Barrier-Free Wheelchair and Mechanical Transmission

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Wheelchairs are widely used around the world to provide mobility to the elderly and disabled [1]. However, the difficulty to access areas with curbs and stairs using a standard electric-powered wheelchair limits the scope of activities, thereby declining the quality of life of those who depend on electric-powered wheelchairs. Although slopes and elevators are being introduced to promote barrier-free locomotion, it is difficult to implement them in all public facilities. Therefore, climbing up and down the stairs is inevitably a critical issue with respect to user safety. With the increasing interest in the aging population and health welfare around the world, various studies on indoor electric wheelchairs for the elderly and disabled are being conducted.

Keywords: wheelchair ; transmission ; stairs-climbing

1. Overview

Wheelchairs are an important means of transportation for the elderly and disabled. However, the movement of wheelchairs on long curbs and stairs is restricted. In this study, a wheelchair for climbing stairs was developed based on a mechanical transmission system that rotates the entire driving part through a link structure and an actuator to change the speed. The first mode drives the caterpillar, and the second mode drives the wheels. When driving on flat ground, it uses landing gears and wheels, and when climbing stairs, it uses the caterpillar; accordingly, a stable driving is possible. The stability of the transmission is confirmed through stress analysis. The method used in our study makes it is possible to manufacture lightweight wheelchairs because a single motor drives both the wheel and caterpillar through the transmission system.

2. Wheelchairs

Wheelchairs are widely used around the world to provide mobility to the elderly and disabled [1]. However, the difficulty to access areas with curbs and stairs using a standard electric-powered wheelchair limits the scope of activities, thereby declining the quality of life of those who depend on electric-powered wheelchairs [2]. Although slopes and elevators are being introduced to promote barrier-free locomotion, it is difficult to implement them in all public facilities. Therefore, climbing up and down the stairs is inevitably a critical issue with respect to user safety [3]. With the increasing interest in the aging population and health welfare around the world, various studies on indoor electric wheelchairs for the elderly and disabled are being conducted [4][5][6].

The recent developments in the field of electric wheelchairs can be categorized into the wheel-type and caterpillar type methods [7]. The representative example of the wheel- type method is iBot. The iBot presents a method of climbing stairs by changing the angle of movement and the center of gravity of the occupant. The other type of method is the caterpillar, which is essentially, a track system. Tracks are often used in military vehicles such as heavy machinery, tanks, and armored vehicles. Because a caterpillar pushes the ground with a wide surface area, the contact pressure is low; therefore, driving in a rough terrain is convenient. However, each type of method has its respective drawbacks. In case of the iBot, owing to the statically unstable two-point grounding of the stairs, the user must hold the railing to maintain balance while climbing the stairs without the assistance of a caregiver [2][8]. The caterpillar is stable while climbing stairs; however, it is unsuitable for driving on level ground.

In this study, the authors attempt to develop a wheelchair that addresses the limitations of the use of only wheels or caterpillars in conventional electric wheelchairs by pro-moving flexibility in the use of wheels on level ground and caterpillars on stairs. Wheelchairs that drive both a caterpillar and a wheel at the same time have already been studied a lot, such as TGR Explorer, TopChair-S and Scewo bro. However, their slightly more complicated structure and higher price partially hinder a more extensive application among the elderly population and persons with disabilities [9]. In the case of Scewo's wheelchair, it is equipped with the iBot function, so it is expensive and very heavy at 101 kg. This study aims to reduce the weight and price with a simple structure, so that it can be applied to more disabled people and the elderly. The target weight of the wheelchair is 65 kg and the weight of the user who can ride it is 100 kg. In addition, it will be possible to provide more convenience by going up and down the stairs alone without the help of a guardian.

In this paper, we designed a transmission and pulley position conversion system to divide the wheelchair into two modes. Through mathematical calculations, the gear specifications of the transmission and the size of the pulley position conversion system are determined. The reliability of the transmission was verified through the stress analysis of the gear, and the drivability, stability, and operability of the wheelchair drive part were verified through the actual production.

