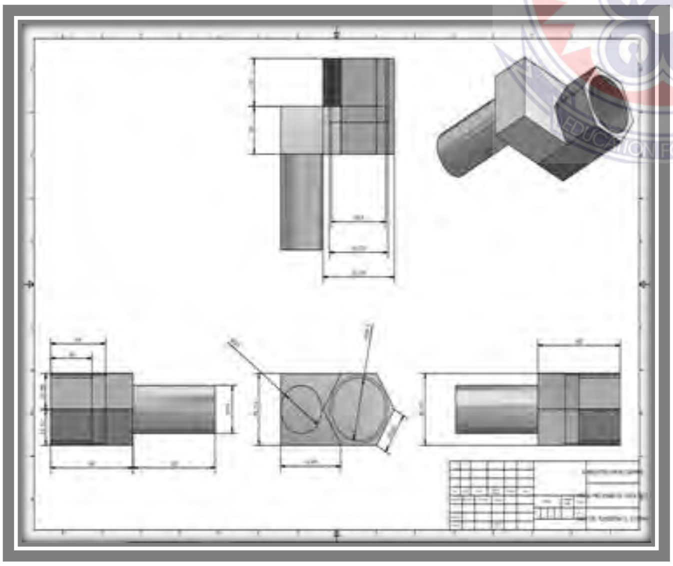

Fig. 7. SN 4B. Mechanical Lock Nut

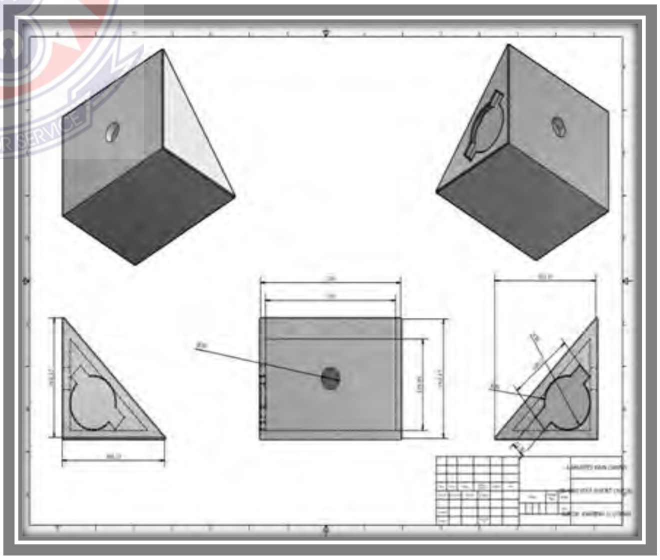

Fig. 8: SN 4C & D. Pole Support Case/ Mobile Phone Case

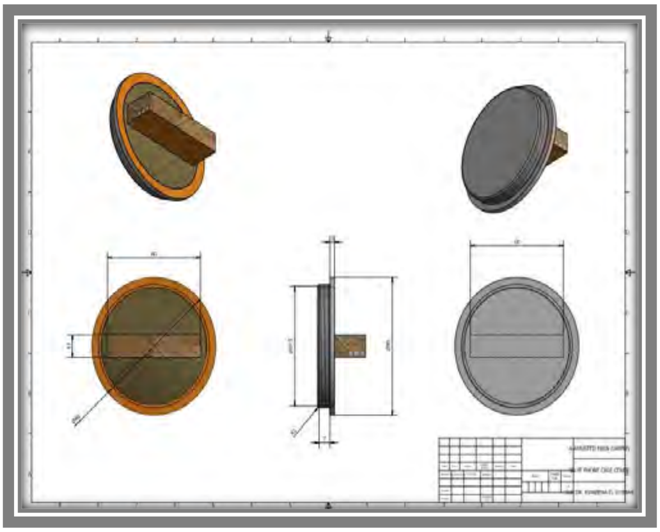

Fig. 9: SN 4F. Pole Support Cover/Mobile Phone Case Cover

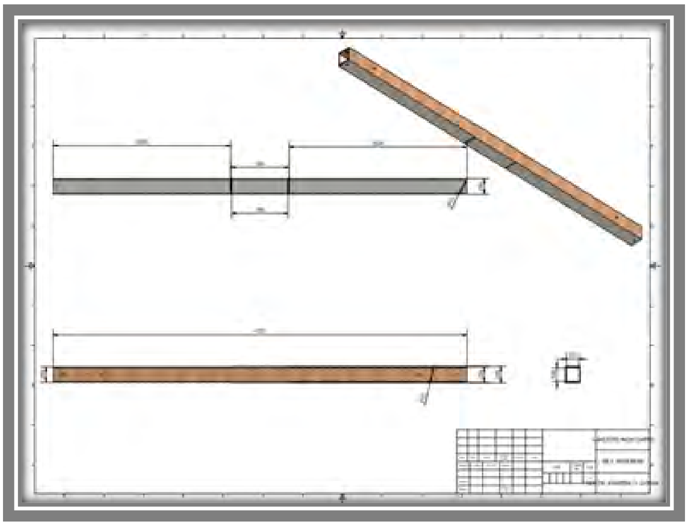

Fig. 10: SN 5. Main Beam

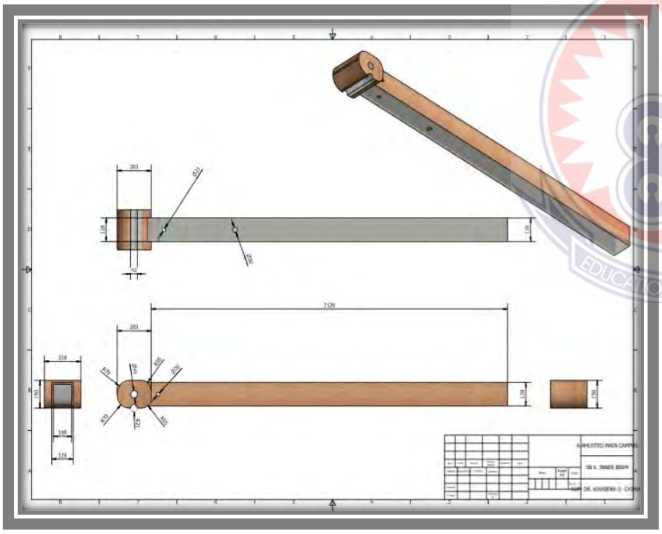

Fig. 11: SN 6. Inner Beam

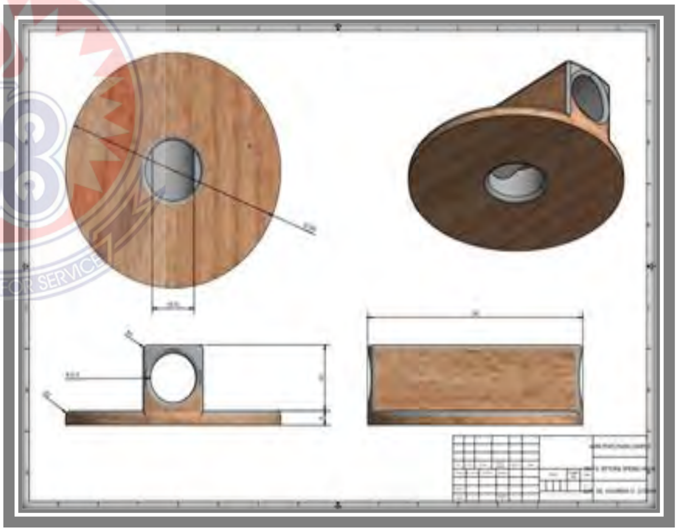

Fig. 12, SN 7A: Inner-Beam Return Spring Hook

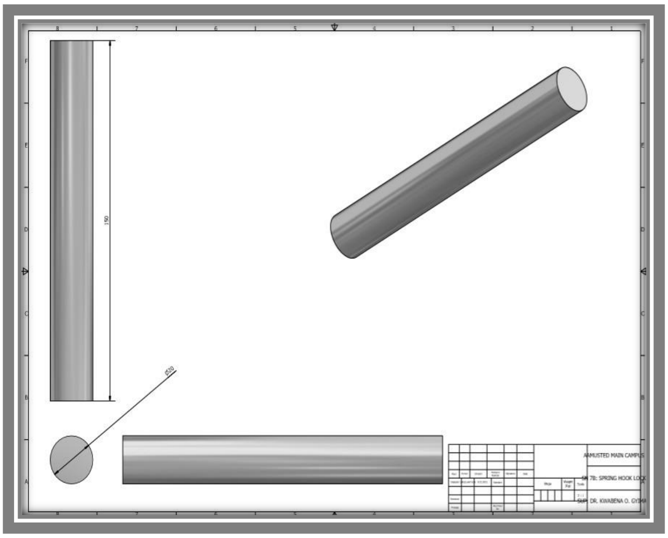

Fig. 13, SN 7B: Inner-Beam Return

Spring Hook Lock

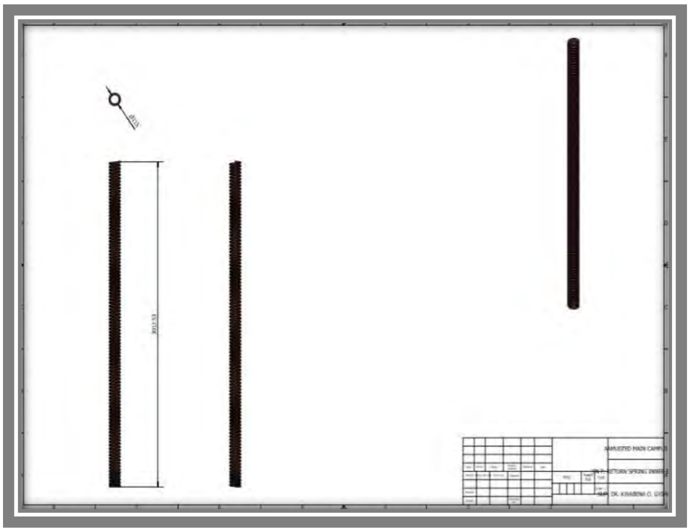

Fig. 14, SN 7: Inner-Beam Return Spring

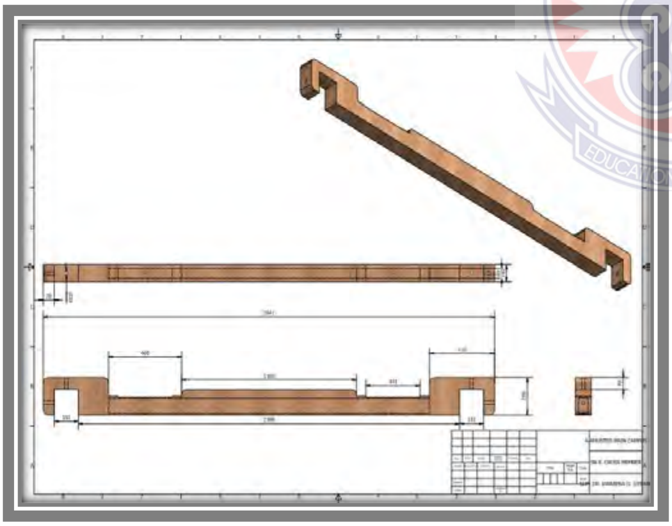

Fig. 15, SN 8: Cross Member

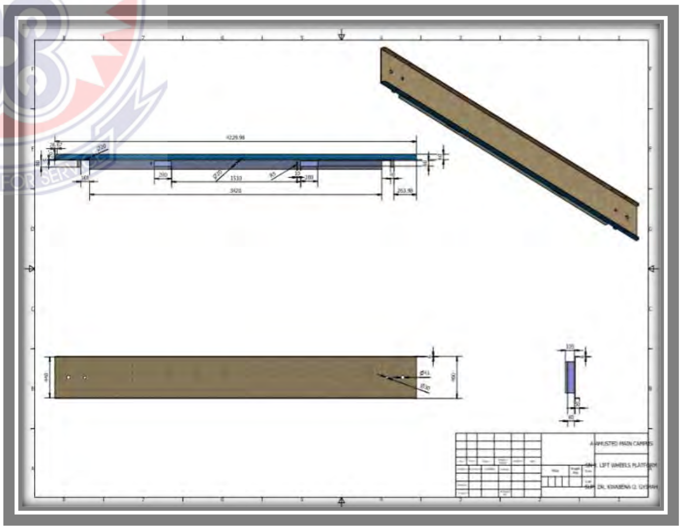

Figure 16 SN 9. Wheels Platform

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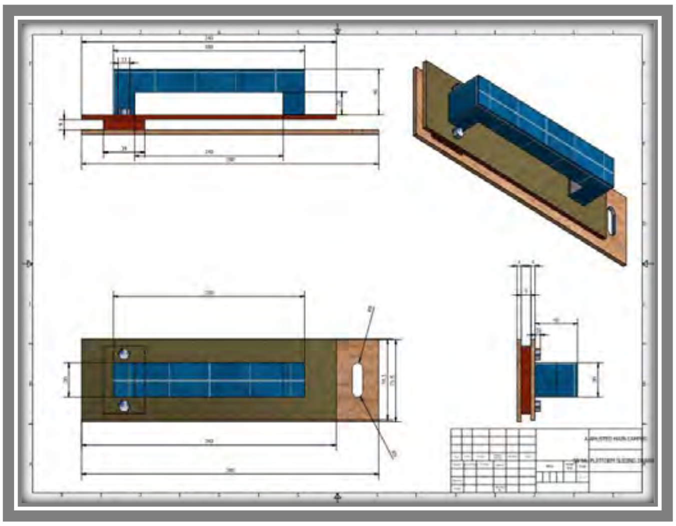


