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TEST BENCH FOR THE ASSESSMENT OF VIBRATIONS OCCURRING IN MOTORCYCLES

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Abstract

The purpose of this publication is to present the construction and adaptation of a test stand intended for motorcycle simulation research. The stand is designed to study the impact of motorcycle vibrations that act on the body of the rider and passenger. Motorcycles belong to one of the types of transport that directly affects users. Excessive vibrations transmitted to the body of the rider and passenger can make riding uncomfortable and even dangerous. The vibrations of motorcycles depend mainly on the technical condition of the vehicle, the structure of the vehicle, and the construction of the engine. The stand was built on the basis of a hydraulic power supply unit, distributor, and electrohydraulic pulsators. The purpose of the construction of the stand is to examine a given group of motorcycles to learn and eliminate vibrations that occur in various areas of motorcycles and affect the comfort, health, and safety of motorcycle travelers. Test studies of the presented stand are presented in this article. The preliminary results of the simulation tests determined the possibility of testing individual elements and motorcycles on the laboratory stand.

Keywords: test stand; motorcycle; vertical dynamics; comfort; safety

1. Introduction

Vibration is one of the main hazards of means of transport on people and the environment [10, 11, 14]. For years, vibration emissions have been subjected to controls and limitations by introducing various types of legal regulations [5, 8, 9] aimed at reducing the level of vibrations generated by means of transport, especially in the field of transport infrastructure. The level of vibrations generated by motorcycles is mainly influenced by: engine, drive system, technical condition of the vehicle, and also their design [4, 6, 12]. Additional factors that affect the level of vibration are the type of surface and the speed of riding [7, 13, 21].

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The development of motorcycles is currently being observed, especially in terms of offering users high comfort and operation. This helps to reduce the level of perceived vibrations by riders and passengers.

Excessive vibrations of motorcycles can make riding uncomfortable and even dangerous. Long-term operation of motorcycles can cause deterioration in user health [19, 22, 25]. Therefore, various types of elements are introduced into motorcycles to reduce vibration transmission from the source to the point of reception [15, 18, 26].

Research conducted by domestic and foreign scientific centers indicates that a change in the amplitude of vibrations in a different frequency range can affect physical and health changes in a person. These studies show that low-frequency vibration ranges affect the dysfunction of internal organs of the human body [23, 24, 27].

Motorcycles belong to one of the types of transport that directly affects users. Close contact of the motorcyclist with the structural elements of the motorcycle causes vibrations to be transmitted directly to the rider and passengers [2, 17, 20].

In the work [1, 3, 16] the issue of building simulation stations that cause vibrations of individual elements and motorcycles was addressed. Research mainly involved the development of a model of vibrations occurring in the vehicle, the limitation of steering-wheel vibrations, and the study of the vehicle's strength. The authors point to the need for further research and the creation of new test stands that will be able to better reflect the conditions on the roads.

2. Research position for simulation tests motorcycles

The test stand for simulation testing of motorcycles built at the Automobile and Tractor Laboratory of Kielce University of Technology is presented in Figure 1. It is built on the basis of electrohydraulic inductors by the MTS company and contains several cooperating systems, which include:

- electro-hydraulic pulsators with servo valves,
- hydraulic distributor assembly,
- hydraulic power supply unit,
- control system with software,
- guide system with motorcycle front fork mounting unit,
- motorcycle swingarm mounting unit.

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Fig. 1. Motorcycle vibration test stand

The task of the first of the electro-hydraulic pulsators is to force the movement of the cross-beam of the guide system to which the fork of the motorcycle was attached. The pulsator is permanently screwed onto the technological plate that rests on the rubber elements. The exciter is equipped with a displacement and force sensor, which is placed between the beam of the guiding system and the pulsator piston rod.

The task of the second electrohydraulic pulsator is to force the movement of the plate together with the bearing assembly to which the swingarm of the motorcycle has been attached. The pulsator was connected to the technological plate by means of a joint, whose task is to reduce the torque load acting on the vehicle during the tests. The exciter is equipped with a displacement and force sensor, which was placed between the pulsator piston rod and the motorcycle swingarm mounting unit.

