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TESTING THE CHARACTERISTICS OF THE DRIVER - MOTORCYCLE - ROAD SYSTEM ON THE TECHNICAL INSPECTION LINE

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RESEARCH ARTICLE

ABSTRACT: The characteristics of the motorcycle in relation to the driver's behavior significantly affect traffic safety. Motorcycle accidents are usually more severe. The specifics of the construction and the very complexity of the kinematics and dynamics of the motorcycle to a considerable extent complicate the comparative implementation of theoretical and experimental research. The research of the stated characteristics was realized on the line of technical inspection. These obtained results could be used in order to educate motorcyclists in order to increase the overall traffic safety

KEY WORDS: motorcycle, experimental measurements, technical inspection, traffic safety

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ISPITIVANJE KARAKTERISTIKA SISTEMA VOZAČ – MOTOCIKL – PUT NA LINIJI TEHNIČKOG PREGLEDA

REZIME: Karakteristike motocikla u relaciji sa ponašanjem vozača bitno utiču na bezbednost saobraćaja. Saobraćajne nezgode sa motociklima su najčešće sa težim posledicama. Specifičnosti konstrukcije i sama kompleksnost kinematike i dinamika motocikla u znatnom stepenu usložnjavaju uporedno sprovođenje teorijskih i eksperimentalnih istraživanja. Istraživanje navedenih karakteristika je realizovano na liniji tehničkog pregleda. Dobijeni rezultati se mogu koristiti u cilju edukacije vozača motocikla radi povećanje ukupne bezbednosti saobraćaja.

KLJUČNE REČI: motocikl, eksperimentalna merenja, tehnički pregled, bezbednost saobraćaja

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1. INTRODUCTION

In road traffic, vehicles of different construction concepts and different characteristics can be found. According to the number of tracks and wheels, it is common for vehicles to be classified into vehicles with one track and two wheels and vehicles with two tracks, ie with four or more wheels. Bicycle and motorcycle are two representative categories of vehicles with one track and two wheels, which meet in traffic and whose dynamic characteristics in interaction with the driver's behavior significantly affect traffic safety [1]. It can be said that the movement of bicycles and motorcycles has a lot in common, but also that it differs significantly from the movement of two-wheeled vehicles [2] [3]. Unlike two-track vehicles, which have the stability of keeping the direction of movement without the help of the driver, single-track vehicles do not have the stability of the direction of movement or the stability of the position in relation to the road [4]. For these reasons, the role of drivers of single-track vehicles is very complicated and difficult [5]. The driver gets tired while driving and is very often the cause of traffic accidents with severe injuries or deaths [6].

In dynamic analyzes of two-wheelers, both theoretical and experimental, a special problem is the inclusion of the influence of the driver [7]. This is due to the fact that in motorcycles the driver's behavior affects the stability and safety of movement more than in other vehicles [8] [9]. The motorcycle can easily be found in a position of unstable balance, because it is stabilized by the dynamic forces that are a consequence of the driving mode [10] [11]. It is known that the bicycle, as a two-wheeler, keeps the rider in direct balance. The equipment used in technical inspections can be part of the experimental measuring system and the results obtained in this way are valuable in testing the characteristics of the rider-motorcycle-road system [12] [13] [14] [15].

2. EXPERIMENTAL MEASUREMENT SYSYTEM

The experimental measurement system [3] used in the tests with the YAMAHA YZF R6 motorcycle is shown in Figure 1.

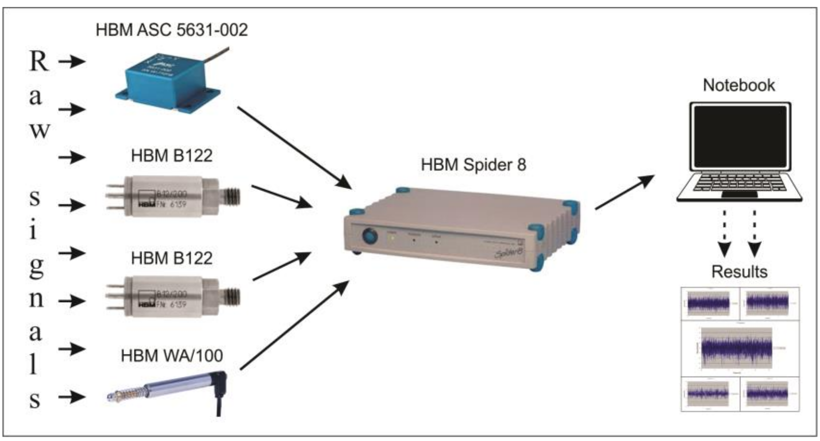

Figure 1: *Experimental testing equipment*

The raw signal (A, B, C and D) act on the transducers, which send the processed signal to the HBM SPIDER 8 amplifier, after which the amplified signal is sent to the PC for further processing. Figure 2 shows the three-axis accelerometer HBM ASC 5631-002 SN W-71003, which is mounted in the center of gravity of the motorcycle and measures three components of acceleration: longitudinal, transverse-lateral and vertical.

