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DESIGN AND ANALYSIS OF MODIFIED FOUR-POST LIFT FOR LIGHT-DUTY VEHICLES

Sherry K. Amedorme
Department of Mechanical and Automotive Technology Education,
Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Kumasi

ABSTRACT

The value of human life cannot be underestimated as far as the growth and development of every establishment is concerned. In many workshops, garages and companies, standard and appropriate tools and equipment are used to ensure safe, efficient and rapid discharge of work and also save people's lives. In motor vehicle most repairs, maintenance and servicing cannot be done without the assistance of a lift, Vehicle lift generally overcome drudgery, injuries, increase timeliness and efficiency in the workplace This paper presents the design and analysis of a modified and improved version of the existing four poles lift that will lift the vehicles effectively and safely from the ground so that the underside of the vehicles can be accessed, as well as elevating the vehicles to an ergonomic working height. The new design incorporates more specific capabilities and features such as lifting the entire vehicle, lifting only the front or rear end of the vehicle, tilting from the front or rear end of the vehicle and a simple exclusive mechanical lock at each pole among others. The required load capacity and preferable materials structural steel, cast iron and carbon steel were selected and comparative analysis was carried out to determine the effectiveness of the device in lifting loads of up to 7 tons, When static structural analysis was performed on the design the results show that equivalent Von-Misses stress for structural steel, cast iron and carbon steel annealed are 50.4MPa, 66.9MPa, 51.4MPa respectively. In terms of deformation, carbon steel 1020 annealed and structural steel have the lowest deformation value compared with cast iron. The unit is considered safe to use after imposing maximum loads without failure which are higher than the rated load of light-duty vehicles.

Keywords: Four-Post Lift. Redesign, Material Failure, Stress, Deformation, Light-Duty Vehicle

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1. INTRODUCTION

Innovation in engineering has been useful over the past decade which has brought different kinds of designs in lift, ramp or hoist into existence. This innovation has been very useful in the automobile industry. Before the invention of vehicle lifts, the mechanics would attempt to slide under the vehicle to find out what was wrong. It was difficult to work freely under the vehicle in the absence of these devices. The technology for lifts continues to be used to help save people's lives with several modifications to the existing car jacks or lifts [1, 2]. Although the existing lifts have served a wide range of purposes in various capacities however there are major safety concerns and issues which have been raised by some users and researchers regarding unanticipated falls and failures. Lee & Cho (2015); Thompson et al., (2018) listed many types of vehicle lifts including their designs and forms such as two posts with swinging arms, four posts with ramps and scissor lifts[3, 4]. They observed that the four-post lift is more preferable in terms of voltage usage and is the most popular one in many workshops. [5, 6]. Burlet-Vienney, Galy & Bertrand (2021) investigated the stability of a vehicle using two- post above-ground automotive lifts focusing on the distribution of forces in arms and support pad slippage[7]. They concluded that the rate of vehicles falling off two-post above-ground (2PAG) lifts in garages is fairly frequent[8, 9]. This is also confirmed by other researchers on the risk of vehicles falling from two-post vehicle lifts in motor vehicle repairs and servicing[10, 11]. A four-post or column lift often referred to as a drive-on lift allows a vehicle to be driven directly onto two runways that lift the vehicle by the tires, exposing the underside of the vehicle. These lifts are also referred to as wheel contact lifts and can come in several sizes, styles, and additions that can serve customer's and shop owners' specific needs. A four-post lift has the advantage of allowing a second car to be parked under the lifted car. This type of lift typically does not have to be anchored to the ground and the four posts "footprint" is generally smaller than a two-post lift[5]. Lee & Cho (2015) indicate that lift should be durable and show an aesthetic sense. They study three different lifts using finite element analysis programme of ANSYS and compared the durability of each configuration [12]. Ahmed, et al. (2019) focused on stability and rigidity tests of portable car lifts after building the prototype to ensure that the design is strong enough to lift a vehicle to change the tires[11].

