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STRUCTURAL ANALYSIS OF BUS LIFTING MECHANISM FOR TRANSPORTATION OF WHEELCHAIR AND PHYSICAL DISABLED PEOPLE INTO BUSES

Wan Mazlina Wan Mohamed[1], Mohamad Afiq Ahmad[2]
[1]Malaysia Institute of Transport (MITRANS), UiTM Shah Alam, Malaysia
[1,2]Faculty of Mechanical Engineering, UiTM Shah Alam, Malaysia
*Corresponding author: wmazlina@uitm.edu.my

Abstract. The aim of this research is to analyse the structure of a modified lifting mechanism in transporting the wheelchair into buses. The design took into account the physical and material properties as well as the safety aspect. The study also include the suitable medium type of load in testing the lifting mechanism. The drawing of the mechanism was carried out using Solid Works and imported into ANSYS for meshing and structural analysis. The analysis of the mechanism include total deformation load and equivalent stress. The results showed that proposed mechanism is able to withstand higher load, thus it indicates that it is safe to support the load of wheelchair with disable person on it. From the view of structural analysis, this solution is viable and it is recommended to carry out dynamic analysis in the future in order to see the motion of the lifting platform during operation.

Keywords:

Person with disability (PWD), wheelchair users, physically disabled, lifting mechanism, simulation

Introduction

Public transportation provides people in communities around the world with accessibility to employment, community resources, medical care, and recreational opportunities This helps those who choose to ride as well as those who have no other choice: more than 90 percent of recipients of public users do not own a vehicle and must rely on public transport (Garrett & Taylor, 1999). It has been widely accepted that disabled people have fewer opportunities and a lower quality of life than normal people. Adding to poor mobility when driving or using public transport, disabled people face more problems and difficulties in travelling or commuting.

According to statistics recorded by the Department of Social Welfare, Malaysia, there were 453, 258 people registered as Person with Disabilities (PWD) as of 2017. PWD in physical category recorded the highest number, which was 35.2 per cent, followed by Learning Disability category (34.8%) and Visually impaired category (8.9%) respectively. In Malaysia, not all public transportation offered PWD accessibility and facilities, thus making PWD especially wheelchair users having challengers in boarding and alighting from bus or train. They are many types of invention in transporting wheelchairs into and out of vehicles (Pourhassana, 2011) such as a platform made up of three hinged parrallel sections which can be withdrawn and folded into two steps. Thorley invented a hidden ramp under the bus steps which able to slides forward to allow easy access to the extended platform (Thorley, 1981). Numerous designs of mechanism and apparayut have been developed in the past to easy the accessibility and mobility for PWD, however, the study on the structural analysis of the aparatus and lifting mechanism werefound to be limited. Therefore, this research focuses on the structural analysis of the wheelchair liftting mechanism of a bus using simulation.

Method

The work started by observing the operation of lifting mechanism that already existed. The proposed design of the lifting mechanism was modelled with SOLIDWORK 3D CAD software

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as it provides a good three-dimensional drawing. It is a user-friendly software compared to other software for drawing a three-dimension design. Figure 1 (a) and (b) show the proposed lifting mechanism of the ramp platform which can lowered and extended when PWD want to board or alight from the bus.

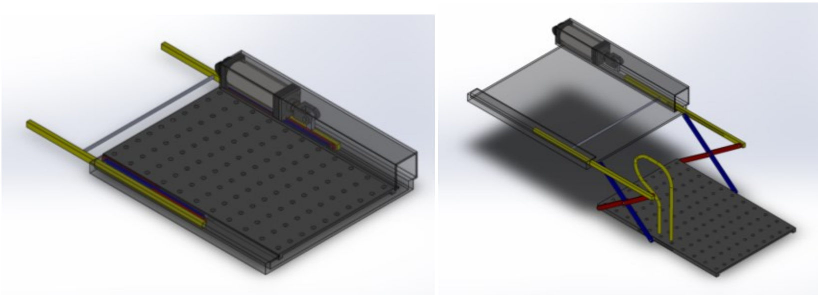

Figure 1: (a) Platform Design, (b) The extended platform

The ramp mechanism consists of two main parts:

