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Improvement of Stair Climbing Trolley

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Abstract: A trolley is a necessary device for transporting materials from one place to another. On flat or straight routes, it is simple to transport big loads with the use of normal wheels, while stairways provide a difficulty. This project represents an alternative method for moving goods in buildings without elevators or escalators. It is a mechanical mechanism that allows a person to carry a load over steps. So, this research objective to design the proposed mechanism using SolidWorks software, analyzed the structural frame design of the proposed mechanism and simulate the proposed mechanism using SolidWorks software. The methodology includes problem identification, a Gantt chart, design and simulation the trolley by using SolidWorks software, and using chart to compare some material to be use on the trolley. A simulation was done to compare between chosen material which are aluminum alloy, stainless steel, and carbon steel. Compared between these three materials, aluminum alloy was the optimum material in term of weight which is the lightest frame that is 14.63kg and highest durability. Simulation motion has been done to simulate the trolley movement into the stair and the motion analysis type was used. For the recommendation, simulation analysis can run by using ANSYS or the ABACUS software to get more detail result. Both of which are capable of doing structural simulations.

Keywords: SolidWorks, Tri-Star wheel, Simulation

1. Introduction

The purpose of this project is to design a system that will make it simpler to carry big items up and down stairs. A creative solution to the transportation of loads across stairs is presented in this research as a potential solution. The design of the trolley creates a configuration with three wheels on each side of the vehicle. This wheel design consists of three tires, each mounted to a separated shaft. These shafts are located at the vertical of an equilateral triangle [1]. This project is being carried out in order to

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provide a solution to the difficulties that users have while carrying out lifting tasks, particularly when moving products upstairs. The method of constructing the trolley design will include the usage of a new trolley and tyre design in addition to a variety of materials that are both cost-effective and unique. So, users may cut down on their consumption of energy as well as the amount of time they spend lifting objects. Manual handling can cause injuries that lead serious implications for the employer. It can occur almost anywhere in workplace, awkward postures, repetitive movements of arms, legs and back or previous existing injury can increase the risk [2,3]. Choosing the right materials is an important part of creating anything with a physical form. The primary objective of material selection in the context of product design is to achieve cost savings while still achieving desired product performance levels [4]. For mildly stressed components like studs, nuts, gears, and shafts, it is required that the material be able to be welded [5]. So, it is essential to choose what material to be use.

In this study, the finite element analysis (FEA) or finite element method will be use to analyze the structural of the product. Based on the book of Finite Element Analysis Concept [6], the finite element method (FEM) rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians because of it natural benefits over prior approaches.

2. Materials and Methods

Flow chart shows the procedure that are going through to complete the whole project. The steps conducted are outlined in this flowchart for the reference.

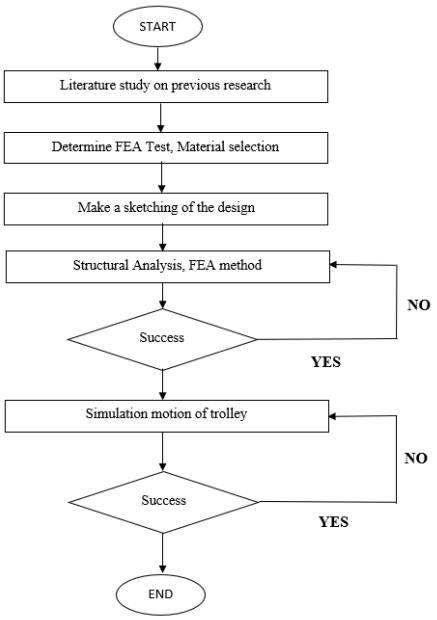


Figure 1: Methodology flowchart

2.1 SolidWorks Design & Simulation

SolidWorks has a variety of purpose that made the software are one of the basic software that has been used in many industries. And after a design has been sketch, a simulation will be done using the same software. 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 behavior for performance and quality during the development process. After the analysis of the product are done in the simulation.

comparison can be done to see whether the new product can match or is there an improvement from the existing product.

