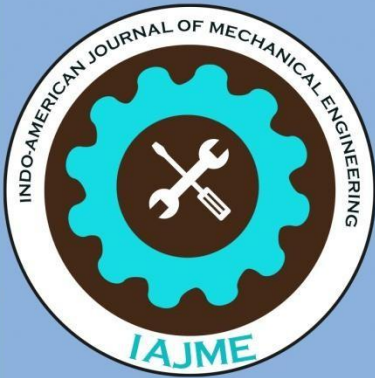


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A REVISED FOUR-POST LIFT SYSTEM FOR LIGHT-DUTY VEHICLES: DESIGN AND ANALYSIS

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ABSTRACT

In terms of progress and improvement for any organization, the worth of a human life cannot be understated. Standard and proper tools and equipment are used in several businesses, garages, and workshops to guarantee the safe, effective, and quick completion of tasks while also preventing injuries and fatalities. The use of a car lift is essential for the majority of automotive repair, maintenance, and service tasks. These lifts eliminate back pain, prevent injuries, and make workers more efficient and timely. This paper details the planning and evaluation of an upgraded four-pole lift system that will raise the vehicles off the ground in a safe and efficient manner, allowing access to their undercarriages and bringing them to a more comfortable working height for the operators. Among the many innovative features and capabilities included in the design is the ability to tilt the vehicle from either the front or the back, raise the whole vehicle, or lift either the front or rear end. Additionally, there is a simple mechanical lock at each pole. The device's efficacy in lifting weights up to 7 tons was determined by comparative study after the necessary load capacity and preferred materials—structural steel, cast iron, and carbon steel—were determined. According to the findings of the design's static structural analysis, the corresponding Von-Misses stresses for structural steel, cast iron, and annealed carbon steel are 50.4MPa, 66.9MPa, and 51.4MPa, respectively. When compared to cast iron, structural steel and carbon steel 1020 annealed have the lowest deformation values. Following the imposition of maximum loads without failure that exceed the rated load of light-duty vehicles, the unit is deemed safe for operation.

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

1. INTRODUCTION

Various designs for lifts, ramps, or hoists have come into existence thanks to technical innovation in the last decade. In the automotive sector, this invention has shown to be quite beneficial. When mechanics didn't have access

to car lifts, they would try to slip beneath the vehicle to diagnose problems. Without these tools, it was tough to move about freely beneath the car. There have been several updates to the current automobile jacks or lifts, and the

technology behind them is still being employed to save lives [1, 2]. The current lifts have done many things well, but some users and academics have voiced serious safety concerns about the possibility of unexpected falls and breakdowns. A variety of vehicle lifts, including scissor lifts, four-post lifts with ramps, and two-post lifts with swinging arms, were detailed by Thompson et al. (2018) and Lee & Cho (2015), respectively[3, 4]. Based on their findings, the four-post lift is the most preferred option in many workplaces and uses less electricity. 5, 6. The authors Bulet-Vienney, Galy, and Bertrand (2021) studied the effects of arm force distribution and support pad slippage on vehicle stability in two-post above-ground car lifts [7]. The researchers came to the conclusion that cars do in fact fall off two-post above-ground (2PAG) lifts in garages on a regular basis[8, 9]. Other studies on the subject of the dangers of using two-post car lifts for automotive maintenance and repairs have also corroborated this[10, 11]. Driving a vehicle onto two runways raises it by its tires in a four-post or column lift, also called a drive-on lift, revealing the vehicle's undercarriage. These lifts, which are also known as wheel contact lifts, are available in a wide range of sizes, designs, and accessories to meet the demands of both customers and business owners. The ability to place a second vehicle underneath a raised vehicle is a benefit of four-post lifts. The "footprint" of a four-post lift is often less than that of a two-post lift, therefore it is not necessary to anchor this form of lift to the ground[5]. Lifts, according to Lee & Cho (2015), should be both long-lasting and aesthetically pleasing. They examined the

longevity of three distinct lift configurations using the ANSYS finite element analysis tool [12]. To make sure the design can support lifting a vehicle to replace its tires, Ahmed et al. (2019) concentrated on stiffness and stability testing of portable auto lifts after the construction of the prototype [11]. When it comes to raising cars, the hydraulic system is crucial [13]. Fluid is propelled by means of a pump in this technological advancement. As previously said, a hydraulic lifting system must include hydraulic equipment that is powered by either a manually driven or an electronically operated pump in order to raise the vehicle to a safe operating load [14]. To prevent accidents in the event of a hydraulic failure, lifts that rely on pistons and other hydraulic devices to elevate the car for repairs should include safety elements like self-locking mechanisms into their operations. Incorporating a basic mechanical lock as a safety feature on the hydraulic jack fixes these issues [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+05
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	0 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.

