CHAPTER 20
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Design and Fabrication of a Child Mobility Device

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INTRODUCTION

An electrically powered vehicle, suitable for children 2-5 years of age with limited mobility, has been designed and fabricated. The device accepts different therapeutic seating systems and can be used indoors or outdoors on flat terrain. The frame of the vehicle has a low center of gravity. To accommodate different stages of growth, the frame is adjustable in the length- and width-wise directions. Four switches provide directional control of two 6 volt DC motors. The vehicle is powered by a rechargeable gel cell battery. The device was designed to be a link between dependent and independent mobility for pre-wheelchair age children. The device is shown in Figure 20.1.

SUMMARY OF IMPACT

This mobility device opens new doors for young individuals who are severely disabled. It has been found beneficial to individuals as young as one year old to be able to be mobile and explore their surroundings. Being able to be mobile at this young age gives them the opportunity of a normal development pattern.

At this time, there are no child mobility devices built to accommodate a one year old. The cost effectiveness of this device makes it financially accessible to the individual whereas third party payers would not purchase an item such as this for this young a client. This mobility device is inexpensive, simple, and very adaptable and allows the young individual to acquire and utilize this device. Use of the device will help train them for future commer-

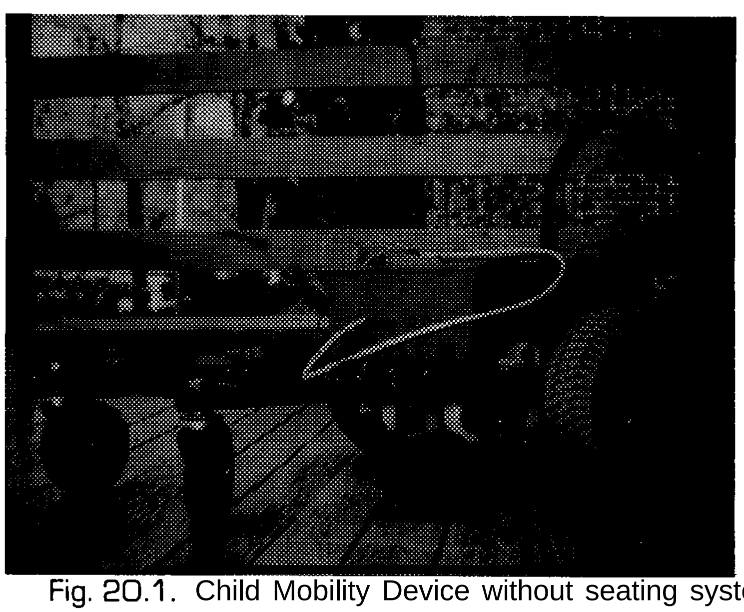

Fig. 20.1. Child Mobility Device without seating system.

PRELIMINARY DESIGN CONSIDERATIONS

The first step in the design process was to develop a goal statement and task specifications. The child's usage environment was examined so that the device could yield maximum maneuverability. The child's physical therapist was consulted to provide current and projected information on his growth patterns and mental and physical capabilities. Also, wheelchair designers and fabricators were consulted for design recommendations.

The goal statement of this project was to design a battery powered, expandable, modular mobility device suitable for use by a two year-old child with moderate spastic Cerebral palsy. The device must accept different therapeutic seating systems and provide a stable adjustable base for the child. The device should provide the child with independent mobility for at least three years.

Performance objectives for the device were specified for three basic sub-systems: 1) power/drive train, 2) electrical control system, and 3) frame and component mounting. The power/drive train specifications established a maximum speed of 3.5 miles per hour allowing the vehicle to operate indoors on rugs and outdoors on 9 degree slopes. The client's therapist recommended an electrical control system using four micro switches, with each switch representing an individual directional command: forward, reverse, left, or right. The switches may be connected to the client's seating system or in any other suitable location on the device that are accessible to the client (such as headrest, tray, etc.). The vehicle should be powered by rechargeable batteries with a minimum service time of 2 hours. The frame must be lightweight, supportive, durable and accept different therapeutic seating systems. Also, the frame should be low to the ground to provide device stability. To increase user flexibility in the 2-5 year old range, the frame should be adjustable in the length- and width-wise directions. All of the device's components must be securely mounted to the frame without hindering its performance. Additional general specifications included a maximum overall weight of 40 pounds for the frame, controls and power/drive train; maximum carrying capacity of 100 pounds (to include the client and his seating system); require minimum maintenance for the client's parents; and be aesthetically pleasing to the client and his family. Safety and ease of manufacturing were also considered. Several preliminary designs were evaluated for stability, component availability and compatibility with the client's seating system.

