MEASURING HEAD FOR OPERATIONAL TESTING OF CAR SUSPENSION SYSTEMS WITH VIBROACOUSTIC METHODS

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Abstract

The article provides a discussion upon the structure of a measuring head designed and manufactured with the purpose of acquisition of data required by a diagnostic system for hydraulic telescopic shock absorbers of passenger cars operating based on vibroacoustic methods. The basis for the design development was a set of initial assumptions adjusted to the multidimensional methods of analysing vibration signals applied. For the design of the measurement track, a block diagram was proposed which was then extended by auxiliary electronic elements of the measuring system conforming with all the relevant requirements. The main components of the measurement track included: a three-axis sensor for vibration acceleration constructed based on one-axis converters, an angular displacement sensor used for measuring the rotation angle and linear velocity of a car and a laser road unevenness sensor. For the computer recording of the signals being measured, an analogue-digital card was used.

The measuring head in question was mounted on a measuring trolley and then test and trial examinations were conducted while driving at various speeds up to 50 km/h in normal operating conditions. The repeatability of the measurement results obtained proved the measuring head's usability in testing.

Keywords: *transport, passenger cars, suspension systems, measurement tracks, vibroacoustic methods*

1. Introduction

A car is a complex system excited to vibrations, composed of numerous masses of discrete-continuous structures. These masses can be divided into sprung and unsprung. There are elastic (springing components) as well as damping (shock absorbers) bonds between these masses. Masses excited to vibrate move. The number of possible displacements of the car masses is large which results from their degrees of freedom. A car body can perform a translational motion along three coordinate axes as well as rotational motions around them. Exemplary motions performed by a car body have been pictured in Fig. 1. Inside the sprung mass, a right-handed coordinate system has been marked having the following axes: x - towards the driving direction, y - transverse to the driving direction, z - vertical. Around the axes, angular displacements α, β and γ occur reflecting the transverse tilt (β), longitudinal tilt (α) and rotation (γ). The car body's vibrations in the transverse plane mainly influence the car's manoeuvrability and stability under the impact of lateral forces. They depend on numerous factors including lateral elasticity of tyres, characteristics of the elastic components and damping characteristics of the shock absorbers. The car body's vibrations along the longitudinal axis (x) are consequences of the impact of the road microprofile (z).

The vibrations are accompanied by variable forces influencing the unsprung and sprung masses, and possibly their components as well. Not only do the variable loads cause damage to the road pavement and reduce the car components durability but also impact the car safety and its operating properties. Among many forces loading the car, an important one is the variable vertical force acting between the wheel and the pavement while driving. It constitutes a sum of the static and dynamic force caused by the kinematic input function of the pavement profile. The change of the dynamic component can reach such a high level that no tangent longitudinal and transverse forces are transmitted between the wheel and the pavement, hence this change is a measure of driving safety. Its opposing characteristic is the driving comfort the measure of which is the accelerations related to the z, γ and β coordinates.