2.2 Morphological Chart

A morphological chart is a table based on the function analysis. Morphological analysis has the various field in the term of analysis of morphology. Morphological analysis or general morphological analysis is a method that used for exploring all possible solutions to a multi-dimensional non-quantified problem. In the morphological chart, three different designs will be used. Design A and Design B from prior research, as well as Design C, which is the proposed design for this study. All three designs will be evaluated based on a few factors, which include the structure, weight of the product, cost required, material utilization, and design. After the assessment is completed, the sum of the evaluations will reflect which of the three designs is the best. Figure 2 shows the best design of trolley.

Table 1: Three different design of trolley

Design A	Design B	Design C
		

Table 2: Morphological Chart

Criteria	Design A	Design B	Design C	Note
Structure	4	5	4	B has more sturdy structure
Weight	4	3	5	C is much lighter than A&B
Cost	5	5	3	The price of material for A & B is much cheaper
Material	3	3	5	Material C is much stronger and lighter
Design	2	3	4	C has more function and usability
Total	17	19	21	**Design C**

Table 3: Table of evaluation

Scale	Statement
1	Very Bad
2	Bad
3	Moderate
4	Good
5	Very Good

Figure 2: Final Design of Trolley

2.3 Simulation Motion

The process of determining the dynamics and kinematics of a new product before it is developed into prototype form using SolidWorks motion simulation is referred to as motion simulation. Motion simulation provides complete and quantitative information about the kinematics and dynamics of all the components of a moving mechanism. Once everything that is necessary for motion simulation has been described in the CAD assembly model, the results of motion simulation need to be acquired virtually. This is because everything that is required to perform motion simulation has been transferred to the motion simulation software.

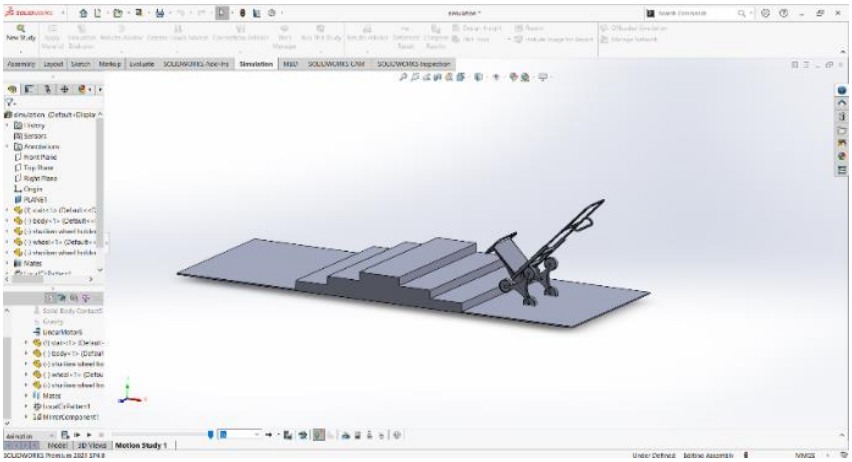


Figure 3: Simulation motion process

3. Results and Discussion

Once the design was simulated in SolidWorks Simulation, and each force will be applied to determine whether the trolley can support the load. In addition, a simulation comparing three alternative materials will be included to determine which one is best and has the highest yield strength.

3.1 Material Selection

These three materials were preferred in earlier studies because of their great tensile strength, making them suitable for bearing heavy loads, and their availability and low cost. It was important to keep costs low throughout the design and manufacturing processes; these three materials were selected. Table 1 show the mechanical properties of selected material.

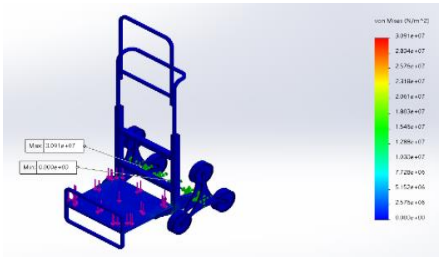
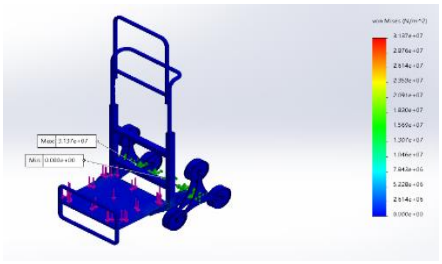
Table 4: Mechanical properties of three materials