Table 1 presents the most important parameters of electro-hydraulic pulsators. The technical data presented are sufficient to conduct motorcycle simulation tests.

Table 1. Technical data of the MTS Model 244.12 electrohydraulic pulsators

Maximum force	25 kN
Piston rod stroke	152 mm and 254 mm
Frequency of movements	100 Hz
Operating temperature	(5–50)°C

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A hydraulic distributor assembly located between the hydraulic power supply unit and the servo valves of the electro-hydraulic pulsers allows operators to start each of the hydraulic circuits individually. The distributor shown in Figure 2 acts as a protection of each circuit against unexpected movement of the actuator, which could damage the tested vehicle or its components. The pressure accumulators placed inside provide energy storage for the highest efficiency, reducing the need for a larger hydraulic power unit. In the supply and discharge lines, the appropriate pressure is maintained to increase the reliability of the entire system and minimize pressure fluctuations, which also results in reduced movement of the hydraulic lines during the operation of the pulsators.

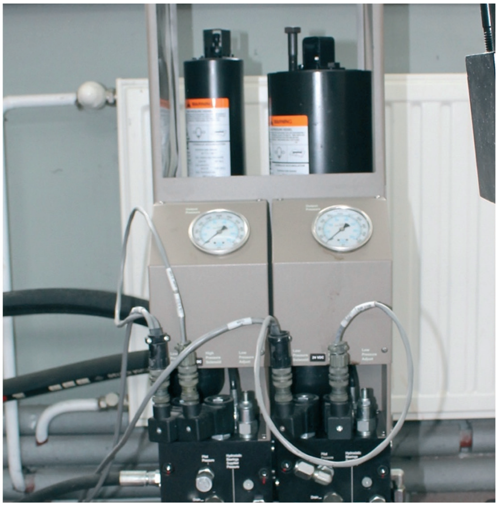

Fig. 2. Hydraulic distributor

The system consisting of a pulsator, power supply, servo valve, and controller allows the pulsator to work in the ranges shown in Figure 3.

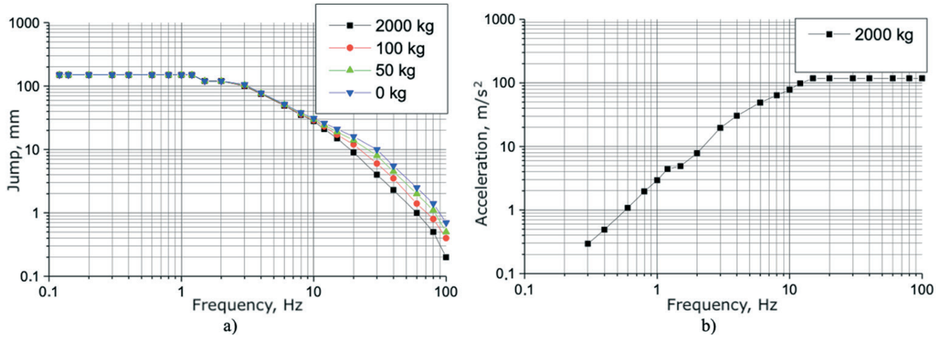

Fig. 3. External characteristics of pulsators: a) jump – frequency, b) acceleration – frequency

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The operating ranges presented are fully sufficient to conduct motorcycle simulation tests, both in terms of identifying the parameters of dynamic models, as well as various analyses in the field of comfort and safety.

The hydraulic supply unit is to supply the hydraulic distributor with oil under a specified pressure, which then goes to the electro-hydraulic pulsators. Control of the power supply unit can be carried out locally from the control panel or remotely by means of the controller. The feed system shown in Figure 4 is water cooled, the water requirement of the heat exchanger being, for example, 42.7 l/min at an ambient temperature of 26.7°C.

Fig. 4. Hydraulic power supply unit

The basic parameters of the hydraulic power supply unit are presented in Table 2. They allow the correct operation of the test bench intended for the test of motorcycles.

