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Simulation Analysis for Big Piston of Hydraulic Bottle Jack

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Abstract: With the advancement of technology, attempts are being made to improve comfort and safety. This can be accomplished by using better design. The goal of this project is running simulation that calculated and analysis the suitable material used for the design product. Finite Element Analysis (FEA) is a computerized method used to predicting how a product reacts to real-world forces. The FEA analysis of the SolidWorks software is to analyze the component stress, strain, displacement under external and internal force loads. SolidWorks simulation features will be used to analyze the part design and the result will show the strength, maximum load that the part testing can withstand. SolidWorks Motion features will be used to simulate the animation and motion of the hydraulic bottle design for the mechanism. Few different material types will be chosen for testing the different to get strength of each material value from analysis. The selected material used for this project will be taken the cost of manufacturing and will be compared to show the suit material regarding the capital of manufacturing with take care off the quality of specific material in term of strength.

Keywords: Solidworks Simulation, Big Piston, Material Optimization

1. Introduction

A hydraulic jack with a hydraulic built in is one that uses a liquid to push on a piston. Pascal's Principle says that the pressure inside a closed container stays the same the whole time. Since the larger cylinder has a larger surface area, the force will be greater. In other words, when the surface area goes up, the force goes up. Finite Element Analysis (FEA) is the primarily focus on this study. Specific material use is analyzed using SolidWorks software. Three different material selected to do a testing and data obtain from simulation. Total part of design hydraulic bottle jack has 11 parts and only big piston part of design will be test in stress. Big piston part is the lifter and the part contacting with car chassis. Numerical method in FEA can analyze and predict the structure and system under loads and constraints. The potential problem and identifying can be done before manufacture the product early on. Load and constraint can apply on digital model design of product from CAD software.

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This study experimental can offer a better insight into problem face. This study can evaluate the drawing CAD design to obtain data for repair the problem hydraulic bottle jack and can be benefit to workshop using hydraulic jack.

1.1 Problem statement

Suit material selection need to do a testing with simulation to choose the better performance and quality. Solution will determine when different material is experimental with equal value of stress and comparison data will obtain. Finite Element Analysis method will run simulation to identify the solution. Fully construct design hydraulic bottle jack using Computer-Aided Drawing (CAD) model for simulation testing is the objective. Structural analysis will conduct on CAD model design and implement the suit material on product.

Determining distribution of stresses and strain analysis in a component is scope of this study. Result from FEA simulate use to optimize the performance of the product or system including the structure.

2. Literature Review

Basic FEA problems, such as static, vibration, and buckling, can be solved with all of the codes. Except for Pro/MECHANICA, which is a p-version FEA, all of these are mostly h-version. SolidWorks Simulation can do both nonlinear analysis and analysis of wear and tear. Pro/MESH is an h-FEA mesh generator in Pro/ENGINEER. It works with commercial FEA codes both before and after they are run. Pro/MESH automatically meshes Pro/ENGINEER parts, lets you define FEA models in Pro/ENGINEER, and has a loose connection to major FEA codes (through ASCII input data files) [5].

2.1 Jack meaning

Product of hydraulic jack is a mechanical device that uses the principles of hydraulics lift heavy loads. It consists of a cylinder and a piston, which move under pressure from a liquid. The force applied to the piston is amplified and used to lift load [1].

2.2 Materials selection

Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. A great design may fail to be a profitable product if unable to find the most appropriate material combinations [2]. The selected material has it specific mechanical properties such as, the advantages and disadvantages, cost, weight, strength, and many more.

Steel is a popular material for a wide range of applications, due to its strength, durability, and affordability. When selecting steel for a specific application, there are several factors to consider.

- Strength: Different grades of steel have varying levels of strength, which is typically measured by its yield strength, tensile strength, or hardness. Steel with a higher yield strength is more resistant to deformation and is often used in structures that experience significant stress.
- Toughness: Toughness refers to the ability of the steel to absorb energy without breaking. Steel with a high level of toughness is often used in applications that require impact resistance, such as construction equipment or heavy machinery.
- Cost: The cost of steel can vary greatly depending on the grade and manufacturing process. It is important to consider the cost of the steel in the context of the overall project budget and to balance the cost against the desired properties and performance requirements.