- A sliding mechanism - the platform can be extended out and slide back in;
- A lifting and descending mechanism – the platform able to elevate from the ground level to the floor level of the bus; and vice versa

Analysis of the Proposed Design

In this phase, the design will undergo structural analysis using ANSYS software. The software is able to provide better simulation and has interfaces that are easy to use in order to obtain the results. The main and basic analyses that used to test the strength and mechanical analysis in ANSYS are total deformation, equivalent total strain, equivalent stress and maximum principal stress.

i. **Deformation -** Physical deformations can be calculated on and inside a part or an assembly. Fixed supports prevent deformation; locations without fixed support usually experience deformation relative to the original location.

ii. **Equivalent Total Strain -** The equivalent total strain gives a total value of strain in any engineering body. The total strain components are calculated by the addition of components of elastic, plastic, thermal, and creep strains and then equivalent total strain is calculated from total strain components.

iii. **Equivalent Stress (von Mises) -** Equivalent stress is related to the principal stresses by the equation below:

$$\sigma_e=\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2}$$

Equivalent stress (also called von Mises stress) is often used in design work because it allows any arbitrary three-dimensional stress state to be represented as a single positive stress value. Equivalent stress is part of the maximum equivalent stress failure theory used to predict yielding in a ductile material.

The von Mises or equivalent strain ε_e is computed as:

where:

$$\varepsilon_e=\frac{1}{1+v}\left(\frac{1}{2}\left[(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2+(\varepsilon_3-\varepsilon_1)^2\right]\right)^{\frac{1}{2}}$$

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ν' = effective Poisson's ratio, the material Poisson's ratio for elastic and thermal strains computed at the reference temperature of the body.

ε = 0.5 for plastic strains.

iv. Maximum, Middle, and Minimum Principal - From elasticity theory, an infinitesimal volume of material at an arbitrary point on or inside the solid body can be rotated such that only normal stresses remain, and all shear stresses are zero. The three normal stresses that remain are called the principal stresses: σ_1 – Maximum, σ_2 – Middle, σ_3 – Minimum.

There are three elements considered in the structural analysis of the design: platform, sliding arms and scissor arms as shown in Figure 1.

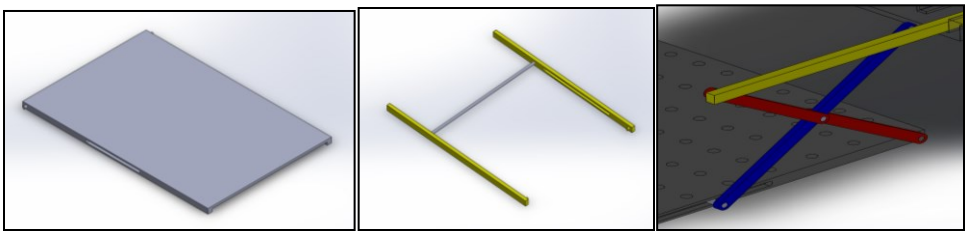

Figure 1: Drawing of Platform, (b) Sliding Arm, (c) Scissor Arm

Platform

The platform is made of steel, and covered with rubber on the surface to increase the grip and to ensure the surface is less slippery. Also, with the help of small holes on the platform it will reduce the movement of wheelchair from moving forward and backward. The dimension of the platform is 1500mm (length) x 1000mm (width) x 40 mm (height). The maximum weight applied on the platform is 350kg (approximately 3400N). The platform has fixed point on both left and right sides.

The drawing was modelled with no holes and holder for faster and simple analysis and to simplify the meshing. Using the standard measurement and average of the wheelchair, the weight or load was applied on the surface of the platform. The material used in the simulation for the platform structure is AISI 1020 steel. AISI 1020 has high strength, high ductility, high machinability and good weldability. The steel is easily to find and machineability and is largely used in the industrial sectors.

The model is then imported from the SOLIDWORK to ANSYS to calculate the meshing. The structure is applied with two fixed supports at the right and left side. Then, force is applied at the surface of the structure and static structure analysis of the platform was carried out. The weights of the wheelchair and disabled people using the platform were contributed evenly on the platform surface to simulate the actual situation.