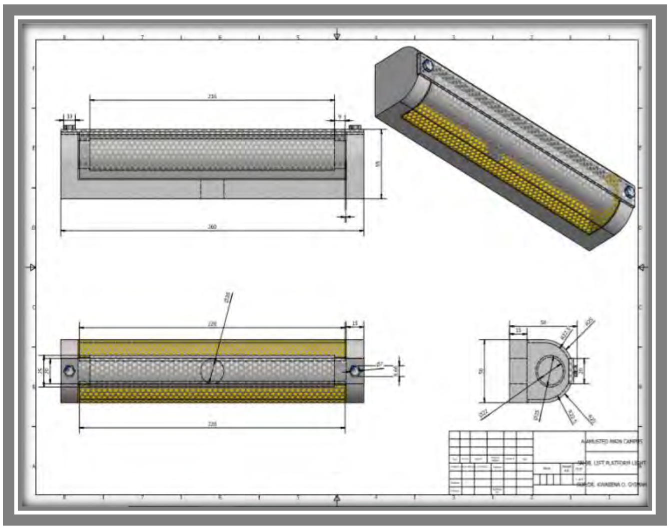
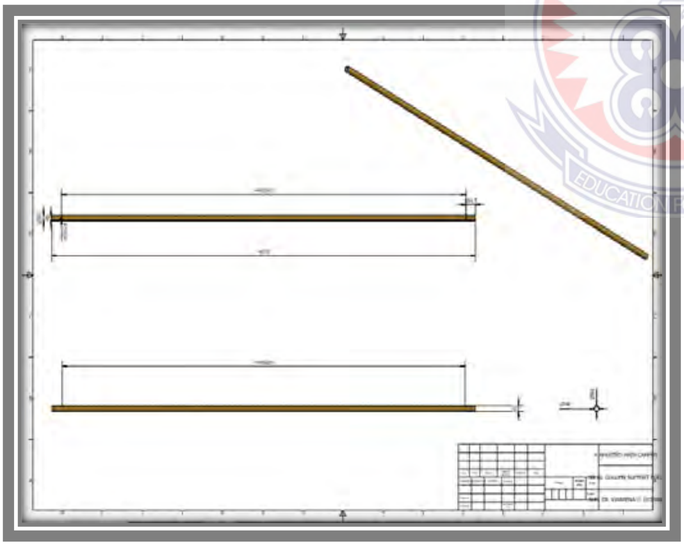


Fig. 17, SN 9A: Platform Sliding Drawer

Figure 18: SN 9B. Platform Light



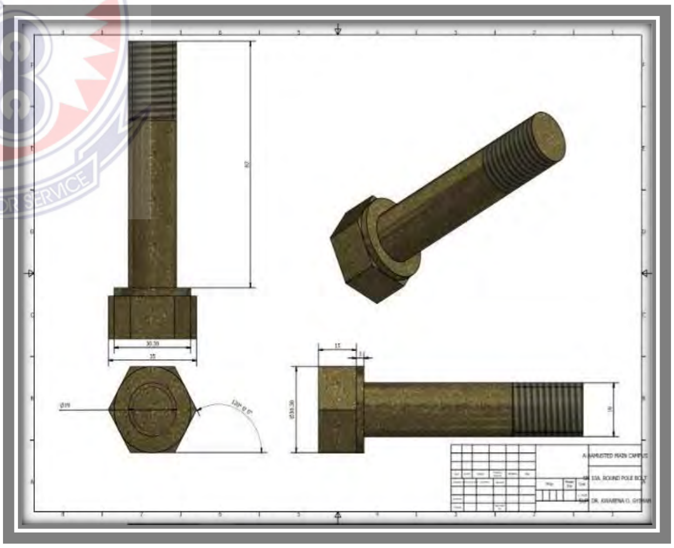


Fig. 19, SN 10: Column Support Pole

Fig. 20, SN 10A: Pole Holder Bolt

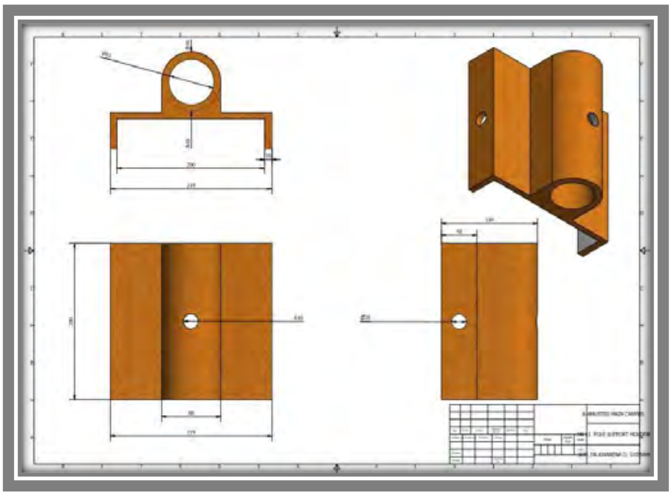


Fig. 21, SN 11: Column Support Pole Holder

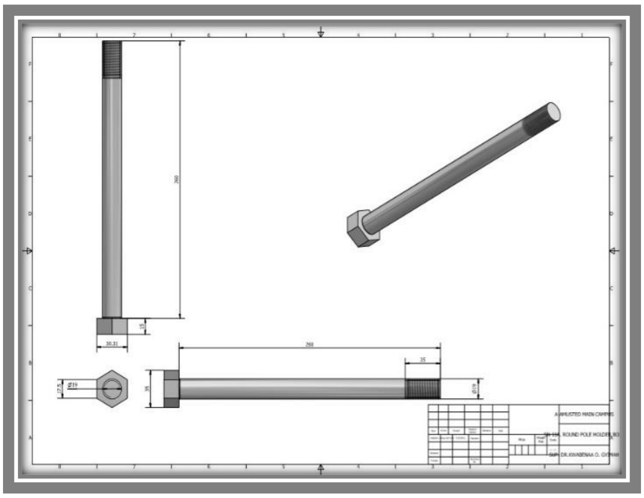


Fig. 22, SN 11 A: Column Support Pole Holder Bolt

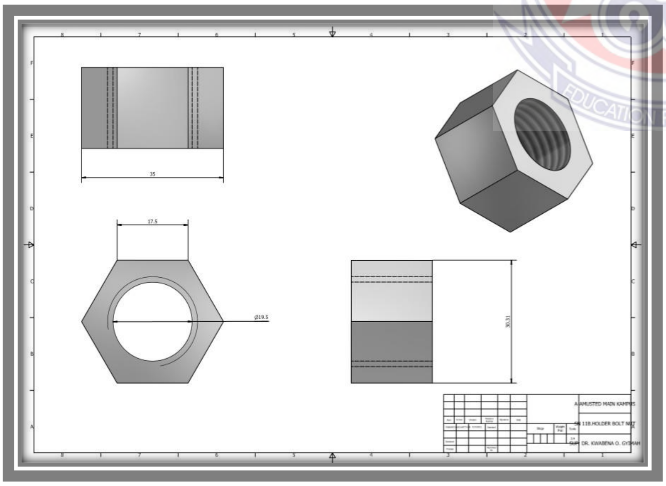
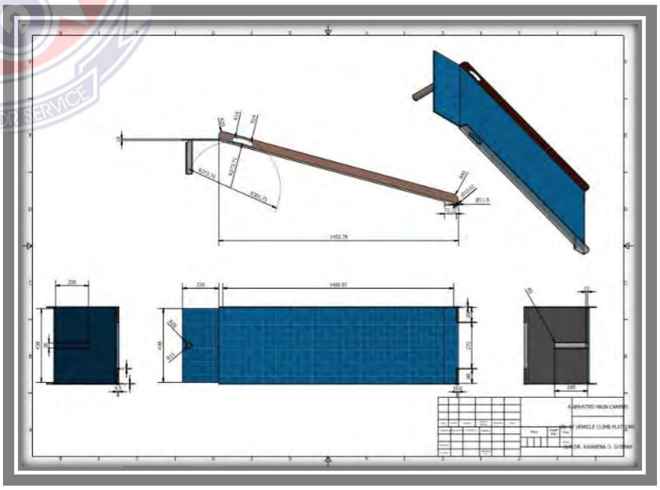


