Mechanical design and simulation of two-wheeled wheelchair using solidworks

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Mechanical design and simulation of two-wheeled wheelchair using solidworks

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Abstract. This article is presented a new design of two-wheeled wheelchair that can balance on two wheels to make it suitable in the narrow areas, especially in the domestic environments; it has the ability to extend the height of the chair to help the user to act independently in the life for example, in the library to pick and put books on the shelves. The 3D model has been built up using SolidWorks Software. Nowadays, SolidWorks environment is considered as a powerful tool that is helping designer to design products and attain its performance before physical prototype stage. SolidWorks simulation model has been employed to test the frame of the wheelchair under the weight of the human body and the upper part of the wheelchair. The static analysis has been done on the frame using steel and aluminium; however the aluminium material has been selected due to its light weight

1. Introduction
In the recent years, the use of wheelchairs has increased tremendously due to the growing number of aged and disabled people [1]. Many researchers have been done for the sake of helping aged and disabled people to have independent life instead of waiting the help of others. Some researches is related to refine the environment around the wheelchair users to make it suitable for them, others try to produce products to make the life of disabled people easier. There are a lot of wheelchairs types; each type has its specifications, size, dimensions and functions. Two-wheeled wheelchairs one of the types that has been discovered in the last few years. Two-wheeled wheelchairs give the users the ability to move in narrow areas easily. In addition to that the ability to extend the height of the seat helps the users to act independently during daily activity, for example when they want to collect books from the shelf in the library.

Many commercial designs have appeared in the recent years. iBot is a powered wheelchair with a lot of abilities working on 4 wheels, balancing on 2 wheels, climbing stair and giving users the ability to join eye-to-eye conversation with people but unfortunately the company has stopped producing it [2]. Genny is another two wheeled wheelchair, it can balance on 2 wheels but it does not has the ability to lift the seat [3].

International Organization for Standardization (ISO) has done standards that are related to the working area of wheelchairs. These standards can help the architectures to design the houses to be suitable for the users of wheelchairs, ISO 7176-5:2008 standard was focused in the determination of
dimensions, mass and manoeuvring space [4]. Regarding to ISO 7176-5 maximum occupied length of manual and powered wheelchair has to be 1300mm, occupied width of manual wheelchair has to be 800mm but electrical type has to be 700mm, and ISO stated that the maximum turning diameter has to be 2000mm for manual wheelchair and 2000 to 2800 in powered wheelchair.

Nowadays, designing such mechanical design has become easier than previous because many software have been found out to help engineering in designing and testing the products. SolidWorks is considered one of the powerful tools to design and simulate the mechanical designs and products [5]. Using SolidWorks, engineers can shorten the required designing time, and optimising and validating the design to reach the optimal design as possible. SolidWorks simulation another important tool is included in SolidWorks software. It can help in implementing many tests on the design to ensure the safety of this design and to test the design under the external forces. R Sam et. al have designed and simulated a robotic systems in the SolidWorks environment to reduce the designing time and test the parts of the robot to reach the optimal design [6]. L Zhao et al have done the virtual design of bike. Simulation of the bike has been done to select the best material for the frame [7].

This paper presents the 3D design of two-wheeled wheelchair design using SolidWorks. Which is the design process is following the systematic steps for designing using CAD software. Finite element analysis has implemented on the frame of the wheelchair to test it under the external loads and select the optimal material for making the weight is suitable.

2. SolidWorks Overview

SolidWorks is an outstanding 3D design tools. It gives designers the ability to sketch out ideas, experiment with features and dimensions and produce models and detailed drawing. 3D design approach is used in SolidWorks. It is start from initial sketch on papers then going to SolidWorks environment to build the parts from the initial sketch after that combining the parts together in one assembly to come out with the final design. 2D drawing is the final step before sending the design to the workshop to build the real prototype. Figure 1 shows the four important sections of SolidWorks [6].

![Figure 1. Systematic steps in designing using SolidWorks](image-url)
3. Three Dimensional Design of two-wheeled wheelchair

Designing steps are following the flow chart in figure 1. First of all, deciding the dimensions of each part to come out with suitable design and to achieve the ISO-standard values. Second step is modelling each part individually. The wheelchair is divided into three parts; rear wheels, the frame and casters. In addition to the parts there are two subassemblies, the lifting mechanism - lifting mechanism- and the chair with human body. Figure 2 shows the parts and subassemblies of the design.