Table 2. Technical parameters of the hydraulic power supply unit

Supply system pressure	21 MPa
Power system performance	63 l/min
Power consumption	30 kW
Supply voltage	(200–575) V AC
Hydraulic oil tank capacity	341 l
System weight with hydraulic oil	817 kg
External dimensions height x width x length	(137x86.4x156.5) cm
Operating temperature	(5–40)°C
Noise measured at a distance of 1 m	63 dB(A)

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The control system with the software is depicted in Figure 5. The software provides complete control of the entire MTS testing system. Control is carried out through the use of a control unit and a program of MTS companies. The software has a graphical interface that facilitates quick configuration of the controller for a wide range of test applications. The multichannel pulsator control system provides the generation of waveforms in the form of sinusoidal, rectangular, triangular in the frequency range from 0.001 Hz to 600 Hz, incremental signal, random signal, and sinusoidal signal with variable frequency. The operator can display selected system status information at any time during the test, including digital meters and oscilloscope displays.

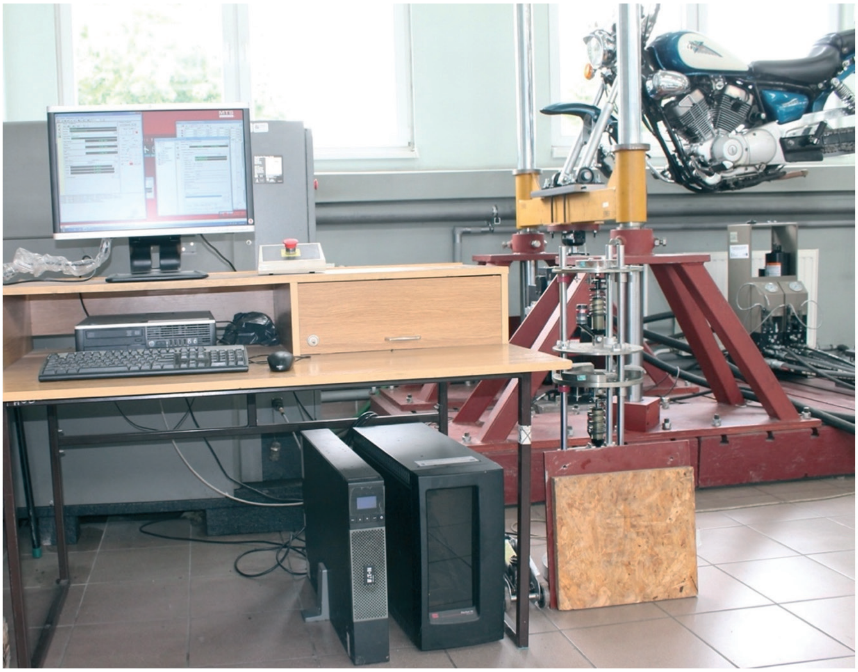

Fig. 5. Control system with software

The guide system with a crossbeam located in the Automotive and Tractor Laboratory of Kielce University of Technology was the basis for the construction of a motorbike simulation test stand. The partially existing stand [28] was equipped with an additional plate with a bearing assembly. This element was attached to the crossbeam to form a supplement to the guiding system. The guiding system shown in Figure 6 consists of two vertical pillars acting as guides of the crossbeam. The posts are fixed in special racks attached to the technological plate. The outer diameter of the posts is 100 mm, which cooperates with the crossbeam, which has sleeves with slide bearings. The beam bearings allow the beam to move, providing low resistance to movement.

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Fig. 6. Guide system with motorcycle front fork mounting unit

The front fork assembly of the motorcycle is attached to the upper part of the crossmember. In the construction of the stand, an element was used to connect the exciter of the pulsator with the mounting plate of the front suspension of the vehicle. The mounting plate was connected using four bolts passing through the crossbar element, connecting the element screwed directly to the pulsator exciter. Such a plate placed with a set of bearings allows the assembly of the front suspension of motorcycles with a spacing of 150 mm to 450 mm. In order to enable the assembly of vehicles with various suspension spacings, T-slots were made along the entire length of the plate to allow the sliding of the bearing units. For each motorcycle, before assembly on the test stand, it is necessary to make individual shafts, mounted in the inner ring of the bearing and in the suspension element.