Fig. 23, SN 11B: Column Support Pole Holder Bolt Nut



24, SN 12: Runway-Lift/Lift Climb Platform

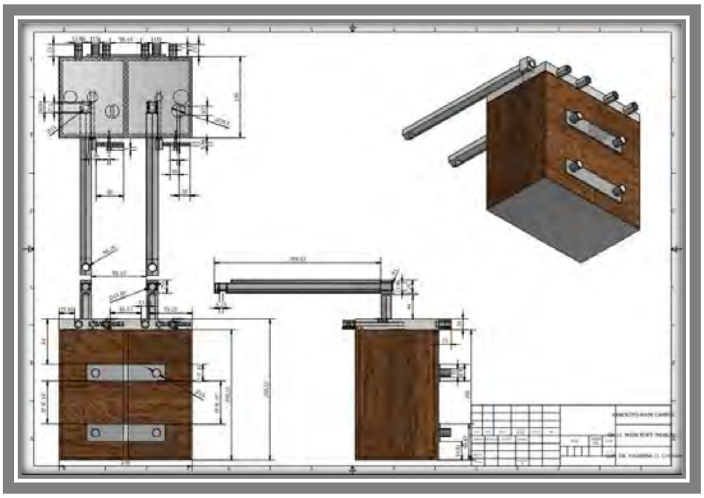


Fig. 25, SN 13: Manual Pump/Port

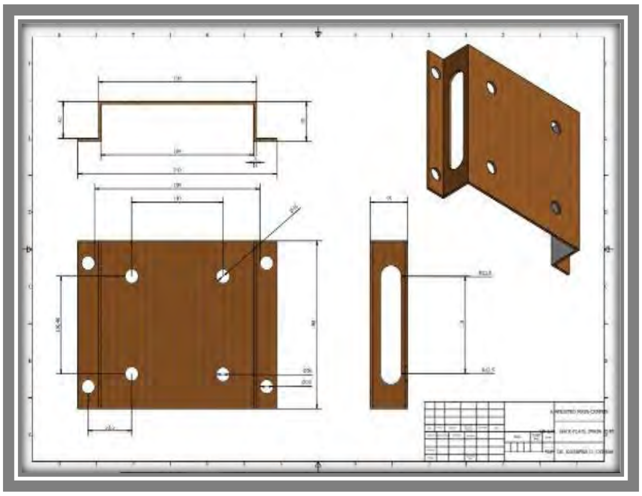


Fig. 26, SN 13A: Manual Pump Back Plate

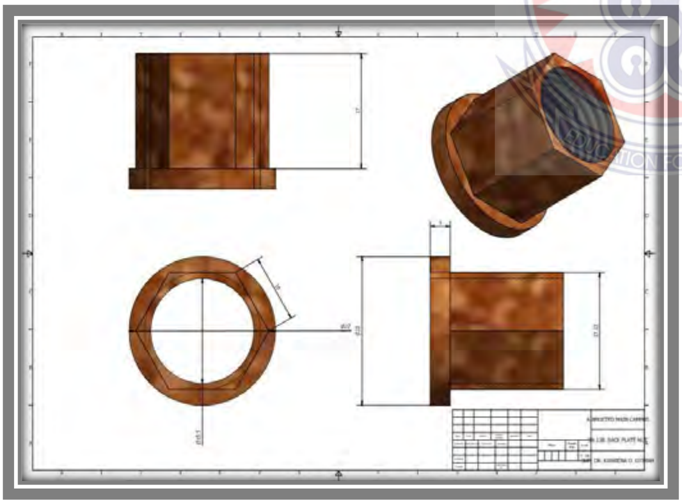


Fig. 27, SN 13B: Back Plate Nut

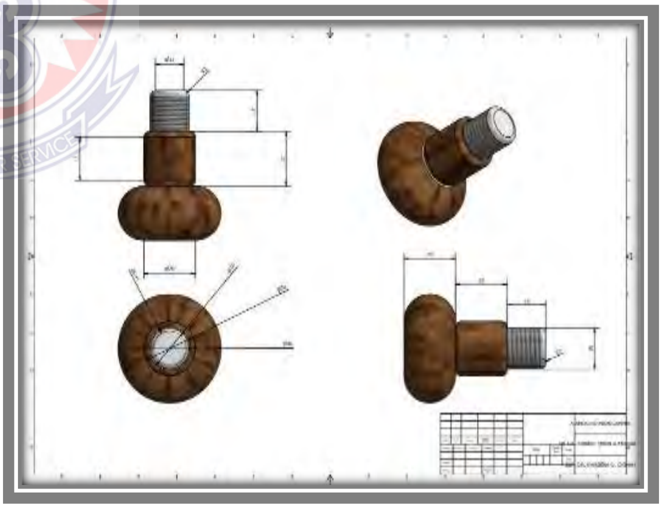


Fig. 28, SN 13C & 47: Handle for Main Piston and Movable Wheel Piston Port/Pump

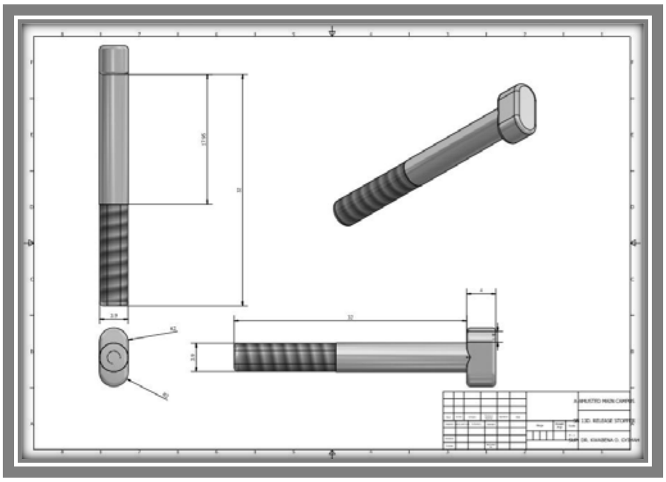


Fig. 29, SN 13D: Main Manual Pump/Port Release Stopper

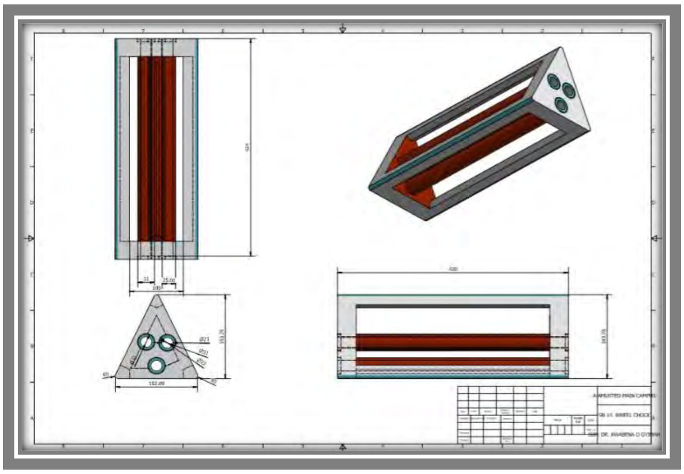


Figure 30: SN 14. Wheel Chock

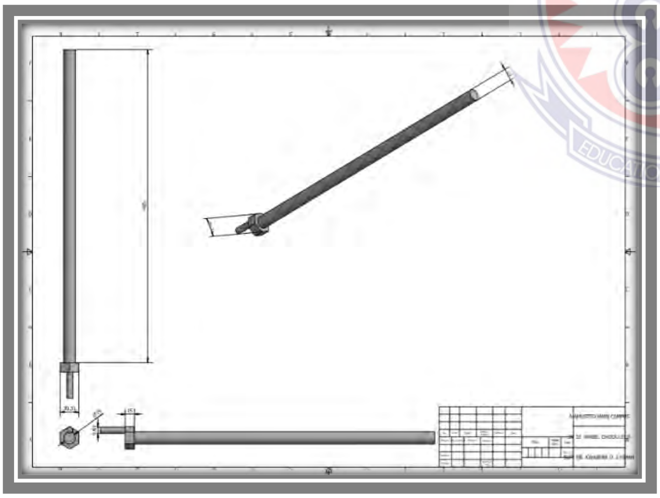


Fig. 31, SN 15: Wheel Chock Lock

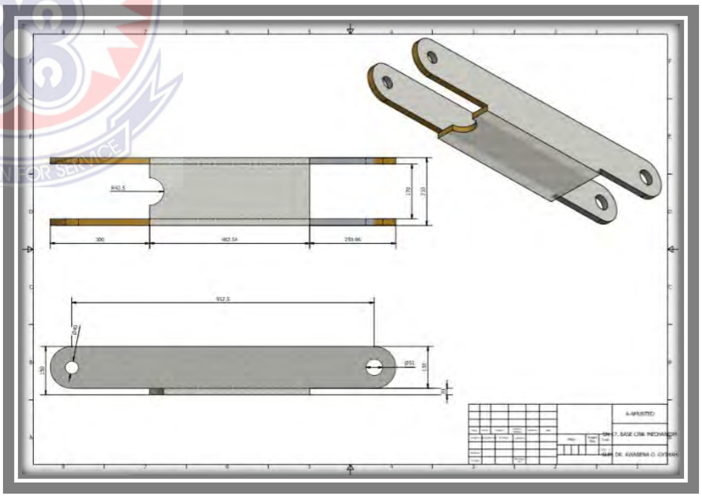


Figure. 32: SN 16, Base Link Mechanism

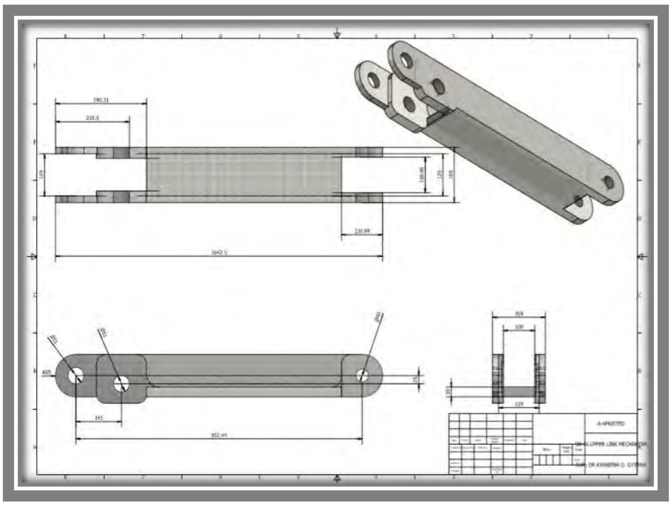


Figure. 33: SN 17, Upper Link Mechanism

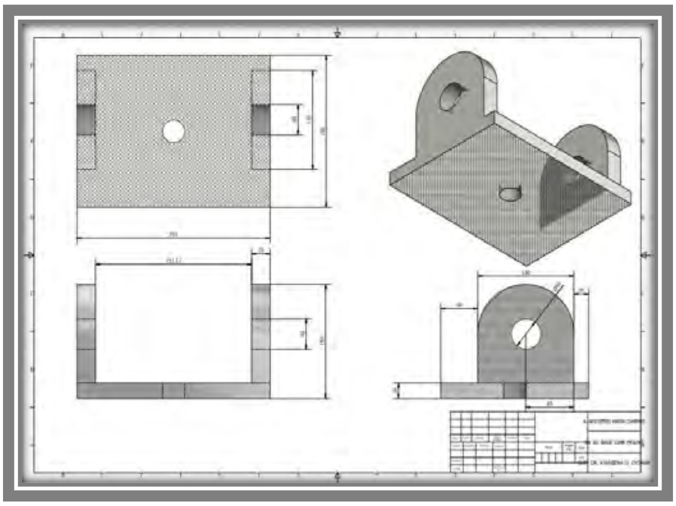


Fig. 34, SN 18: Base Link Mechanism Mount

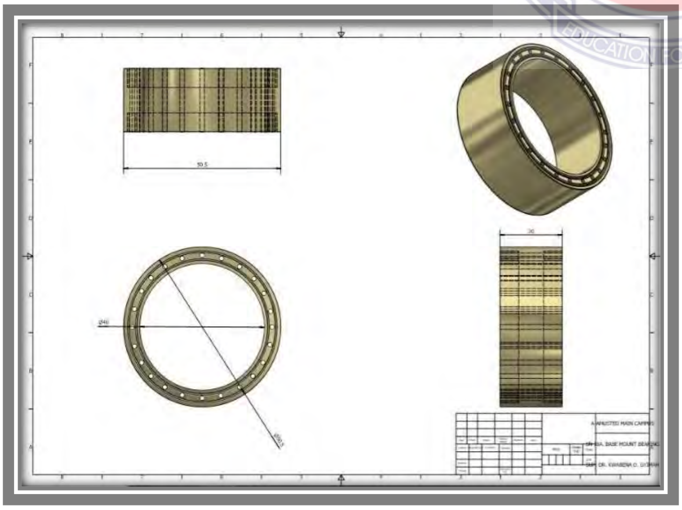


Fig. 35, SN 18A: Base Mount Bearing

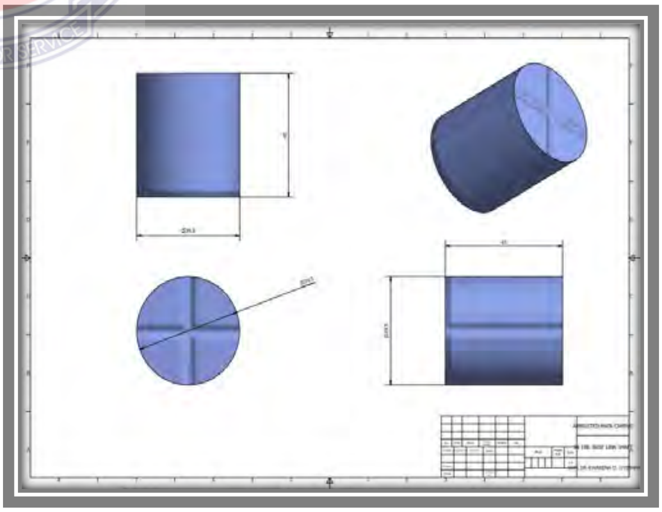


Fig. 36, SN 18B: Base Mount Bearing Shaft

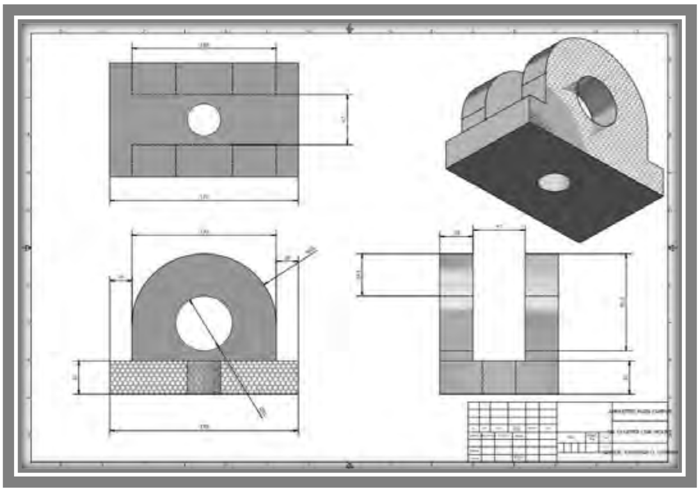


Fig. 37, SN 19: Upper Link Mechanism Mount

