Development of a Novel FES Tricycle for Children

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It is a challenging task for children with a spinal cord injury(SCI) to make exercises or participate recreational activities. This increases their risk of developing cardiovascular diseases and can affect child's natural development. Lower-limb cycling by means of functional electrical stimulation (FES) of the paralyzed muscle groups have been used to improve the cardiorespiratory health of SCI individuals. The primary aim of this study was to develop pediatric FES-cycling equipment with motor assist.

Introduction

Better cardiovascular fitness and bone strength are the main benefits of adequate physical activity in childhood. Children with a spinal cord injury (SCI), cerebral palsy (CP), or other neurological deficits are faced not only with psychological challenges, but also physical limitations which prevent them performing adequate exercise required for their natural growth and development. Reported data suggest that cycling with functional electrical stimulation (FES) has positive health benefits not only for adults but also for children with neurological impairment.

The main idea of FES cycling is to stimulate paralysed muscles using an external stimulator. Stimulation is coordinated with pedal position to achieve continuous cycling movement. Stimulation intensity can be controlled automatically or manually, and this directly affects pedal torque and cadence. The muscle groups normally stimulated are the quadriceps, hamstrings and gluteal muscles.The main goal of this master thesis was to develop a novel FES tricycle for children with lower-limb paralysis.

Methods

A child's sports trike (KMX Cyclone) was modified for FES. Due to the weak muscles of Children with SCI or CP, higher torques are needed to move the entire tricycle The pedal movement is assisted by a DC motors, but the inertia of the trike still has to be overcome. In order to solve this problem, main idea was to have two independent drives: one for the pedals and legs, coordinated with stimulation, and the other for moving the entire trike. A DC motor (Maxon EC90 brushless 90 Watt motor) with a 21:1 gearhead was implemented at the pedals. A toothed synchronous belt drive system was designed to transmit power from the motor to the pedals using a belt of 15 mm width and 5 mm pitch. In order to retain the original shaft, additional mechanical parts were used to fix the drive system to the trike.

A 350 W hub motor (Crystallite) with 40 Nm torque and 23 km/h maximum speed with a 20" rim was mounted in the rear wheel to move the entire trike. A thumb regulator is used to throttle the motor and with the help of the controller the motor speed can be adjusted. Control software was developed to connect the rear and front drive systems. This was implemented in Matlab/Simulink. The Real-Time Windows Target was used for analogue inputs and outputs.

Results

The angular speed, maximum torque and power were experimentally calibrated. The FES stimulator was tested and its connection to the throttle and front motor verified in recreational cycling tests. The response time and time delay between front and rear drive was checked. The trike's mobile performance was tested by throttle and torque feedback control trials.

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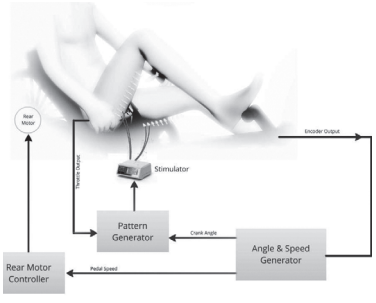
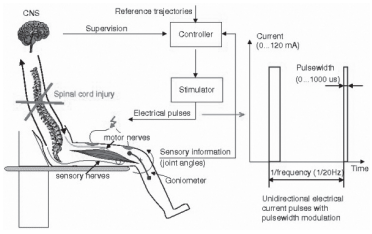
Modified Tricycle with trailer



Control Strategy



Stimulation