Design and Development of a Wheelchair Prototype

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ABSTRACT

The rate of people with disabilities in Vietnam is about 7% out of a total of 98 million. Wheelchairs are popular assistive devices for disabled people and are often found in many places around the world, including Vietnam. This study proposes a novel design of a prototype electric wheelchair to support people with disabilities in Vietnam. The electric wheelchair model was successfully simulated and manufactured, fully meeting the proposed technical requirements. The proposed model works well and is suitable for the shape and physical strength of Vietnamese people.

Keywords-disabilities; wheelchair; prototype; design; manufacturing

I. INTRODUCTION

People with disabilities in Vietnam account for about 7% of the total of 98 million. The disability rate tends to increase with age, whereas women account for 58% and men for 42% [1-2]. These people have difficulty moving from one place to another. Wheelchairs are popular assistive devices for disabled people and ca be found in many places around the world, including Vietnam. A conventional wheelchair is operated manually by the person sitting on it, sometimes making the user feel stressed and tired. In many cases, even though there are wheelchairs to assist disabled people, they still need the help of others to move. This dependency makes people with disabilities feel helpless and depressed. Therefore, electronic wheelchairs have been developed, which is a type of motor-controlled wheelchair that allows users to move more easily to the desired place without much effort.

In [3], an electric wheelchair was proposed, which was equipped with mecanum wheels, allowing it to move in any desired direction and speed using a joystick controller. In [4], an electric wheelchair equipped with a joystick controller was presented to serve as a personal mobility device for people with disabilities. In [5], a mechanical design for a wheelchair was presented that was capable of transitioning between sitting, lying, and standing positions. The upright position helps patients access elevated areas and participate in physical activity. In [6], the durability of the materials used in standing electric wheelchairs was examined. This study focused on evaluating the strength of the materials when subjected to different patient weights, ranging from 40 to 90 kg. In [7], a design for an automated multiposition dynamic wheelchair was proposed, which could transport quadriplegic patients by modifying the structure of a manual wheelchair. In [8], a new wheelchair was introduced, which incorporated a body posture adjustment feature. This innovative design aimed to meet the specific needs of older people and individuals with disabilities. In [9], a method was proposed to detect and classify a step and subsequently autonomously climb it safely. In [10], a design optimization study of non-pneumatic castors for wheelchairs was carried out using Finite Element Analysis (FEA). This study compared the mechanical properties of these castors with those of a pneumatic castor with similar characteristics. In [11], a scientific examination of ten distinct ramps was carried out to assess the structures that directly impact the sense of comfort or discomfort experienced by wheelchair users with assistance, as well as the coefficients of friction of various flooring surfaces. In [12], a detailed examination of an automated control system was presented, which allowed a robotic assistant to push a wheelchair upstairs. In [13], SmartWheels was proposed, which is a method for identifying urban characteristics by analyzing data from inertial sensors that are generated by wheelchair movements. In [14], the design and development of a 4-wheel driven omni wheelchair was presented, which was specifically designed for indoor navigation and aimed to minimize wheel slippage and vibration. In [15], a design process for a new electric wheelchair controller was proposed, which allowed both wheelchair users and their caregivers to have control access.

Due to advancements in science and technology, machines equipped with integrated electrical control systems have become increasingly familiar [16-23]. This study aims to establish a systematic approach to develop and produce a wheelchair prototype that is both cost-effective and equipped with comprehensive support features that help people with disabilities. The electric wheelchair model was successfully simulated and a prototype was manufactured, fully meeting the proposed technical requirements. This machine worked well and was suitable for the shape and physical strength of the Vietnamese.

II. METHODOLOGY

A. Design Object

The vehicle's parameters for wheelchair design are heavily influenced by the user's physical characteristics. The fundamental variables consist of width, length, height, and allowed load. The average height of Vietnamese is approximately 1.65 meters, while their average weight is approximately 70 kg. The width of the chair ranges from 380 to 450 mm, and the width from the backrest to the knee measures approximately 400-500 mm. The selected dimensions were width×length = 380×480 mm. The height varies between 900-1000 mm. The proposed electric wheelchair was designed with dimensions of approximately 1000×700×920 mm, considering the average physical condition and height of Vietnamese people. Additionally, the vehicle weight is less than 30 kg. Figure 1 illustrates the configuration of the wheelchair prototype, with the control box positioned on the right side, which is typically the dominant-hand side for most people.