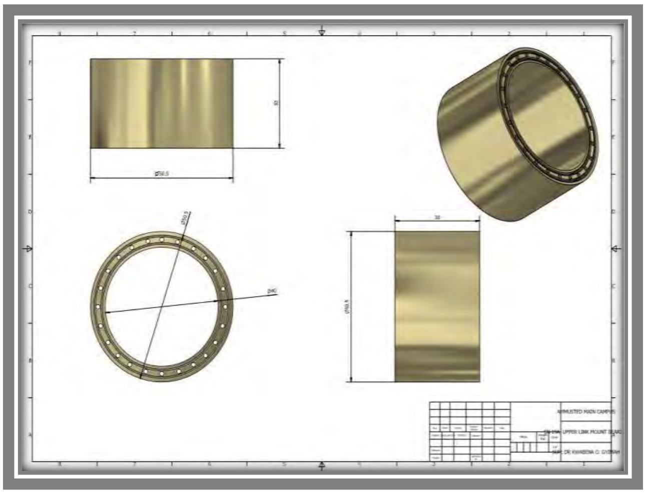


Fig. 38, SN 19A: Upper Link Mount Bearing

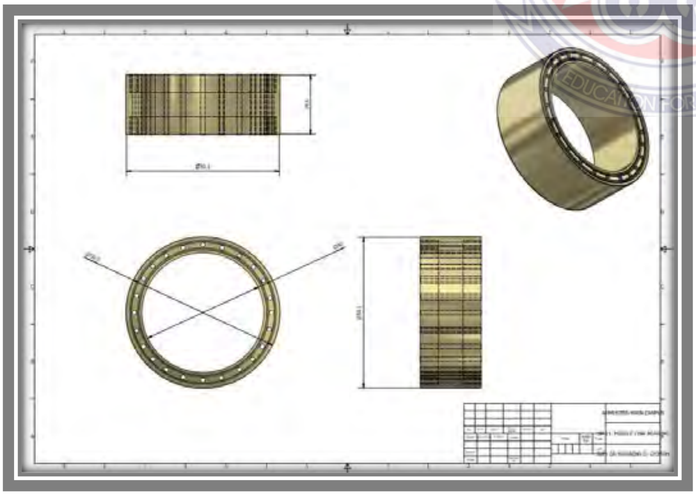


Fig. 40, SN 21: Middle Link Mount Bearing

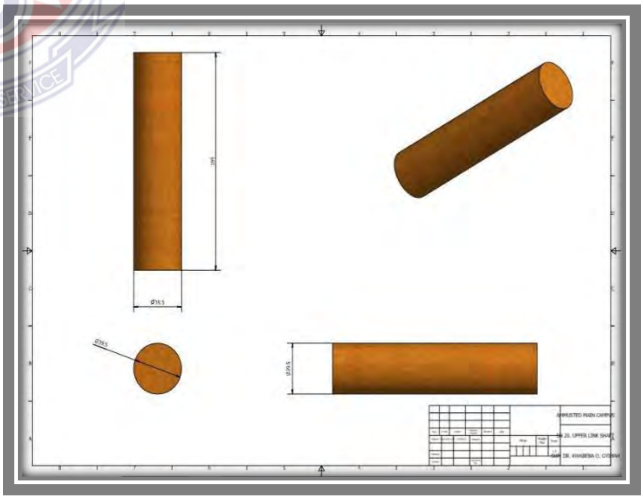


Fig. 39, SN 20: Upper Link Mount Shaft

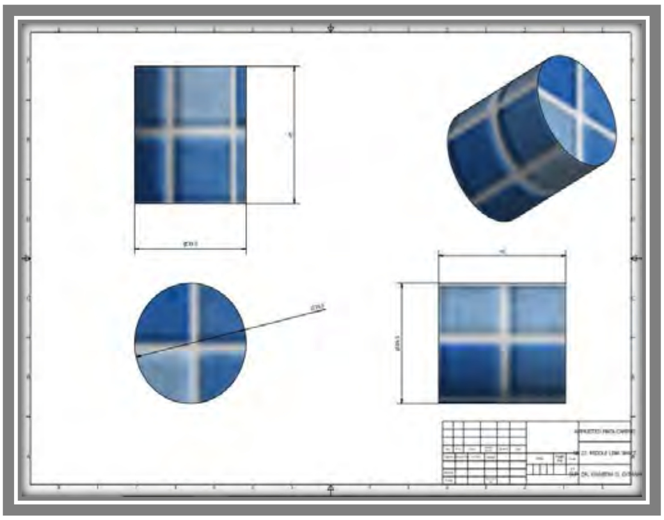


Fig. 41, SN 22: Middle Link Shaft

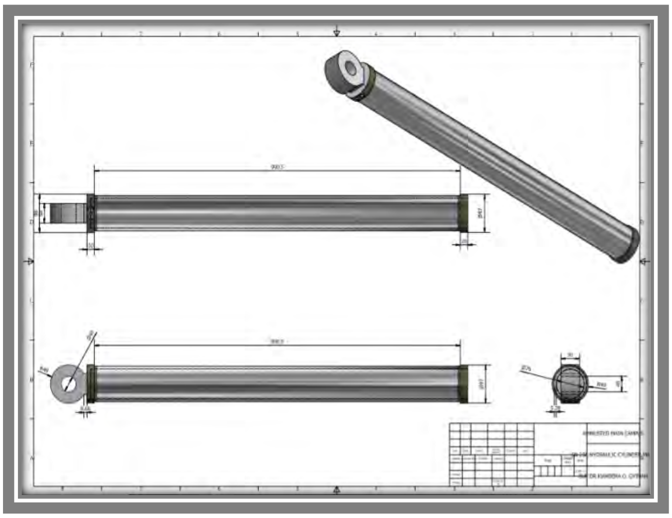


Figure 42: SN 23A Main Hydraulic Piston Cylinder

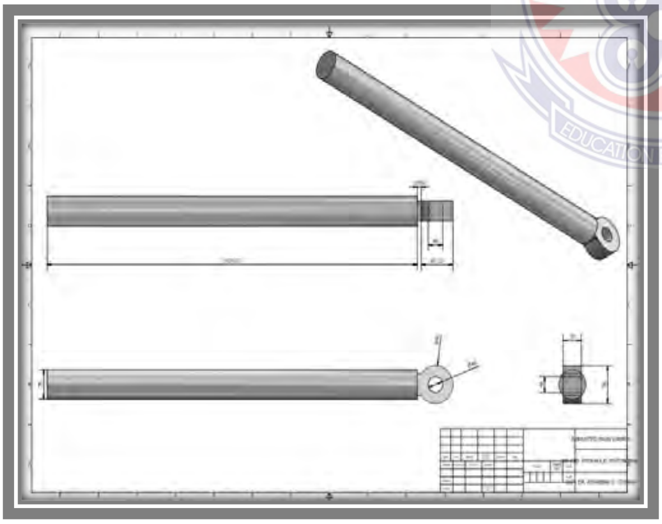


Fig. 43, SN 23B: Main Hydraulic Piston

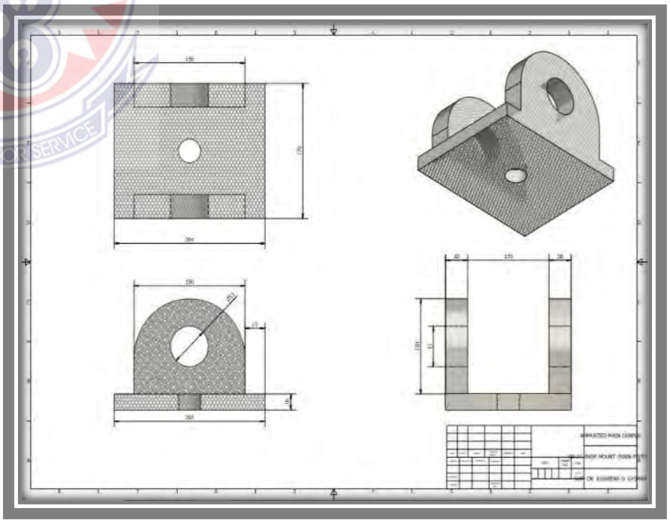


Fig. 44, SN 24: Main Hydraulic Piston Base Mount

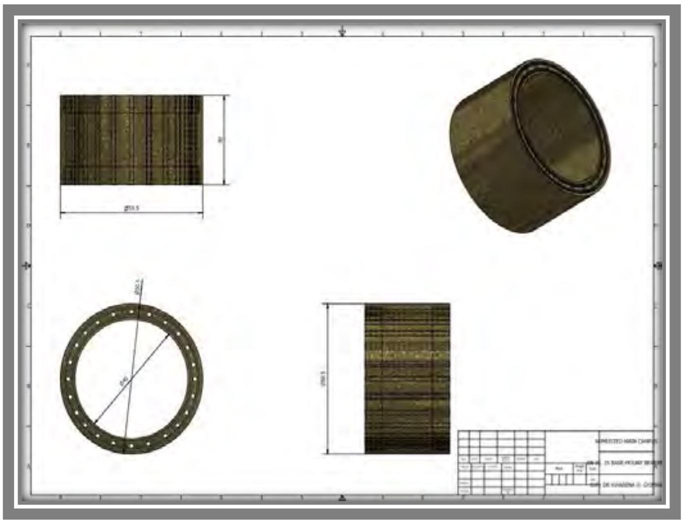


Fig. 45, SN 25: Main Hydraulic Piston Base Mount Bearing

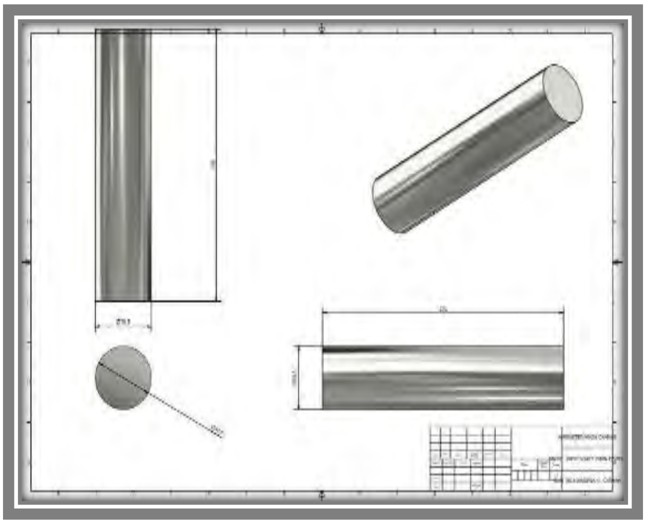


Fig. 46, SN 26: Main Hydraulic Piston Base Mount Shaft

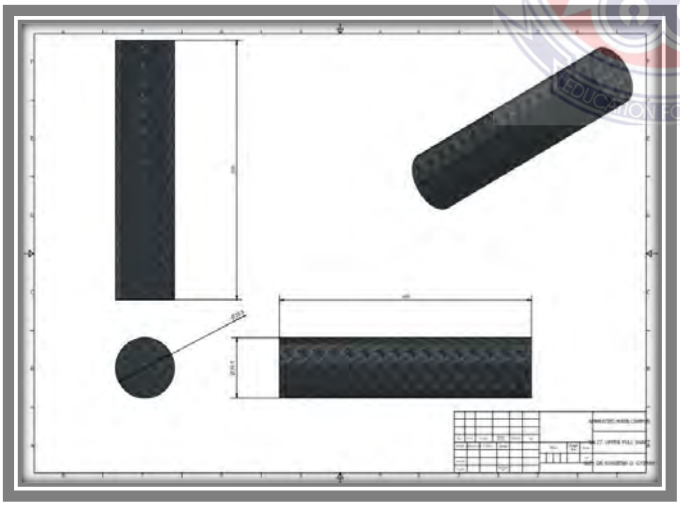


Fig. 47, SN 27: Upper Top Pull Shaft (Upper Link Mechanism)

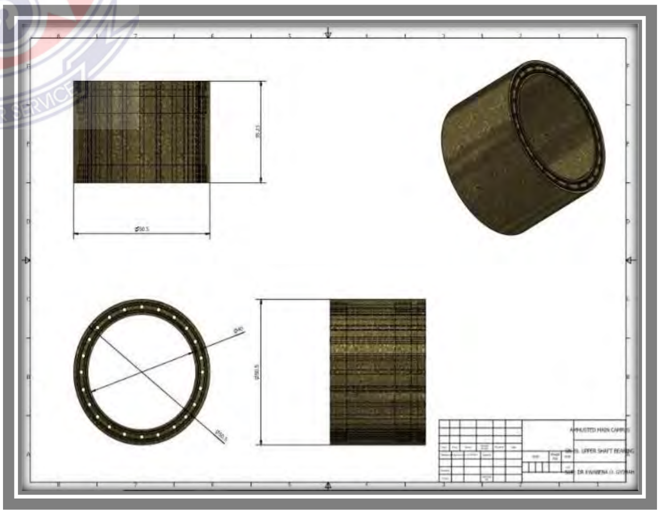


Fig. 48, SN 28: Upper Pull Shaft Bearing

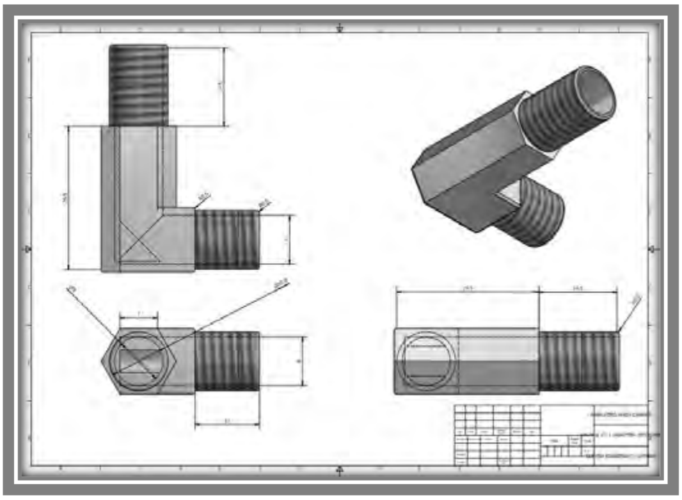


Fig. 49, SN 29&37: L-Adapter for Main and Movable Wheel Pistons

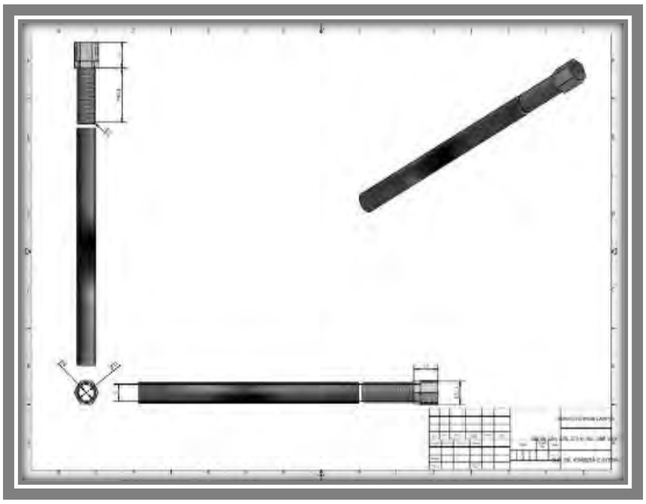


Fig. 50, SN 30, 32A, 32B, 37A & 46A: One-Way Adapter & Hose for Main and Movable Pistons