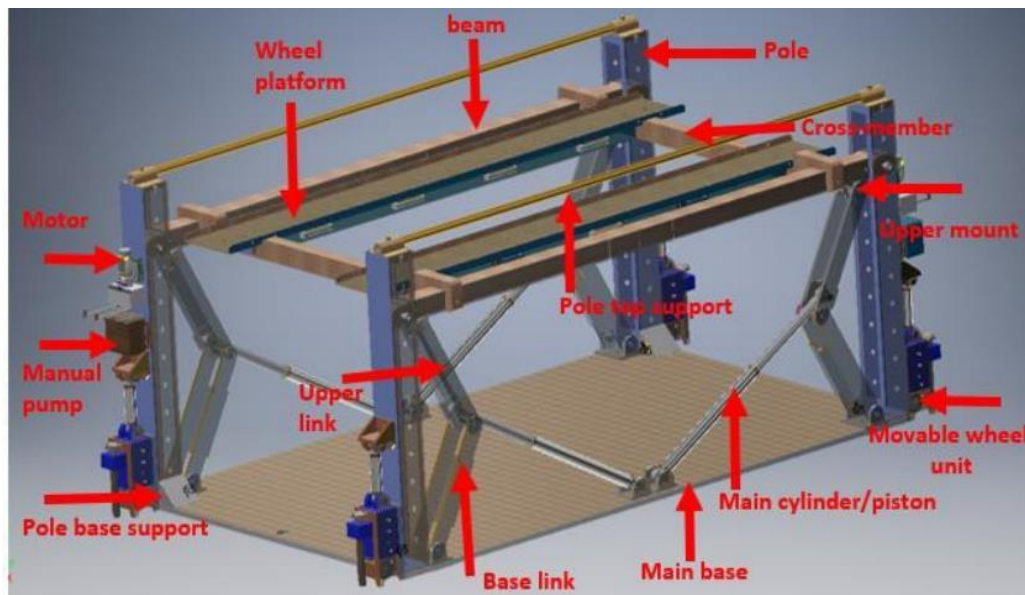


Figure 1 Modified four posts lift with labelled parts

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

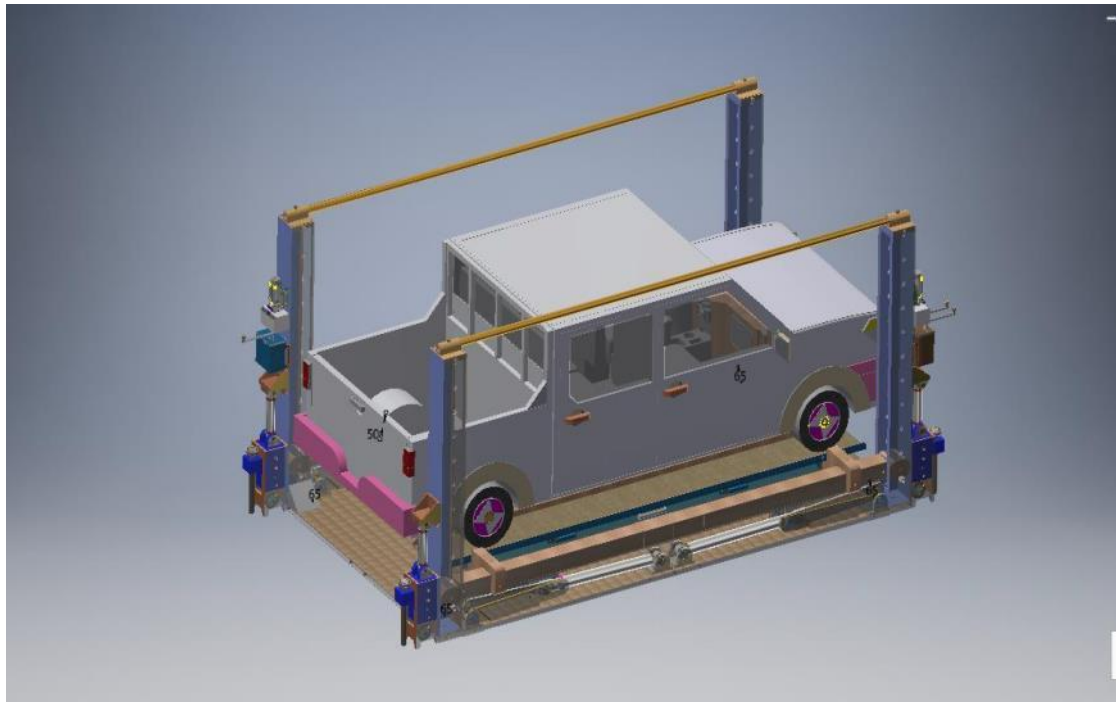


Figure 3 Model pick-up on the modified four post lift at low level

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.