Hydraulic system plays key role in lifting vehicles [13]. This technology uses fluid with the help of a pump: It is indicated that a hydraulic lifting device will require hydraulic apparatus with the help of manual or electronic operated pump to lift the vehicle according to the safe working load of the lift [14]. Lifts that emphasize using pistons and hydraulic means to raise the vehicle for repairs should have safety features such as self-locking mechanisms in its operations in case of hydraulic failure. These problems are remedied in the hydraulic jack by incorporating a simple mechanical lock as a safety measure on the jack [2, 15, 16].

2. MATERIALS AND METHODS

The materials selected and used for the analysis are structural steel, carbon steel 1020 annealed and cast iron and a comparative analysis was carried out to determine the most suitable material for the lift. The rated loads of the vehicles to be repaired were considered in selecting the materials for the unit. Table 1 displays various mechanical properties of the materials under consideration

Table 1 Mechanical Properties of Sampled Materials

Properties	**Structured steel**	**Cast iron**	**Carbon steel**
Density	7.85e-06 kg/mm^3	6.999e-06	7.85e-06
Young’s modulus	2e+05 MPa	8944	2.124e+05
Poisson’s ratio	0.3	0.26	0.29
Bulk modulus	1.6667e+05 MPa	62111	1.6857e+0.5
Shear modulus	76923	35492	82326
Isotropic secant coefficient of thermal expansion	1.2e-05 1\ oC	1.196e-05	1.143e-05
Compressive Ultimate Strength	O MPa	141.4	393
Compressive yield strength	250 MPa	79.81	2935

2.1 Modelling of four-post lift

The model of individual components of the multi-function modified four-post lifting device was done using Autodesk Inventor Professional 2017. Steady-state static structural simulations were performed using the ANSYS version 2022 R2. The 3D modelling shown in Figure 1 of the individual components was done by considering the standard base dimensions of 2800 kg capacity lift located at Kumasi Technical Institute and 4000kg lift at Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) automotive workshops.

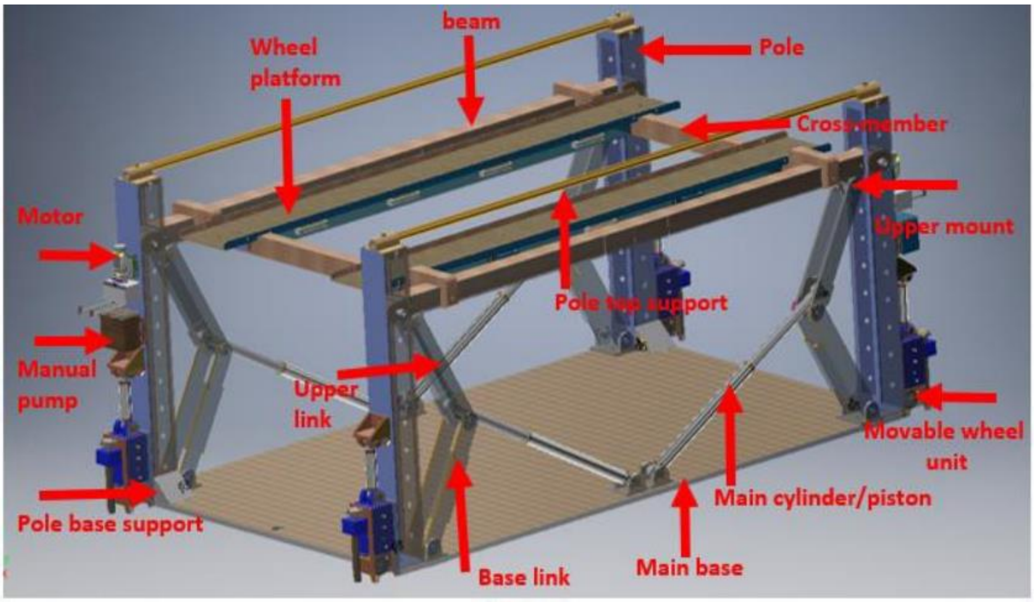


Figure 1 Modified four posts lift with labelled parts

Figures 2 and 3 show the models of the modified four-post lift with the vehicle at high and low positions of the lift. To obtain a faster and more accurate solution polyhedral mesh of 236161 nodes and 100455 elements were generated. A fixed constraint was applied to the main base of the lift with a concentrated load imposed on the vehicle. The behaviour of the lift was analysed at three levels (high, inclined and Low) under four different rated loads 30000N, 40000N, 50000N and 70000N.