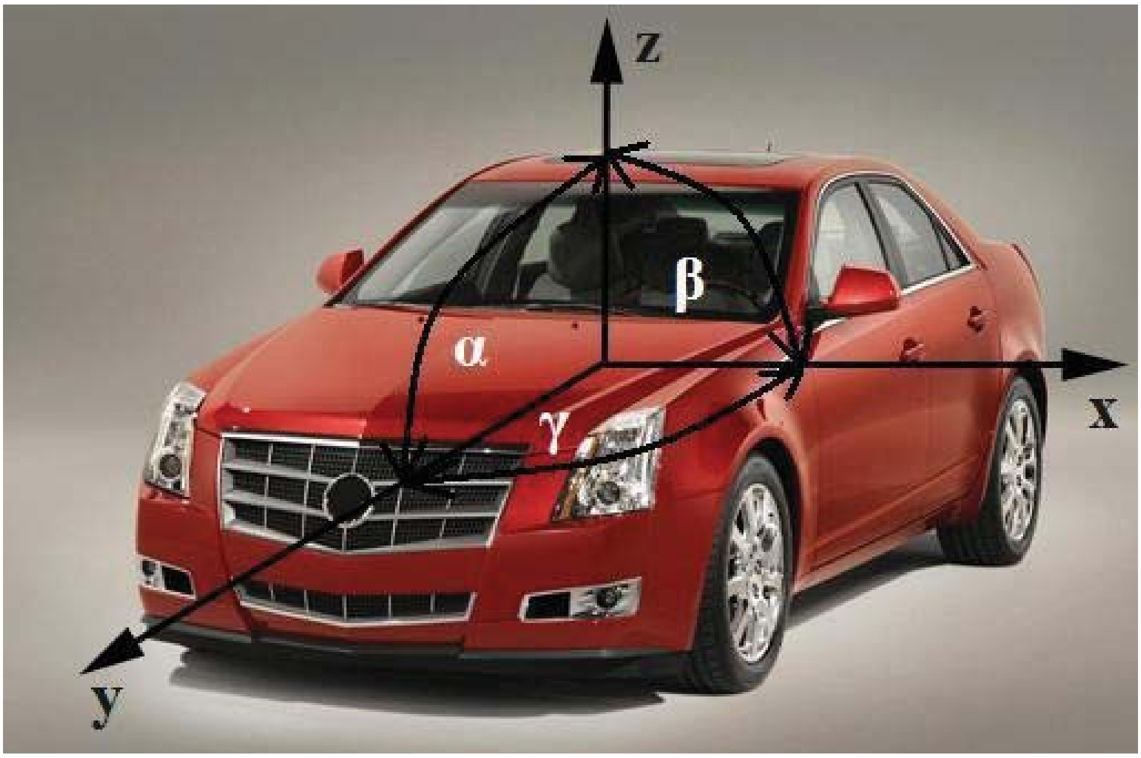

Fig. 1. Car main axes

In conclusion, there is a need to conduct road measurements of cars in normal operating conditions. For that purpose, numerous apparatus sets are used the basic unit of which is the so-called measuring head. The measuring head described in the following sections was designed and manufactured at the laboratory of basic measuring techniques (PTP) of the Faculty of Transport at the Silesian University of Technology.

2. Measuring head

For the sake of the measuring head design, it was assumed that it was to be mounted on a measuring trolley (the so-called fifth wheel) towed by the car being examined. The main objective was to develop a measurement track providing information required for vibroacoustic diagnostic of shock absorbers in passenger cars. It was assumed that the measurable parameters were to be:

- vibration accelerations in the longitudinal direction,
- vibration accelerations in the transverse direction,
- vibration accelerations in the vertical direction,
- angles of the measuring trolley's wheel rotation,
- car driving speed (measured with high precision),
- road pavement microprofile.

A portable computer was to be used for the signal data recording.

2.1. Design of the measurement track

Based on the assumptions made, a measurement track was designed. Its block diagram has been provided in Fig. 2

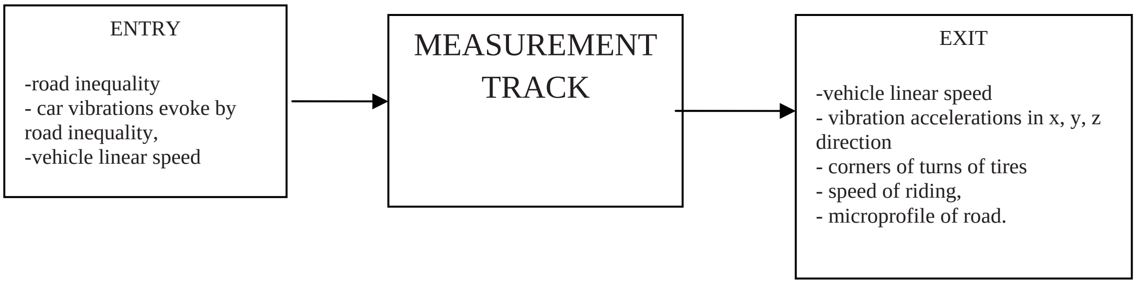

Fig. 2. Measurement track schema

The main components of the measurement track were:

1. analogue-digital card (DAQ) connected with the laptop,
2. three-axis vibration acceleration sensor built on the basis of the ADXLxxxEB components manufactured by Analogue Devices,
3. angular displacement converter based on the IM 08-2N5PS-ZW1 induction sensor,
4. road pavement unevenness converter based on the ILD1402-200 optoelectronic system.

The MicroDAQ-Lite analogue-digital card used in the measurement track was characterised by the following parameters:

- interface USB 1.1 / USB 2.0,
- no. of A/D channels 8/4 (with shared mass/differential),
- A/D resolution 12-bit,
- sampling frequency 49 kHz,
- input voltage range ± 10 V,
- no. of D/A channels 2,
- D/A resolution 12-bit,
- output voltage range ± 10 V,
- no. of DIO channels 8 input and 8 output,
- power source USB.

USB MicroDAQ is supported by a set of applications running under the Windows and Linux operating systems. Based on the assumptions made, a measurement track was designed enabling application of the LabWiev, MatLab and WaveView for Windows applications.

For measurement of vibration accelerations in three perpendicular axes connected with the car coordinate system applied in the tests, a converter based on type ADXLxxxEB parametrical acceleration sensors was used. Type ADXLxxxEB sensors are manufactured as integrated circuits with an option of their settings adjustment to the given purpose. They require direct current power supply which, in the case of the measuring system developed, was provided by the DAQ card's output circuits. Another important property of the acceleration sensors used is their transfer band beginning at f=0 [Hz].