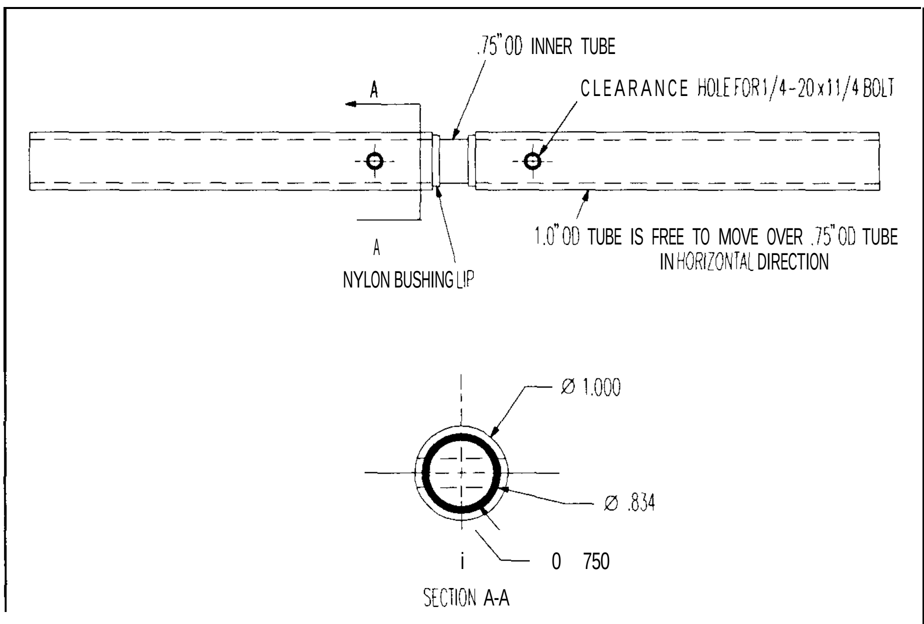

Fig. 20.2. Control System Wiring Diagram

TECHNICAL DESCRIPTION

Given the basic performance specifications and objectives listed above, the students decided to design the device using as many available components as possible. In this way, other individuals could manufacture similar devices without extensive need for custom manufactured parts. The motor and gearboxes selected were from the Power Wheels Co. 12 volt "Jeep Safari" toy. The motor and gearbox are attached to the frame as a single unit. Two 6 volt gel cell rechargeable batteries, wired in series, provide the necessary power for up two hours of device use. The power is transmitted to each rear drive wheel by a rotating drive shaft supported by two pillow block bearings. The final maximum output speed, taking into account rolling resistance and mechanical losses, is 3 miles per hour. The maximum torque in the operating range is 14 foot pounds.

Four microswitches control the movement of the vehicle through a system of double-throw 12 volt relays in a hard-wired configuration. Each microswitch represents an individual directional command: forward (both motors forward) , backward (both motors in reverse), or turn left or right (one motor forward, the other off). Relays were selected because they could be located in a control box separate from the directional switches and allow more flexibility on the placement of the microswitches. The control system wiring diagram is shown in Figure 20.2. If more than one directional switch is activated simultaneously, the relay system interrupts the motor current. Logic and Boolean algebra using truth tables and Karnaugh mapping were used to simplify the overall control system design. A "kill" switch is also provided for a supervising adult. The relays have a continuous current capacity of 25 amps, selected based on the power requirements of the Power Wheels motors. When traveling on a 9 degree slope at constant speed, the current drawn by the motor is 15 amps.

The frame was constructed out of 0.75" and 1.0" OD Aluminum alloy (6061 T6) tubing to be durable, lightweight, supportive and inexpensive. The frame was painted cherry red to be pleasing to the child. The frame is adjustable by 4" in length and 2" in width. The adjustability mechanism consists of an outer tube, a nylon bushing, and an inner supportive tube as shown in Figure 20.3. When all three components are bolted together, the frame is structurally sound. When unbolted, the outer tube and bushing can slide over the inner support tube to increase the width or length of the frame.

