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Smart Trainer Homologation for Virtual Cycling

• Sports Integrity • Cycling • Smart-Trainer

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While adoption has been increasing since its inception in the mid 2010's, the popularity of smart trainers and virtual cycling has substantially increased since the onset of the COVID-19 pandemic. This proliferation has seen the introduction of virtual racing championships, but no standards exist to ensure the equipment is accurately reporting rider output to the virtual platform, potentially creating a non-level playing field. This project developed a physical testing apparatus and data analysis method to identify the accuracy of the trainer's measured rider output, examining the trainer's response time to accelerations and decelerations as well as steady state accuracy.

The apparatus combines measurements from accurate torque and rotational speed sensors corrected with an efficiency factor to account for transmission loss to accurately measure power input to the trainer and assesses a series of simulated road conditions and rider outputs. These measurements are then compared to power measurements collected from the trainer's sensors via ANT+ protocol to evaluate the accuracy of the trainer.

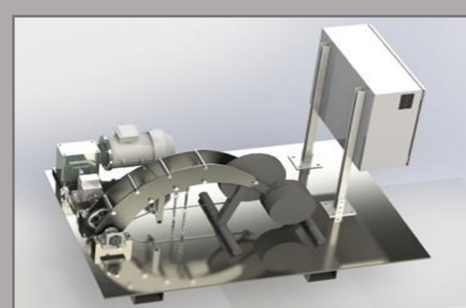

Fig. 1 Homologation Apparatus with Trainer

PROJECT OVERVIEW

Work on this project began shortly after COVID-19 ground the world to a halt. The team (originally comprising of Justin, Teal, and Diana) accepted the opportunity and had to begin work remotely on proposed hardware design and operating methods. Once students were allowed to return to campus, work could begin on the construction of the physical apparatus and development of testing algorithms. The device, operating and analysis software have since undergone continuous improvement focusing on increasing the repeatability of test results and verifying the accuracy of the apparatus' sensors. The goal of the project is to construct and operate the system that certifies trainers against a standard of fairness and accuracy for use in competitive virtual cycling events. Currently, the team has created a robust drive and measuring apparatus, a precision-controlled torque brake for characterizing drivetrain loss, developed an operating interface for automatic and manual trainer testing and developed an analysis program for interpreting and presenting millions of datapoints per test. This semester, in conjunction with the UCI, the team met with representatives from major smart-trainer manufacturers to introduce the idea of homologation and certification. Moving forward, the team will work closer with the industry to ensure proper criteria are tested.

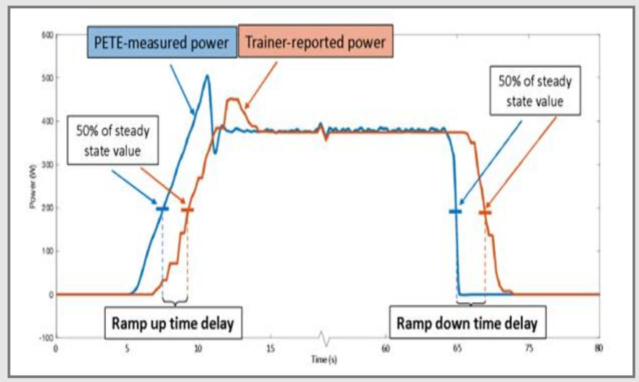

Fig. 2 Example power profile of a test interval showing trainer response to increased speed, overshoot, and eventual steady state

PROJECT METHOD AND RESULTS

This section will describe the key features of the hardware and software of the testing apparatus and analysis program. A 3.7kW drive motor connects to the main drive side of the rig and acts in place of a rider to supply power to the trainer. A rotational speed encoder and torque sensor on this driveshaft measure the power delivered to the system using a simple torque and rotational speed multiplication. Power is then transferred to the trainer through a standard bicycle drivetrain consisting of a drive sprocket, bicycle chain, cassette, and derailleur to allow testing in multiple gear ratios to achieve the desired trainer speed. This transfer of power necessitates consideration of drivetrain losses, which was achieved using an electronic brake and second torque sensor to measure the difference between

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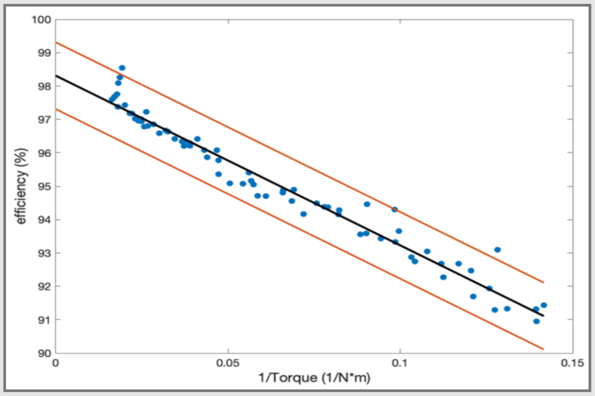

Fig. 3 Power transmission efficiency results at 1:1 gear ratio

PROJECT METHODS AND RESULTS CONT.

torque supplied by the motor and received at the trainer. This efficiency factor was found to be a linear function of torque with parallel offsets at different gear ratios. Higher torques had higher efficiencies while higher gear ratios had lower efficiencies. Once these losses were characterized the exact amount of power being delivered to the trainer could be measured and compared with the trainer's measured power. The apparatus is controlled with a python-based GUI that allows direct user control or automatic testing based on preloaded "recipes". A recipe is the testing method used in the project that prescribes a target power based on variable factors such as road gradient and rider speed, as well as constant factors such as road surface type, rider weight, and rider aerodynamics. A complete recipe tests the trainer's measured output from -8 to 15% road gradient, and 200 to 800W.