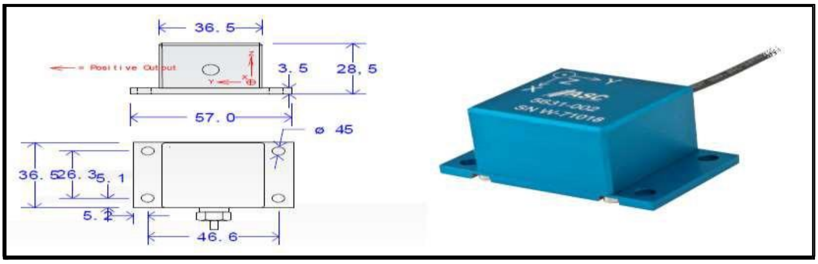

Figure 2: *Triaxial acceleration sensor Hottinger Baldwin Messtechnik-HBM*

Figure 3 shows the HBM WA/100 translational displacement transducer mounted on the handlebars of the motorcycle and shows the displacement of the motorcycle when cornering.

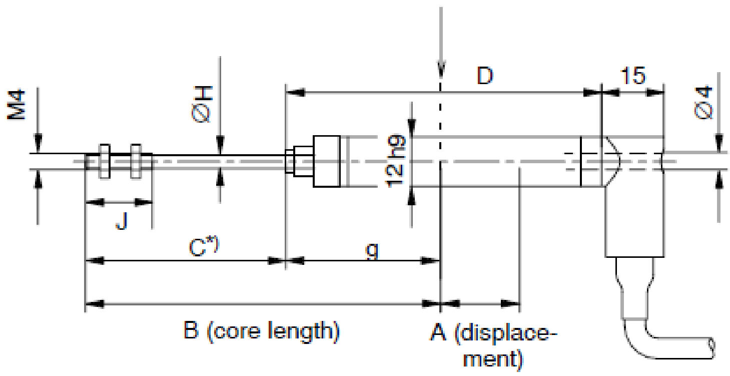

Figure 3: *Translational displacement transducer HBM WA / 100*

Figure 4 shows the uniaxial HBM B12 accelerator transducer located in the centers of the front and rear wheels and which followed the movement in the vertical direction.

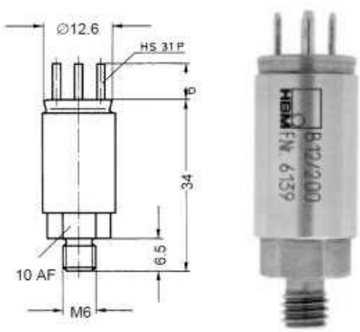

Figure 4: *Single-axis acceleration transducer HBM B12*

The HBM Spider 8 amplifier was used in the experiment. HBM Spider 8 is a simple, universal amplifier that can have from 4 to 8 usable channels (inputs) and has a connection to a PC on which, with the software support, measured signals are processed. The amplifier is shown in Picture 5.

Figure 5: *HBM SPIDER amplifier*

HBM Spider 8 is a multi-channel electronic measuring unit PC for parallel, dynamic measurements and data processing. It is an integrated and more cost-effective alternative to systems consisting of external units. The entire measuring system must be pre-connected with cables and configured. With the HBM Spider 8 measuring system, everything needed to perform the measurement is housed in a compact housing. Unlike older systems, there are no redundant switches, potentiometers and no plug-in card with code and address is required to configure the system, so the Spider 8 simply connects to a computer and printer, via a printer port and is ready to use immediately

Each channel in Spider 8 provides pulses for passive converters, amplifiers, filters and has its own A/D converter. All A/D converters operate in sync and can provide up to 9,600 measurements from each channel with a resolution of 16 bits. The base unit has four 4.8 kHz frequency amplifiers (ie 600 Hz for the type Spider 8-30), stable and noise-tolerant, which allow the general application of the Spider 8. It allows the measurement of force, lenght, pressure and other mechanical quantities by means of voltage measuring systems and inductive transducers. Spider 8 can be expanded to 8 channels in one device or to a total of 64 channels from 8 devices. Plug-in modules are available in two versions for expansion in the device: one as an additional CF channel amplifier and the other as a DC version, with electrically insulated inputs for temperature measurements with thermocouples or for measuring direct voltage, direct current and resistance.

3. SETTING MEASUREMENT EQUIPMENT ON MOTORCYCLE

To investigate the influence of the dynamic characteristics of the driver - motorcycle - road system [3] on traffic safety, an experimental measurement system was designed and implemented on a YAMAHA R6 motorcycle Figure 6.

