TECHNOLOGY AREA

Consumers, experts, industry contacts and researchers interviewed, identified manual wheelchair propulsion as an area in need of technological advancement. This technology area includes methods of wheelchair propulsion other than manual wheel turning, as well as wheelchair component design changes to facilitate efficient propulsion. There are over 1.4 million wheelchair users and about 75% of them use manual wheelchairs. There has been little change in the design of the manual wheelchairs over the last decade. Manual wheelchairs are complex systems and wheelchair design can limit propulsion, independence and accessibility. The investigation of manual wheelchair propulsion has become increasingly important because the population of individuals using wheelchairs is growing and requires efficient mobility to maintain a quality of life equivalent to the general population. Several attempts have been made at improving manual wheelchair propulsion, such as changes in the wheels and tires, adding gears and designing alternative propulsion systems. Still, experts and consumers generally agree that innovation in propulsion is still needed.

THE NEED

There are 3 main reasons that improvements in manual wheelchair propulsion technology are important.

Users Achieve Greater Independence

Individuals who use manual wheelchairs need to be as active as the population at large in order to seek and maintain gainful employment, pursue recreational activities and past times, and achieve greater independence in daily activities. Everyday obstacles such as ramps, door thresholds, uneven terrain, soft carpet, and travel distances often require more strength and endurance than is available to some individuals. Improved propulsion technologies will reduce physical fatigue and effort required for wheelchair propulsion, and improve wheelchair maneuverability. Such technology would especially benefit the elderly who generally have less strength, and decrease stress on the upper body and joints for the average user.

Users Benefit Physically

Pain and upper extremity injury is common among manual wheelchair users. Shoulder related injuries have been shown to be present in up to 51% of manual wheelchair users. In addition, the prevalence of elbow, wrist and hand pain has been reported to be 16%, 13%, and 11% respectively (Koontz, et.al., 1998). The incidence of carpal tunnel syndrome and rotator cuff tendonitis, for example, is greater than 50% for people who regularly use manual wheelchairs as compared to 3% for the general population (Snowbeck, 1998). During wheelchair propulsion, users must exert large forces in order to propel the chair forward. In addition, the component of force that is directed in towards the hub does not contribute to forward motion but is necessary in order to provide friction between the hand and the pushrim (Koontz, 1998).

The User Population is Significant

Individuals who use manual wheelchairs generally have lower extremity weakness, paralysis, or amputation making walking unsafe or difficult at best. They may include individuals with spinal cord injuries, hemiplegia and other types of paralysis, multiple sclerosis, cerebral palsy, spina bifida, arthritis, and lower limb amputations. The majority of these individuals could benefit from improved wheelchair propelling efficiency at various times in their day. Jones & Sanford (1996) reported an estimated 1,363,026 manual wheelchair users in the United States alone. This market is expected to continue growing at a rate of about 10% per year into the year 2002. Medicare expenditures over a three-year period for a manual wheelchair averaged $98,000,000 annually from 1995-1997 (HCFA, 1997).

BASIS FOR DISCUSSION

Factors affecting propulsion include power assists, gears, steering methods, hand rim configuration, wheel diameter, wheel camber, tire hardness, user's center of gravity and caster design and alignment. This paper will review the three areas of technology affecting wheelchair propulsion that experts mentioned could benefit from improved technology. They include 1) power assisted technology, 2) geared technologies, and 3) one-arm drive technology.

POWER ASSISTED PROPULSION TECHNOLOGY

Statement of the Problem

Experts and industry contacts mentioned power assisted add on units for manual wheelchairs as an area for further technology development and improvement. There are various units currently available and the weight of the attachment, how it is mounted, how it is controlled and the amount of power it provides vary. A national consumer focus group evaluation conducted by the RERC/TET in 1998 revealed that power assist devices in general were selected by the participants as an area that needed improvement. Experts and researchers participating in this project identified the problems as the following:

- Adding a power assist unit to a manual wheelchair will increase the weight of the wheelchair and may offset the distribution of mass or balance and center of gravity possibly making it more difficult for the user to propel when the power assist is disengaged (Brubaker. 1990).
- Heavy power assist units can stress the wheelchair frame if the wheelchair is not specifically designed to accommodate the unit.
- Some of the units are cumbersome to attach and detach requiring the assistance of a second person.
- Some power assist devices incorporate friction rollers that push against the tires to propel the chair. They can produce excessive tire wear.
- Some power assist devices do not work on cambered wheels.
- Most power assist devices utilize a rechargeable battery and include a battery charger as an accessory that requires access to an electrical outlet.
- Power assist devices cost between $2100 to $7000 depending upon the design and model.

Current Solutions

The objective of a power assist device for manual wheelchairs is to provide an inexpensive, portable unit which can temporarily convert a manual wheelchair into a power operated chair. This is usually accomplished by attaching a battery operated drive system to the wheelchair. Power assist components typically include batteries and a charger, a motor, a mechanical interface between the motor and drive wheels, mounting hardware, and a driving interface for user control.

