

Power-Assisted Tricycle

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INTRODUCTION

The tricycle has been designed for Sam, a seven-year-old boy that has been diagnosed with Osteogenesis Imperfecta. Osteogenesis Imperfecta (OI) is a genetic disorder characterized by bones that are essentially too brittle. This condition leads to bone fractures occurring often with little or no apparent cause. Sam has Type III OI and exhibits symptoms of a short stature (he is the size of a three-year old), bones that fracture easily, loose joints, poor muscle development, and bone deformity. Sam can sit in an upright position, but his legs must be supported underneath and positioned in front of him. The development of this tricycle for Sam has been an engineering design challenge due to the customization for his small size, restricted range of motion, and physical limitations.

There are commercially available handicap tricycles on the market. However they are mainly designed for people with simple balance problems to more involved cases of cerebral palsy, spina bifida, Downs syndrome, muscular dystrophy, and autism. There are no known commercially available customized tricycles available for persons with OI. Even if a commercial design were available, it is highly likely that it would be too large for Sam and not provide adequate support.

SUMMARY OF IMPACT

The most significant impact of this project is directly on Sam. The opportunity to overcome physical limitations will provide an increased sense of confidence in his abilities as an individual. The developmental therapists that work with Sam anticipate that use of the tricycle will promote his bone growth, muscle mass, strength, coordination, and range of motion. It is hoped that the opportunity for continual physical growth through use of the tricycle will ultimately result in the necessary strength development that will allow Sam to stand upright and perhaps take his first steps ever.

The broader societal impact of this project can be seen throughout the entire development of the specialized tricycle for Sam. Seeing Sam achieve is a proud accomplishment for both the University of Wyoming and the Laramie community as a whole. Creating the opportunity for Sam to further his physical development is a rewarding experience for everyone involved. The benefits of this project were graciously made possible through financial support granted by the National Science Foundation.

TECHNICAL DESCRIPTION

The frame of the tricycle is made from 1" AISI 1020 steel tubing. Steel tubing provides the necessary strength properties for the tricycle. The frame alone is nearly 38 inches long, 13 inches tall, and 24 inches wide. These dimensions allow the seat to be at least 18 inches off the ground, as well as, enabling the tricycle to fit through standard handicapped doors. With these dimensions, the tricycle is also very stable with an overall center of mass just below Sam's posterior. This is vital in preventing tipping.

The steering motion will be the same as in conventional bikes; however, the fork of the front wheel will not be directly under the handlebars as in conventional bikes. The fork will be located approximately 20 inches in front of Sam's reach. Due to Sam's limited range of motion, the handlebars were replaced with a ten-inch steering wheel. The steering wheel is connected to a steering column that attaches to the fork via two U-joints. The U-joints are required to be at a combined angle of 57° so Sam will be able to steer the tricycle. This angle was found by using measurements of Sam, the location of the fork, the size of the u-joints, and simple trigonometry. The turning radius of the tricycle is designed to be approximately 4.0 feet. A limit in the steering capability was incorporated for safety reasons.

A commercially available Tumble Forms® seat has been incorporated into the design. The seat has a built in three-point restraining device. A seat frame has been designed to attach the seat to the tricycle frame through standard clamps. The seat frame has been designed so that the restraining belts will also help stabilize the seat. The seat frame was made from 0.09 inch aluminum sheet.

Linear-type pedal motion has been accomplished through use of a right angle bevel gear system. Two pedal cranks have been designed from ½ inch steel rod to attach the pedals to the gears. The height of the crank arm is seven inches. A small shock absorber was mounted to one of the crank arms to add resistance to the pedal stroke. The shock absorber mounting is adjustable along the crank arm to allow for increasing resistance as needed. The pedaling system has variable stroke that is independent of the pedaling speed and will never force Sam's legs. Foot restraints have been positioned on the pedals to prevent Sam from rotating his legs laterally during load cycles.

The pedal stroke has been coupled to a linear velocity transducer (LVT). When Sam pedals the tricycle, the LVT triggers the power supply to the motor. The signal from the LVT requires conditioning before entering the microprocessor. This is accomplished through a precision full-wave rectifier with gain. Then the signal is sent through a low-pass filter, which will provide the microprocessor with a smooth signal ranging between 0 and 5 volts. This signal transmits the rate at which Sam is pedaling to the HC12 microprocessor.

The output of the microprocessor is sent through additional signal conditioning. An H-Bridge circuit controls the current necessary to drive the motor. In the past, senior design groups have spent the whole semester working on an H-bridge and rarely getting it to work. Due to the complexity of the design an H-Bridge rated at 12 volts, and 35 continuous Amps was purchased.

Electrical feedback of the tricycle speed ensures that the motor is running at a speed proportional to the work being done by Sam. A Hall Effect sensor located on the fork of the tricycle provides this feedback. Hall Effect sensors vary in their ratings as well as the type of feedback signal they produce. A Hall Effect sensor that is capable of producing a signal directly to the microprocessor with no conditioning is being used.

The drive train component took a very long time to design and evaluate. The main system of the drive train rests on the differential in the rear axle. Since the tricycle is rear-driven, the differential allows for rotation of the rear tires at different angular velocities when cornering. The differential is driven by a 152 in-lb, 0.25 horsepower gear motor through a 1.13:1 ratio chain drive. The motor is powered by a 12 VDC lead acid battery. A standard wall outlet battery charger is also incorporated into the electrical design.

To translate the angular velocity of the axle to the wheels, a friction slip clutches were employed. Friction washers were placed on either side of the hub, along with a spring washer and 2 notched washers to make the wheel rotate when the axle rotates. Since the diameter of the axle is 1", the wheel hubs had to be modified. An Acetal sleeve bearing was incorporated so that the wheels could spin freely on the axle when the friction drive was not engaged. To engage the friction drive a quick-release cam nut, similar to that on a standard bicycle tire, was used. Disengaging the wheels was important so that the tricycle could be moved when not in use.

When Sam discontinues his effort to pedal the tricycle, the motor ramps down for a smooth stop. From the stop position, the tricycle can be put into reverse gear. In the unlikely event that the motor should suddenly stop during operation, the slip clutch on each rear axle will prevent rear wheel lockup.



Figure 1. Specialized Tricycle