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Measurement and analysis system for bicycle field test studies

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Abstract

The work presented describes the development of a measurement and analysis system for bicycle field test studies capable of measuring structural responses including strain and acceleration. The system incorporates 24 sensors measuring strain, 4 sensors measuring acceleration, a stand-alone data acquisition unit weighing 1.7kg which can be mounted behind the seat post and an offline programme analysing the data obtained. The system has been fully implemented on a BMX bicycle for the work presented herein. Piezo-electric accelerometers and resistance strain gauges are used as sensors which are wired to the data acquisition (DAQ) unit. The DAQ unit consists of a controller-chassis, 4 signal conditioning modules and specific application software. The software which controls the measurement process performs sensor calibration, simultaneous 24 bit data acquisition with a sampling frequency of 1000Hz, signal conditioning and data storage. The sampling frequency was established as optimal in specifically designed assessment tests. The data is post-processed to determine the frequency responses, maximum accelerations and strains and to illustrate the time behaviour of accelerations and strains. The measurement and analysis system is validated in common cycling scenarios and a race simulation on a race track. The system is applicable to different types of bicycles and enables comprehensive investigations of structural phenomena.

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Keywords: Bicycles, field test studies, stand-alone measurement system, data acquisition

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1. Introduction

To improve the engineering design of a bicycle it is necessary to thoroughly understand the complex load cases to which it is subjected to. The bicycle is constantly subjected to loads from the riding surface (at the wheels) and the rider at three potential points of contact (the handlebars, the pedals and the seat). Measuring the structural responses of a bicycle in a realistic field test is the only certain method of obtaining actual data on what a bicycle is subjected to under use and abuse scenarios. To achieve this, a measurement system is required capable of acquiring structural responses during cycling.

The aim of the work presented was the development and validation of such a measurement and analysis system. While this is not the first attempt to develop such a system, it has been done in a more systematic way and with more attention to detail than other systems presented within the literature.

The outcome of this work is a low weight, flexible, stand-alone measurement and analysis system enabling the acquisition of a comprehensive amount of data on the structural responses of strain and acceleration with signal acquisition properties determined to be optimal for realistic cycling conditions.

2. Current state of art

There exist a number of studies describing the development of some form of measurement system for bicycle field test studies. Publications have been found describing the use of a measurement system in field test studies with mountain bicycles (e.g. Champoux et al. (2004), De Lorenzo and Hull (1999)), road bicycles (e.g. Bluemel et al., (2007)) and even foldable city bicycles (Pirnat et al. (2011)). Many studies stored the data acquisition (DAQ) unit in a backpack; others mounted the system directly to the bicycle. Except that by Barski et al. (1995), no research aiming at acquisition of structural responses implemented wireless signal transmission. The signal acquisition in Barski et al. (1995) is limited to eight channels without providing information about the sampling frequency used.

From the literature, some observations regarding measurement systems used can be made. Considering the sampling frequency, the arguably most important signal acquisition property, a range of 200-2500Hz has typically been used. This demonstrates a degree of uncertainty about what is considered an optimal sampling frequency. This is crucial as it indicates that research may have been impeded by a loss in information (sample frequency too low), or an overwhelming amount of data and a degree of introduced noise in the signal (oversampling).

The systems previously used provided ADC resolution in a range of 8-24bit and anywhere from 4 to 32 measurement channels were implemented in measurement systems depending on the aim of the research. Considering the literature, a measurement system incorporating at least 20 channels could be considered as comprehensive. For such systems, the lowest weight documented is found in Bluemel et al. (2007) with 3*kg* for a 23 channel measurement system. The lowest mass of 1.2*kg* is mentioned in Drouet et al. (2009) for a measurement system offering only four channels to measure loads on the pedals.

Regarding the physical quantities acquired, most studies measured forces at points close to load inputs (e.g. handlebars, stem, pedals and hubs); however, almost no information is available regarding strains and deformations on the frame. Moreover, within the literature, studies measuring loads did not measure accelerations and vice versa; except of Barski (1995) who; however, does not provide information on accelerations measured. This is significant, as it means that the connection between the external dynamic inputs from the rider and environment and the strains experienced by the frame is not well understood.

3. Measurement system definition

The development of the measurement and analysis system was based on requirements defined following the outcome of specifically designed assessment tests to determine what constitutes an optimal acquisition of signals of structural responses on bicycles in field test studies, as well as information provided within the literature regarding the state-of-the-art for such systems. In addition, the system developed should be easily configurable and applicable to any type of bicycle.