2.3 Methods

Using features FEA on SolidWorks software. SolidWorks Simulation is a FEA programmed that is part of the Computer Aided Drawing (CAD) environment of SolidWorks. Simulation gives designers and engineers the tools they need to test and iterate on their concepts fast and intelligently [4].

Structural analysis technique is the finite element of employ into design drawing. Structures made by civil engineering, like bridges and buildings, as well as structures made by naval, aeronautical, and mechanical engineering, like ship hulls, aircraft bodies, and machine housings, as well as mechanical parts like pistons, machine parts, and tools, are all included in the word "structural" [3].

3. Methodology

Firstly, fully functional hydraulic bottle jack for CAD drawing is construct regarding follow the objective criteria. The list for hydraulic bottle jack part use:

Table 1: Part description of design hydraulic bottle jack

No	Component part	Quantity
1	Body part	1
2	Big piston	1
3	Big seal	1
4	Cylinder nut	1
5	Handle	1
6	Piston nut	1
7	Return valve	1
8	Small cylinder	1
9	Support plate	1
10	Small seal	1
11	Small piston	1

Three different materials chosen and simulate analysis to obtain data. Alloy steel, alloy stainless steel and cast alloy steel is conduct on this study.

3.1 SolidWorks CAD drawing

A part drawing in SolidWorks is a detailed technical drawing of an individual component or a larger assembly. Dimension, tolerances and material specific include. Mating and fit together each part drawing for drawing assembly. Assembled and additional component of drawing information include and provide a wide range of tools create a detail technical drawing.

3.2 Features on SolidWorks

Can done parts and assembling a product part design. The "Part" feature icon makes room for drawing or designing. All the editing tools needed to develop a product design are included in the layout. There must be one component file per part. Create each product's component in a separate part file in this manner. All the individual product elements may be put together using the "Assembly" feature icon.

Then, make an interference checking into design. Interference is a technique that is used to guarantee that the pieces of goods that are assembled to inspect the parts to ensure that they are a good fit and perform appropriately. The absence of interference guarantees that there are no improper fits or mismatches in the final product.

Apply FEA simulation analysis. SolidWorks simulation is a set of 3D engineering tools that enable product engineers, in all industries, to set up virtual real-world environments to test product behaviour for performance and quality during the development process.

Run animation and rendering drawing in 3-Dimensional (3D) the functional assemble product. Animate the files for the pieces or the assembly. To test the functioning of the design, animations and graphics should be created. Time is saved by using animation rendering techniques, which increases both the design's productivity and its marketability.

Able to estimate costing and produce documentation details. The cost calculation may be done quickly and easily with SolidWorks. Using the automated manufacturing cost tools that are integrated, the cost of producing a particular product was compared against it.

3.2 Finite Element Analysis (FEA0 using SolidWorks

Simulate the operability of design equipment in CAD system. List of FEA feature can found the data using the software features:

- Static analysis
- Buckling analysis
- Drop test analysis

Static and drop test analysis consists three element data simulate which is stress, displacement and strain obtain from analysis. Buckling analysis simulate the critical value of the design.

4. Result and discussion

Three different material is select to run and simulate the testing using SolidWorks software to obtain the result and data. Each material for alloy steel, alloy stainless steel, cast alloy steel have a specific mechanical property. FEA simulate and calculate the result from run the simulation process. Mechanical properties for alloy steel, alloy stainless steel and cast alloy steel show in Table 2.

Table 2: Mechanical properties for selected material

Mechanical properties	Types of material		
	Alloy steel	Alloy stainless steel	Cast alloy steel
Elastic Modulus	210 GPa	210 GPa	190 GPa
Poisson’s Ratio	0.28	0.28	0.26
Shear Modulus	79.0 GPa	78.9 GPa	78.0 GPa
Mass Density	7700 kg/m^3	7700 kg/m^3	7300 kg/m^3
Tensile Strength	723.8 MPa	723.8 MPa	448.1 MPa
Yield Strength	600 MPa	620.4 MPa	590 MPa