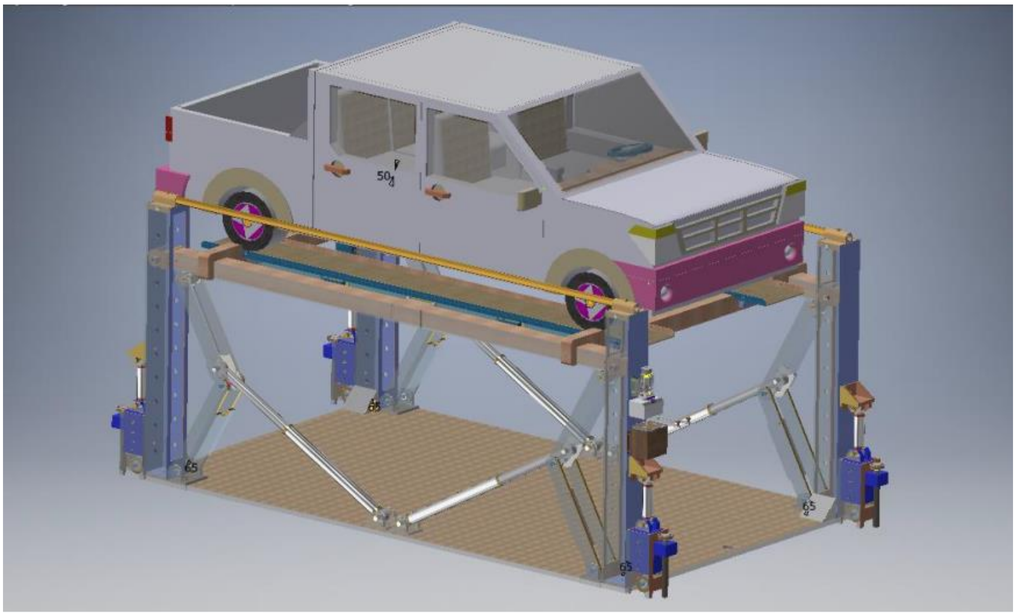


Figure 2 Model pick-up on modified lift at high level

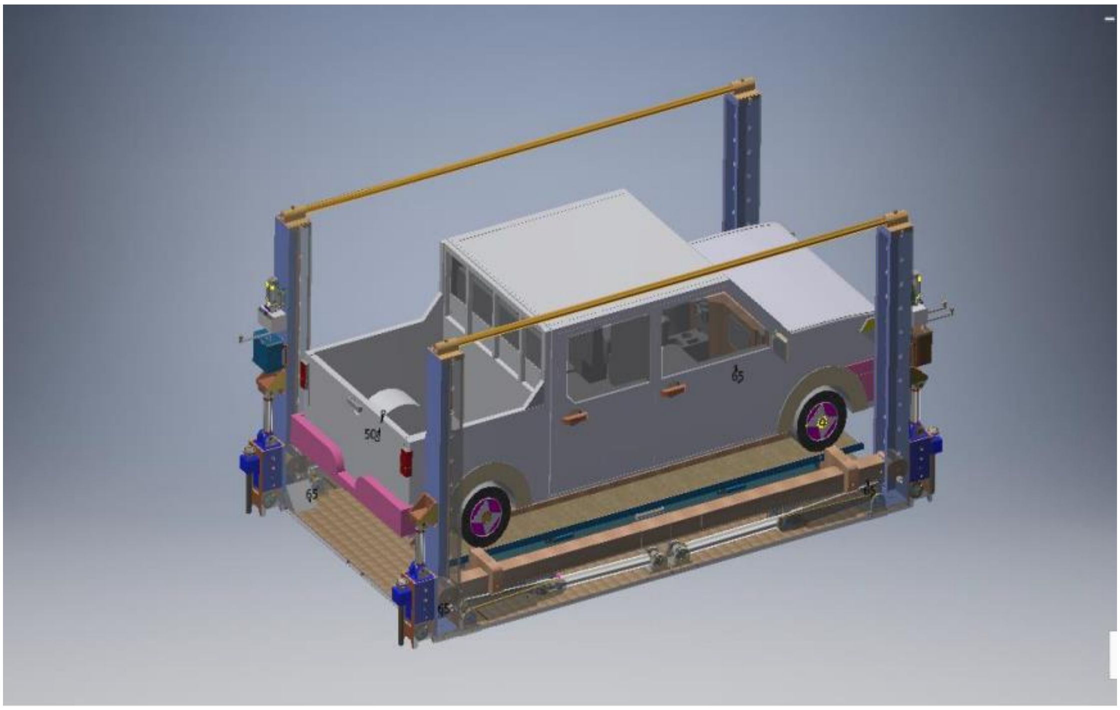
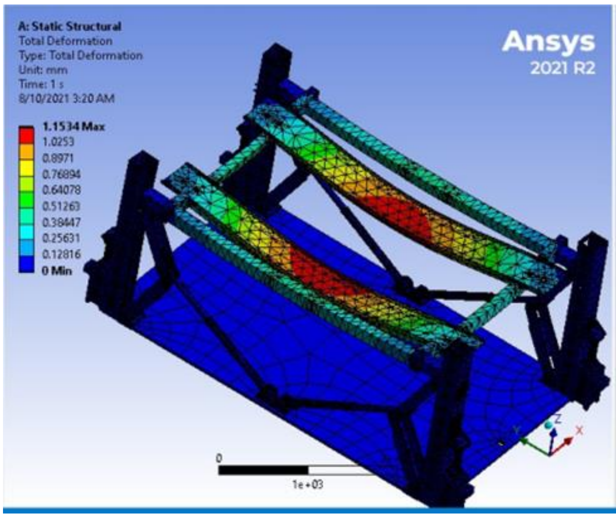


Figure 3 Model pick-up on the modified four post lift at low level

3. RESULTS AND DISCUSSION

Figures 4 to 5 present the design of a four-post lift at a high level using structured steel and a rated load of 30000N. The result shows a total deformation of 1.1534, von