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Test Protocol for In-Situ Bicycle Wheel Dynamic Comfort Comparison

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Abstract

Bicycle comfort is very important especially for enthusiastic road cyclists who can spend several hours astride their bicycle in a single ride. Being an abstract concept, several researchers proposed to assess bicycle comfort by measuring the level of vibration transmitted to the cyclist. This can be measured in a controlled laboratory environment but it requires cumbersome and expensive road excitation simulation setup. *In-situ* measurements are an alternative solution but the experiment repeatability is not as good as in the laboratory because many experimental factors are difficult to control while riding a bicycle on the road (e.g. cyclist's posture on the bicycle). This paper presents a test protocol to evaluate bicycle comfort with minimal uncertainty inherent of the *in-situ* experiment. Three main elements are used to enhance measurement repeatability and therefore increase the differentiating capability of the protocol: the measurand selection, the bicycle propulsion and the design of experiments. The power absorbed by the cyclist is used to quantify the level of vibration transmitted to the cyclist because it is far less sensitive to variation of cyclists' posture than to the other measurands used to assess comfort such as acceleration. The bicycle is propelled from an external source which increases precision of the bicycle speed control during the experiment and eliminates measurement noise coming from the bicycle drivetrain. The experiment is specifically designed in term of test runs' duration and replication to improve its repeatability. The protocol is presented in this paper as a case study of bicycle wheel comfort comparison and can be extended to any components or a complete bicycle comfort comparison. The same case study has been performed with different test methods in the laboratory which are used to assess and validate the accuracy of the presented *in-situ* protocol.

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Keywords: Bicycle Dynamic Comfort; Bicycle Testing; Vibration Measurement; Comfort Measurement;

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1. Introduction

In recent decades, significant developments have been made on the weight, stiffness and aerodynamics of road bicycles to improve their performance. In order to further improve road bicycles another characteristic has become increasingly important for cyclists: comfort. Once properly fitted to the cyclist, a more comfortable bicycle is one that transmits less road-induced vibration to the cyclist.

To improve bicycle comfort, it is imperative to adequately measure physical quantities closely related to the perceived vibration transmitted to the cyclist. Indoor (in-laboratory) and outdoor (*in-situ*) measurements are commonly used for this purpose. In-laboratory measurements can be undertaken using a cyclist riding a bicycle on a treadmill [1-3] or using actuators to control the vertical displacement under the wheels. Actuators can excite the bicycle (with a dummy cyclist [4, 5]) using swept-sinusoidal displacement, or to provide a more realistic road excitation, they can replicate actual road profiles [6, 7].

Evaluating the comfort of a road bicycle in the laboratory has many advantages (e.g. better measurement repeatability), but the setup required to replicate the road excitation is complicated and expensive. In contrast, taking measurements outdoors is less expensive, as the bicycle is excited by simply riding along the road. A portable data acquisition system is also required for these measurements and is easily available nowadays. *In-situ* measurements also have the advantage of ensuring that a realistic

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excitation is applied to the bicycle. Several research studies on rider comfort using *in-situ* measurements have been reported [8-12]. The principal drawback of *in-situ* measurements is the lack of repeatability. Various factors that are difficult to control during measurements on the road and can explain this lack of repeatability. For instance: the variation of the cyclist's position has an effect on the dynamic behavior of the bicycle/cyclist system, while the variation in the bicycle speed also plays an important role on the excitation applied to the bicycle. Therefore, assessing cyclist comfort on the road (*in-situ*) is far from trivial and requires careful consideration.

Comfort is a subjective concept; however it could be evaluated using different measurands of the vibration transmitted to the cyclist. The most common for both in-laboratory and *in-situ* measurements is the acceleration transmitted to the cyclist [3-6, 8-12]. This measurand, for the most part, follows the recommendations outlined under ISO standards 2631[13] and 5349[14] on the evaluation and the measurement of vibration transmitted to humans. The force transmitted to the cyclist is also used by some researchers as a comfort measurand [1,2,6]. A third measurand has also been used to assess comfort: the power absorbed by the cyclist [7, 8-9]. According to Pelland et al. [15], this measurand is less sensitive to variation in the cyclist's position and may be well-suited to *in-situ* measurements.

The aim of this paper is to propose a test protocol that can properly evaluate the comfort of bicycles using *in-situ* measurements. The level of power absorbed by the cyclist is used to quantify comfort and no sensory perception qualification and assessment was performed. The protocol is presented in this paper as a case study of bicycle wheel comfort comparison and can be extended to any components or a complete bicycles comfort comparison. The success of this protocol revolves on the measurand selection, the bicycle speed control technique and the design of experiments which consists of comparing the comfort of the same bicycle equipped with two different sets of wheels in several short randomized measurement runs. The same case study has been performed with different test methods in-laboratory which are used to assess and validate the accuracy of the presented *in-situ* protocol.

2. Methodology

While riding a bicycle, cyclists can change their position in different ways. They can put their hands in different locations on the handlebar and can also change their position to apply more or less downward static force on the handlebar. The effects of the cyclist's posture on the vibration transmitted to his hands and buttocks during in-laboratory testing were described by Lépine et al. [6]. In this in-laboratory study, the cyclist's hands remained at all times on instrumented brake hoods and the level of static force applied on the handlebar was monitored and kept as constant as possible. It is, however, more difficult for the cyclist to maintain a constant static force in *in-situ* measurement conditions. This is because the cyclist has to operate the bicycle, and therefore, cannot precisely control the force applied on the handlebar. At the opposite, the bicycle does not move in the laboratory, so the cyclist does not need to operate the bicycle and can more precisely control the static force using an instantaneous force display feedback. On the road, the cyclist has to operate the bicycle and, for safety, it was decided during the test that the cyclist should not be disturbed by an instantaneous force feedback display as used in the lab. Therefore, the cyclist was instructed, as best as possible, to keep the position of his hands constant without any on-site feedback.

To minimize the effect of position variation during the test runs, the power absorbed by the cyclist (absorbed power) was used to assess bicycle comfort. Compared to the acceleration and force measurement, the absorbed power is less sensitive to variation in the cyclist's posture [15]. The absorbed power is measured at the cyclist's hands and buttocks using instrumented brake hoods (Fig. 1) and seat post (Fig. 2) designed for dynamic measurements [16]. The brake hoods were also used to measure the static forces applied by the cyclist in order to evaluate the leaning force on the hood related to the cyclist's position on the bicycle.

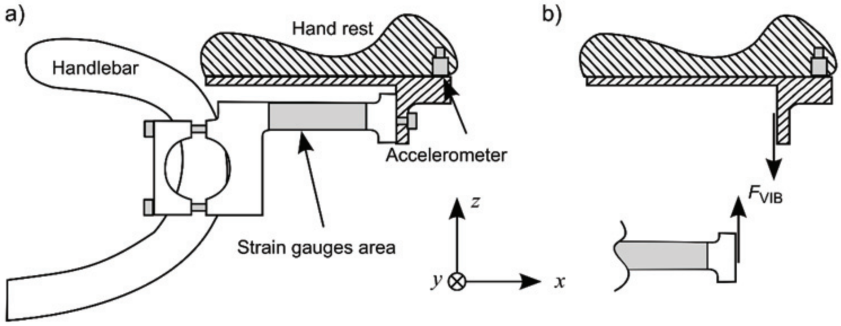

Fig. 1. Instrumented brake hood: (a) transducer position; (b) force measurement point