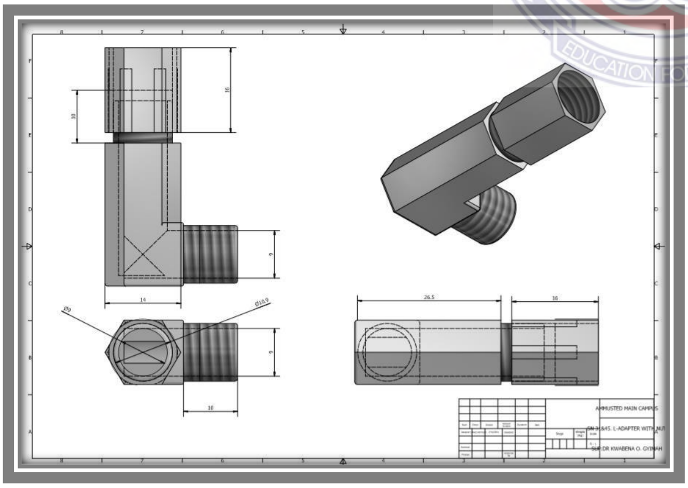


Fig. 51, SN 31&45: L-Adapter and Nut for Main, Movable Wheel Port and Motors

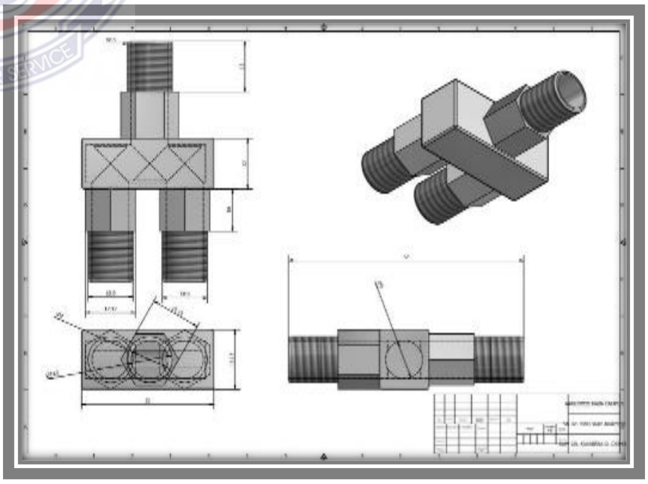


Fig. 52, SN 32: Two-Way Adapter for Main Piston Ports/Pumps and motor

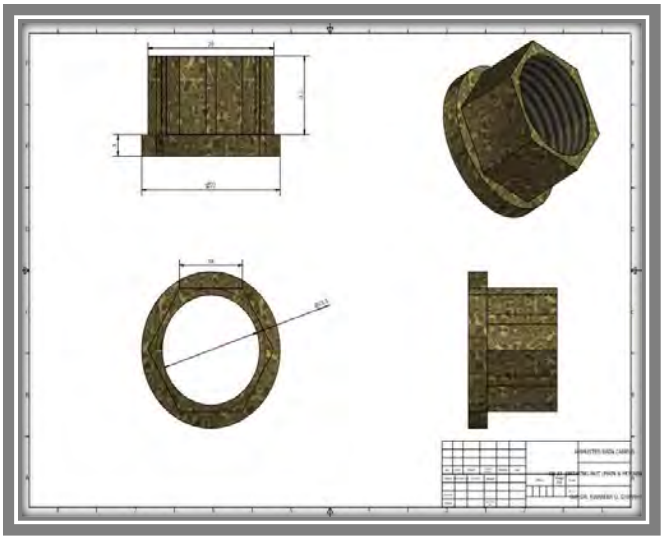


Fig. 53, SN 33: Main and Movable Wheel Securing Nut

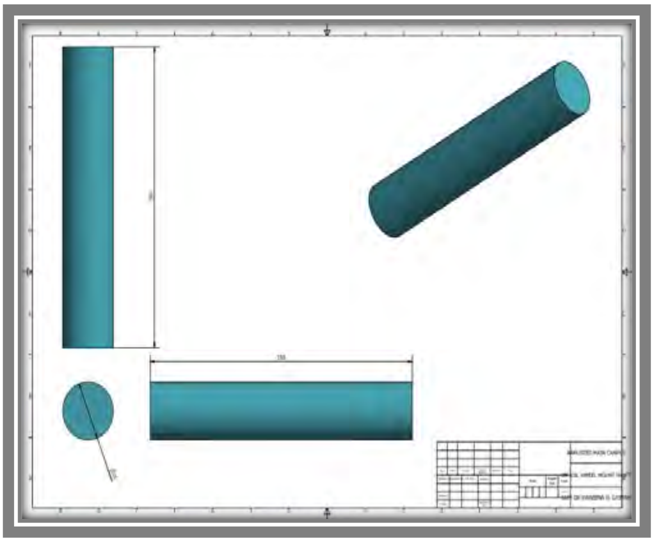


Fig. 54, SN 33A: Movable Wheel Shaft

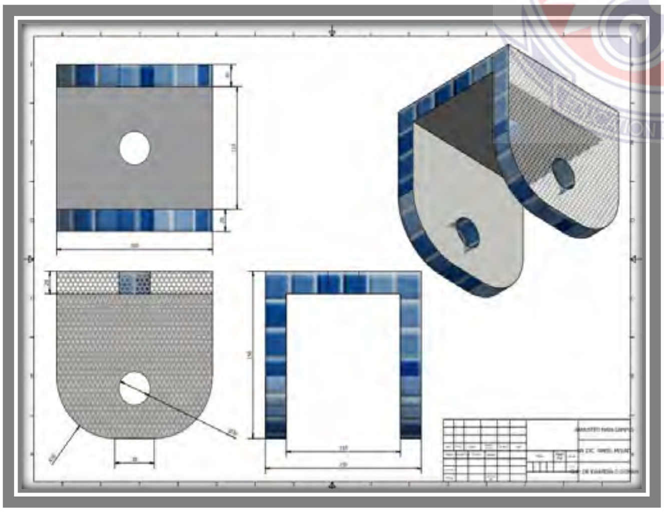


Fig. 55, SN 33C: Movable Wheel Mount

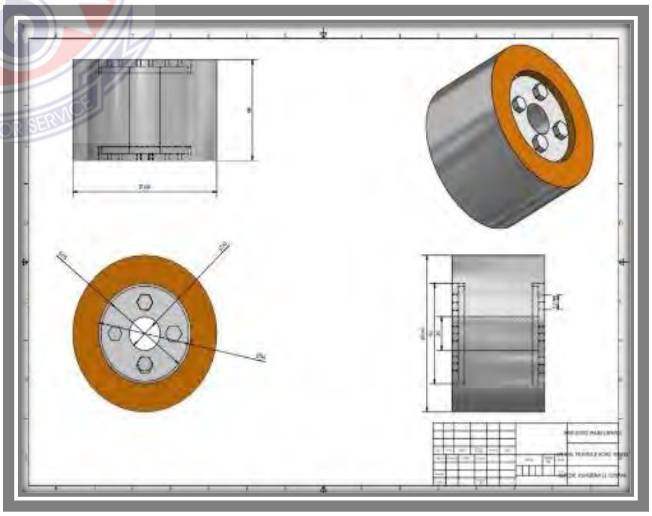
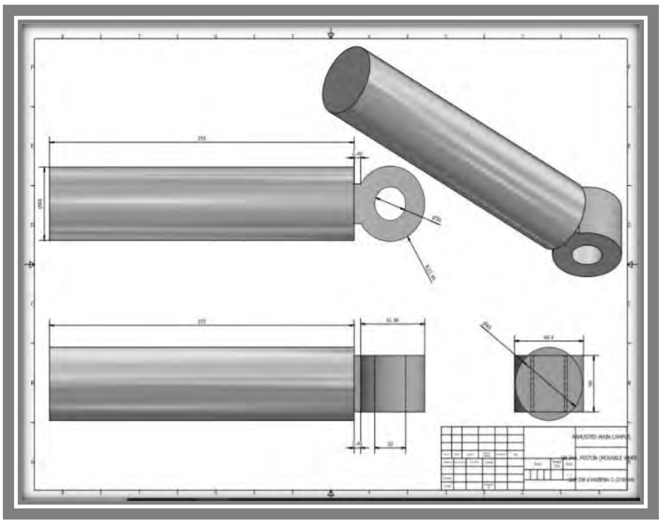


Fig. 56, SN 34: Movable Wheel



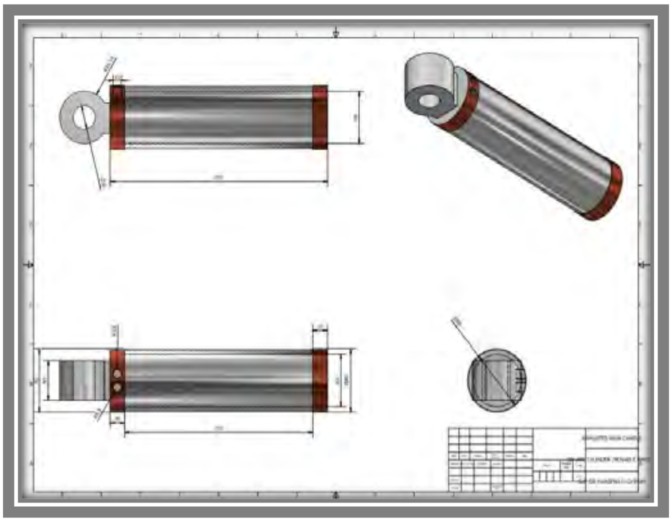
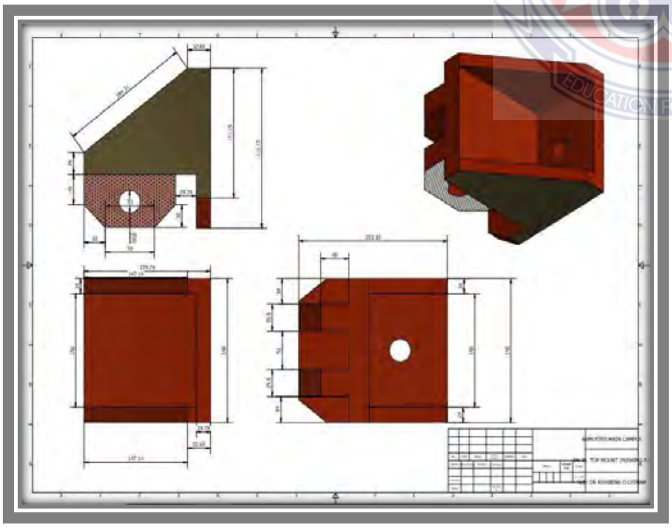


Fig. 57, SN 34A: Movable Wheel Piston

Fig. 58, SN 34B: Movable Wheel Piston Cylinder



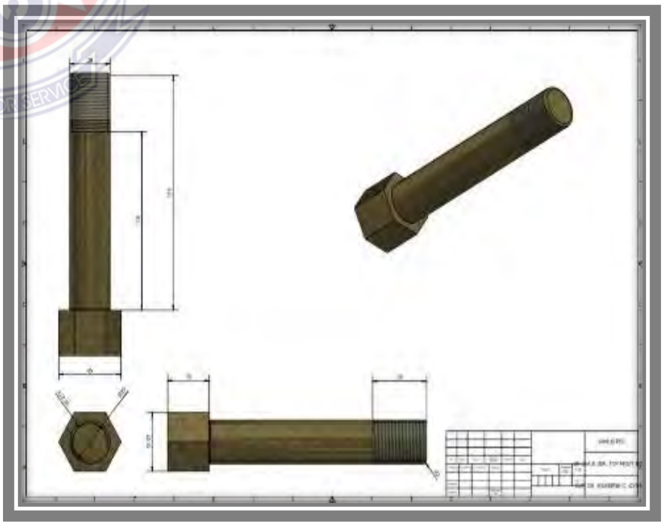


Fig. 59, SN 35: Pushing Piston Top Mount

Fig. 60, SN 35A & 38A: Top Mount Bolt, for Pushing Pistons & moving wheel post.