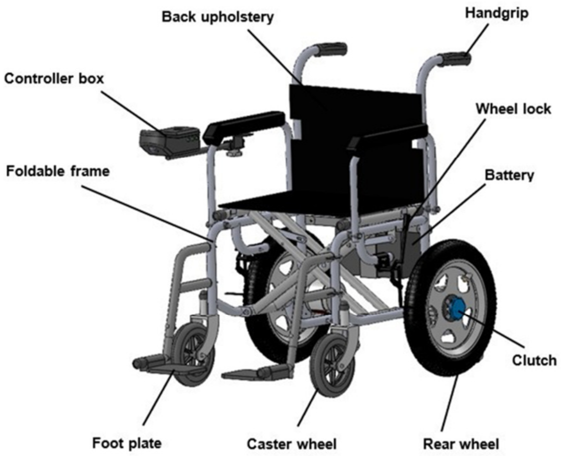

Fig. 1. The mechanical structure of the electric wheelchair prototype.

B. Mechanical Design of Wheelchair

Figure 2 illustrates the force system exerted on the wheelchair frame. The force balance equations is described in (1):

$$\vec{F} + \overrightarrow{F_{ms}} + \overrightarrow{F_{qt}} + \vec{R} + \vec{G} + \vec{N} = 0 \quad (1)$$

$$\begin{cases} F - F_{ms} - F_{qt} = 0 \\ R + G - N = 0 \end{cases} \quad (2)$$

$$N = R + G \quad (3)$$

$$F = f * N + \frac{R+G}{g} * a = (f.g + a) * \frac{R+G}{g} \quad (4)$$

where a is the acceleration of the vehicle when the speed changes from v_o= 0 km/h to v = 6 km/h.

$$a = \frac{v - v_o}{t} = \frac{5}{6}\ (m/s^2) \quad (5)$$

$$F = \left(0{,}005 * 9.8 + \frac{5}{6}\right) * \frac{(70+30)*9.8}{9.8} = 150\ (N) \quad (6)$$

Using two motors for propulsion results in the distribution of torque on the shaft of each motor:

$$T = \frac{150}{2} * \frac{16*2.54}{2.100} = 15\ (Nm) \quad (7)$$

The power of the motor is:

$$P = \frac{T * n}{9.55} \quad (8)$$

and the motor shaft revolutions are:

$$n = \frac{1000 * v}{\pi . d} = \frac{1000*6}{\pi*16*25.4*0{,}06} = 78.3 \text{ rpm} \quad (9)$$

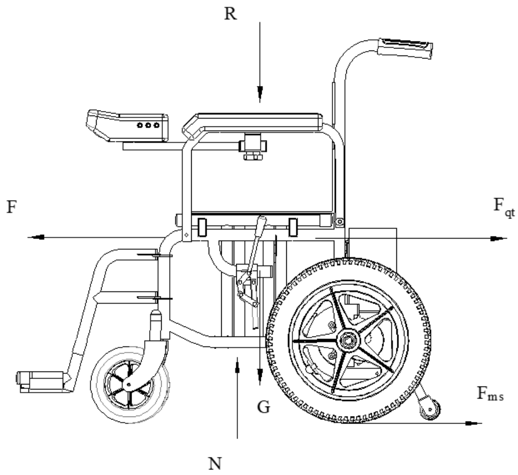

Fig. 2. Forces acting on the wheelchair.

C. Finite Element Analysis

Simulation analyses are necessary to verify that the prototype satisfies the required technical specifications before fabrication [24-28]. The numerical simulation process was carried out using SolidWorks software, as shown in Figure 3. The frame material is stainless steel SUS 304 which has an elastic modulus of 1.9×10^5 Mpa, a Poisson ratio of 0.29, and a yield strength of 206.807 Mpa. The external force acting on the frame is the weight, which is set for the most common simulation, equal to 70 kg. This force is transferred to two blue rods, as shown in Figure 3. In addition, the supporting points are set at the bottom of the frame. Figures 4 and 5 show the simulation and test results for strength and displacement. Stress analysis indicates that the frame provides complete durability assurance, with the highest stress measured at 23 Mpa, far below the allowable limit of 250 Mpa. The displacement analysis indicates that the maximum displacement measured is 0.122 mm, indicating an insignificant magnitude of displacement. The results indicate that the wheelchair structure fully satisfies the technical specifications.