![Figure 2. The parts of two-wheeled chairs](image)

Next step is to combine all parts and subassemblies together to build the final design. In this step bottom-up technique is used, which it starts by building the parts then integrate these parts together using mates. Mates create the geometric relations, such as coincident, perpendicular and tangent. These mates help in restricting the movement of the parts. Figure 3 shows the full design after combining the parts together.

![Figure 3. Full design of two-wheeled wheelchair](image)

4. Working area and dimensions:

International Organization for Standardization (ISO) has set the standard dimensions and turning radius of powered wheelchairs. Whereas the maximum occupied length and width should be 1300mm and 700mm respectively. While the maximum turning radius should be 2800 mm. The proposed
design achieves the ISO-7176-5 standards of dimensions and turning radius, where it is occupied length and width are 904.34mm and 660.65 respectively these dimensions with the ability to work on two wheels give this design the ability to work in narrow areas. Figure 4 shows the occupied length, occupied width and turning radius of two-wheeled design.

![Figure 4](image)

**Figure 4.** Occupied length and width and the turning radius of the design

5. **Finite element analysis:**
The static analysis was employed on the frame of the wheelchair to check its ability to stand under the weight of the human body, check the deformation under this load and the safety factor for two selected materials. Table1 shows the material that is selected to build up the frame. The steel frame has mass of 47891.30 grams, while the aluminium one has almost third of this mass.

<table>
<thead>
<tr>
<th></th>
<th>Steel AISI1020</th>
<th>Aluminium alloy 1350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic Modulus (N/m^2)</td>
<td>2e+0011</td>
<td>6.9e+0010</td>
</tr>
<tr>
<td>Density (Kg/m^3)</td>
<td>7900</td>
<td>2700</td>
</tr>
<tr>
<td>Yield strength (N/m^2)</td>
<td>351571000</td>
<td>27574200</td>
</tr>
</tbody>
</table>

The frame was analyzed through static analysis test. 980 N external force has been applied at the upper side of the frame this external load considered as 100 KG is up to the frame. The static test has been done using steel and aluminium.

5.1 **static analyses for steel frame:**
Figure 5. Shows that the steel frame is pass the test successfully, due to the many criteria. First of all from the stress graph it is clear that the maximum stress is less than the yield strength, so the part will not broke under this external load. Secondly, the maximum deformation is very small, it is 2.964e-1mm. Finally, for safety factor it is clear from the graph that all the graph has the blue colour and there is not any red area which this is meant that the part is pass the test successfully.
5.2 static analyses for aluminum frame:
Figure 6 shows that the aluminium frame is pass the test successfully, due to the many criteria. Firstly from the stress graph it is clear that the maximum stress is less than the yield strength, so the part will not broke under this external load. Secondly, the maximum deformation is very small, it is 8.409e-1mm, but it is almost three times the value of steel. Finally, for safety factor it is clear from the graph

Figure 5. The result of static analysis for steel frame
that all the graph has the blue colour and there is not any red area which this is meant that the part is pass the test successfully.

Figure 6. The result of static analysis for aluminum frame
5.3 material selecting
The previous graphs show that there are differences between the using of steel and aluminium. Regarding to stress analysis the stress of both materials is almost same. It is 17610692N/m^2 and 17290958N/m^2 for steel and aluminium respectively. For the displacement graph it is clear that the aluminium material presented more distortion than steel, it is deform three times more than the steel. Going to the factor of safety graph it is evident that both of the materials don’t have any red areas, so both material success in the analysis. But aluminium steel is selected because of the Light weight.

6. Conclusion
In this paper a bottom-up assemblies is used to build the 3D model of the two-wheeled wheelchair. Starting from building the parts, then integrate it together in one assembly to reach the full 3D model. SolidWorks simulation has been used to ensure the capability of the frame to Stand under the influence of an external force – human body weight –. Finite element analysis has been done using steel and aluminium to build up the frame, both material success in the test, but aluminium has been selected because of its light mass.

References