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The electro-hydraulic pulsator with the assembly that allows the assembly of motorcycle rocker arms was connected to the technological plate using a joint (Figure 7). The joint is constructed from two steel plates, a bearing assembly, a shaft, and two end shaft supports. This type of connection is intended to reduce the torque load acting on the motorcycle during the performed tests. The base of the joint was attached to the technological plate. The other part of the joint was attached to the base of the electrohydraulic pulsator. In the upper part of the pulsator, a plate with a set of bearings has been tightened, which allows the installation of motorcycle wishbones with a spacing of 100 mm to 450 mm. To assemble vehicles with various rocker arm spacings, T-slots were made along the entire length of the plate to allow sliding of the bearing units. For each motorcycle, before assembly on the test stand, special rollers are necessary, mounted in the inner ring of the bearing and the element of the rocker arm.

Fig. 7. Electro-hydraulic pulsator with joint and plate enabling the installation of motorcycle control arms

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3. Preliminary test results

The purpose of the preliminary research carried out on the site was to check the correctness of its operation. The measuring system consisted of three directional acceleration sensors and an LMS conditioning system. A laptop with LMS software was used to archive data from acceleration sensors. The values measured during the tests were the acceleration of the handlebars, seat, and plate together with the bearing unit on which the motorcycle fork was mounted (Figure 8). On the laboratory stand, attempts were made to generate vibrations acting on the motorcycle. During the preliminary tests, sinusoidal vibrations with frequencies from 2 Hz to 20 Hz were generated with a maximum amplitude acceleration of 0.25 g. The motorcycle was properly loaded with a weight of 65 kg.

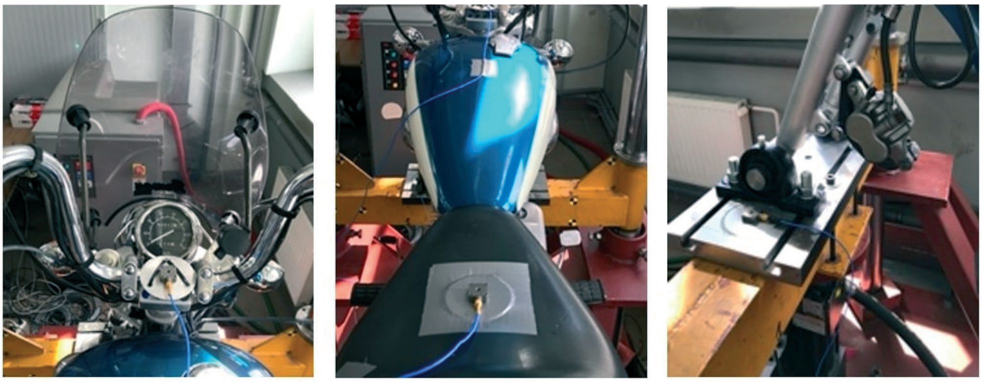
a) b) c)

Fig. 8. Location of individual acceleration sensors;
(a) steering wheel, (b) seat, (c) plate with bearing assembly

The preliminary results of the conducted simulation studies have determined the possibility of testing particular elements and motorbikes on a laboratory test stand. Example time courses of vertical vibrations recorded on the handlebars, the seat, and the plate are shown in Figures 9 to 11. On the basis of the obtained results, some conclusions can be formulated. The highest accelerations were recorded on the motorbike seat in the 2.5 Hz to 4 Hz interval, with an average value of 1.09 m/s^2, while on the plate, accelerations with an average value of 2.18 m/s^2 were recorded. On the handlebars of the motorcycle, accelerations with an average value of 0.04 m/s^2 were recorded in this range. The lowest accelerations on the seat were recorded between 9 Hz and 20 Hz with an average value of 0.13 m/s^2. Figure 10 shows the accelerations recorded for the motorbike seat during a test conducted at a forcing frequency of 3 Hz. The highest motorbike handlebar accelerations were recorded between 12 Hz and 16 Hz, with an average value of 0.26 m/s^2, while average accelerations of 1.75 m/s^2 were recorded on the plate. On the seat of the motorbike, average accelerations of 0.13 m/s^2 were recorded in this interval. The smallest accelerations on the handlebars were recorded between 2 Hz and 10 Hz with an average value of 0.05 m/s^2. Figure 11 shows the accelerations