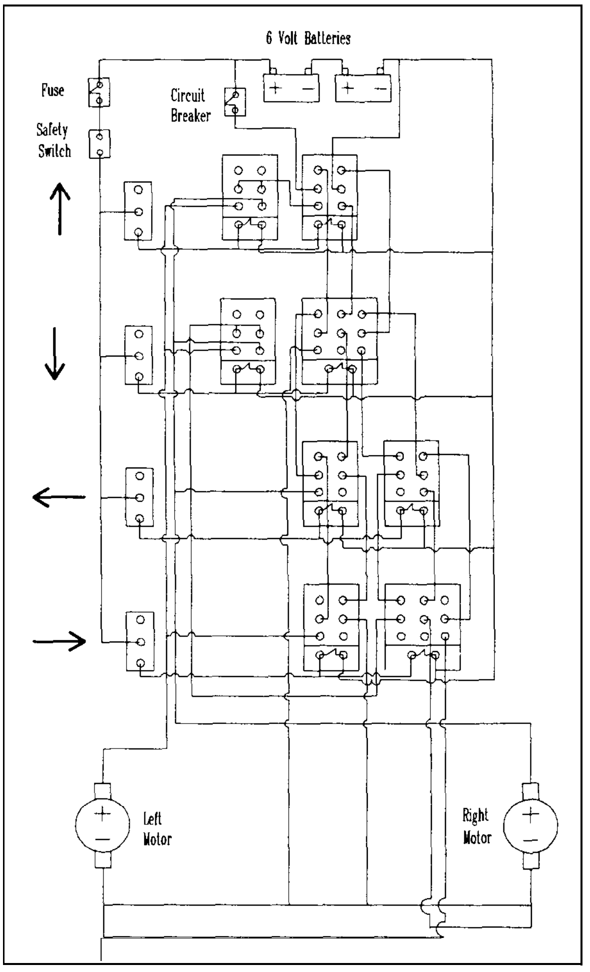

Fig. 20.3. Design of Adjustability Mechanism.

Medium-duty 5" diameter castors with non-marking rubber and threaded stem mounts were chosen over conventional wheelchair castors for low cost and ease of mounting. In order to avoid unnecessary bending of the aluminum frame, 10" diameter drive wheels are required with the 5" castors. The drive wheels selected were also made using non-marking rubber. With this frame configuration compared to a conventional wheelchair, the user is placed in a lower operating position. The device's frame is 5-5/8" from the ground level. This lowers the center of gravity of the vehicle providing increased stability in all seating positions.

Additional considerations in the design of the frame included positioning of various components to allow for overall device stability, maintenance access to the electrical control system and batteries, freedom of body movement for the client around the forward portion of the vehicle, access to frame adjustability locations, and mounting of the control switches and handles.

Since the device is a pre-wheelchair trainer, it may take a fair amount of time before the child develops advanced driving skills. Situations may arise when the child needs assistance in maneuvering out of constricted areas. A lifting mechanism consisting of two aluminum handles can be pinned to the rear of the frame. This provides for easy lifting of the rear of the device from a standing position. Dimensions for the handles were determined based on ergonomic factors. At the rear of the vehicle in reach of a supervising adult, there is a disabling switch which interrupts power to the user's directional switches. One 25 amp thermal circuit breaker protects the relay network and motors from excess current while a 3 amp fuse protects the directional switches.

Although this device was designed for a specific two year-old client, it can be used as a prototype for the development of similar devices. Due to the adjustability of the device, minimum changes would have to be made to accommodate most 2-5 year old disabled patients. A simple interface may be constructed to accommodate any existing or future seating system for the client. The device's components were selected to be either available for purchase in the New England area or made in a basic machine shop. In this way, similar devices can be built for a modest cost when compared to the purchase cost of a child's wheelchair. The batteries, gearboxes and motors for this project were donated by Power Wheels, Inc., with an estimated value of $150. All additional materials cost approximately $475.

Design of an Orthopedically Correct and Lightweight Wheelchair

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INTRODUCTION

This project consists of the design of a lightweight wheelchair with a rigid seat and back which incorporates orthopedic cushions, lightweight materials and a collapsible back for ease of transportation. The orthopedic cushions are most beneficial when used in conjunction with rigid support. Rigid seats and backs currently available are heavy and clumsy to use, and fail to strengthen the wheelchair. In this new design they are integrated into the frame and utilize composite materials for weight savings. This allows a lightweight wheelchair user to gain the benefits of using orthopedic cushions without adding the additional weight of current rigid supports. Specifications for the recipient of the final design were collected and the chair was optimized for weight reduction using stress analysis and modeling with a finite element analysis program, yielding a net weight loss of 4 pounds. The chair is shown in Figure 20.4.

SUMMARY OF IMPACT

The prototype of an orthopedically correct lightweight wheelchair was tested and found to be a very good wheelchair. What the chair offers is proper positioning and maximum performance from a wheelchair. Using the seating as an integral part of the frame allowed for a significantly lighter chair than is currently available. A wheelchair of this design also offers more efficient propulsion because less energy is being absorbed in the seating. Overall, the chair responded well under normal conditions. Future development of this chair could prove to have a great impact on the disabled community.

TECHNICAL DESCRIPTION

The project goals are to fulfill, in one product, three criteria which commercially available wheelchairs currently do not meet. First, there is the need for adequate support of the buttocks and lumbar regions of the back. Second, wheelchairs must be lightweight enough so that the individual has maximum mobility for sports and everyday activities. Third, the wheelchair must be easily transported in a common vehicle such as a car. This may require the wheelchair to be collapsible or compactable.