Current product literature on power assist devices was reviewed. These products and components currently weigh anywhere between 46 and 85 pounds. Batteries account for 20–22 pounds. Power assist units achieve variable ranges of speeds of 4 to 4.7 mph, can drive up 15% grade and can cover up to 10 miles per battery charge on flat surfaces. They can operate over distances of 10 to 20 miles on a single charge of the battery.

Power assist devices are attached on the back of the chair, can be incorporated into the wheels, be attached underneath the chair, and can have various steering mechanisms such as joysticks or steering columns. One unit includes a 12-volt charging cable that works from the cigarette lighter socket of the car, and functions as a generator each time the driver brakes or changes direction.

Issues to Consider

- Under what conditions would users of power assists be eligible for third party reimbursement?
- Is there a way to decrease unit size and weight?
- Can the products work across a wide range of wheelchairs?
- Can the unit be easily engaged and disengaged as a function of power demand?

- Can the products be less cumbersome to attach and detach?
- Can distance traveled on one charge be increased?
- Could the evolving technology used for electric bicycles and other electric vehicles be transferred to the manual wheelchair industry?

GEARED TECHNOLOGIES

Statement of the Problem

Actuation of gears is typically achieved through cables. Cables tend to get caught on parts of the chair. Users do not like the look of the cables. They also require an additional lever for operation. Another approach to multi-gear control is by using multiple rims but this increases the width of the chair and may impede access through narrow spaces. There are increased safety hazards associated with increasing speeds and propulsion such as the greater risk for tipping.

Current Solutions

Manually operated single geared hubs are the state of the practice. Like the power assist add-ons, they could be particularly advantageous to the elderly or those with limited endurance to increase their independence and maneuverability. They are especially helpful when traveling indoors and outdoors, over varied terrain, up inclines, and over long distances. They add extra weight to the wheelchair but can reduce the amount of force needed to propel the chair.

Geared hubs act as an interface between the push rim and drive wheel of the wheelchair. A low gear ratio provides mechanical advantage at decreased operating speed, while higher gear ratios provide high operating speed at lower mechanical advantage. A low gear ratio is useful for going up inclines or over soft surface areas. A higher gear ratio is useful for fast travel over hard, level ground or declines. Without gearing there is a 1 to 1 ratio - between the rotation of the handrim and the rotation of the wheel. With a 2 to 1 ratio, a complete rotation of the hand rim results in one half rotation of the wheel.

When considering hub redesign, experts have also mentioned a need for improved hub brakes. Manual wheelchair brakes are designed as dynamic or parking. A dynamic brake allows the user to apply force on the wheels while the chair is in motion. These can be hub brakes or caliper brakes (similar to bicycle brakes). Parking "brakes" are wheel locks that are sold as accessories to most manual wheelchairs (Thacker, 1994). These brakes are usually cam lever, toggle lock, or push-to-lock wheel locks, although pull-to-lock locks are also available. Users of wheelchairs brake using several methods. They use their hands to pull back on wheel handrims. This is very hard on hands and can cause hand injury. Others chose to pull back on wheel locks to stop which causes excess wear and damage to tires.

Issues to Consider

- What are the market issues for geared hub and brake technologies?
- What are the system requirements for geared hub and brake technologies?
- What technologies exist in parallel industries which might be successfully transferred, perhaps providing economies of scale?
- Which user populations would most benefit from improved geared hub and brake technologies? In what ways would they benefit?
- What impact would geared hub and brake technologies have on user's safety, performance, access to environments, independence and so forth?

ONE ARM DRIVE AND LEVER TECHNOLOGY

Statement of the Problem

One armed drive technology may be confusing for some to learn as it is not necessarily intuitive, and the users generally require good upper body strength. Alternative steering methods designs must be intuitive and reasonably functional especially for the elderly population. Despite the potential benefits of lever drive propulsion; few lever drive wheelchairs

are commercially manufactured or widely used. These wheelchairs tend to be larger, heavier and more difficult to fold and transport.

Current Solutions

The one-arm drive wheelchair is a manual wheelchair with both handrims mounted on one side. One arm drive wheelchairs have been available for some time, and a few lever type drive systems have also been available. These are generally designed for one-handed use. They are not add on units and must be purchased as a complete wheelchair. One arm drive wheelchairs are manufactured by some of the larger wheelchair manufacturers. They consist of a wheel with two hand rims and the wheels are basically tied together so that they can be controlled by one hand. Lever driven or ratchet arm systems have been explored. They consist of a lever-operated drive attached to the hub of each wheel. Applying a push/pull motion to the top end of the levers propels the wheelchair. The user moves the lever forward and backward to propel the chair and turns it left and right to turn the chair. A number of studies have shown that lever propulsion is more efficient than handrim propulsion for paraplegics as well as quadriplegics.

Issues to Consider

- What are the technical problems of the ratchet/lever arm systems and how can they be overcome?
- Could one arm drive and lever chairs be designed to be more intuitive?
- What is needed to make it easier to propel a one-arm drive?
- What are the system requirements for ratchet/lever arm systems?
- What technologies exist in parallel industries which might be successfully transferred, perhaps providing economies of scale?
- Which user populations would most benefit from improved ratchet/lever arm systems?
- What impact would ratchet/lever arm systems have on user's safety, performance, access to environments, independence and so forth?

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