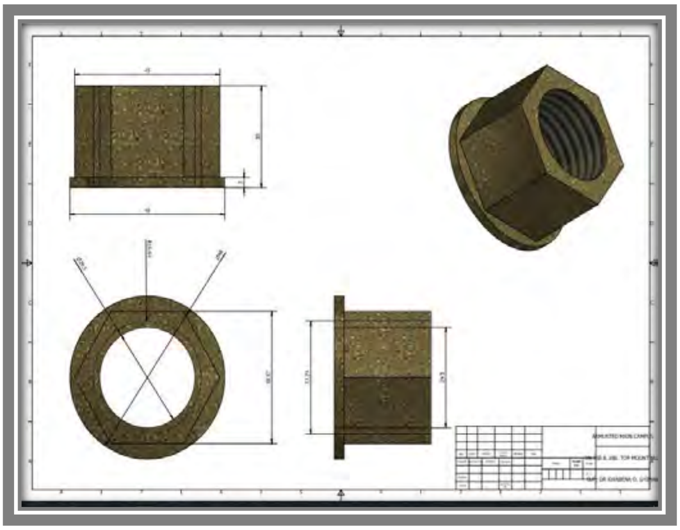


Fig. 61, SN 35B & 38B: Top Mount Nut, for Pushing Pistons & Moving Wheel Post

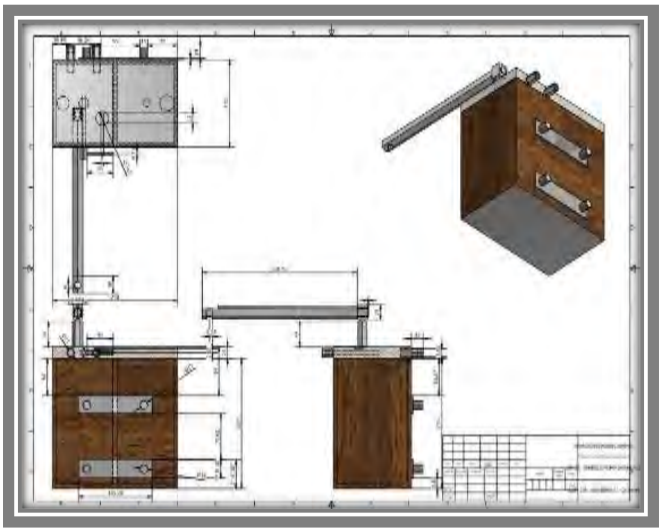


Figure 62: SN 36. Movable Wheel Port/Pump (Manual)

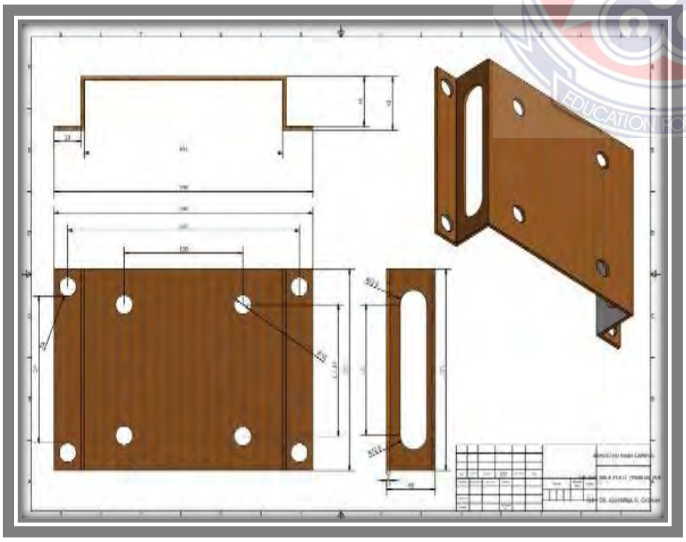


Fig. 63, SN 36A: Movable Wheel Port/Pump Back Plat

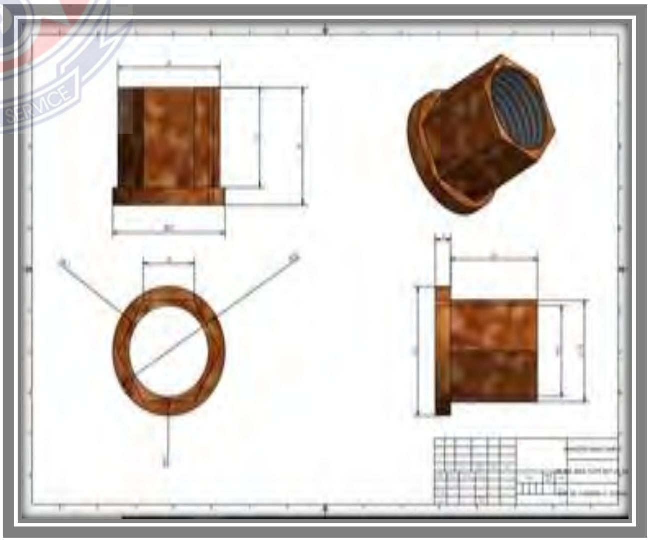


Fig.64, SN 36B: Movable Wheel Port/Pump Back Plat Nut

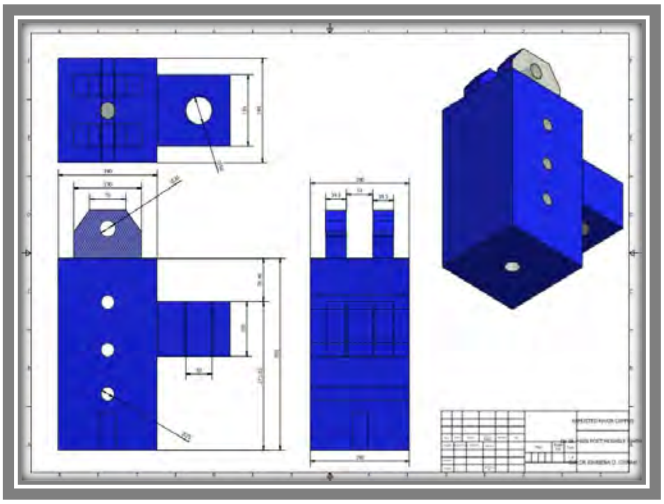


Figure 65: SN 38: Movable Wheel Main Post

Figure 66, SN 39: Movable Wheel Main Post Operating Housing

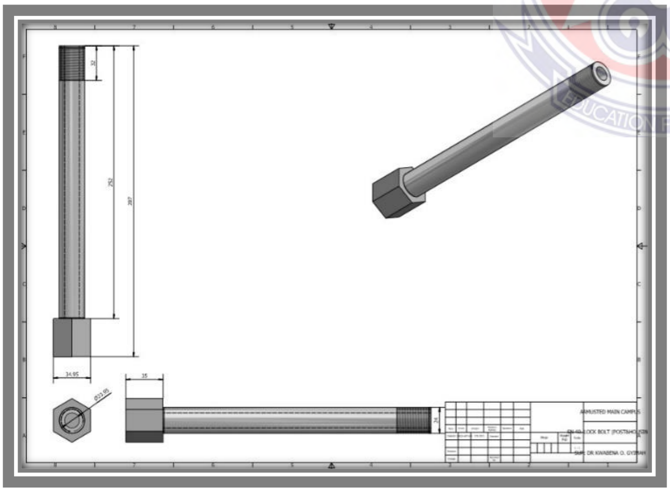


Fig. 67, SN 40: Operating Housing Lock Bolt

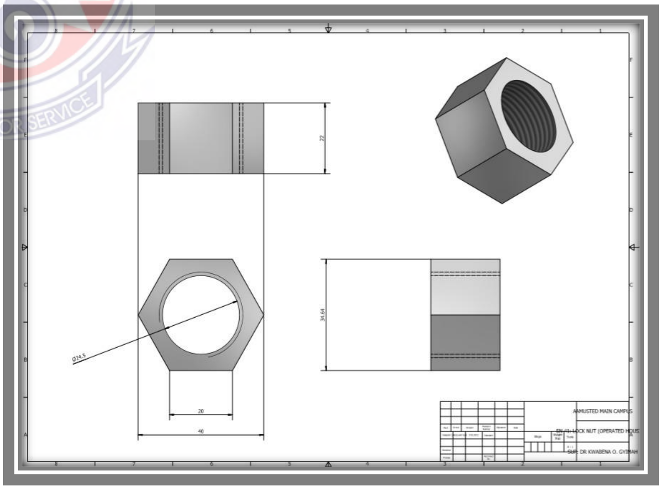


Fig. 68, SN 41: Operating Housing Lock Nut

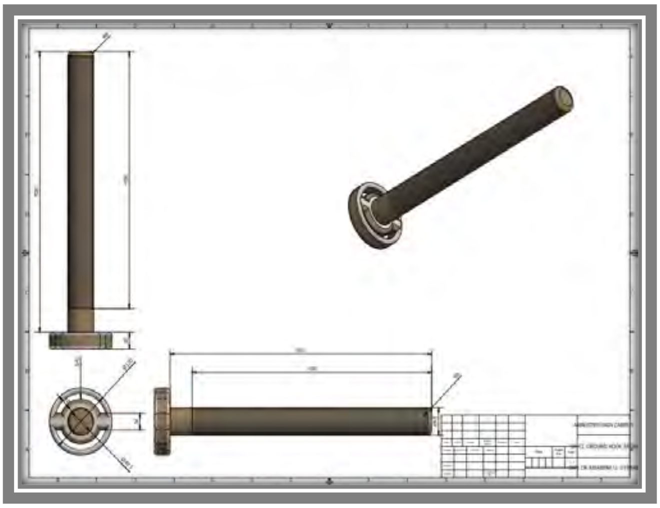


Figure. 69: SN 42, New Lift Ground Mount Securing Screw

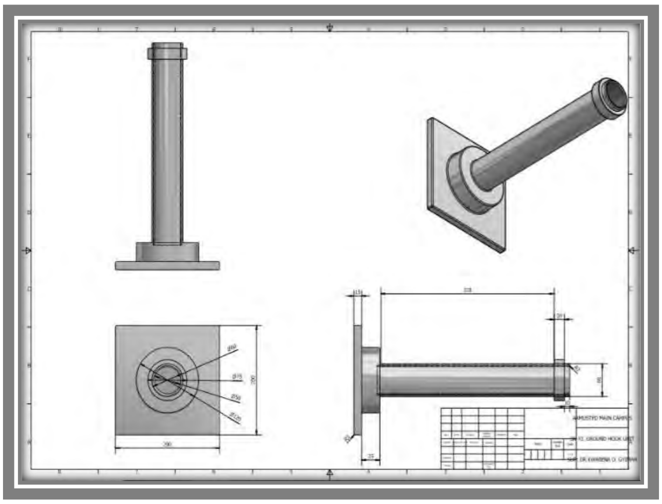


Figure 70: SN 43: Ground Hook Nut

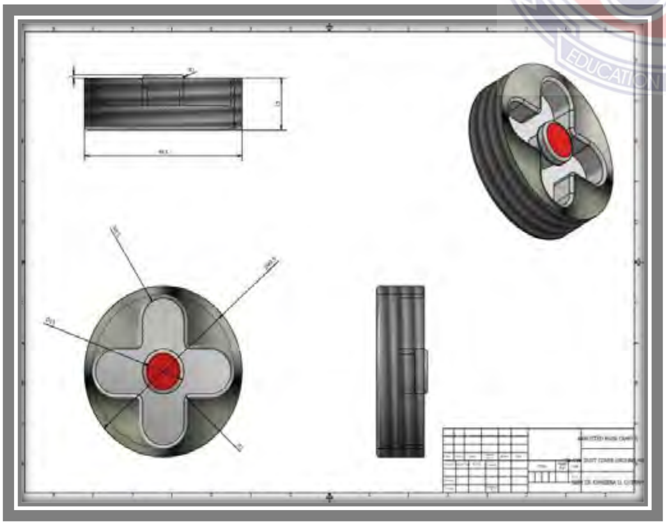


Figure 71: SN 43A: Ground Hook Dust Cover

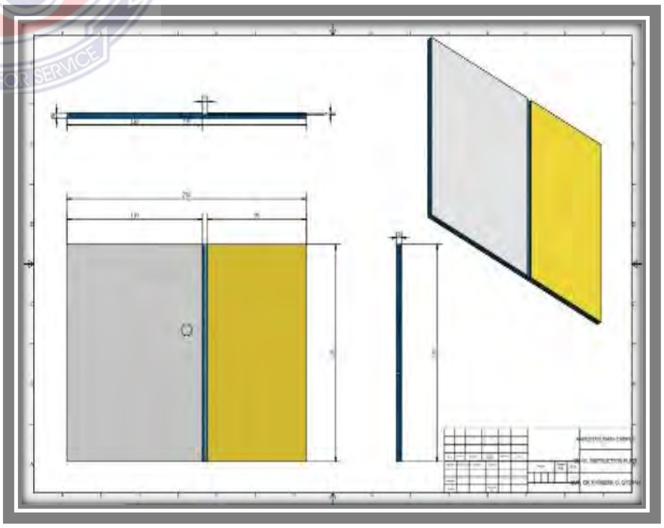


Fig. 72, SN 44: Instruction Plate

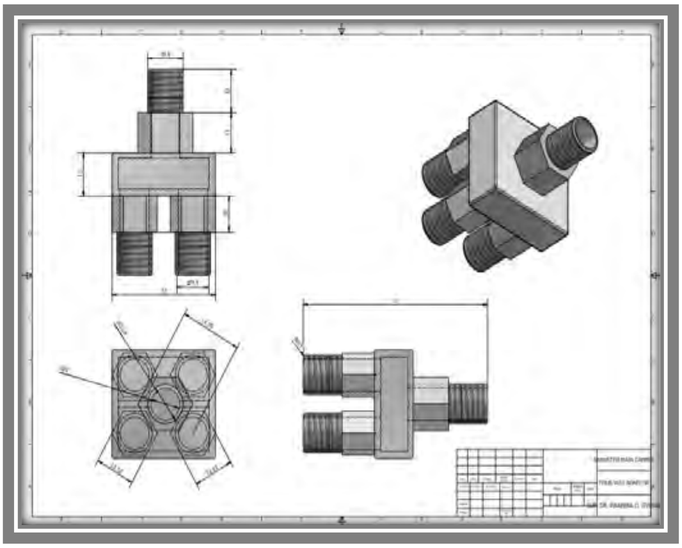
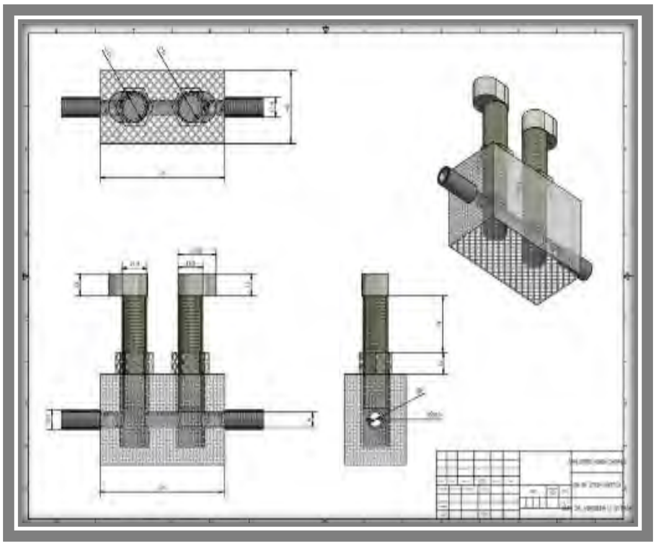