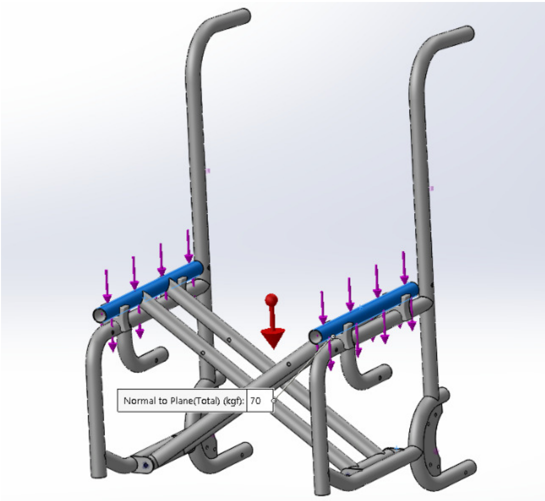

Fig. 3. Simulation in Solidworks.

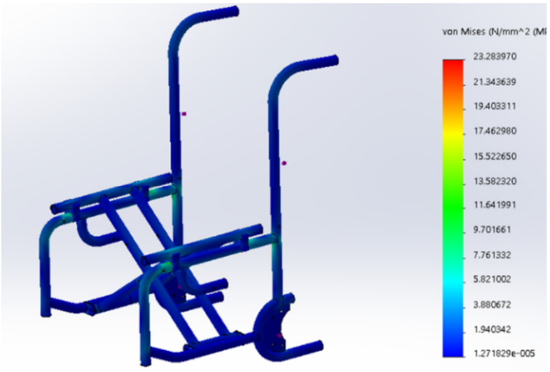

Fig. 4. Stress result.

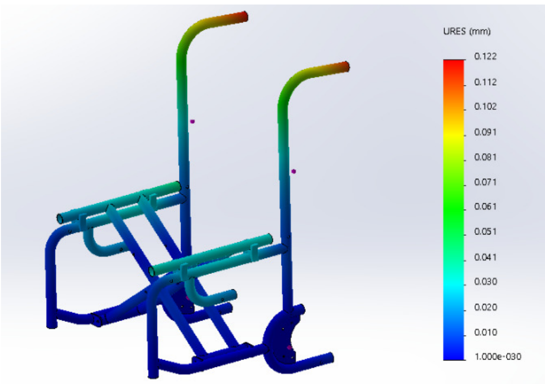

Fig. 5. Displacement result.

III. RESULTS AND DISCUSSION

Figure 6 illustrates the prototype wheelchair that was successfully manufactured. The prototype's dimensions were 1000×670×930 mm (length×width×height). When folded, its length was reduced to 330 mm. The wheelchair has a speed range of 2 to 6 km/h, a maximum travel distance of 20 km, and can climb slopes with a maximum inclination of 35°. Furthermore, the wheelchair is equipped with an integrated GPS position tracker.

Fig. 6. A prototype of the electric wheelchair.

Fig. 7. Testing of the wheelchair.

Three men in good health, weighing between 55 and 70kg, were recruited to evaluate the electric wheelchair prototype. Figure 7 shows a momentary representation of the wheelchair control process. The results indicate that the mechanical movements exhibit a high degree of fluidity, allowing the vehicle to navigate with smooth motion and effortless control operations.

IV. CONCLUSION AND FUTURE WORK

This study presented the design and development of a prototype electric wheelchair to assist disabled people. The electric wheelchair model was successfully simulated and manufactured, fully meeting the proposed technical requirements. The machine works well and is suitable for the shape and physical strength of Vietnamese people. Future work could be done to improve the vehicle's ability to overcome obstacles and optimize the lifting and lowering ability of the handrail. In addition, it is possible to integrate more advanced techniques into electric wheelchairs, such as the ability to control the vehicle via Bluetooth and add electronic brakes.

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