Design and Feasibility Test of an Indigenous Motorized Wheel for Manual Wheelchair

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ABSTRACT

The wheelchair is essential for people with either spinal injury, limb injury, or trauma patients. The need at present is to customize the wheelchair based on the requirements of the disabled person. The maintenance and customization of a manual wheelchair is both simple and cost-effective when compared to powered wheelchairs, which are expensive and difficult to maintain in the long run. Accordingly, in this article, an attempt has been made to bring the facilities available in a powered wheelchair into the manual wheelchair, making it affordable to common people. Feasibility of a distinct manual wheelchair rear wheel rim is examined for various hub motor weights. The rear wheel of the manual wheelchair was replaced with an in-wheel direct drive hub-motor system. The proposed wheel model was designed using CATIA – V5 and an analysis was done using ANSYS software. A structural analysis was carried out to check the reliability and durability of the proposed wheel for different materials by changing hub-motor weights at various loading conditions. The nature of vibrations with respect to natural mode frequencies are found through modal analysis. Finally, the dynamic behavior of the proposed motorized wheel was examined using harmonic response analysis. Simulation results show the robustness of the proposed design and viability for real-time implementation.

KEYWORDS

Deformation, Design, Frequency, Hub-motor, Strain, Stress, Structure, Von-Mises, Wheel

1. INTRODUCTION

The wheelchair is an essential device to assist disabled persons. According to the World Health Organization (WHO) statistics in the year, 2011 shows that 5.1% of the disabled persons are children (Avutu et al., 2017). The usage of the wheelchair in India is increasing rapidly because of road accidents (Avutu et al., 2017) and miss-happenings at home, etc. According to Census of India in the year 2011, out of the total Indian population, approximately 20% of people are disabled and belong to below poverty line category (Avutu, 2016). These people with different mobility impairment(s) are unable to afford an expensive powered wheelchair and need an appropriate wheelchair to perform activities of daily living (ADL) without assistance. The appropriate wheelchair design depends on the nature of the mobility impairment, age, type of job and the living place environment. The customization of the wheelchair is not unique among all wheelchair users. The long-term usage of the manually propelled wheel

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wheelchair is not advisable since it may lead to a shoulder injury and difficult for the aged people. Although powered wheelchair is readily available in the market, but not affordable by common people and it is observed, they tend to employ using a manual wheelchair with a lot of discomforts. In India, more people use a manual wheelchair and experience pain while propelling it compared with the traditional powered wheelchair (Frank et al., 2012) due to a lack of proper customization. The main objective of this work is to replace the manual wheelchair rear wheel with a direct-drive motorized wheel, which can fit for any model of the manual wheelchair and is cost-effective leading to increase in affordability when compared with traditionally powered wheelchairs available in the global market.

In the rest of the paper, the difference between a manual and powered wheelchair in design perspective and related work is explained in the section – 2. The proposed methodology is explained in section – 3. The robustness of the proposed method is discussed in section – 4. Section – 5 provides concluding remarks and viability of the proposed design.

2. RELATED WORK

2.1. Difference Between Manual and Powered Wheelchair

The wheelchairs available in the Indian market are classified as standard and Ergonomic wheelchairs. These wheelchairs including tricycles must be reliable and durable for long-term usage by the patient. The durability of any wheelchair is dependent upon the material used, type of welding, the size of the wheelchair frame, loads acting on the frame and nature of the place where it can be used. The basic model of the traditionally available manual and powered wheelchair in the Indian market is shown in Figure. 1. The difference between manual and powered wheelchair in design perspective is as shown in Table.1

2.2. Related Work

Leaman et al. (2017) discussed the Past, Present and Future trends of the powered wheelchair and concluded that it should be customizable to individual users. Lee, Hyuk et al. (2016), used direct current (DC) motor for power assistance. Kim and Gwan et al. (2015) explained the driving mechanism that can be attached to a manual wheelchair, which occupies more space and is not suitable for indoor use.

“All-Terrain Wheelchair” by Podobrik and Rejc et al. (2017) explained about the wheel-track hybrid design. Vedaraj and Rao (2010) explained about the wheelchair design which can be stable

<table>
<thead>
<tr>
<th>Manual wheelchair</th>
<th>Powered wheelchair</th>
</tr>
</thead>
<tbody>
<tr>
<td>The design is simple</td>
<td>The design is complex</td>
</tr>
<tr>
<td>Lightweight</td>
<td>Heavyweight</td>
</tr>
<tr>
<td>Easy maintenance and repaired by a local mechanic</td>
<td>Maintenance is costly and professional was needed for any repairs</td>
</tr>
<tr>
<td>Run by human power</td>
<td>Run by battery power</td>
</tr>
<tr>
<td>The 6061,7000 series aluminum, 4130 series steel material are employed</td>
<td>The 6061,7000 series aluminum, 4130 series steel material are employed</td>
</tr>
<tr>
<td>Customization is easy</td>
<td>Customization is difficult</td>
</tr>
<tr>
<td>Spare parts availability in the local market is high</td>
<td>Spare parts are available with the manufacturing company and its distributors only</td>
</tr>
<tr>
<td>The driver wheels are fixed in the rear position</td>
<td>The position of the drive wheels may change based on the model</td>
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