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recorded for the handlebars of a motorbike during a test conducted at a forcing frequency of 14 Hz. Figure 12 shows the accelerations recorded for the front suspension mounting plate during a test conducted at a forcing frequency of 5 Hz.

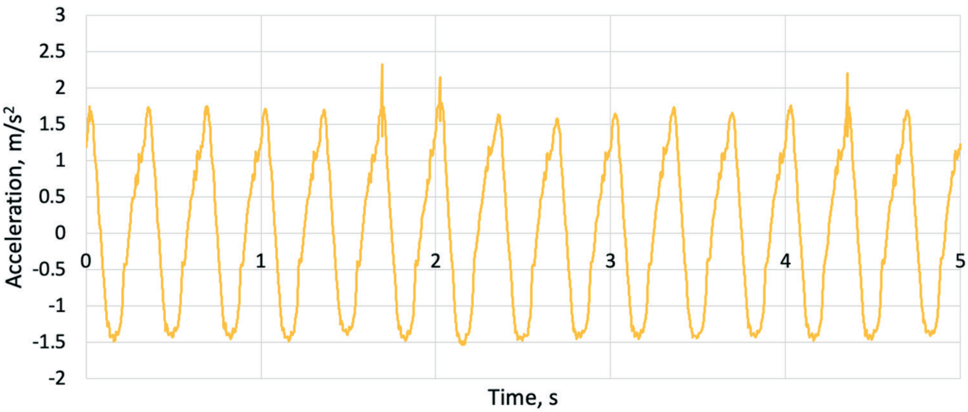

Fig. 9. Time histories of the accelerations recorded on the motorcycle seat during the test carried out at an exciting frequency of 3 Hz

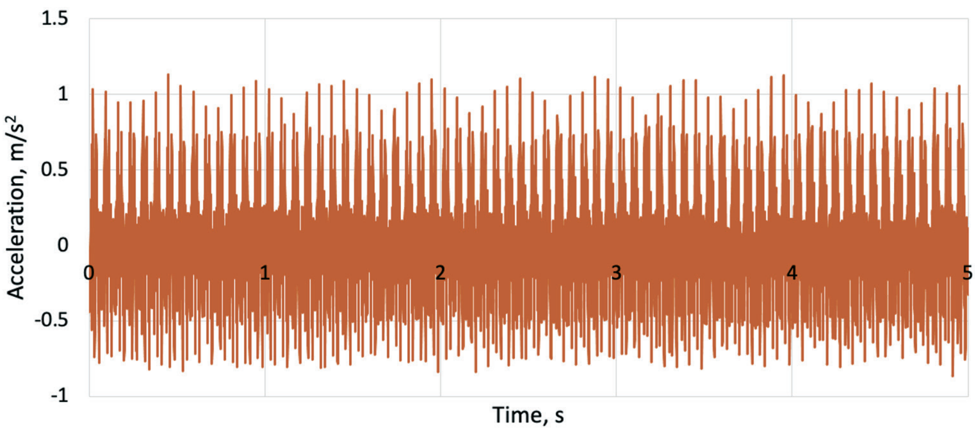

Fig. 10. Time histories of the accelerations recorded on the motorcycle handlebars during the test performed at an excitation frequency of 14 Hz

