Development of a mobile wheelchair lift for a high-floor bus

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ABSTRACT: The purpose of this project is to introduce a new mechanism and improve the existing method to help wheelchair users to board a regular bus with 45° stairs. A survey was conducted among 30 civilians that included some person with disabilities and some university students. Through the data obtained, a House of Quality was produced to convert the customer requirements into the engineering characteristics. Product Design Specification was generated in order to be used as a project target specification that must be met. A morphological chart was created to obtain some conceptual designs where the final configuration was selected through the Weighted Decision Matrix. Then, the 3D model of the final design was produced using SolidWorks 2016, in which a motion study was conducted to observe whether the product design is able to lift the required load. Next, a simulation on stress analysis was conducted to obtain the stress data so that the factor of safety of the product design can be determined.

Keywords: *wheelchair, machine, bus*

1. INTRODUCTION

Various mechanisms have been used in order to help wheelchair users to get into a bus that include a bridge plate, a ramp and a wheelchair lift. Some mechanisms have disadvantages especially when implemented with regular older model buses in Malaysia. The wheelchair lift which is widely used for the buses in more developed countries is expensive and it require a wide opening of bus entrance door. In Malaysia, the majority of the buses have narrower doors. Next, the use of bridge plate need a suitable high to deploy from a vehicle whereas the ramps are widely used for some buses in Malaysia. However, with steep 45° stairs, boarding can be a real hassle. This project aims to introduce a new mechanism and improve the current mechanism to help the persons with walking disability to board the bus on wheelchairs.

One option is to use the standard winch that is normally used to pull a load horizontally to a relatively surface level location. Meanwhile, a hoist is usually used to lift a load vertically when the load is hanging in the air [1]. A load being pulled up on an inclined surface is considered as lifting operation because the surface level is not horizontal and the load tends to slide down due to the gravitational pull if there is no support to hold the load. Table 1 shows the product target specification.

Table 1 Product Design Specification

Specification	Explanation
Product identification	• Able to carry a wheelchair into and exit the bus. • It must fit over standard bus stairs. • It can collapse and be folded for easy storing. • It must be able to lift a (mass) load up to 200 kg. • Easy to maintain.
Market, Life cycle, Safety	• For use by healthcare providers for people with walking disability. • Priced between RM 500 to 1000 per unit. • Environmentally friendly. • Safe according to OSHA and relevant regulations.

2. MATERIALS AND PROCEDURE

Pulley is a type of simple machine that helps to multiply the forces needed to lift an object thus making the lifting process become easier. By having more wheels and loops of rope around the wheels, the lifting will become much more convenient and the weight of the object becomes light as it will divide the weight of the object to each ropes [2]. For each number of wheels use in a pulley, it has their own mechanical advantages (MA). The more the number of wheels used in the system contributes to a higher MA value which means that the lifting will become much lighter. The dimensionless MA value is calculated as follows, with W_L being the load and F_{in} the input force.

$$MA = \frac{W_L}{F_{in}} \quad (1)$$

Preliminary function structure is a block in the Free Body Diagram (FBD) which consist of some blocks that represent the process of the machine and some arrows that represent the forces. Solving this is crucial to get the torque required to pull the load up.

Next, the function of the House of Quality (HOQ) is to create relationships between the customer needs from a product and the overall performance parameters and features of the product which are the most critical things to fulfil [3]. By using HOQ, the customer requirements and engineering characteristics can be related in order to obtain the relationship between both factors.

A set of Product Design Specifications (PDS) put together the results of the design planning process that control the engineering design tasks in the product development process. The PDS works as a reference document and the basic control for the design and the product manufacture plus it is a type of document that stores the facts which related to the product development [3,4]. The angle of the stairs is about 45° and the maximum overall mass should be 170 kg (< 200 kg). The linear speed in lifting is about 5 to 8 m per minute.

A morphological analysis is one of the ways of generating new forms and a way of structuring the problem synthesis of different components in order to acquire the exact functionality needed [3]. From the morphological chart, three conceptual designs were generated. These were then put through the screening and selection process that resulted in the final design as shown in Figure 1. This integrates a hoisting motor that costs less than RM 500 [5].

