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GENERAL ARTICLE

DESIGN ANALYSIS AND TOPOLOGY OPTIMIZATION FOR SCISSOR CAR JACK USING STATIC LINEAR APPROACH

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ARTICLE DETAILS

ABSTRACT

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Vehicles are used for transporting people or goods, especially on land. Generally, vehicles come with jacks as standard tools in assisting people to change flat tyre. They tend to use this tool whenever tyre/s need to be changed in flat tyre condition or replacing worn tyre/s in the workshop. The aims of this project are to analyze different types of scissor car jacks for sedan model in Malaysia using Finite Element Analysis (FEA) software and propose a new design for upper and lower arm scissor car jack using topology optimization technique. The structural model of scissor car jack was developed using computer aided design (CAD) software. The analysis and optimization were performed using SOLID THINKING INSPIRE 2016 software by Altair. A linear static analysis was performed to study the deflection of scissor car jack. The results based on topology optimization technique indicate the original weight of scissor car jack is 2.1 kg. However, after undergoing topology optimization, weight of the new design is 1.4 kg which is reduced by 35% from the original design.

KEYWORDS

Finite Element Analysis (FEA), Static Analysis, Topology Optimization, Weight Reduction.

1. INTRODUCTION

Vehicle is a thing that used for transporting people or goods, especially on land such as car, truck, or cart. It brings ease to people by reducing the usage of time to reach at destination. Moreover, the demand of car increases annually. When it comes to travelling by car, mishaps and unwanted incidents such as tyre/s puncture, low air pressure in tyre/s are extremely common. Spare tyre is acknowledged as a necessity and the second most important tool used in changing the tyre is a jack. So indirectly, without the jack there is no way to lift the vehicle off the ground easily.

Jack is a mechanical device use in lifting heavy loads or in situation when great forces applied. Jack employs a screw thread or hydraulic cylinder in order to apply very high linear forces. However, as noted in Ramachandra et al., (2013), jack comes in difference types and weight ratings. By choosing the most fitted kind of jack for the work being performed is a crucial key not only for safety of the mechanics but also for the vehicle as well [1].

Thus, the jacks weight difference are connected with different type, design and material used. As for scissor jack, there are various design of body jack and it design affects the weight for vehicle when the car is in static or in movement. Therefore, the needs to reduce weight for a car jack are very important. In addition, a lightweight vehicle is the most successful production nowadays with approach from topology optimization.

There are many concepts and design of scissor jacks in these centuries. People tend to use the jacks when they were changing the tire or when in the workshop. Scissor car jacks come in variance design, material used, and weight. There are many concepts and design of scissor jacks in these centuries. People tend to use the jacks when they were changing the tire or when in the workshop. Scissor car jacks come in variance design, material used, and weight.

Topology optimization is the most general type of structural optimization, being performed in the initial phases of the design. All feasible domains are considered, the aim being to find the most advantageous material distribution inside this domain, with respect to the design objectives

states by Razwan and Lucian (2014). It is a method that combines FEA results. In this method the goal is to find a solution with optimum material distribution in a certain volume. This volume is called design space. Design space is meshed with finite elements. The iteration determines which elements will be empty and which will represent the material [3].

The topology optimization method solves the problem of distributing a given amount of material in a design domain subject to load and support conditions, such that the stiffness of the structure is maximized. The application of the topology optimization method in various fields of engineering may significantly improve design cost and quality which is important in global competition. Therefore, the needs to reduce weight for a car jack are very important. In addition, a lightweight vehicle is the most successful production nowadays with approach from topology optimization. As result, this study will be focusing on reducing weight of the scissor car jack by using topology optimization.

2. METHODOLOGY

The process of designing the 3D part of scissor car jack has been done by using Creo Parametric. Those jacks were redesign according to the actual dimension and exact size with the real scissor car jack. It shows that the designs were chosen from three different type's car which is Proton Persona, Toyota Vios, and Honda Accord respectively in Figure 1.

Figure 1 Type of Scissor Car Jacks

The material properties that applied to scissor car jack were CK45, AISI 1045 steel shown in Table 1. It is the medium tensile steel supplies in black hot rolled or normalized condition. The material characterized by

good weld ability, good machinability, and high strength and impact properties either in normalized or hot rolled condition. It lack of suitable alloying elements, hence it does not respond to the nitriding process.

Table 1 Material Properties of CK45, AISI 1045 Steel

No	Properties	Value
1	Elastic Modulus, E	210 GPa
2	Yield Strength	490 MPa

In order to perform a linear static analysis shown in Figure 2, the design was imported into SolidThinking software. Each design was applied with different load which is Honda (7357.5N), Toyota (9810N), and Proton (5886N). The constraint was placed on the surface of the bottom stand for each scissor car jack. Then, material set for three types of scissor car jack was Steel (CK45). After that, element size changes to 10mm and run analysis. In post-processing SolidThinking platform, its consist variables of result such as: Displacement, Factor of safety, Percent of yield, Tension and compression, Maximum shear, Von Mises Stress, and Major principal stress.