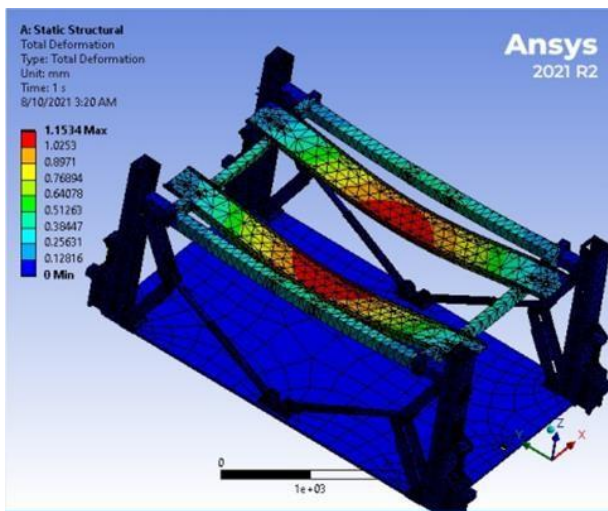


Figure 4: Total deformation;

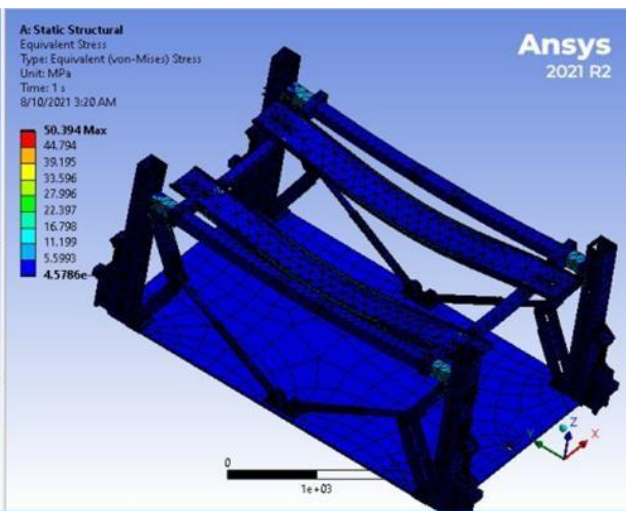


Figure 5: Von-Mises stress

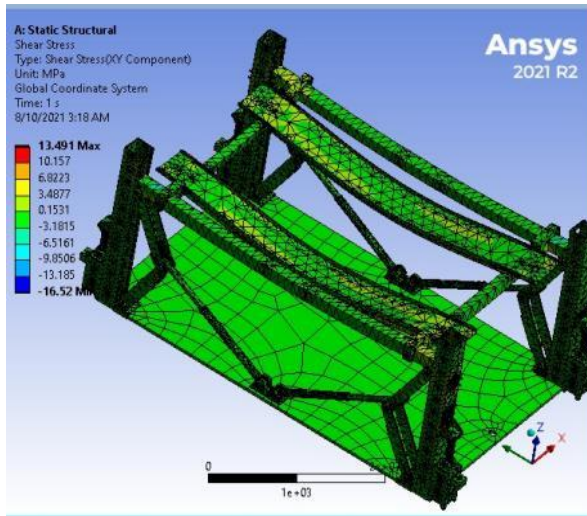


Figure 6: Shear stress

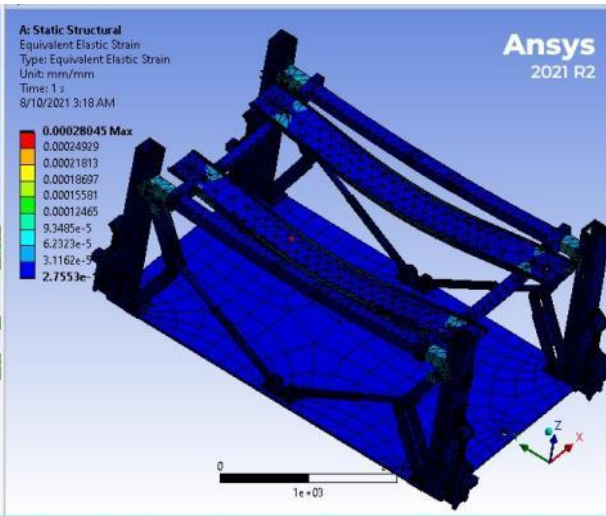


Figure 7: Equivalent strain

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

