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technical note*

Lever drive system for wheelchairs†

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Abstract—The various stages of development of a lever drive system are described. The use of both roller and friction clutches are discussed and the means for controlling forward, reverse, and braking are included. The current system allows good maneuverability without requiring hand skills and may be effective for quadriplegics.

INTRODUCTION

Lever drives for wheelchairs have been in common use in Europe for many years. The typical design, which is similar to that used on a steam locomotive, uses connecting rods from the lever to the drive wheel. Steering is accomplished by turning a handle on the lever, the handle being connected to a front caster. Bennedik, Engel, and Hildebrandt (1) established that this is a more efficient method for propelling a wheelchair compared to handrims. However, there are some associated disadvantages. Top speed is limited by the maximum stroking rate, and it is not possible to rest between strokes since the lever is always connected to the drive wheels. Also, maneuvering is much more difficult in close spaces since castering action is not possible and a lever might have to be started at a position of dead center. This last feature contributes to the difficulty in mounting a ramp from a standing start.

One of the reasons for increased efficiency probably stems from the fact that power is applied while pushing and pulling. However, Brubaker et al. (2) established that by using only the push stroke, levers could be more efficient than handrims, particularly if the appropriate mechanical advantage was used. To exploit this possible increase in efficiency, Bruning (3) designed a lever system that used a roller clutch to drive a sprocket on the drive wheel like a bicycle. This allowed pausing between strokes as well as choosing the length of stroke. Reverse was achieved by designing a reversing roller clutch which was controlled by pressure of the palm of the hand for forward motion and by finger pressure for reverse. Neutral or free wheeling occurred when no pressure was applied. The concept proved to be quite effective, but the only braking possible was by engaging reverse, which locked the drive wheels. This did not allow speed and directional control while descending slopes. Caliper, bicycle style, and brakes were tried with the hand levers mounted on the main levers. This required three hand functions for controlling forward, reverse, and braking, which provoked too much for fast action; it was not uncommon to strike a wall or other object before the brakes could be applied.

In attempting to further the development of a lever system that allowed maneuverability similar to handrims, several prototypes were built that combined a brake with the drive system. Typically, the roller clutch was used for forward propulsion and an ancillary lever or handle mounted on the main lever could be used to select neutral and then engage a friction clutch; this in turn could be used as a dynamic brake or, when fully applied, to rotate the wheels in reverse. Handgrip levers proved ineffective. Rotation of the handgrip was more promising, but a

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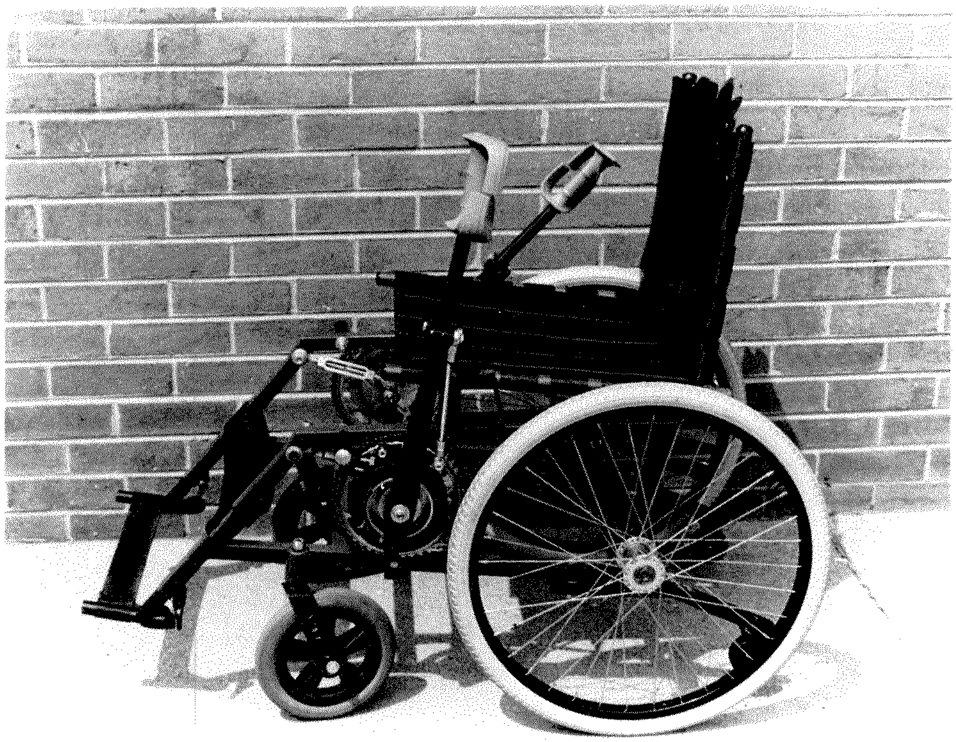

FIGURE 1
The University of Virginia lever drive system mounted on a specially built wheelchair.

second hinge point on the lever that utilized inward motion of the hands proved to be a satisfactory control means and promised to be useful for quadriplegics and others with limited use of the hands.

Further experiments showed that selecting neutral (i.e., releasing the roller clutch) was not easily achieved; and the operator was never quite sure if the system was in forward, neutral, or reverse until the stroke was engaged. Meanwhile the clutch system was greatly improved; it required little force and motion to engage or disengage.

Brubaker suggested disconnecting the roller clutch and using the friction clutch for all three functions: forward, reverse, and braking. The current prototype (Fig. 1) is based on this concept. When the levers are in the normal or rest position, the clutch is disengaged. Inboard movement of the levers engages the clutch, allowing propulsion in either direction or use as a brake. The clutch currently in use is a brake drum using external brake shoes with nonasbestos brake lining. Propelling the wheelchair is similar to rowing or skulling a boat, with the lateral motion of the levers comparable to feathering the oars so that they do not drag on the return stroke. This requires some practice for effective use, but once achieved allows maneuverability that is comparable to handrims.

It is not apparent in the present prototype that propulsion is more effective or more efficient than handrims for skilled users or athletes, although this may be a matter of choosing the appropriate wheels, mechanical advantage, etc. What is apparent is that new design possibilities emerge. For example, smaller drive wheels can be used which can fit under the seat for a narrower and shorter wheelchair with no obstruction in transferring. Furthermore, the hands and clothing are less likely to be soiled. Perhaps the most important application is the use by quadriplegics and others with limited hand function. Using ski pole handgrips and elastic bandages, several quadriplegics have tried the system with favorable results, particularly in the access to brakes. Stops at the forward travel of the levers prevent the levers from being pulled away from the user when applying brakes. Thus steering and speed control while descending hills is easily accomplished. The need for a suitable handgrip for quadriplegics is indicated for further trials. The system described has merit in that it is inherently a lightweight low-cost system with excellent maneuverability, requiring only inward motion of the levers to select all functions.

Further work on levers is indicated to exploit other possibilities. Seeliger (4) has developed a system that allows power to be applied during the pull and push part of the stroke. This is a smooth efficient drive system, but must be disconnected for reverse and close-quarter maneuvering with handrims. Further possibilities with the University of Virginia system include the return to the double-action system but using inboard motion to activate the brakes. The Matsunaga wheelchair uses wrapped spring clutches and connecting rods from the lever to the hub. Forward motion is achieved by forward motion of the lever from a neutral position, whereas reverse is engaged with rearward motion of the lever from the neutral position. Undoubtedly, many other possibilities exist and should be tried. The potential use for levers in wheelchair drive is apparent and continued investigation will lead to one or more acceptable systems which will enhance the mobility of manual-wheelchair users. ■

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