Sliding Arm

The sliding arm is the component that works as moving the platform to front and back. The component connected to the base and scissor arms. The sliding arm has two horizontal bars on the right and left side of the platform. The bars are connected to each other with one shaft located near the end of the bars for the bars moving simultaneously together. There is one vertical bar that connected directly to the hydraulic actuator, working to move vertical bars front and back. The sliding arms dimensions are 1500mm (length), 30mm (width) and 40mm (height).

The part is imported to the ANSYS and the chosen material is AISI Steel 1020 because the material meets the conditions of a successful analysis and has suitable characteristics for the arm. After the mesh, fixed support and the force are generated on the moving parts and static structural analysis were conducted.

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Scissor Arm

A scissor arm is a mechanism that moves in vertical direction using criss-cross 'X' pattern (Kumar, 2016). The two sets of scissor arms are having the same characteristics each of the sides of the platform. The strength analysis was done for the one set on the secondary scissor arm. The main scissor is movable part with non-fixed joints to adjust the level of platform and secondary arms are fixed joints and connected the platform to the main arm and the base together. The reason the secondary arms are split by two is because when the platform is going up, the scissor joint will not collide each other when the platform is lift inside the bus.

The dimensions for the scissor arms are 480 mm (length), 40 mm (width) and 20 mm (height). The radius of the two (2) extruded circles are 10 mm. The force applied is 350kg (approximately 3400N) and been divided equally to all four (4) joints, 3400N/4 = 850N. The modelled parts were imported into ANSYS to simulate the stresses, the deformation and the strain of the sliding arms.

Discussion and Result

Platform

The static structure analysis of the platform is shown below. Taking into consideration of the weight of the wheelchair and disabled people that are using the platform, they are contributed evenly on the platform surface for the analysis.

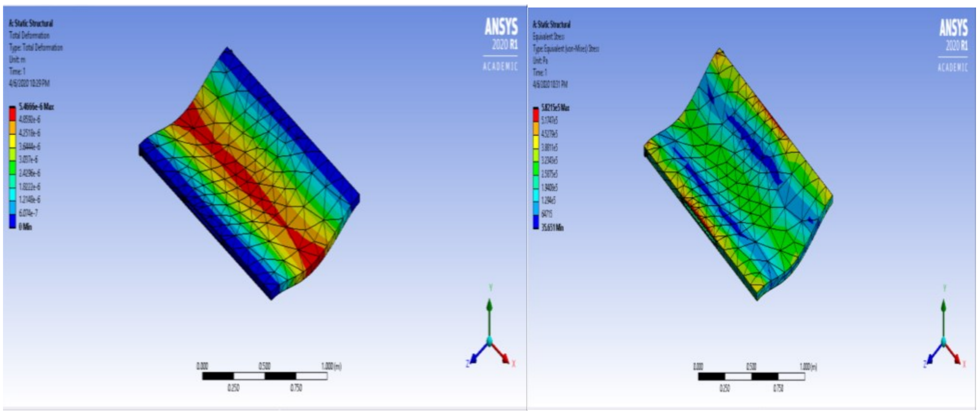

Figure 2: (a) Total deformation of platform, (b) Equivalent stress of platform

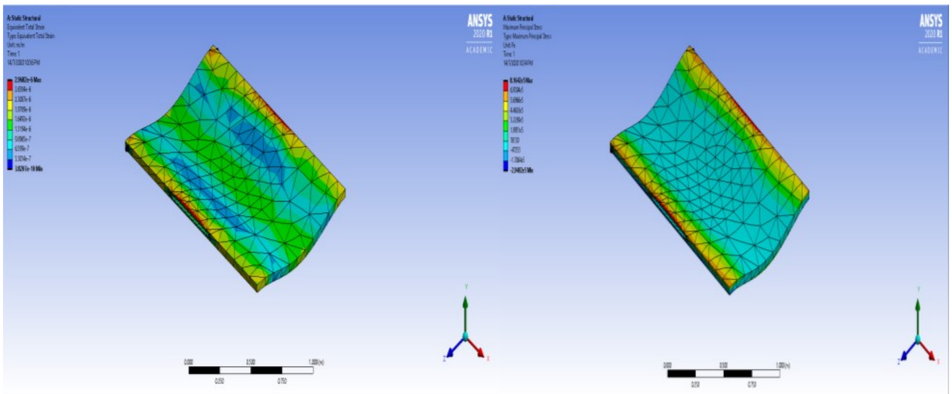

Figure 3(a) Equivalent total strain of platform, (b) Maximum principal stress of platform