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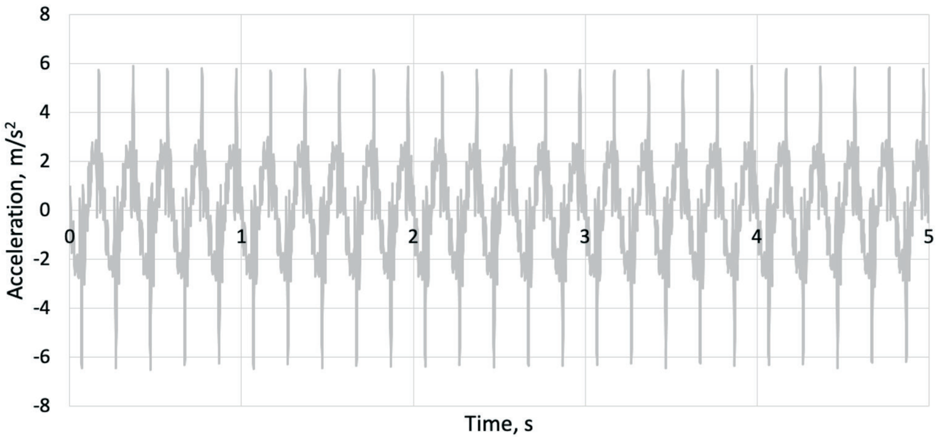

Fig. 11. Time histories of the accelerations recorded on the front suspension mounting plate during the test carried out at an excitation frequency of 5 Hz

Based on the recorded acceleration waveforms, an analysis was performed in the frequency domain by determining and comparing the values of the acceleration transmittance modules of the plate to the motorcycle seat, and the plate to the motorcycle handlebars. To determine the transmittance of accelerations, the relationship between the input of the front suspension mounting plate and the response in the form of accelerations recorded on the seat and handlebar of the motorcycle was used. The study of frequency characteristics was carried out by determining the relationships between the input signal and the output signals. Figure 12 shows the calculated transmittance modules for the acceleration plate to the motorcycle seat, and the plate to the motorcycle handlebars.

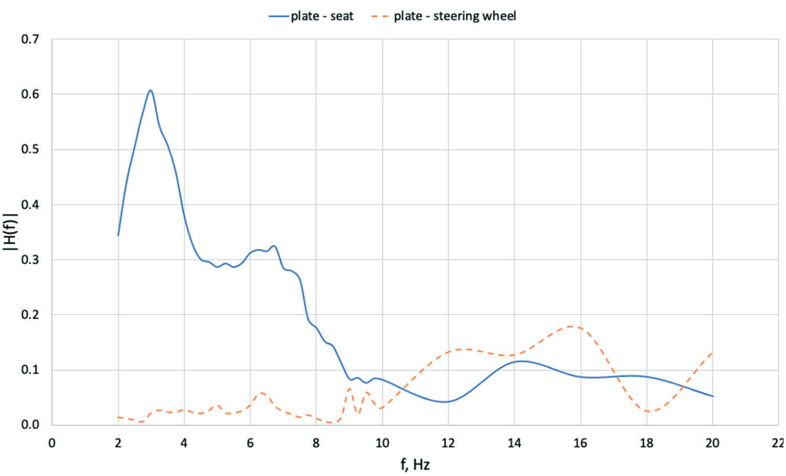

Fig. 12. Graphs of transmittance modules

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The transmittance curves show that the greatest differences in vibration damping between the steering wheel and the seat are in the range of 2 Hz to 10 Hz. In this range, the handlebars of the motorcycle dampen vibrations more effectively. At higher frequencies, the differences between the curves are smaller. The least effective damping for the plate to the seat system is observed for the frequency of 3 Hz. In the case of the plate to the steering wheel system, the least effective damping was observed at 15.75 Hz. These types of characteristics, determined in an appropriately planned series of tests, will be used to identify its own form of a dynamic model of the motorcycle – rider system and to identify the parameters of this model.

4. Conclusions

The presented laboratory stand, together with the tests carried out to assess the work of the station, will be used in the future in the cycle of experimental research. The results obtained will allow for a thorough analysis of the construction of motorcycles and their individual elements. This will allow the introduction of additional elements or structural changes to eliminate harmful vibrations that cause deterioration of health, increasing the comfort and safety of travelers. In the future, the test stand will also be used to identify the characters of the dynamic model of the motorcycle and its individual parameters.

5. Nomenclature

MTS Materials Test Systems
LMS Data Acquisition System

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