The basic parameters of a motorcycle are:

- Working volume: H = 599 cm3,
- Maximum power Pemax / np = 89.7kW, at 13000 rpm,
- Net weight: ms = 183 kg.

Figure 6: *Test motorcycle YAMAHA YZF R6*

Measuring system HBM Spider 8, connected to a PC on the front passenger seat in a special housing attached to the frame of the motorcycle Figure 7.

Figure 7: *The measuring system HBM Spider 8*

The three-axis accelerometer HBM ASC 5631-002, is set at the position of the approximate center of gravity of the rider-motorcycle system (Figure 8). The first uniaxial accelerometer HBM B 12, is attached to the carrier approximately in the center of the front wheel of the motorcycle, as shown in Figure 9.

The experimental system shown could be expanded, if necessary, by introducing an appropriate number of uniaxial HBM B12 accelerometers. These accelerometers that can be placed on the motorcycle frame at the front and rear elastic wheel suspension systems connection, the center of mass of the system, the driver's and front passenger's seat, driver's belt and helmet, etc. In this way, it could ne measured the levels of oscillations to which the components of the system are exposed, as well as indicators of the dynamic redistribution of the load on the wheels during starting and braking.

Figure 8: *Three-axis accelerometer*

Picture 9: *Single axle*

HBM ASC 5631-002	*accelerator HBM B12 on the front wheel*

Figure 10 shows the measurement process of the YAMAHA YZF R6 motorcycle on the technical inspection line - measuring rollers.

Figure 10: *Motorcycle YAMAHA YZF R6 on the line of technical inspection - measuring rollers*

4. MEASUREMENT RESULTS

With the Yamaha YZF R6 motorcycle, a number of measurements in different test conditions were performed on the technical inspection line. The presented measurement results refer to the identification of the motorcycle acceleration tested on the measuring rollers placed on the line of technical inspection. In different modes of operation of the motorcycle engine, starting from the mode when the engine is not running and the rollers are turning, to the mode when the engine is running at the maximum number of revolutions (which were allowed by the test conditions). The accelerations on the wheels and in the center of gravity of the motorcycle were measured with uniaxial and triaxial accelerometers. All modes were repeated several times to prove the validity of the measurement.

It is important to note that the research was done on a YAMAHA YZF R6 motorcycle, manufactured in 2005, and cannot generally apply to all motorcycles. The test was performed on the technical inspection line of "Tandem" d.o.o. in Kragujevac.

The analysis of the recorded accelerations led to the conclusion of how much amplitude of dynamic forces we can expect at the front and rear point in different modes of operation of the motorcycle engine. These variations in the amplitude of the dynamic force directly have the consequence of changing the braking force, and thus the stability of the motorcycle in braking conditions. No braking force was measured during the test, but the rollers were used to drive the motorcycle and test in stationary conditions. The research was performed to determine the phenomenon of lateral acceleration in motorcycles.

The modes were used during the experiment are presented in the Table 1.

Table 1: *The experimental modes*

Exper imental mode	Roller speed	Revolution per min (rpm)	Numbe r of measurements
I	*5 km/h*	*/*	*3*
II	*5 km/h*	*800 o/min*	*4*

III	*0 km/h*	*2000 o/min*	*3*
IV	*5 km/h*	*2000 o/min*	*3*
V	*5 km/h*	*4000 o/min*	*3*
VI	*5 km/h*	*6000 o/min*	*3*

During the processing of the results, a standard deviation was found for all measured quantities and further analyzes were performed with it.

Measurements were performed on the motorcycle in three positions:

- Rear wheel center (vertical component)
- Motorcycle center of gravity (three components: longitudinal, lateral, vertical)
- Front wheel center (vertical component).

The measurements are systematized as measurements I, II, III, IV, V, VI. The accelerations in the wheels were measured with single-axis accelerometer, while the three-axis accelerometer measured the accelerations at the measuring point placed in the center of gravity of the driver-motorcycle system. The measurements and obtained results provide the possibility of comparison within the same group of measurements, as well as deviations and specificity in comparison with road tests. The results of the performed measurements is given in table 2.