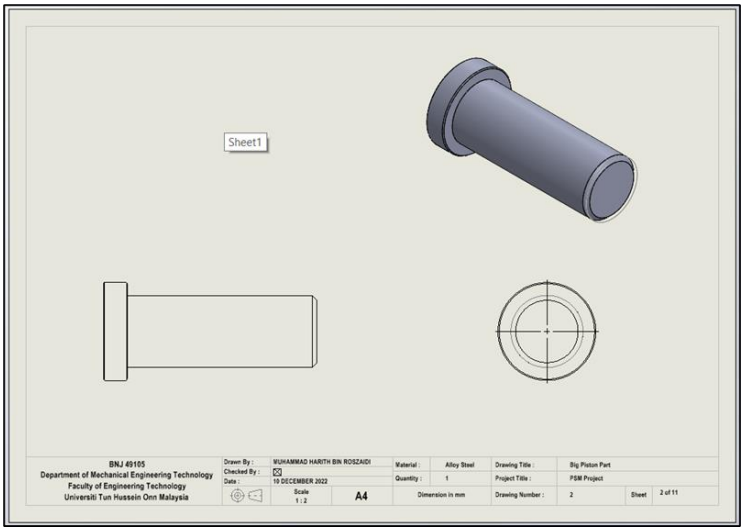
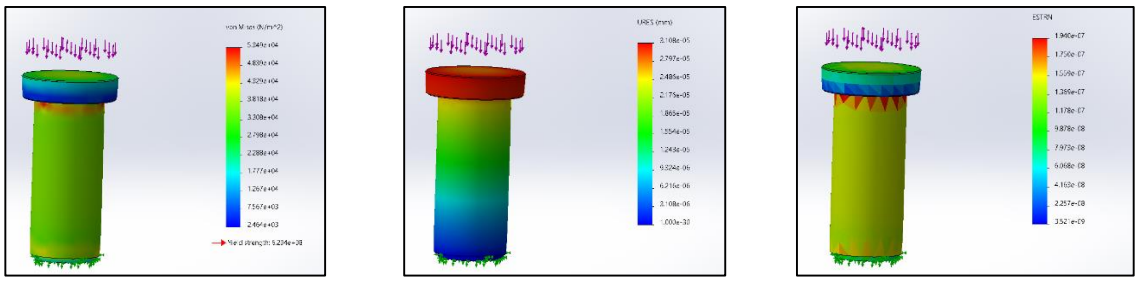


Figure 1: Exploded view of big piston drawing

The main component of the product is the method to Finite Element Analysis (FEA) to analyze the product failure. To standardize based on the functions, all measurement units were in SI units. Big piston is the main component used in the FEA study to determine the performance and safety standards.

4.1 Static FEA for big piston



Von Mises stress | Displacement | Strain

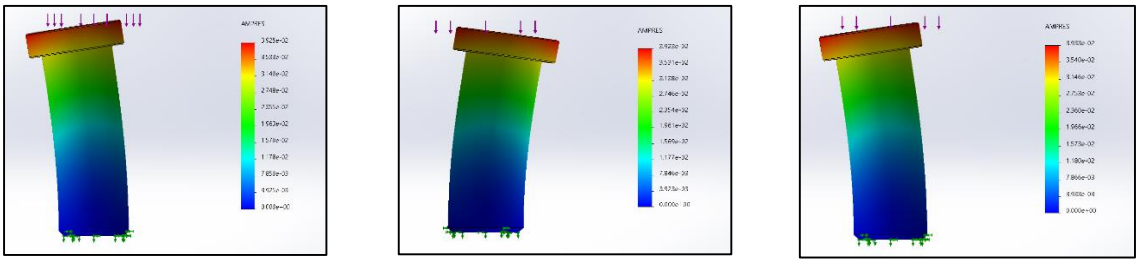
Figure 2: Static FEA for alloy steel

Table 3: Simulation static data obtained

Static analysis	Alloy steel	Alloy stainless steel	Cast alloy steel
Von Mises stress (Pa)	5.349e^4	5.323e^4	5.372e^4
Displacement (m)	3.108e^-5	3.092e^-5	3.447e^-5
Strain	1.940e^-7	1.931e^-7	2.120e^-7

Table 3 show the data obtained from simulation of static with three different materials used for this study. Von Mises stress, displacement, and strain value test from using SolidWorks data that calculate and analyze gathered.