Mises stress of 50.393MPa, shear stress of 13.491 and an equivalent strain of 0.00028045 when static structural analysis was performed on the modified lift at a high level. This indicates the lift is safe and can sustain the load at this height without failure since the stress value is smaller than 250 MPa minimum yield strength of structured steel.



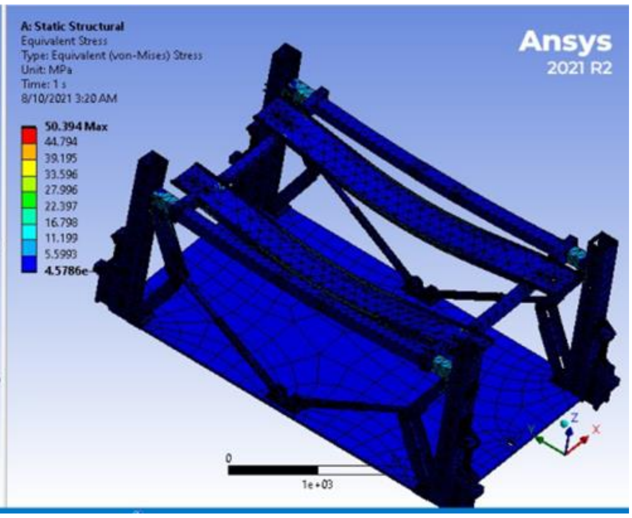
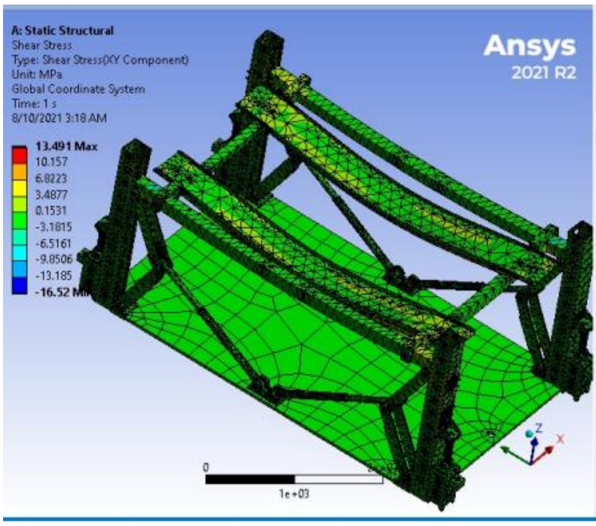