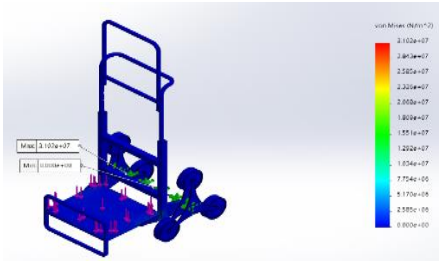
Mechanical Properties	Aluminum 6061	Carbon Steel	Stainless Steel
Elastic Modulus	68.9 GPa	20.5 GPa	19 GPa
Poisson's Ratio	0.33	0.29	0.29
Shear Modulus	26 GPa	80 GPa	75 GPa
Mass Density	2700 kg/m³	7850 kg/m³	8000 kg/m³
Tensile Strength	310 MPa	585 MPa	517 MPa
Yield Strength	275 MPa	283 MPa	206 MPa

3.2 Result for Stress Analysis

All of these materials are tested to the same 40 kg of force. The stress obtains to know which material has better durability. Since the force applied was same, the more stress obtains the harder material to break.

Table 5: Comparison maximum stress analysis of frame between three material

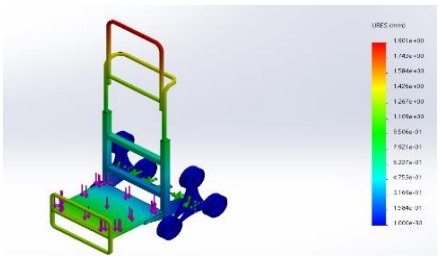
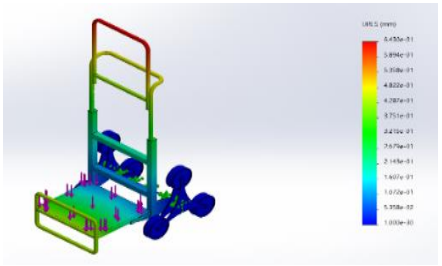
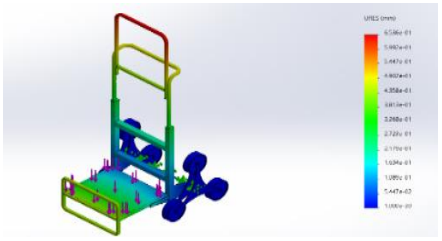
Diagram	Maximum Stress
Aluminum Alloy	
	3.091×10^7 N/m²
Stainless Steel	
	1.221×10^7 N/m²

Carbon Steel 	1.239×10^{7} N/m²

3.3 Result for Displacement Analysis

This analysis focus on how much displacement of these three materials when the same force applied on the plate. The less displacement gets from the result, the better the material to be use.

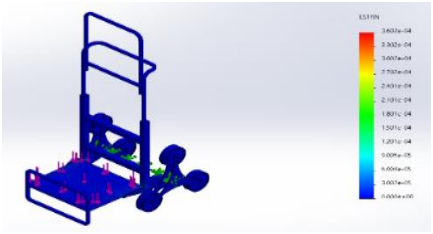
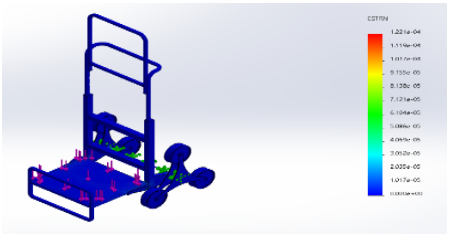
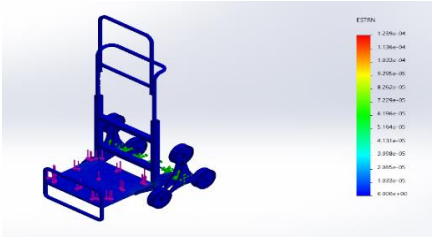
Table 6: Comparison maximum displacement analysis of frame between three material

Diagram	Maximum Displacement
Aluminium Alloy 	1.901×10^{-3} mm
Stainless Steel 	6.430×10^{-4} mm
Carbon Steel 	6.536×10^{-4} mm

3.4 Result for Stain Analysis

Strain is a material's distortion caused by stress. It is the ratio of the length change to the original length. So, the more the value of maximum strain, the better the material.