Figure 2 Flows for Linear Static Analysis

After static linear analysis, all the designs will be perform for topology optimization shown in Figure 3 below. Firstly, the new design was imported into SolidThinking software. Load that applied on this new design is 9810N, the load is chosen according to aspect of analyzing the new design of scissor car jack and constraint is place on the surface of bottom stand of scissor car jack. Material Steel (CK45) maintained for comparison with previous design. There are three types of shape control which is single draw, split draw and extrusion. For this optimization, the single draw was used and applied to upper and lower arm. Upper and lower arm selected as design space, the design space that chosen was use to optimize. Then, run optimization. There are two options of objective which is maximizing stiffness and minimizing mass. The objective of optimization is maximizing the stiffness and mass target for the design is 30% of total design space volume. The constraint's thickness set at least 5mm and then run optimization

Figure 3 Flows for Topology Optimization

3. RESULTS AND DISCUSSION

3.1 Linear Static Analysis

A linear static analysis applied at three different types of sedan model car, loads of those models are 5886N (600kg) for Proton, 7357.5N (750kg) for Honda, and 9810N (1000kg) for Toyota with same material of Steel C45K are applied for this analysis. The analysis showed the results for displacement, factor of safety, Von Mises Stress, and total mass for each load case. From the three types of sedan model car, the highest value of load which is 1000kg is used for new design.

Table 2 Data for 3 types of Sedan Model Car using Linear Static Analysis

Type of Analysis	Sedan Model Cars		
	Proton	Honda	Toyota
Von Mises Stress	114.6 MPa	127.8 MPa	159.1 MPa
Displacement	0.3506 mm	0.3580 mm	0.6383 mm
Factor of Safety	4.274	3.833	3.081
Total Mass	1.62557 Kg	1.66471 Kg	2.14232 Kg

3.2 Optimization for Upper and Lower Arm

The loads were applied 1000 kg and divided equally at the top surface of top holder part for the new design scissor car jack. Meanwhile, a constraint was placed at the bottom of stand part. The upper and lower arm was selected as the design space, and has been optimized in symmetrical shape control. Figure 4 below shown the optimized profile/shape proposed by the software within 30% of stiffness from the actual design.

Figure 4(a): Upper arm

Figure 4(b): Lower arm

Figure 4: Optimized Profiles/ Shape for New Design

3.3 Redesign Design Recommended by Solid Thinking

Design was changes from suggested of Solid Thinking due to operation open and close of scissor car jack. Figure below shows that optimized design were redesign for upper and lower arms.

Figure 5(a): Design proposed **Figure 5(b):** Redesign

Figure 5: Upper Optimization

Figure 6(a): Design proposed **Figure 6(b):** Redesign Optimized

Figure 6: Lower Optimization

Figure 7(a) Von Mises Stress **Figure 7(b)** Displacement

Figure 7(c) Factor of Safety

As depicted in Table 3, the results show that the overall data comparison of Von Mises Stress, displacement, factor of safety and weight for different designs of model sedan car. The loads applied based on their own manufacture specification. The higher value of load is taken to use in applying to the new design for obtained capability to withstand 1 Tan scissor car jack. According to Von Mises Stress, the design of Proton, Honda, Toyota, design optimized, and new design of optimized has value below of yield strength material Steel CK45 which is 490Mpa that means the designs still can accepted. The factor of safety for new design show 2.182, industry need value 1.2 that mean the value of new design is relevance and can handle 2 times more than from value stated. The mass of fine-tuned optimized design for new design is stated as much 1.388646 kg, and it show has reduction of mass of the design.

Table 3: Data Comparison for Different Types of Designs

Types of Design	Data from Static Linear Analysis				
	Load (kg)	Von Mises Stress (MPa)	Displacement (mm)	Factor of safety	Mass (kg)
Proton	600	114.6	0.3506	4.274	1.62557
Honda	750	127.8	0.3580	3.833	1.66471
Toyota	1000	159.1	0.6383	3.081	2.14232
Optimized Design	1000	224.6	0.4231	2.182	1.50814
Fine Tuned Optimized Design	1000	226	0.4656	2.168	1.38646
		Yield Strength (490 MPa)		FOS (1.2 and above)	

Figure 8 below shows a fine-tuned optimized design for new design has the highest value of on Von Mises Stress which is 226MPa while Proton has the lowest value which is 114.6MPa.

Figure 8: Data of Von Mises Stress

Figure 9 shows the location of maximum Von Mises Stress for fine-tuned optimized design for new design.

Figure 9: Location of Maximum Von Mises Stress for Fine-Tuned Optimized Design for New Design

From Figure 10, the results show Toyota has the highest value of displacement which is 0.6383 mm while Proton has the lowest value which is 0.3.

Figure 10: Data of Displacement

Figure 11 shows the location of maximum displacement for fine-tuned optimized design for new design.

Figure 11: Location of Maximum Von Mises Stress for Fine-Tuned Optimized Design for New Design

Figure 12 shown a fine-tuned optimized design for new design has the lowest factor of safety value which is 2.168 while Proton has the highest value which is 4.274

Figure 12 Data of Factor of Safety

Figure 13 shows the location of minimum Factor of Safety for fine-tuned optimized design for new design.

Figure 13: Location of minimum Factor of Safety for Fine-Tuned Optimized Design for New Design **Figure 14:** Data of Mass

4. CONCLUSION

In this study, the analysis of linear static and optimize design by reducing weight is presented. The new design proposed was capable to stand 1000kg and more because the factor of safety was stated that optimized design with value 2.2 according to prediction by SolidThinking Software. It's observed that, the new proposed design was completely safe to used, when the load were decrease and the factor of safety will increase.

The material applied is a medium steel CK45 that is used by automotive part. The new proposed design with optimize material layout within a given design space, and best design were suggested. The results based on topology optimization technique indicate the original weight of scissor car jack is 2.1 kg. However, after undergoing topology optimization, weight of the new design is 1.4 kg which is reduced by 35% from the original design.

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