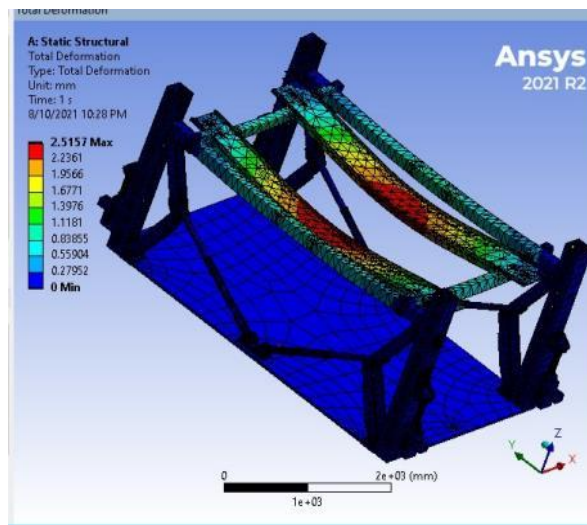


Figure 8: Total deformation

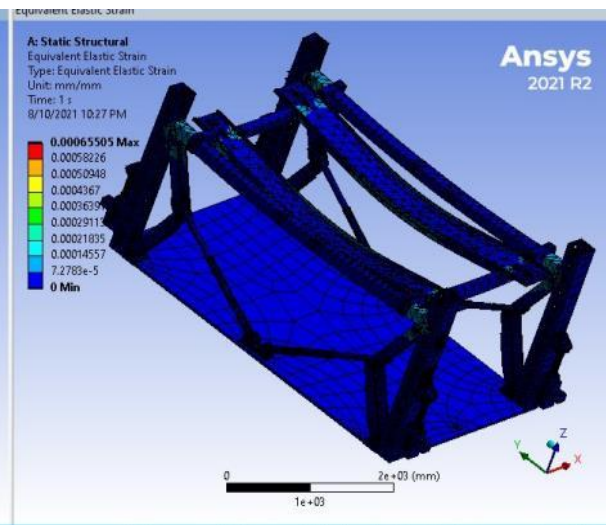


Figure 9: Von-Mises stress

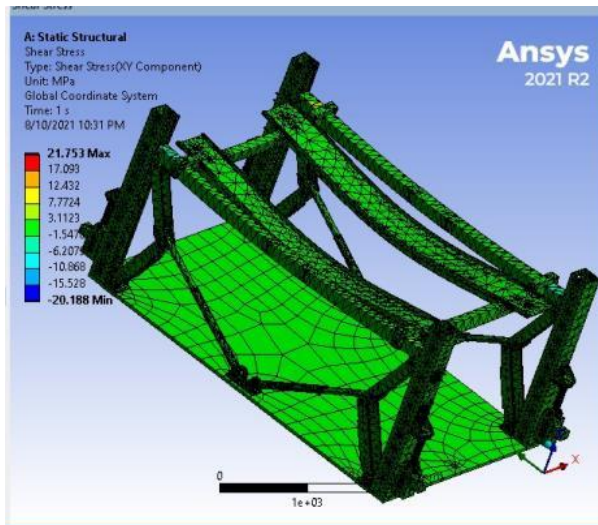


Figure 10: Shear stress

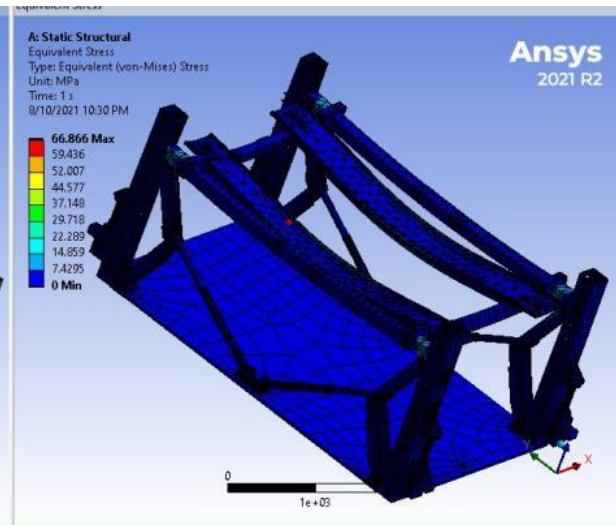


Figure 11: Equivalent strain

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.