The addition of an ABS plastic rigid seat and back onto a lightweight wheelchair frame, which is a current practice, increases the weight by approximately 6 pounds. To alleviate this problem, a composite seat was integrated into the frame as a load carrying member. This reduced the size of some of the traditional load carrying members and saved weight in the frame as well as in the rigid seat.

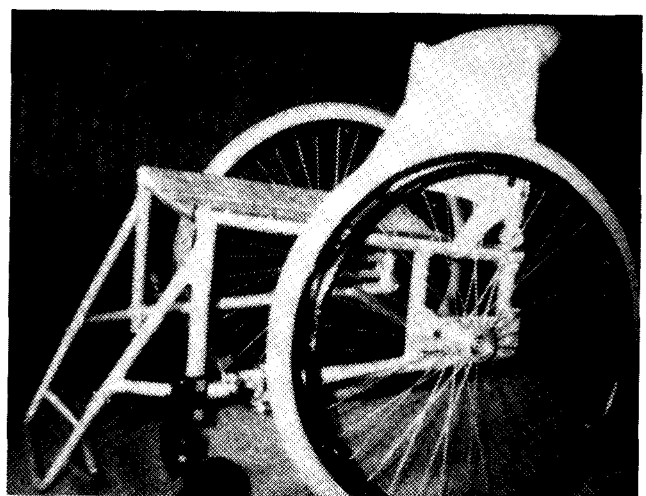

Fig. 20.4. Orthopedically Correct Lightweight Wheelchair.

Interviews with the client resulted in a list of specifications including:

- physical dimensions of individual
- performance restrictions
- transportation requirements
- typical use patterns

The performance restrictions place constraints on the location of the center of gravity (CG) of the person and chair in relation to the position of the rear wheels. Since the rear wheel positioning has such an influence, our design allows for 2 inches of rear wheel adjustability so that the most suitable position may be achieved.

To fulfill the transportation requirements, the design consists of a rigid frame with a forward tilting back and easily removable rear wheels. This allows for quick disassembly and vehicle transportation. For comfort, the back has angular adjustability of plus or minus 5 degrees from vertical.

Initially, the loadings the chair is subjected to during everyday and minor sports usage needed to be determined. Through conversation with wheelchair users, data about speeds attained and bumps encountered were collected. This information was used to coordinate an experiment that consisted of a wheelchair and passenger traveling on a platform and hitting a bump. Data were obtained including the vertical forces on the wheels at impact and the velocity of the chair before and after hitting the bump. A computer program was developed to calculate loading at other locations on the seat, back and footrests of the chair. These loads were used in the finite element model of the wheelchair design.

Several design possibilities for the chair were investigated including monocoque designs using composites, and traditional tube frames with a composite seat and back. The monocoque design was rejected due to the difficult manufacturing processes and our limited budget of $500. The tubing frame design considered the strength, cost, availability, and manufacturability of several types of tubing. An aluminum alloy tube, 6061-T6, was determined to have the best combination of properties. This tubing did not have the best strength-to-weight ratio, but was cheaper, readily available, and was easiest to work with. The composite materials needed in the design were also readily available.

Next, the restrictions imposed by the specifications were compiled and a preliminary frame was designed. At the same time, the designs of the seat and back were developed. Many design iterations were generated in an effort to add the most strength to the frame while keeping the weight as low as possible. These designs were modeled using a finite element analysis program to determine the stresses. The designs were altered accordingly to reduce the maximum stresses. This program also allowed us to determine optimum tubing sizes.

In the final design, a composite of Kevlar 49 and epoxy was used in the seat and back because of its superior strength-to-weight ratio. The back is contoured to provide the required lumbar support and accept the orthopedic cushion. It consists of 5 layers of 0.01” thick composite attached to two side tubes, which connect to the frame using "L" shaped brackets. It weighs 0.6 Ibs, compared to 1.75 lbs for the ABS back. The seat is constructed from a thin sheet of aluminum and layers of composite. The 0.032” thick aluminum is welded on all four sides to frame members. Three composite layers that approximate a sling shape comprise the top portion of the seat, while the aluminum and one layer of Kevlar-epoxy comprise the bottom. This seat has a weight of 1.8 lbs compared to 4.6 lbs for a commercially available ABS seat. The frame weighs 5.5 lbs compared to 5-6 lbs for a typical lightweight wheelchair.

A transportable, lightweight wheelchair with adequate support of the buttocks and lumbar regions of the back was designed. This was accomplished utilizing orthopedic cushions in conjunction with solid supports fabricated from composite materials and integrating the solid seat into the frame. The design provides the user with the physiological benefits of adequate support while remaining approximately the same weight as a wheelchair without rigid supports. The final cost of the wheelchair was approximately $290, not including casters and wheels.