DESIGN OF A POWER-ASSIST WHEELCHAIR FOR PERSONS WITH HEMIPLEGIA

Allen H. Hoffman and Keith N. Liadis
Mechanical Engineering Department
Worcester Polytechnic Institute
Worcester MA 01609

Introduction

Common causes of hemiplegia include stroke, cerebral palsy and trauma with stroke being the most common. Within the United States there are over 4.5 million people managing stroke with 600,000 cases occurring annually. Individuals with severe hemiplegia require specialized manual wheelchairs. Powered wheelchairs are not considered to be a viable solution, since they do not encourage an appropriate level of physical activity for the user. Currently, there are two common designs for one-arm drive manual wheelchairs. Both designs exhibit substantially degraded performance when compared to a standard manual wheelchair. The lever arm design propels only one wheel, increases the turning radius of the wheelchair and is a specialized design that cannot be modified to change the side of the lever nor converted back to a standard wheelchair. The dual pushrim design is an accessory that is added to a standard wheelchair. This design exhibits poor ergonomics. The wheelchair can be folded by removing a transverse drive axle, however that operation is difficult even for an able-bodied person. The user/technology interface is a critical element in the design of any assistive device (1). The design of both types of one-arm drive wheelchairs results in degradation of the user interface.

Objective

The objective of this work was to produce a functional prototype of a power-assist manual wheelchair for persons with hemiplegia that would exhibit the maneuverability associated with a standard manual wheelchair and retain a similar ability to fold.

Major Design Goals

The major design goals were;

1. To produce an *add-on system* of components for a manual wheelchair that would allow the user to effectively propel their manual wheelchair with one arm.
2. To retain the existing folding feature of a manual wheelchair that allows it to be easily transported in an automobile rather than in a van.
3. To provide an intuitive user/technology interface.
4. To meet ISO and ANSI/RESNA wheelchair testing standards.
5. To allow a typical user to travel at speeds above 5 mph.

Prototype Design

The unaffected hand is used to drive the wheel on that side, while a motor and gear train is used to drive the wheel on the affected side. The steering interface is operated by rotating the unaffected foot. Encoders are attached to both rear wheels and track the wheel positions. For travel in a straight line, the control system matches the velocity of the motor driven wheel with the velocity of the hand driven wheel. The steering interface contains a rotary encoder whose output is used in conjunction with a lookup table to determine the desired speed differential between the hand driven and motor driven wheels. The prototype retains the overall dimensions

of the original manual wheelchair. The original wheelchair weighed 24 lbs. The mechanical components to convert the wheelchair to power-assist weighed 6 lbs. The controls system including the battery was suspended in a backpack behind the chair and weighed 18 lbs. The weight of these components could be reduced in a next generation prototype.

Testing and Evaluation

Testing was performed based upon ISO and ANSI/RESNA standards for static and dynamic stability, brake effectiveness, overall dimensions and turning space. The prototype met each of these standards. Qualitative testing was used to evaluate driving performance. Straight-line driving included driving over obstacles of different heights. The prototype was able to achieve speeds of up to 6.2 mph on level surfaces. The wheelchair was able to travel over a ¾ inch barrier with no run-up and over a 2 inch obstacle with run-up. A figure-eight course around two markers spaced 30 inches apart was used to evaluate maneuverability. Four types of wheelchairs were evaluated by the same user. The average times (seconds) to traverse the course based upon 5 trials were; standard manual wheelchair (10.5), power-assist wheelchair (16.7), lever action wheelchair (33.8) and dual pushrim wheelchair (46.9).

Discussion

The user/technology interface of the prototype wheelchair retains similar characteristics to a standard manual wheelchair. Propulsion on the unaffected side of the user is unchanged. Steering which is normally executed by controlling the velocity of both wheels is replaced by a rotary input using the unaffected foot. Tests showed that the prototype wheelchair demonstrated superior maneuverability when compared to existing one-arm drive wheelchairs. Less strength and endurance were required of the user, thereby potentially increasing the range of travel. The performance and maneuverability characteristics of the prototype were generally similar to a standard manual wheelchair. In addition, the folding ability of the wheelchair was retained.

Reference

1. Cook, A.M. & Hussey, S.M., Assistive Technologies Principles and Practice, 2nd ed., Mosby, St. Louis, 2002.

Author Contact Information

Prof. Allen H. Hoffman
Mechanical Engineering Department
Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609 -2280

Phone (508) 831-5217
Fax: (508) 831-5680
Email: ahoffman@wpi.edu