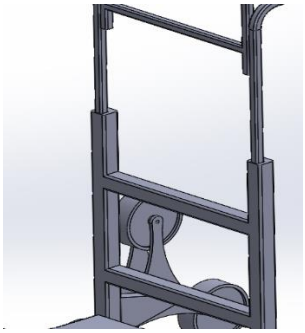
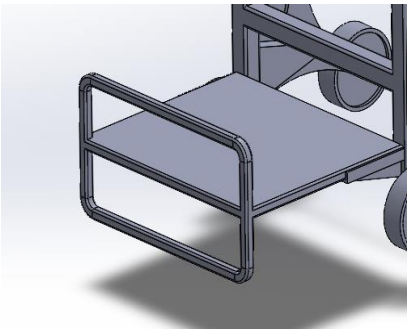
Table 7: Comparison maximum strain analysis of frame between three material

Diagram	Maximum Strain
Aluminium Alloy 	3.602×10^{-4}
Stainless Steel 	1.221×10^{-4}
Carbon Steel 	1.239×10^{-4}

3.5 Comparison of Three Selected Materials

It can be seen that stainless steel and carbon steel has lower maximum stress than aluminum alloy. Since there is less maximum strain on stainless steel and carbon steel, they break more easily. All three of these materials are tested to the same 40 kg of force, therefore a high stress resistance indicates that they are more durable and less likely to crack under stress. Since the mechanical properties for three material almost the same, this is why the result obtained almost identical. Then for analysis for stress and strain, aluminum is the highest. The comparison is based on the result that was acquired and later converted into table and graph form. Aluminum alloy is the material of choice since it has a higher yield strength than the other materials, meaning that it will take significantly longer for the material to fail than the other two options. The material is cost low and easy to handle with, thus it's affordable to produce. So, for long-term use, it is much better to use aluminum alloy for fabrication process because it is lower in weight and high of durability.

3.6 Improvement of Design

Height Adjustable	Two Ways Handle	Item Barrier
		

These are some improvements that have been accomplished include developments that are designed to make things simpler for consumers and to improve the safety of items that are transported using trolleys.

4. Conclusion

This project main objective was to design a proper tool to carry a load using climber trolley mechanism. This objective was achieved as the mechanism has been drawn using SolidWorks software. A few features have been added to ease people workload which is height adjustable, two-way handle and item barrier. A casing on the trolley that will decrease the probability for the load to fall apart and using a Tri-Star wheel as opposed of the standard wheel. Although the modification was not much, but it can help to ease the workload of the cleaner by half. Next, to analyzed the structural frame, Finite Element Analysis method was applied to obtain the stress, strain and displacement analysis result. A simulation was done to compare between chosen material which is aluminum alloy and two others material which is stainless steel and carbon steel. And between these three materials, aluminum alloy was the optimum material in term of weight of the frame and costing. And simulation motion has been done to simulate the trolley movement into the stair and the motion analysis type was used. Although the process to simulate the movement was a bit difficult to achieved, but with a practice and trial and error method, this objective able to be achieved.

Acknowledgement

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References

[1] R. Syam, "Design of Wheeled Monile Robot with tri-star wheel as Rescue RObot," Int. J. Smart Mater. Mechatronics, vol. 1, no. 1, pp. 28-31, (2017).

[2] T. Manual, H. Operations, and T. Regulations, "Manual handling at work," Appl. Ergon., vol. 20, no. 1, p. 76, (2005).

[3] R. Alaspure, C. Barmase, S. Chambhare, M. Mandhre, G. Yogesh, and Y. Joshi, "Fabrication of Stair Climbing Wheel Mechanism: Alternate for lifting goods," Int. Res. J. Eng. Technol., vol. 3, no. May, p. 4, (2016).

[4] J. E. Akin, "Finite Element Analysis Concepts," Finite Elem. Anal. Concepts, (2012).

[5] Raj, P. Jey Praveen, et al. "Design and Fabrication of Stair Climbing Trolley. "International Journal of Advancement in Engineering Technology, Management and Science Apllied 3. Movex Inovation Canada. " Stair climbing Equipment solutions. (2016)

[6] Lawn, Murray J., and Takakazu Ishimatsu. "Modeling of a stair-climbing wheelchair mechanism with high single-step capability." IEEE Transactions on Neural systems and rehabilitation engineering 11.3 (2003): 323-332.