4.2 Buckling



Alloy steel | Alloy stainless steel | Cast alloy steel

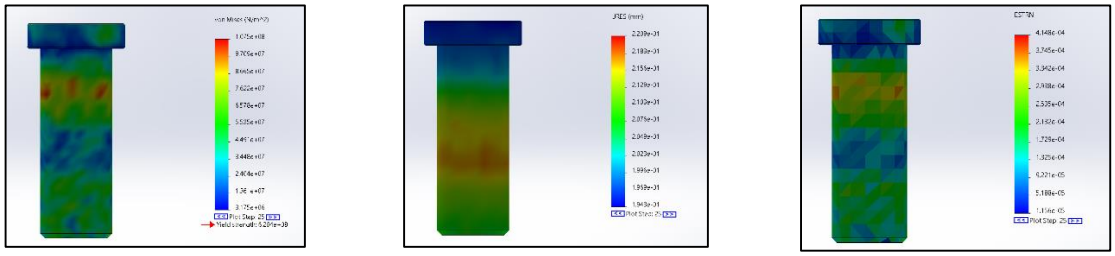
Figure 3: Buckling FEA

Table 4: Simulation critical load buckling data obtained

Alloy steel (N)	Alloy stainless steel (N)	Cast alloy steel (N)
3.923e^-2	3.925e^-2	3.933e^-2

Table 4 show the data of critical load value for each three different materials selected. The calculated critical load value and analyze from SolidWorks software is collected.

4.3 Drop test



Von Mises stress | Displacement | Strain

Figure 3: Drop test FEA for alloy steel

Table 5: Simulation trajectory drop test data obtained

Drop test analysis	Alloy steel	Alloy stainless steel	Cast alloy steel
Von Mises stress (Pa)	1.075e^8	9.905e^7	1.086e^8
Displacement (m)	2.209e^-1	2.209e^-1	2.155e^-1
Strain	4.148e^-4	4.148e^-4	4.862e^-4

Table 5 show the data obtained from simulation of trajectory drop test with three different materials used for this study. Von Mises stress, displacement, and strain value test from using SolidWorks data that calculate and analyze gathered.

4.4 Cost estimate

SolidWorks feature use to estimate cost of material use and weight of different material use. Cost and documentation are evaluated and generate using SolidWorks features.

Table 6: Cost estimation different material

Types of material	Price per kg (RM)	Weight (kg)	Cost (RM)
Alloy steel	9.33	4.02	84.49
Alloy stainless steel	12.72	4.02	115.03
Cast alloy steel	8.48	3.81	72.74

Alloy steel | Alloy stainless steel | Cast alloy steel

Figure 4: Cost estimation

Table 6 show the list for material weight of material, weight, and cost regarding it weight for each different types of material used in these studies. Each three different types of material are calculated and generate the documentation for estimating cost using SolidWorks software.

5. Conclusion

Based on the goal, a fully functional CAD model of the hydraulic bottle jack was built and used for the FEA analysis and to figure out how much it would cost. For each of the three different materials, a simulation was done to see how they compare. Based on the data collected, the best material is alloy steel because it can handle high stresses and costs less than alloy stainless steel, which has a different price range but can also handle high stresses and impacts.

Acknowledgement

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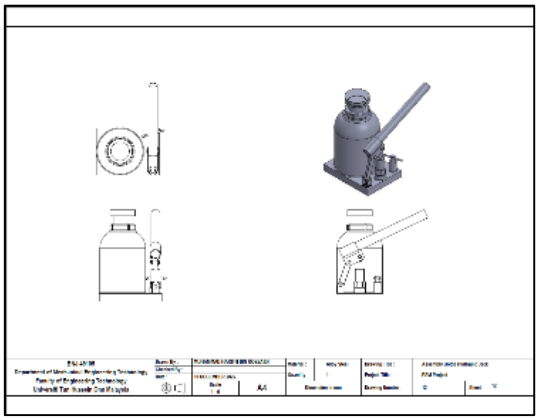
Appendix A



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