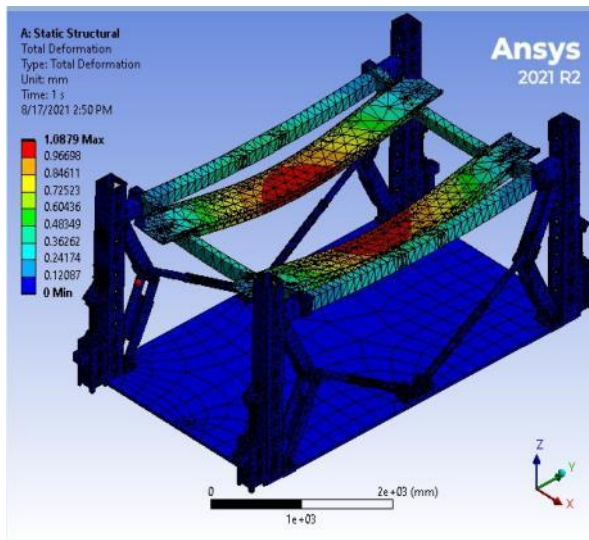


Figure 12: Total deformation;

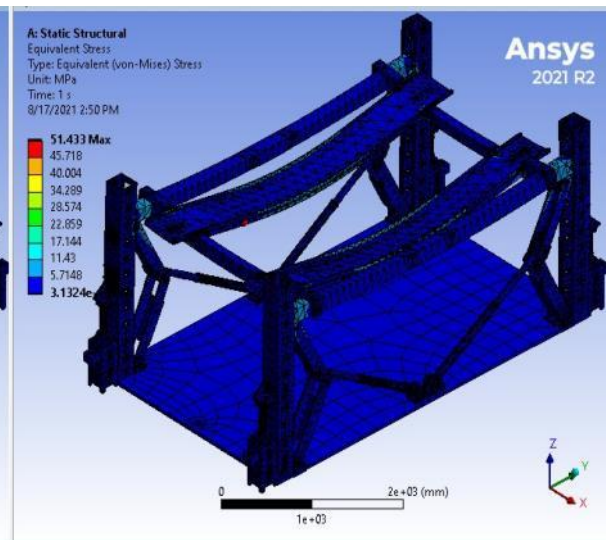


Figure 13: Von-Mises stress

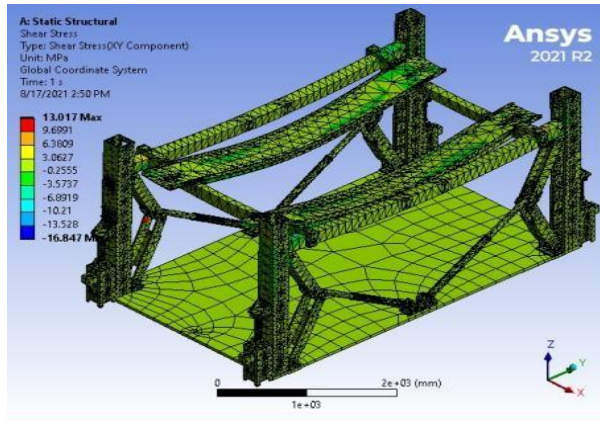


Figure 14: Shear stress

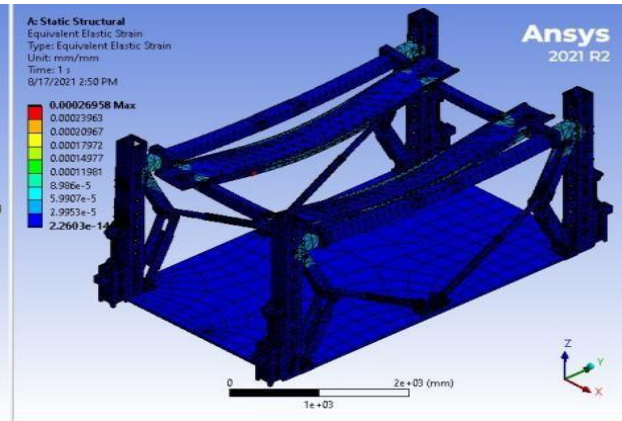


Figure 15: Equivalent strain

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-Mises 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

Based on the rated loads of light-duty vehicles, this research aimed to adapt a suitable lift from three different materials for use in automotive industries, garages, and shops. The new design is easy to use and has safety elements that stop people from utilizing lifting supports that aren't prescribed. The results and the prototype indicate that the device is safe to use. After applying the varied loads that exceed the rated load of light-duty vehicles, a safety factor was taken into account. All the attachments needed to carry out various activities are already on board the lift. A mechanical lock mechanism ensures safety in the event of hydraulic failure, allowing it to undertake slope or high-level lifting. Many consumers would choose this

adjustment as their preferred lift because of its visual appeal.

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