Data analysis consists of identifying the three target metrics within a single test number. Test data was separated by recipe lines (test numbers) and within each section, the steady state plateau was identified by finding

Fig. 4 Example of Test Apparatus user interface.

PROJECT METHODS AND RESULTS CONT.

the range of data falling within a certain standard deviation. The average value of this plateau is used to identify ramp up/down times as the time delay between when the testing apparatus measures 50% of the tests average value and when the trainer reports the same value. This average value is also used to determine the steady state accuracy of the trainer comparing the power measured by the apparatus, the power reported by the trainer, and the target wattage from the ANT+ formula relating rider speed, gradient, and other factors.

Initial testing has shown promising results demonstrating the consistency and repeatability of the system's measurements. Trainer performance has demonstrated low accuracy at low speed, high torque scenarios and better accuracy at high-speed, low torque scenarios. Trainers have also shown a tendency to overheat during testing which has a significant effect on accuracy and has required the need for additional cooling measures during testing

CONCLUSIONS AND FUTURE WORK

- Smart trainers for virtual cycling have demonstrated inconsistent accuracy, potentially leading to an unfair competition environment
- A homologation procedure is being developed to measure steady state accuracy, resistance command accuracy, and trainer reporting delays
- Initial testing of the procedure, associated system and analysis methods are promising
- Further work to improve the reliability and precision of the system is necessary

RELATED PUBLICATIONS

Heflin, D., Miller, J., Dowd, T., Rodgers, M., & Mansson, J.A. (2022). Homologation and certification approach for smart bike trainers. *Proceedings of 14th ISEA Engineering of Sport Conference 2022.* https://doi.org/ 10.5703/1288284317531

Dowd, T., Miller, J., Heflin, D., Sweldens, W., Krasilnikau, A. & Mansson, J.A. (2022). Smart trainer homologation system. P*roceedings of 14th ISEA Engineering of Sport Conference 2022.* https://doi.org/ 10.5703/1288284317531

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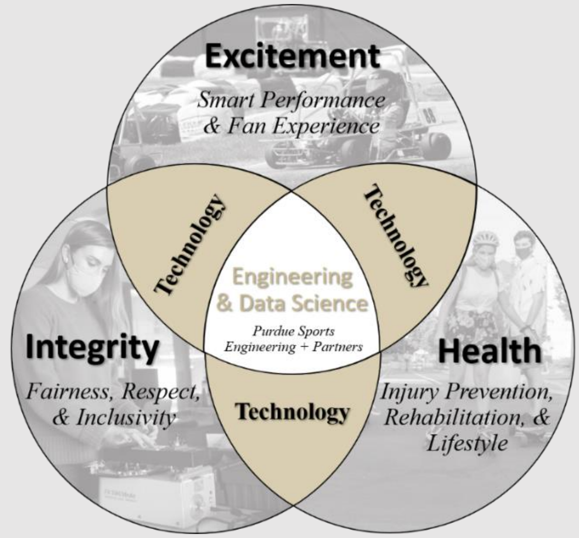
ABOUT RESEC

The Ray Ewry Sports Engineering Center (RESEC) was launched as a joint collaboration between Purdue College of Engineering and Purdue Intercollegiate Athletics, highlighting Purdue's reputation as the Cradle of Quarterbacks and Astronauts.

Sports have the power to unite, to teach, to challenge, and to initiate change, and those are our goals for RESEC. We are driven by our passion for sport and a deep understanding of the influence it has in shaping society. As technology continues to advance, there is enormous room for opportunity to rethink how athletes train, coaches coach, fans engage, and event organizers plan events. We collaborate closely with partners in athletics, industry, academia, and more to create the solutions that will help bring sports into the future, specifically in the three key research areas highlighted below.

- Smart Performance & Fan Experience
- Injury Reduction & Rehabilitation
- Sports Integrity, Fairness, & Societal Integration



WHAT IS SPORTS ENGINEERING?

Sports engineering is a global, fast-paced, and multidisciplinary industry that brings people from different backgrounds, cultures, and experiences together. It is an industry that is heavily influenced by advances in other sectors as well as societal pressures and shifts, making working as a sports engineer very exciting. However, it also means being keenly aware of how these innovations and discoveries can be integrated and applied, especially as digitalization expands and what people – the athletes, fans, coaches, governing bodies – expect from sport evolves.

Engineering and data science are at the center of excitement, health and safety, and the integrity of sport, and by bringing a data-driven, human-centered approach to this industry, we can address the growing need and desire to increase participation and engagement of athletes and fans.

WHO IS RAY EWRY?

A Boilermaker track and field athlete, Ewry (1873-1937) won eight gold medals in three Olympic Games from 1900 to 1908. But his story is relatively unknown: at the age of five he became an orphan, and at seven he contracted polio and was confined to a wheelchair. Doctors had little hope he would be able to walk. Later nicknamed "The Human Frog," Ewry won gold in the standing long and high jumps and standing triple jump. By the end of the 1908 Games, Ewry had set a medal count record that lasted more than 100 years.

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