In the system used for measuring of the angular displacement of the measuring trolley's wheel, the IM08 induction sensor was used in cooperation with a toothed disk of 39 notches on the circumference. The signal sent by the sensor, after being differentiated, enables obtaining information on the spot speed of the fifth wheel moving together with the test vehicle. The IM08 system is characterised by the following parameters:

- switching frequency 2,500 Hz,
- status indicator (LED),
- short-circuit protection,
- anticorrosive casing with the end M8 x 1 mounting thread of fine threading,
- sensitivity zone 2.5 mm,

- supply voltage 10...30 V DC,
- voltage drops ≤ 1.2 V,
- power consumption ≤ 20 mA,
- resistance to impact load 30 g, 11 ms from 10 to 55 Hz, 1 mm,
- operating temperature range -25...+70°.

The technique of the angular displacement sensor mounting has been depicted in Fig. 3

Fig. 3. Measuring system for the wheel's angular displacement and linear driving speed

For measurements of the pavement unevenness, the ILD-1402-200 laser sensor was used. It is a displacement measuring system with an integrated controller based on a signal microprocessor. For measuring of the instantaneous distance value, the converter applies the triangulation method. A built-in laser diode projects a light spot on the surface of the object being examined. Dispersed light reflected by the surface tested is then corrected by an optical system and the light beam is directed to the light-sensitive converter (CCD line). The change of the distance between the object examined and the ILD sensor results in a change of the light spot position on the CCD line surface. The changes recorded by the image CCD are computed by the integrated signal processor into voltage values proportional to the instantaneous value of the distance between the sensor and the object measured. The schematic measurement principle has been depicted in the figure below.

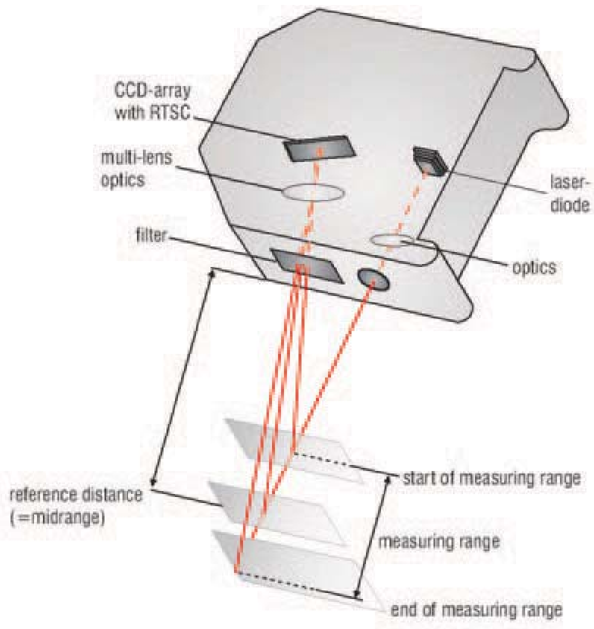

Fig. 4. Principle of the distance measurement applied in the ILD-1402 sensor

The parameters of the ILD system used are as follows:

- measuring range 200 [mm],
- measuring range beginning 60 [mm],
- measuring range centre 160 [mm],
- measuring range end 260 [mm],
- linearity 500 [μm] ±0.25% ,
- static resolution 20 [μm],
- dynamic resolution (for sampling frequency of 1 [kHz]) 100 [μm],
- programmable sampling frequency: 1.5 [kHz]; 1 [kHz]; 750 [Hz]; 375 [Hz],
- laser 1 [mW], 670 [nm] (red), laser class: Class 2 (II) acc. to DIN EN 60825-1 03.97,
- light spot diameter 2,100 - 2,3000 [μm],
- impact resistance up to 15 g / 10 Hz ... 1 kHz,
- weight 100 [g],
- temperature stability 0.08% FSO/°C,
- operating temperature 0 … 55 °C,
- input signal: analogue 4 ... 20 mA (1 ... 5 V with the PC 1402-3/U cable) or digital RS422,
- supply voltage11 … 30 VDC, typical 24 VDC / 50 mA.

The whole measurement process was performed in a non-contact manner which enabled obtaining information of the current pavement unevenness while driving in a dynamic system. The measurement process conducted while driving has been presented in Fig. 5

Fig. 5. Measuring trolley used for the road tests

For acquisition of the measurement data obtained in the course of the road tests, laptops with appropriate software, powered by the car’s electric system, were used.

3. Conclusions

Usability of the measuring heads designed and manufactured was verified in road conditions while driving a car towing a measuring trolley, and the tests conducted proved correct operation of the measurement track and repeatability of the results obtained. The verification measurements were performed at various driving speeds up to 50 km/h. Despite the fact that the measuring head was designed for measurement and data acquisition in vibroacoustic diagnostic of hydraulic telescopic shock absorbers in passenger cars, the measuring trolley equipped with the measuring head can also be used in other operational examinations, e.g. tests of vehicles’ traction properties.

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