Figure 4: Total deformation; **Figure 5:** Von-Mises stress



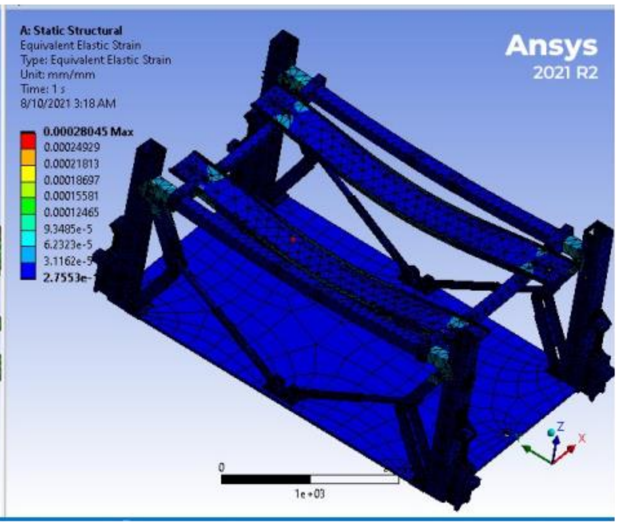
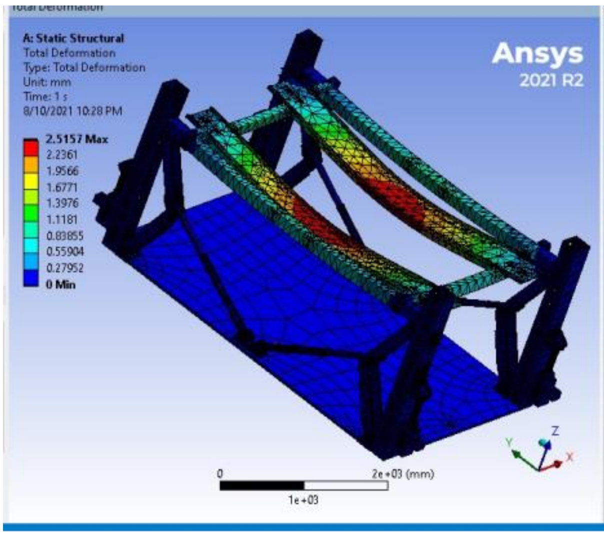


Figure 6: Shear stress **Figure 7**: Equivalent strain

Figures 8 to 11 show the design of a four-post lift cast iron at a high level and load of 30000N. The results display the total deformation of 2.5157, Von-Mises stress of 66.87MPa, the shear stress of 21.732MPa and equivalent strain of 0.00065505 under static Structural Analysis



