Optimization of Stimulation Patterns for FES cycling

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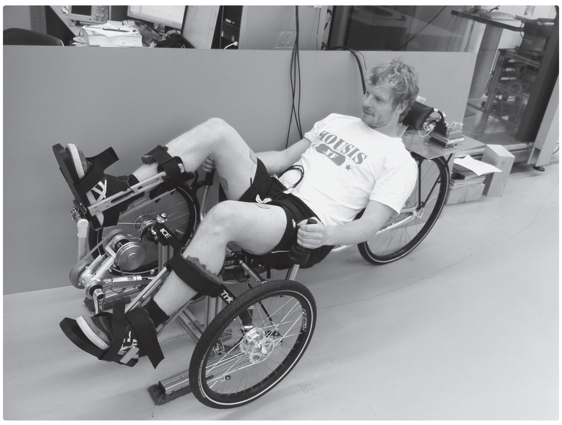
Functional electrical cycling is an alternative way of cycling for paraplegics. FES works by creating an electrical field through muscle tissue, depolarizing nerve cells which then contract muscles and cause motion. Muscles stimulated by FES generate little power and fatigue fast. Goals of the thesis were to improve an existing FES tricycle test bed to measure power output generated by riders and to conduct a validation study to investigate different stimulation patterns. 1

Materials and Methods

The base of the test bed was an Adventure tricycle by ICE. It was equipped with a Maxon motor and motor controller to turn the pedals, to simulate cycling movement in passive riders and a brake chopper to turn excessive energy, generated by stimulated riders, to heat. The chain drive of the bike was replaced by a belt drive by Mädler to reduce play and friction. The belt drive was connected to the motor. An analogue X-Cell RT torque and position sensor by Thun AG was used to measure power output. FES stimulation was applied through a RehaStim stimulator by Hasomed. Communication with the sensors and actuators as well as design of the user interface was done using Matlab and Simulink.

Stimulation algorithms were written in Simulink to either stimulate with a constant frequency of 35 Hertz or with a stochastic time delay between stimulation pulses from seconds. Test cases for short-term (4 * 2.5 min per stimulation pattern) and long-term (40 min, one stimulation pattern) stimulation were implemented to find differences in stimulation algorithms regarding power output.



FES tricycle test bed in use

Results

The existing test bed was improved. The torque of the left leg was measured with a resolution of 10 mV/Nm in a 5 Volt range with zero Nm at 2.5 Volts. The power output can be extrapolated to total power output by assuming symmetry of both legs. Pedal position tracking was done with a precision of 3°; and a pedal play of 1.5°, allowing high stimulation timing precision. Further a GUI was implemented in Matlab to communicate with the sensors and effectors on the test bed and to control electrical stimulation as well as display the current measurement parameters of the system.

Differences in power output by different stimulation patterns were investigated in a technical validation study conducted on the 4 members of the FES cycling project team. A mean power output increase per leg of 0.88 watt for constantly pulsed stimulation and 0.64 watt for stochastic pulsed stimulation compared to unstimulated power output was found in short-term measurements.

Discussion

The goal of setting up a cycling test bed to apply FES stimulation to a person and measure generated power output was reached. A novel stimulation pattern was implemented and applied successfully.

The technical validation study showed that the test cases could be run and that the test bed works aside from issues with computational power of the PC used causing timing errors in stimulation pulses. Furthermore electrode placement must be revised to gain better results in terms of power output. Power output was additionally limited by pain experienced by riders caused by the stimulation. This limitation is not applicable to people with spinal cord injury which are the end users of the test bed. Overall the test bed implemented is a good basis for further research as it is simple in handling, measures power with high precision and can easily be adapted to new tasks thanks to its modular design.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