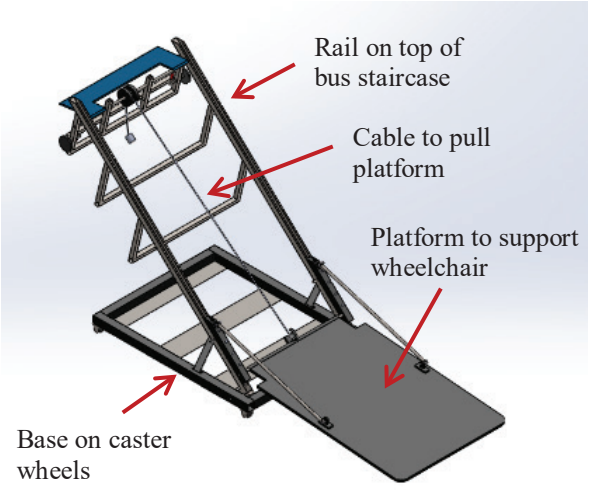

Figure 1 The lifting machine is placed over the stairs

3. RESULT AND DISCUSSION

From the result obtained through the analysis, it is found that a 200 kg hoist with a 5 m per minute speed manages to lift 1200 N of load. The lifting process takes around 12 seconds from the bottom to reach the top. This is quite logical because a 200 kg hoist has 0.133 m/s speed where 0.133 times 12 will give 1.60 m and the value is same with the length of the rail. In the analysis, the lifting velocity is 134 mm/s or 0.134 m/s and it is constant over time as the path of the lifting is linear and stable. The overall factor of safety ranges in the ballpark values of between 1.89 and 6.43. Material used is an alloy steel like AISI 1340. Figure 2 shows the pre-processing stage for the finite element analysis in SolidWorks.

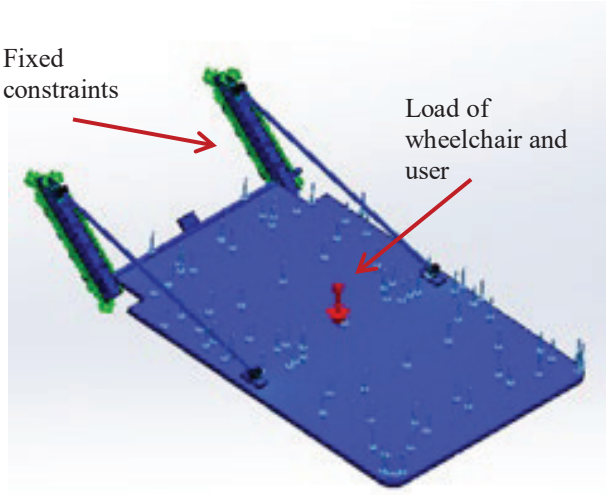

Figure 2 The pre-processing of the alloy steel platform that resulted in 328 MPa maximum stress.

4. CONCLUSION

Based on the simulation and analysis outcome, it is determined that this product design is likely to function well and safely. With a design load of 1200 N, the motion analysis shows that with the force, speed, and the power of the 200 kg hoist is capable to lift the load on the platform.

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REFERENCES

[1] Joel, *Winch vs Hoist: What's the Difference?*, SafetyLiftinGear.com, April 15, 2018. Accessed on: April 20, 2020. [Online]. Available: : https://industrialrope.com/safe-working-load-limits-what-you-need-to-know/

[2] C. Woodford, *Pulleys*, Explainthatstuff!, September 14, 2020. Accessed on: June 22, 2021. [Online]. Available: : https://www.explainthatstuff.com/pulleys.html

[3] G. E. Dieter and L. C. Schmidt, *Engineering Design, 5th ed.* New York, NY: McGraw-Hill, 2013.

[4] K.T. Ulrich and S. D. Eppinger, *Product Design and Development.* New York, NY: McGraw-Hill, 2000.

[5] M. A. A. Abdul Nasir, "Development of a machine to assist wheelchair users to board a bus," Final Year Project report, Universiti Teknikal Malaysia Melaka, 2020.