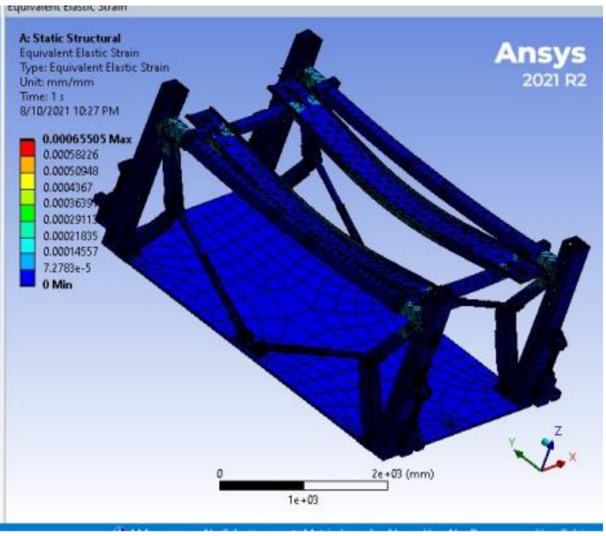


Figure 8: Total deformation **Figure 9**: Von-Mises stress

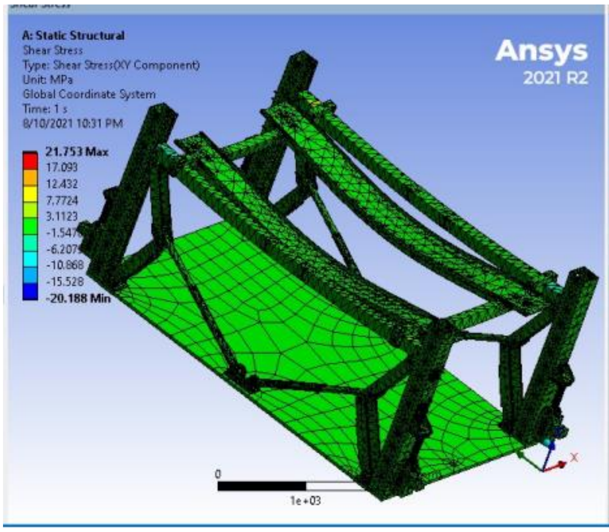


Figure 10: Shear stress

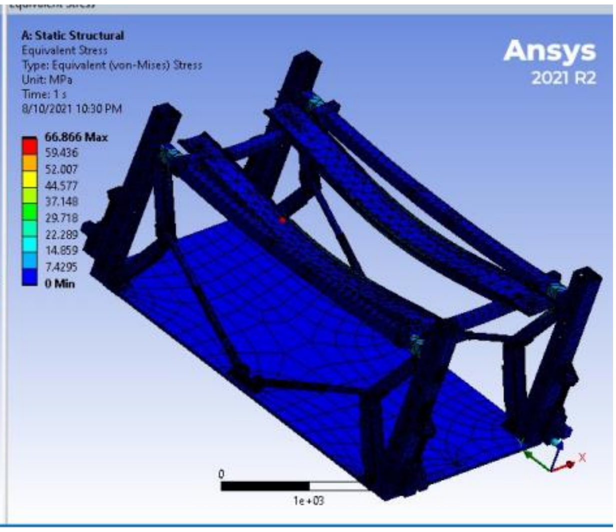


Figure 11: Equivalent strain

Figures 12 to 15 depict the design of a four-post lift with a weight of 30000 N applied to it at a high height. The adjusted lift at a high level made of cast iron material yielded a total deformation of 1.0879, von-Mises stress of 51.43 MPa, shear stress of 13.02 MPa, and equivalent strain of 0.00026958 under static structural analysis.

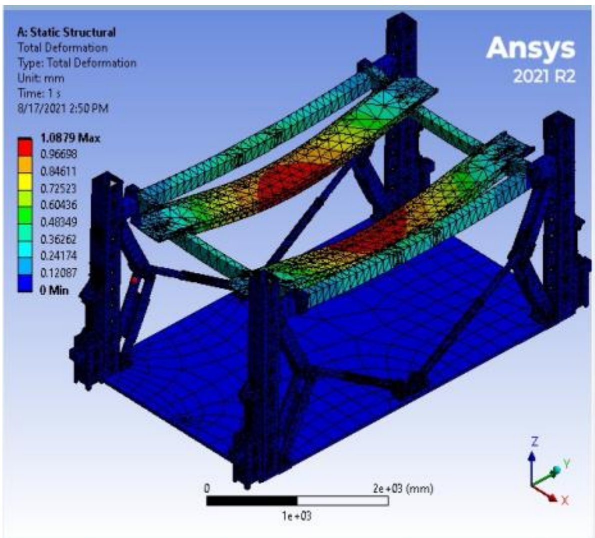


Figure 12: Total deformation;