Fig. 73 SN 46: Four-Way Adapter for Movable Wheel Port/Pump/Motor



74: SN 49 Stop Switch

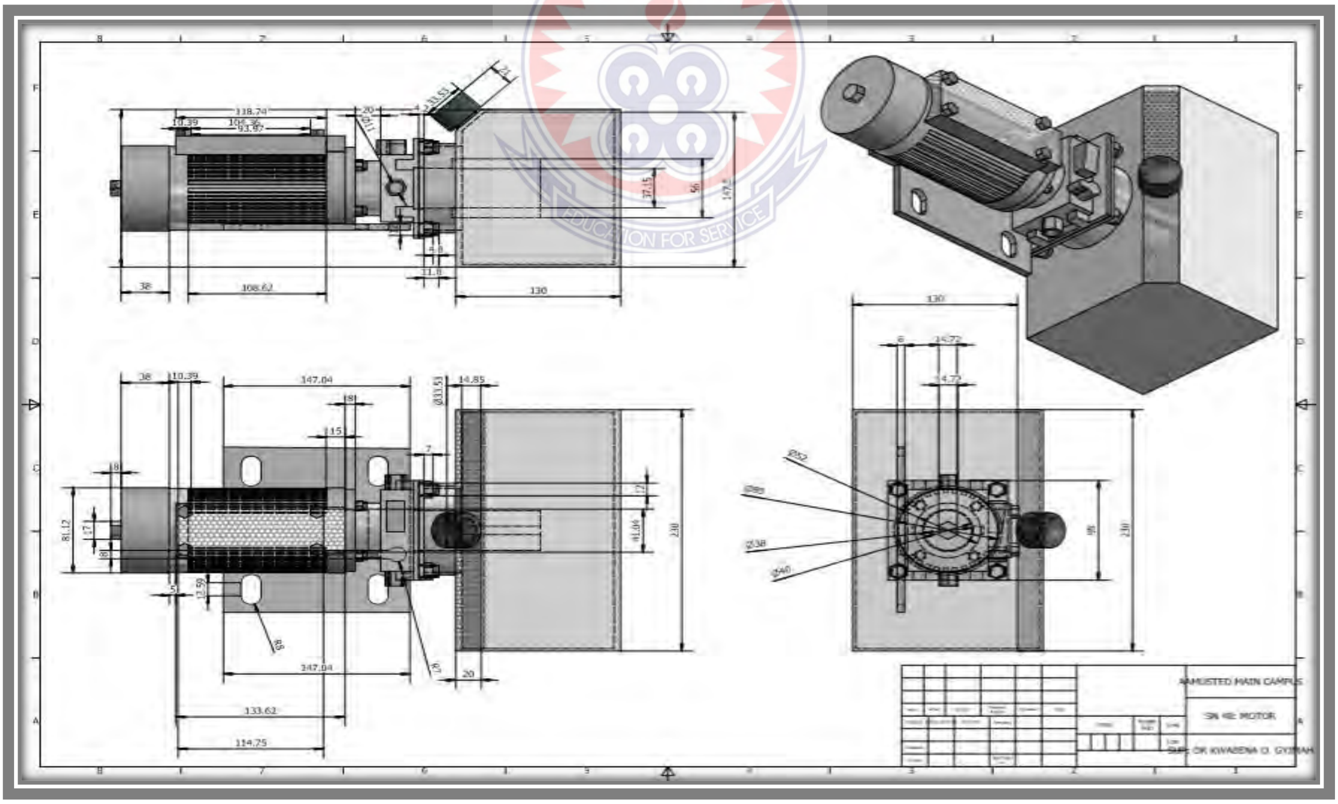


Figure 75: SN 48: Hydraulic Motor

APPENDIX B:

ASSEMBLY OF THE UNIT IN FIVE STAGES/ DESIGN MODIFICATIONS

The vehicle placed on the new lift in Figure 77 and 79 has an approximate dimensions according the wheel base and track length of a normal car. The distance between the two-wheel centre- lines of the front and rear wheels are 370 cm or 3300mm, approximately the same as Nissan NAVARA. It was used for practical demonstration on the lift.