Figure 2 shows the maximum platform deformation is 0.0054666 mm. This indicates that the platform is strong and stable since steel is a rigid structure. Figure 3b shows the stress on the

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platform is high on the both sides of the structure because the support were at the sides. The average stress applied was 0.177 MPa, thus the structure can stand higher weight.

Sliding Arm

The results of the simulation for the sliding arm can be seen in Figure 4 and Figure 5.

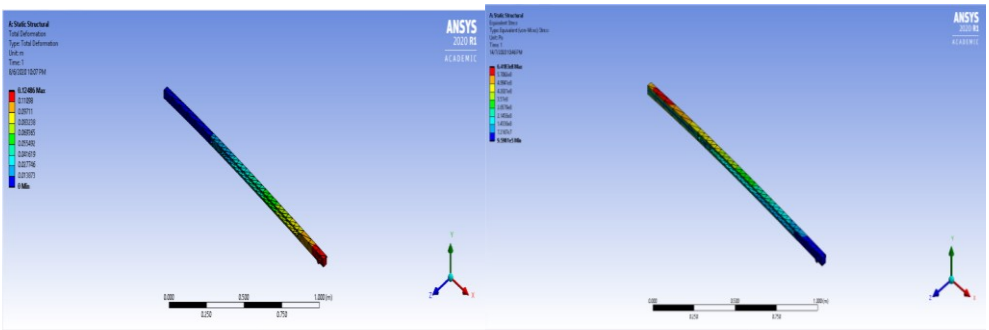

Figure 4: (a)Total Deformation of sliding arm, (b) Equivalent stress of sliding arm

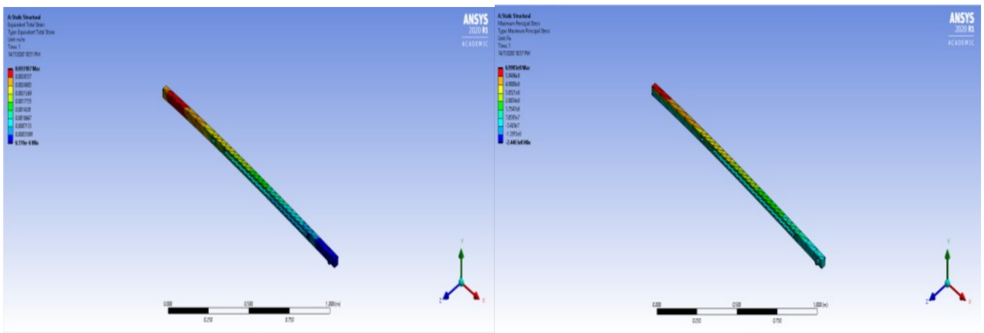

Figure 5 (a) Equivalent Total Strain of sliding arm, (b) Maximum principal stress of sliding arm

Sliding arm is one of important parts that connected directly with base and scissor arm. The reactions and forces acting on the sliding arm were checked with the values obtained from doing the analyses. The maximum total deformation recorded is 0.12486 m (refer to Figure 4); the value is quite high for the part that needs to hold both of the passengers and the weight of the platform. So, some adjustment needs to be done to reduce the deformation on the part. The other analyses (refer to Figure 5) showed that the parts did not exceed the allowable limit.

Scissor Arm

The simulation results of the scissor arm are illustrated in Figure 6 and Figure 7.