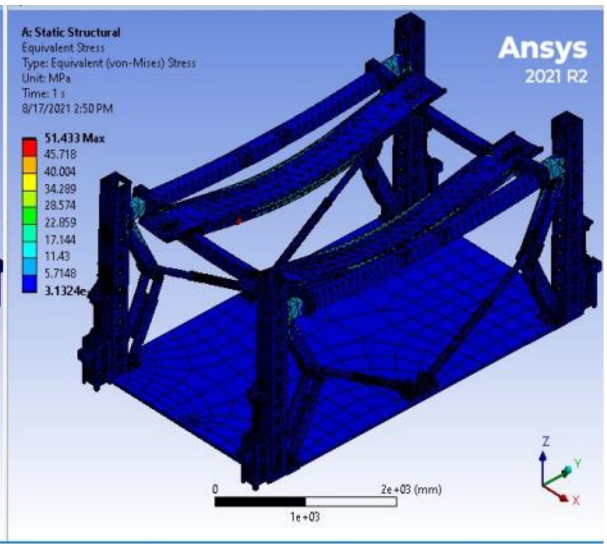
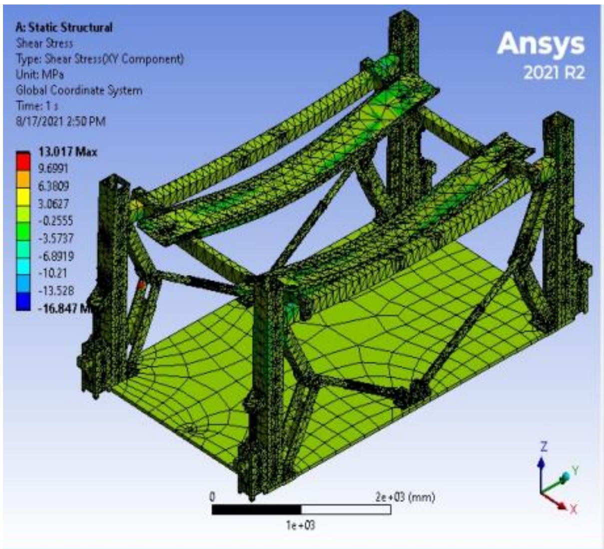


