Homologation and Certification Methodology for Smart Bike Trainers

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Motivation

Smart trainers and virtual cycling have expanded the world of professional cycling, with virtual racing platforms bringing the excitement of cycling into athletes' homes [1]. As professional races such as the UCI World Championships moved indoors due to the COVID-19 pandemic, questions of fairness and equipment accuracy arose [2], forcing race organizers to choose between permitting athletes to use their own smart trainers or bearing the cost and logistical difficulty of sending identical trainers to each rider.

With these challenges in mind, a set of homologation parameters was developed to capture the most important factors that can affect both rider experience and virtual race performance. Further, a rigorous test procedure was developed to capture the full range of conditions that a rider may experience during a virtual ride. The resulting parameters establish a framework for the performance of a smart trainer, allowing for a level playing field in virtual cycling across multiple trainer makes and models.

Homologation Procedure

The six homologation parameters in our patent-pending process[3] are outlined below:

- Steady state accuracy: compares known power input to power measured by trainer
- Ramp up time delay: quantifies time delay between a rider's increase in speed and the trainer's response
- Ramp down time delay: quantifies time delay between a rider's decrease in speed and the trainer's response
- Resistance command accuracy: measures trainer's ability to accurately supply the requested torque
- Inertial resistance accuracy: quantifies how accurately the trainer simulates rider inertia with changing rider speed
- Coasting resistance accuracy: quantifies how accurately the trainer simulates rider inertia during coasting

These parameters are quantified by collecting trainer data at a range of rider powers from 100-800W across simulated road gradients from -8% to 15%.

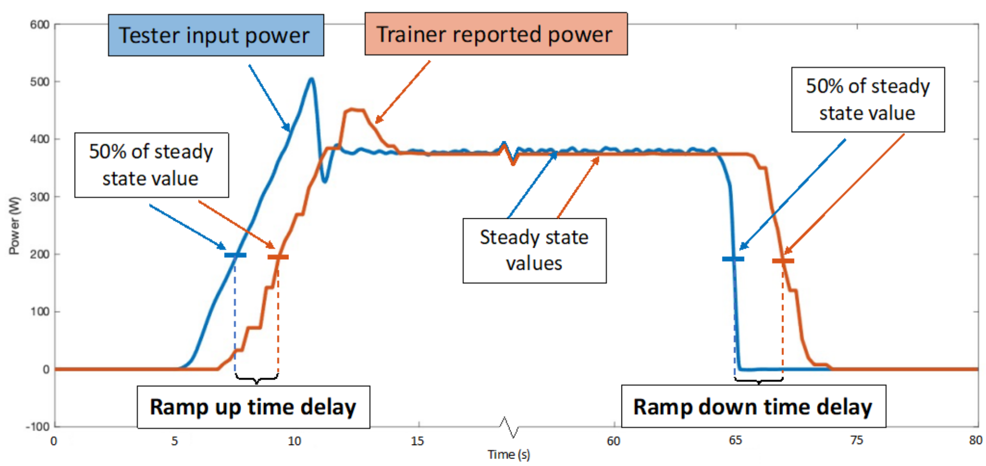

Figure 1. Graphical depiction of steady state accuracy, ramp up time delay, and ramp down time delay.

For a trainer model to be homologated, testing must be conducted on multiple smart trainer units of the same model number and firmware version. Each of the units will be analyzed individually and given a score for each of the six homologation criteria outlined above, as well as an overall score describing trainer performance. The trainer model receives a score corresponding to the lowest overall score of a trainer unit.

Results

Figure 2 compares the steady state accuracy of two different trainer models, referred to here as "Trainer

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X" and "Trainer Y." Both trainers were tested at a total of 99 different road gradient and power combinations, and a limited number of representative results are presented here for clarity. A negative value indicates that the trainer is overestimating rider input, while a positive value indicates that the trainer is underestimating rider input.

Trainer X consistently falls within the proposed range for "A" certification of steady state accuracy. Trainer Y, on the other hand, appears to struggle to accurately capture rider performance in high torque situations, such as a 15% simulated road gradient. The inaccuracy of Trainer Y at low power across all gradients is related in part to the relatively small magnitude of the power at these points—the magnitude of the difference between the input and reported power is consistent across all power levels.

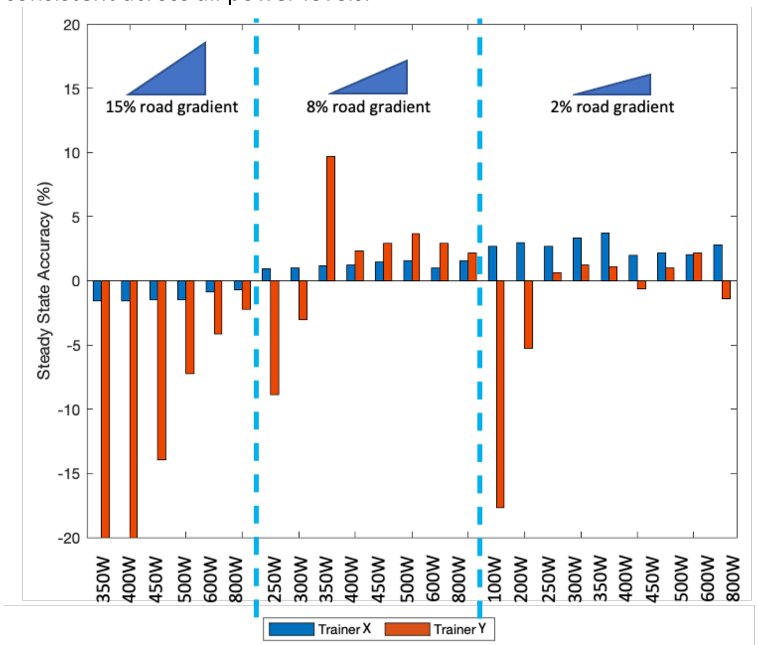

Figure 2. Steady state accuracy performance of two different smart trainer models under selected test conditions—15%, 8%, and 2% simulated trainer road gradients.

The cumulative results for Trainer X and Trainer Y are summarized in Table 1. Both trainers perform similarly in the time delay and command accuracy categories, with the major difference coming in steady state accuracy, illustrated in Figure 2. Steady state accuracy is given highest priority in the overall trainer score because this will be the factor that has the greatest impact on the outcome of a virtual race.

Table 1. Homologation Accuracy Levels for Trainers X and Y.

	Trainer X	Trainer Y
Steady State Accuracy	High	Low
Ramp Up Time Delay	High	High
Ramp Down Time Delay	High	High
Resistance Command Accuracy	Medium	Medium
Overall Accuracy	**High**	**Low**

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References

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