Table 2: *The results of the measurements*

Experimental modes		Center of gravity (X)	Center of gravity (Y)	Center of gravity (Z)	Rear wheel	Front wheel
I	Stdev*	0.087363	0.287621	0.242389	0.284783	0.175867
	Average	-0.00604	-0.01392	0.011588	0.011533	0.018555
	RMS**	0.087572	0.287957	0.242666	0.285017	0.176843
II	Stdev	0.524582	2.188214	1.037928	0.44751	0.266237
	Average	0.001875	-0.01715	0.007026	-0.00599	0.019273
	RMS	0.524586	2.188281	1.037952	0.44755	0.266933
III	Stdev	0.818491	4.332546	1.306306	0.376482	0.839195
	Average	0.135181	0.391819	0.140271	0.003846	0.012531
	RMS	0.829579	4.350227	1.313816	0.376502	0.839289
IV	Stdev	0.966637	5.793635	1.77192	0.496649	0.841698
	Average	0.273508	0.146934	-0.1004	-0.00596	0.003348
	RMS	1.004586	5.795498	1.774762	0.496685	0.841704
V	Stdev	2.745689	2.851367	2.798665	1.492879	1.30541
	Average	0.103086	0.084769	-0.34257	-0.01229	0.026109
	RMS	2.747623	2.852627	2.819553	1.49293	1.305671
VI	Stdev	2.354594	2.715101	2.864484	1.738071	2.073573
	Average	-0.25947	-0.26244	-0.29972	-0.00352	-0.00721
	RMS	2.368847	2.727756	2.880122	1.738074	2.073586
* Stdev – Standard deviation ** RMS – Root Mean Square						

For the whole record in the time interval, the mean values of the standard deviation were found, which are shown in Table 3.

Table 3: *Standard deviations of the obtained results*

Experimental modes,	Center of	Center of	Center of	Rear	Front

experimental number and average		gravity (X)	gravity (Y)	gravity (Z)	wheel	wheel
I	No. 1	0.087363	0.287621	0.242389	0.284783	0.175867
	No. 2	0.081666	0.289754	0.232399	0.309762	0.171898
	No. 3	0.086047	0.296877	0.245645	0.334654	0.182863
	Average	0.085025	0.291417	0.240144	0.309733	0.176876
II	No. 1	0.524582	2.188214	1.037928	0.447510	0.266237
	No. 2	0.425928	1.327984	1.073978	0.409906	0.243223
	No. 3	0.326165	1.093907	0.790957	0.368447	0.241885
	No. 4	0.314499	0.824464	0.836635	0.350278	0.247671
	Average	0.397794	1.358642	0.934874	0.394035	0.249754
III	No. 1	0.818491	4.332546	1.306306	0.376482	0.839195
	No. 2	0.884504	4.403498	1.406201	0.380782	0.834731
	No. 3	0.733019	3.982337	1.532768	0.377452	0.850148
	Average	0.812005	4.239460	1.415092	1.522654	0.841358
IV	No. 1	0.966637	5.793635	1.771920	0.496649	0.841698
	No. 2	1.085818	6.888796	1.599797	0.553871	0.790123
	No. 3	1.044752	5.902189	1.598560	0.516292	0.830319
	Average	1.032402	6.194873	1.656759	0.522271	0.820713
V	No. 1	2.745689	2.851367	2.798665	1.492879	1.305410
	No. 2	2.811196	3.195967	3.235410	1.520104	1.311694
	No. 3	2.825407	3.232931	2.935280	1.396834	1.381601
	Average	2.794097	3.093422	2.989785	1.469939	1.332902
VI	No. 1	2.354594	2.715101	2.864484	1.738071	2.073573
	No. 2	2.412932	3.116204	3.147391	2.160495	2.283178
	No. 3	2.217954	3.092894	3.114779	1.811462	2.610930
	Average	2.328493	2.974733	3.042218	1.903343	2.322560

Based on the obtained results, a significant component of lateral acceleration in the center of gravity of the motorcycle can be noticed, although the measurements were realized in quasi - static conditions, on the line of technical inspection. We can interpret the above as a specificity of the construction of a single-track vehicle, as well as the behaviour of the driver, who managed to keep the motorcycle in balance and maintain approximately vertical position of the motorcycle. Figure 8 shows the impeller blade design for the following basic parameters: Y = 360 J/kg, Q = 0.3 m^3/s, n = 1000 rpm, D_1=0.27m, D_2=0.36m, b_1 = 0.095m, b_2 = 0.055m.

5. CONCLUSION

Experimental tests of acceleration measurements at stationary modes were performed on the line of technical inspection. By analyzing the measured values, we come to the conclusion of how much dynamic force we can expect at the front and rear wheel, as well as at the center of gravity of the driver-motorcycle system at different modes of operation of the motorcycle engine. Variations of dynamic forces in the center of the front and rear wheels result in a change in braking force, and thus directly affect the stability of the motorcycle in braking conditions. The forces in the center of gravity, in addition to affecting the stability of the motorcycle, also affect the oscillatory comfort, comfort of the rider and co-driver. If the driver-motorcycle system is exposed to prolonged vibrations, various negative effects occur, which can affect driving safety, as well as the health of the rider ("white toe syndrome"). Motorcycle and moped riders are most exposed to these vibrations, who use this vehicle to perform their primary activity (postmen, traffic police, couriers, fast food suppliers, etc.).

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