3. Proposed Wheelchair Concept

Conventionally, electric wheelchairs comprising wheels and caterpillars are extremely heavy because the motors that drive the wheels and caterpillars are separate. In this study, the authors attempt to develop a lightweight electric wheelchair, incorporating both driving wheels and caterpillars in tandem, using a single motor. Figure 1 show a 3D model of an electric wheelchair. On flat ground, the wheelchair is driven by wheels and a landing gear located in front of the wheelchair, and while climbing stairs, it is driven by a caterpillar.

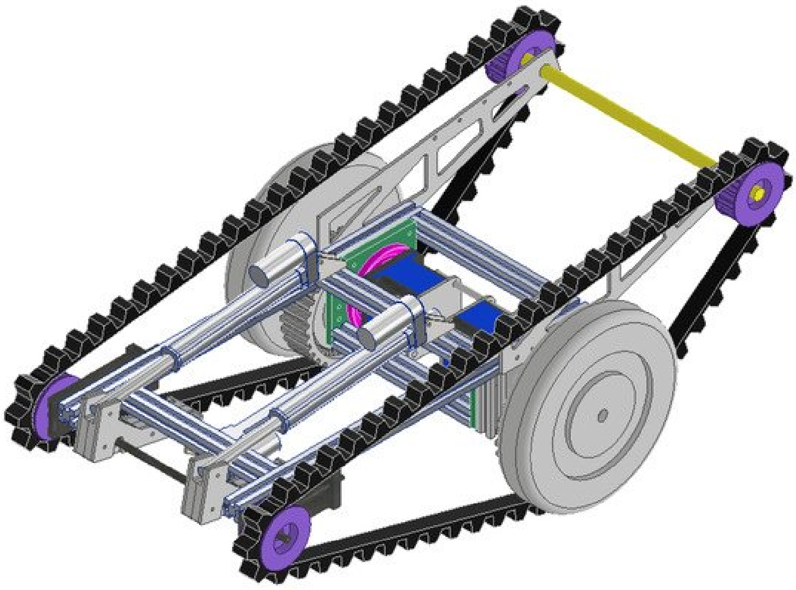

Figure 1. 3D model.

Basically, stairs are climbed by forming an entry angle using the landing gear, and when the front part of the caterpillar hits the first step of the staircase, the landing gear is folded and accordingly, a step of the staircase is climbed using the caterpillar. When one reaches the last step of the staircases, the landing gear is spread to prevent impact on the wheelchair. While descending the stairs, the first step is approached in a similar manner as that while ascending. After folding the landing gear and entering the staircase, the landing gear is spread again, before the center of gravity is completely crossed to prevent impact; thereafter, the landing gear is folded again and accordingly, the user descends the stairs. In the last step after having descended the stairs, the extended caterpillar at the rear of the caterpillar prevents impact.

4. Conclusions

In this study, an electric wheelchair drive unit capable of climbing stairs and moving on level ground was developed based on a caterpillar and wheel in tandem. Through a 3:1 reducer, comprising a sun gear shaft and ring gear, the caterpillar and wheels were driven at different speeds simultaneously, allowing one to stably ascend/descend stairs. Because driving the caterpillar and wheel simultaneously could cause interference between them, a device that could changes the position of the pulley was incorporated to prevent interference, and the specifications, such as, the pulley angle, pulley radius, and system eccentricity, were calculated to determine the optimum value. The reference efficiency of the gear, was calculated to be 0.994, and the stability was confirmed through stress analysis. A lightweight electric wheelchair was developed in this study by removing the additional power required to drive the caterpillar and using a single motor to drive both the wheels and caterpillar.

However, this study has certain limitations, particularly in terms of the reliability of the wheelchair in climbing stairs. Unsafe situations arise because we devised a method ascend and descend stairs through only a mechanical mechanism without electronic control. We intend to address this limitation through additional research on climbing and descending stairs more safely through electronic control methods and structural completion. In addition, research on a wheelchair with a chair tilting system through electronic control is also necessary. Since there may be a risk due to a change in the center of gravity when ascending and descending stairs, we aim to devise a chair system that is suitable for this drive system through further research.

This study developed a wheelchair drive unit capable of climbing stairs to provide a barrier-free life to the elderly and the disabled. It is expected that this study can provide a more pleasant environment to the disabled. Furthermore, the proposed driving unit presents the possibility of creating more efficient driving units not only for wheelchairs, but also for vehicles that are driven on both rough and flat terrain such as military vehicles, heavy equipment, and unmanned robots.

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