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Model Based Automated Cycling Ergometer

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Abstract

Laboratory testing of cyclists is currently undertaken using turbo trainers or cycle ergometers. The benefits of laboratory testing are the ability to measure performance: (i) more accurately and repeatedly and (ii) under controlled conditions enabling, for example, video analysis to determine joint-specific power production or enable novel instrumentation to be applied to the bicycle, for example, to measure seat interface pressure. Influence of the bicycle fit on torque production have been presented by Irriberri et al(2008) and Peveler et al(2007). Market leading bicycle ergometer manufacturers, such as Lode and Monark, provide feedback on performance metrics including cadence and force measurement. However, neither ergometer provides real time adaptation of bicycle fit to the resolution (i.e. < mm precision) required by elite athletes or allows adjustments to position whilst cycling under simulated road / track conditions. The objective of the research presented in this paper is to demonstrate and provide initial validation results for a novel, fully automated cycle ergometer that incorporates faster, repeatable and more accurate adjustments to bicycle geometry. The ergometer also allows the cyclist to use their preferred handlebars and saddle to accommodate the different cycling disciplines, e.g. track, road, mountain and BMX. The ergometer enables fitting adjustments to be controlled whilst cycling and aims to reduce initial set-up times for different athletes to about 30 seconds as opposed to 30 minutes (required by the end-users current ergometer instantiations). Instrumented cranks have been fitted to monitor the torque and force generated by the crank movements in 2-axes through 360 degrees of crank motion. The ergometer can be coupled (via a user selectable clutch mechanism) to an AC servo motor within the drive chain which supports the application of models of bicycle performance to the ergometer to enable torque versus position versus speed profiles as derived from road and / or track trials to be readily mapped into the laboratory environment

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1. Introduction

Turbo trainers, rollers, treadmills or cycle ergometers are commonly used training devices to conduct performance based testing of elite cyclists and enable users (coaches, sport scientists or the cyclists) to take measurements of performance, both mechanical and physiological, more accurately, repeatedly, under safe and controlled environments. Performance features measured in a laboratory include adding strain gauges to the handlebars to measure the force exerted by the arms reported by Champoux et al(2004) or measurement of force at the saddle using pressure pads detailed by Potter et al(2008). Turbo trainers, rollers and treadmills require the cyclist to use their own bike to perform tests, whereas a cycle ergometer has to be *fitted* to each individual. Additionally a cycle ergometer also allows changes in bicycle fit to be examined and also permits the integration of instrumentation to measure performance which may be awkward for a normal bicycle due to lack of access or additional wiring. The effects of bicycle geometry fittings on parameters such as force production, torque production and power production have already been reported by Rankin et al(2010), Iriberri et al(2008) and Vrints et al(2011) respectively. However, bicycle geometry fitting is a slow process that can take up anywhere from 30 minutes to several hours, depending on technical skills and precision required, and generally cannot be adjusted whilst cycling.

2. User Goals and Test Scenarios

Consultations with end-users identified the need to have a fully automated bicycle ergometer which permits faster, reliable and more accurate fitting adjustments as opposed to 30 minutes as required by current manual fitting techniques. Additional requirements were identified to quantify cycling performance features like torque and force produced at the cranks whilst cycling, the angular velocity at the cranks and the angular position of the cranks. The key requirements (as seen in Table 1) represent the accuracy in the actual positions (mm level), promptness of the automated movements, ability to use personalised handlebars / saddle / pedals and the ability to make small adjustments (mm level) in the fitting while the ergometer is in use, the ability to display meaningful performance metrics (e.g. left/right leg torque, cadence) and the ability to include controllable resistance mechanisms.

Based on the user requirements, a novel cycle ergometer has been designed, allowing automated set-up in seconds via motor controlled actuators. The addition of a motor driven linkage at the cranks has been designed to create a unique system for producing controllable resistance profiles while cycling. A crank sensor has been integrated to monitor performance features such as torque (τ) and force at each crank, the angular velocity (ω) through 360° of crank motion. A torque transducer has also been included to measure the torque generated at the crank axis and is used to validate the torque measured by the crank sensor. Further provisions have been made to support the generation of torque profiles based on models generated from road bicycle trials. This system allows the end-users(cyclist and the researcher) the (1) ability to include performance based cycling power model to replicate the road based trial either by programming the motor driven linkage with actual power/torque values or calculating the different components of the total resistive force the cyclist needs to overcome whilst cycling on the road from the weather and terrain information and (2) the ability to view performance metrics such as power, torque, force and cadence produced at the cranks through 360 degrees of crank motion.

Table 1. Requirements for the ergometer.

Requirement	Explanation	Test Cases
Automated fitting adjustments	The ability to have automated movements on the various axes (i.e. Saddle horizontal SH, saddle vertical SV, handlebar horizontal HH and handlebar vertical HV) of the ergometer	Three set of measurements taken to test the variability of the positional adjustments
System accuracy	Defines how accurate the actual positions are in comparison to the target positions	Three set of measurements taken to test the variability of the positional adjustments
Motion speed	Defines how promptly the target positions are achieved	Three set of measurements taken to test the variability of