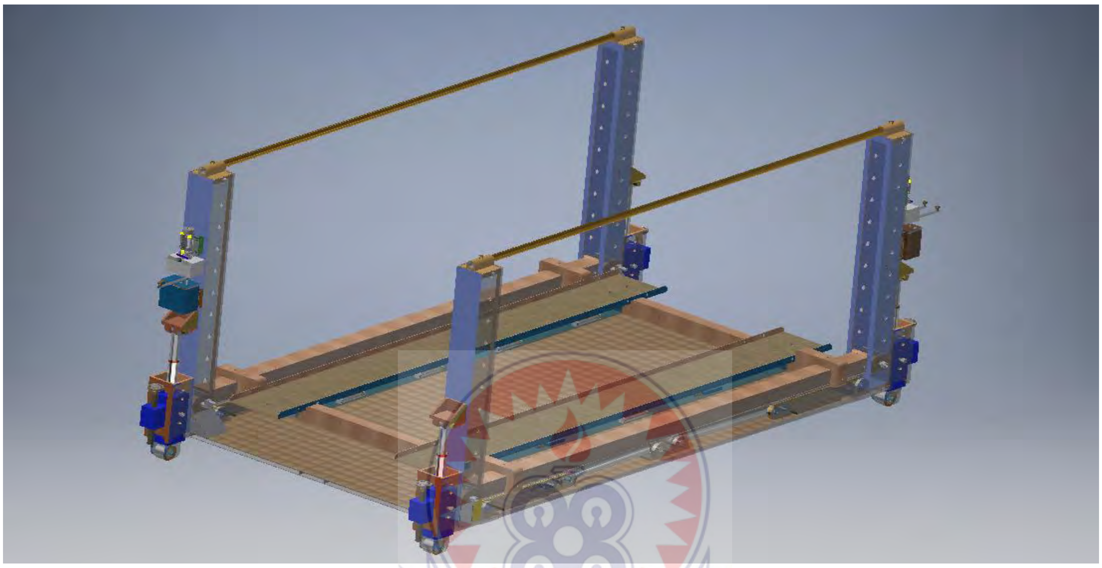


Fig. 76, Assembly of the new modified lift with Wheels in Operation

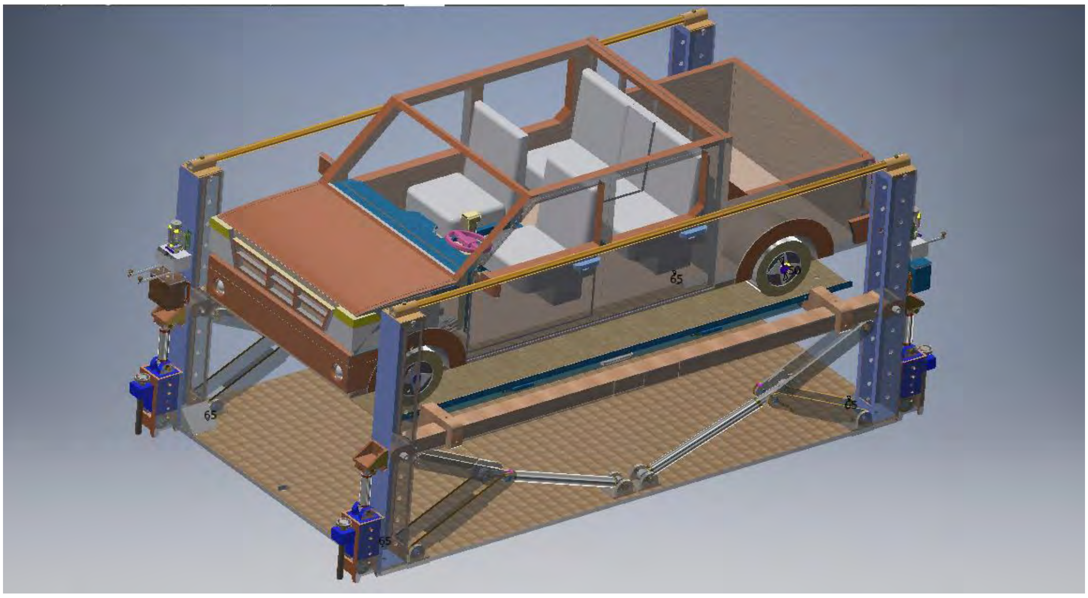


Fig. 77 Model pick-up on new designed Lift at Middle Level

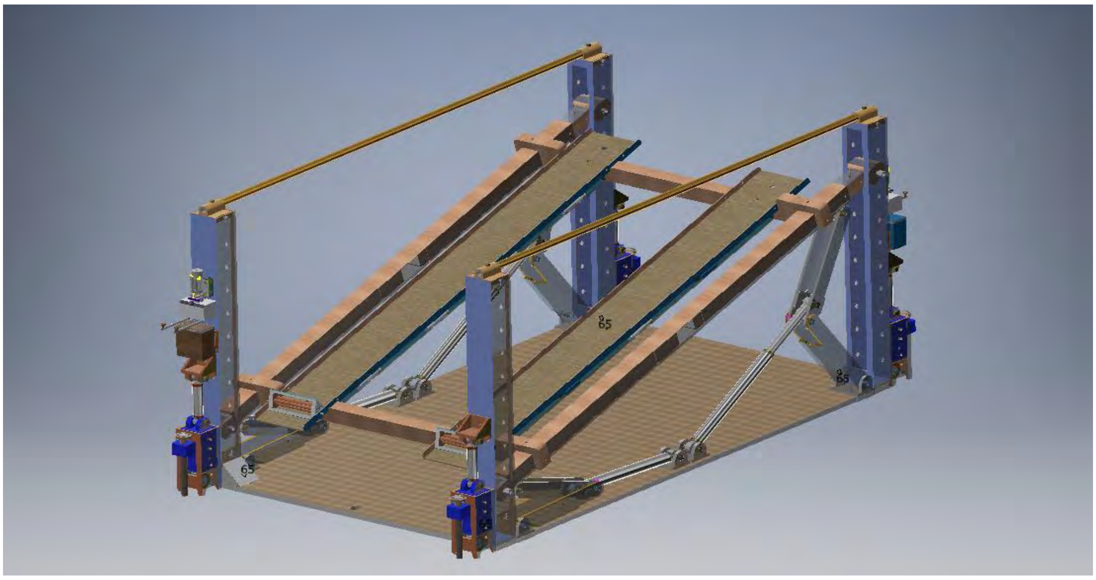


Fig. 78, Newly Designed Vehicle Lift at Inclined Level with Wheel Chocks

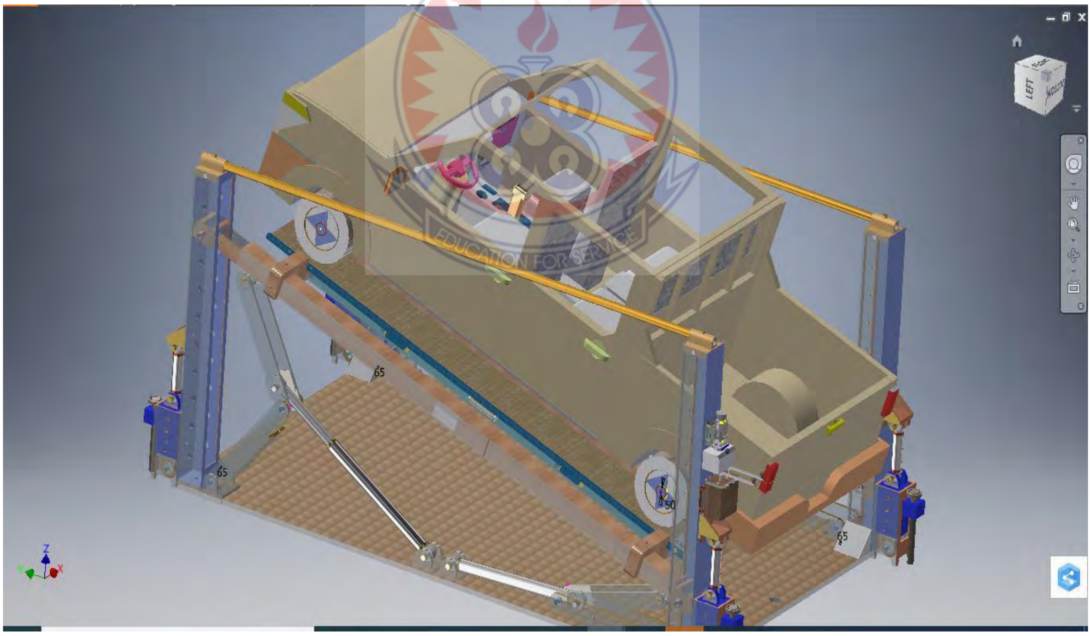
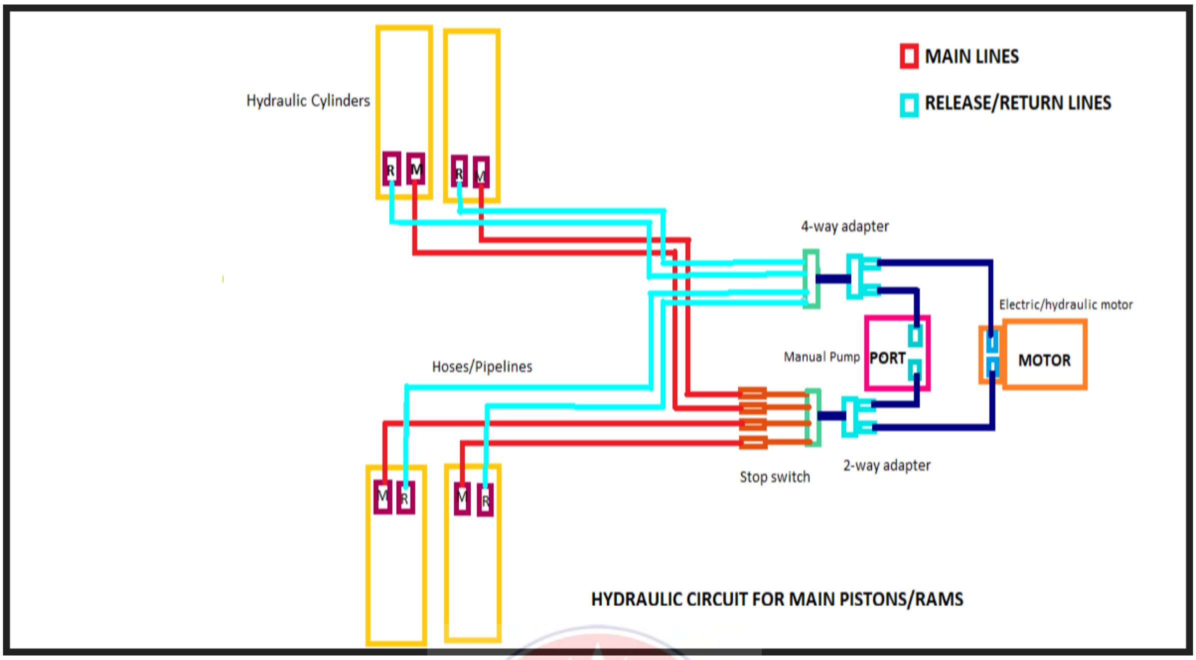


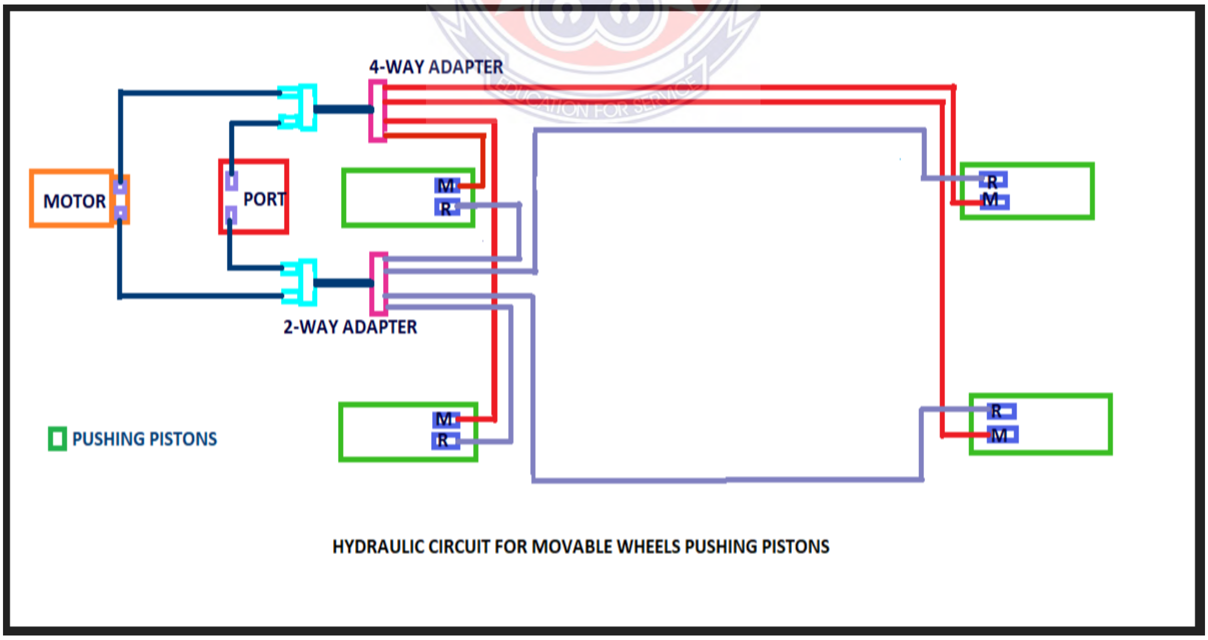
Fig. 79, Model pick-up on new designed Lift at Inclined Level with Wheel Chocks

APPENDIX C:

HYDRAULIC CIRCUIT LINE DIAGRAMS OF MAIN AND WHEELS PISTONS



Hydraulic circuit for main piston/rams (During Lifting)

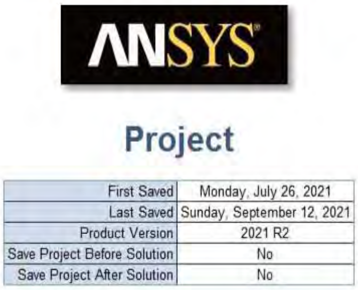


hydraulic circuit for moving wheel pistons (When moving the unit)

Note: the hydraulic system will also incorporate other accessories such as return/release valves and non-return valves/delivery valves.

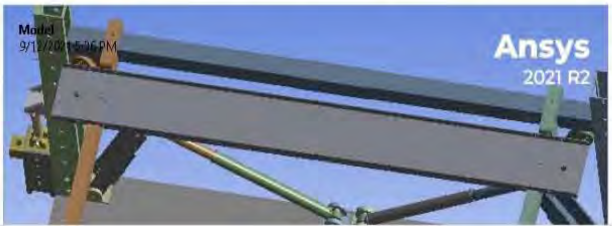
APPENDIX D:

Report Generated on Structural Steel as It Appears to Be the Best in Von-Mises Stress



Project

First Saved	Monday, July 26, 2021
Last Saved	Sunday, September 12, 2021
Product Version	2021 R2
Save Project Before Solution	No
Save Project After Solution	No



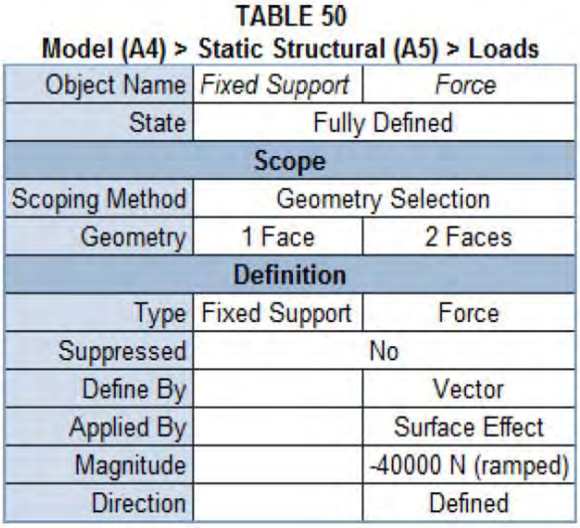
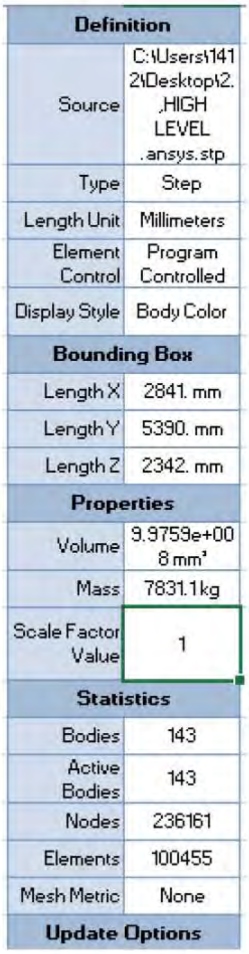


TABLE 50
Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Force*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	2 Faces
Definition		
Type	Fixed Support	Force
Suppressed	No	
Define By		Vector
Applied By		Surface Effect
Magnitude		-40000 N (ramped)
Direction		Defined

TABLE 53
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Stress*	*Total Deformation*	*Equivalent Elastic Strain*	*Shear Stress*
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Definition				
Type	Equivalent (von-Mises) Stress	Total Deformation	Equivalent Elastic Strain	Shear Stress
By	Time			
Display Time	Last			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation				XY Component
Coordinate System				Global Coordinate System
Integration Point Results				
Display Option	Averaged		Averaged	
Average Across Bodies	No		No	
Results				
Minimum	6.1048e-010 MPa	0. mm	3.6737e-014 mm/mm	-22.026 MPa
Maximum	67.192 MPa	1.5379 mm	3.7394e-004 mm/mm	17.989 MPa
Average	2.2305 MPa	0.10836 mm	1.3965e-005 mm/mm	1.2511e-003 MPa
Minimum Occurs On	SN1 MAIN BASE. Solid1			SN 8. CROSS MEMEER ,,,,,|Solid1[2]
Maximum Occurs On	SN 8. CROSS MEMBER ,,,,,|Solid1	SN. 9. LIFT PLATFORM.,,|Solid1	SN 8. CROSS MEMBER ,,,,,|Solid1	SN 21 MIDDLE LINK MECHANISM BEARING|Solid1[5]



Definition	
Source	C:\Users\1412\Desktop\2.,HIGH LEVEL .ansys.stp
Type	Step
Length Unit	Millimeters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	2841. mm
Length Y	5390. mm
Length Z	2342. mm
Properties	
Volume	9.9759e+008 mm^3
Mass	7831.1kg
Scale Factor Value	1
Statistics	
Bodies	143
Active Bodies	143
Nodes	236161
Elements	100455
Mesh Metric	None
Update Options	

TABLE 46
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 276*	*Contact Region 277*	*Contact Region 278*	*Contact Region 279*	*Contact Region 280*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	3 Faces	12 Faces			
Target	3 Faces	8 Faces			
Contact Bodies	SN 5. MAIN BEAM. ...|Solid1[2]	SN 8. CROSS MEMBER ,,,,,|Solid1		SN 8. CROSS MEMBER ,,,,,|Solid1[2]	
Target Bodies	SN 8. CROSS MEMBER ,,,,,|Solid1[2]	SN. 9. LIFT PLATFORM.,,|Solid1	SN. 9. LIFT PLATFORM.,,|Solid1[2]	SN. 9. LIFT PLATFORM.,,|Solid1	SN. 9. LIFT PLATFORM.,,|Solid1[2]
Protected	No				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Program Controlled				
Trim Contact	Program Controlled				
Trim Tolerance	16.319 mm				
Suppressed	No				
Advanced					
Formulation	Program Controlled				
Small Sliding	Program Controlled				
Detection Method	Program Controlled				
Penetration Tolerance	Program Controlled				
Elastic Slip Tolerance	Program Controlled				
Normal Stiffness	Program Controlled				

TABLE 46
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 276*	*Contact Region 277*	*Contact Region 278*	*Contact Region 279*	*Contact Region 280*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	3 Faces	12 Faces			
Target	3 Faces	8 Faces			
Contact Bodies	SN 5. MAIN BEAM. ...|Solid1[2]	SN 8. CROSS MEMBER ,,,,,|Solid1		SN 8. CROSS MEMBER ,,,,,|Solid1[2]	
Target Bodies	SN 8. CROSS MEMBER ,,,,,|Solid1[2]	SN. 9. LIFT PLATFORM.,,|Solid1	SN. 9. LIFT PLATFORM.,,|Solid1[2]	SN. 9. LIFT PLATFORM.,,|Solid1	SN. 9. LIFT PLATFORM.,,|Solid1[2]
Protected	No				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Program Controlled				
Trim Contact	Program Controlled				
Trim Tolerance	16.319 mm				
Suppressed	No				
Advanced					
Formulation	Program Controlled				
Small Sliding	Program Controlled				
Detection Method	Program Controlled				
Penetration Tolerance	Program Controlled				
Elastic Slip Tolerance	Program Controlled				
Normal Stiffness	Program Controlled				