Figure 13: Von-Mises stress



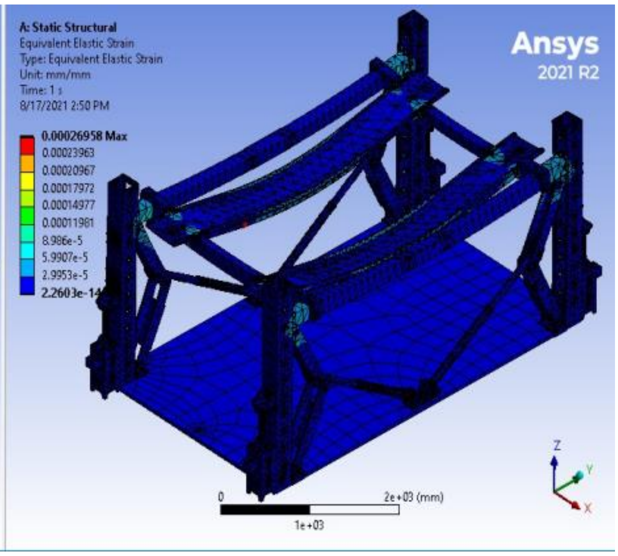


Figure 14: Shear stress

Figure 15: Equivalent strain

Table 2 shows the von Mises stress under various loading conditions 30000N 40000N, 50000N and 70000N for the three materials at high, inclined and low levels. The result shows that the equivalent von-Misses stress of the structural steel at high levels is the smallest compared to carbon steel annealed and cast iron under the same load and boundary conditions. This implies that a four-post lift made of structural steel is less stressed, safe and insusceptible to failure compared to carbon steel annealed and cast iron. At the inclined level, carbon steel annealed and structural steel have less stress than cast iron. At the low position, greater von-Mises stress of 58.295MPa is induced in the steel compared to high and inclined levels which is smaller than the yield limit of the same material. The result also shows the equivalent von Mises stress is increasing with increasing load on the lift.

Table 2 Load and von Mises stress for three materials at high, inclined and low levels

LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
30000	HIGH	50.394	66.866.	51.433.
	INCLINED	53.072	83.73	52.916
	LOW	58.295	58.457	58.339
40000	HIGH	67.192	89.154	68.578
	INCLINED	70.762	111.64	70.555
	LOW	77.727	77.943	77.787
50000	HIGH	83.989	111.44	85.722
	INCLINED	88.453	139.55	88.194
	LOW	97.159	97.429	97.233

70000	HIGH	117.59	156.02	120.01
	INCLINED	123.83	195.37	123.47
	LOW	136.02	136.4	136.13

Tables 3 and 4 show total deformation at various loading conditions. The result shows that carbon steel 1020 annealed has the lowest deformation compared to the other two materials. The same trend is observed at the various positions of loading. The result of equivalent elastic strain indicates that structural steel and carbon steel annealed have produced lower results compared to cast iron at high inclined and low levels under the same loading conditions.

Table 3 Load and total deformations for three materials at high, inclined and low levels

TOTAL DEFORMATIONS				
LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
30000	HIGH	1.1534	2.5157	1.0879
	INCLINED	1.2108	2.6466	1.1414
	LOW	0.65843	1.4693	0.61989
40000	HIGH	1.5379	3.3542	1.4505
	INCLINED	1.6144	3.5288	1.5219
	LOW	0.87791	1.9591	0.82651
50000	HIGH	1.9223	4.1928	1.8107
	INCLINED	2.018	4.411	1.9023
	LOW	1.0974	2.4489	1.0331
70000	HIGH	2.6913	5.8699	2.5349
	INCLINED	2.8252	6.1754	2.659
	LOW	1.5363	3.4284	1.4464

Table 4 Load and equivalent elastic strains for three materials at high, inclined and low levels

Equivalent Elastic Strains				
LOADS	LEVELS	STRUCTURAL STEEL	CAST IRON	CARBON STEEL 1020 ANNEALED
30000	HIGH	0.00028045	0.00065505	0.000269958
	INCLINED	0.00028989	0.00067547	0.00027859
	LOW	0.00032175	0.00071952	0.00030295
40000	HIGH	0.00037394	0.0008734	0.00035944
	INCLINED	0.00038652	0.00090063	0.00037145
	LOW	0.00042901	0.00095935	0.00040394
50000	HIGH	0.00046742	0.0010917	0.0004493
	INCLINED	0.00048315	0.0011258	0.00046432
	LOW	0.00053626	0.0011992	0.00050493
70000	HIGH	0.00065439	0.0015284	0.00062902
	INCLINED	0.00067642	0.0015761	0.00065004
	LOW	0.00075076	0.0016789	0.00070689

4. CONCLUSION

This study sought to modify an acceptable lift for automotive industries, garages and shops from three different materials in relation to the rated loads of light-duty vehicles. The new design which can be operated without any difficulty incorporates some safety features that will prevent vehicle users from using unprescribed lifting supports. Based on the findings and the prototype the unit is considered safe to use. A factor of safety has been considered after imposing the varying loads which are higher than the rated load of light-duty vehicles. The lift is equipped with all the necessary accessories for performing different tasks. It can undergo high-level or inclined lifting with a mechanical lock system as a safety measure in case of hydraulic failure. The aesthetic sense of this modification will attract many customers as their preferred lift.

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