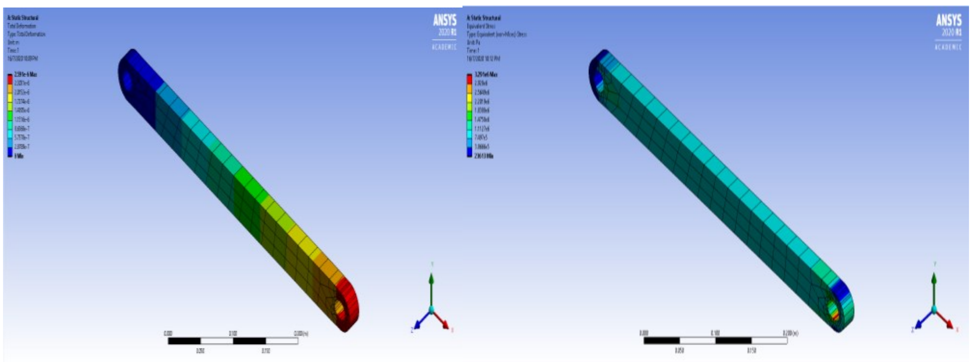

Figure 6(a) Total Deformation of scissor arm, (b) Equivalent Stress of scissor arm

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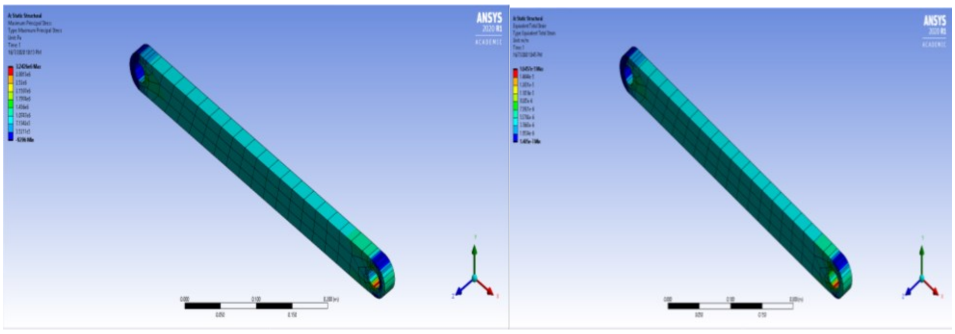

Figure 7(a) Maximum Principal Stress of scissor arm, (b) Equivalent Total Strain of scissor arm

The scissor arm behaves well under the given conditions. The highest total deformation on the part when the 850 N is applied is 2.591×10^{-6} m. As shown in Figure 6, the scissor arm can accommodate higher load and able to function properly. For equivalent stress and maximum principal stress analysis (refer Figure 7), the highest stress applied on the part that connects with the platform with 3.291×10^{6} Pa and for equivalent total strain analysis the strain also applied at the connection with average 4.5341×10^{-6} m/m shows that the elongation is very low.

Conclusion

In conclusion, lifting mechanism for PWD is one of the major concerns of our transportation sectors. There is a wide range of available methods and design that have been developed to assist the mobility of PWD, but some designs were less user-friendly to PWD, and require assistance from others. Thus, by having a simple automated mechanism, or moveable door step system (Rahman, 2014) which allow the lifting of a wheelchair into a bus would be an effective way to make public buses accessible for PWD.

During the design of the lifting platform, there were some limitations encountered such as there are not many the lifting platforms available at the city area so the dimension of the existing mechanism cannot be taken. However, the dimension of the platform created is based on the dimension of the wheelchair and the dimension of door bus. The dimensional, dynamic and strength analysis have shown that the selected mechanism is functional and reliable for its purpose.

There are few recommendations that can be implemented for further research regarding designing and simulation of lifting mechanism. As this research only focused on strength analysis for the mechanism with standard static structural analysis, it is possible if future studies would be using rigid dynamic to analyse about the motion of joint so we can see clearly the motion of lifting platform during its operation. Besides, the design of lifting platform for each part can be improved to reduce the stress and deformation occurred. By adjusting the dimension and changing with better material can increase the strength and durability of the mechanism. If it is possible to further studies by comparing the result of lifting platform with different material and dimension of each part, then it can be shown clearly which one is more effective for the lifting mechanism for PWD mobility.

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