Developing a Test Site for Testing the Suspension of Vehicles with Omnidirectional Wheels

Sławomir DUDA
Silesian University of Technology, Department of Theoretical and Applied Mechanics, Konarskiego 18A, 44-100 Gliwice, slawomir.duda@polsl.pl

Olaf DUDEK
Silesian University of Technology, Department of Theoretical and Applied Mechanics, Konarskiego 18A, 44-100 Gliwice, olaf.dudek@polsl.pl, Etisoft Smart Solutions Sp. z o.o. ul. Szara 21, 44-100 Gliwice

Grzegorz GEMBALCZYK
Silesian University of Technology, Department of Theoretical and Applied Mechanics, Konarskiego 18A, 44-100 Gliwice, grzegorz.gembalczyk@polsl.pl

Tomasz MACHOCZEK
Silesian University of Technology, Department of Theoretical and Applied Mechanics, Konarskiego 18A, 44-100 Gliwice, tomasz.machoczek@polsl.pl

Abstract

The paper presents a test site for determining the excitations that occur as a result of the contact between the omnidirectional wheel and the road and affect the single suspension column in motor vehicles. The specific nature of these excitations during the movement of omnidirectional wheels is caused by the irregular envelope of the wheel. The proposed test site enables to determine the vertical displacements of the wheel that is rolling along the paving of the road. The conducted experiment demonstrates that the test site was constructed correctly.

Keywords: omnidirectional wheel, stand for determining excitations

1. Introduction

While the vehicle is moving, vibrations of the body are excited by movement of the wheel on rough surface. These vibrations result from the transmission of these irregularities through the wheel suspension system, to the body of the vehicle. This leads to a decreased driving comfort, or the deterioration of tracking properties resulting from the combination of the vibrations of chassis and the body. In order to minimise the vibrations and prevent their negative consequences that emerge in the elements of both the body and the chassis, shock-absorbing elements are used in the wheel suspension system [1]. The selection of optimum suspension parameters plays an important role in the reduction of vibrations. The attempts to reduce the power consumption by autonomous vehicles used in industrial applications (Fig. 1) resulted in their miniaturisation and thus forced the development of new types of transport chassis. An example might be the multi-directional wheels, also referred to as omnidirectional wheels that are used in mobile robotics in order to improve the manoeuvring capacity [2]. An omnidirectional wheel is defined as a wheel with rollers along the wheel edge (Fig. 2).

Figure 1. AGV E01 tractor type [own photo: Etisoft Smart Solutions Sp. z o.o]

Figure 2. Industrial, triple-row omnidirectional wheel manufactured by Rotacaster, with marked possible movement directions [11]

This type of wheels is characterised by a small working field with the possibility to drive in the transverse direction. The small working field allows to save space, which, for swivel wheels would have to be designated for manoeuvring. The disadvantage of omnidirectional wheels is the fact that they generate additional kinematic excitations that result from the irregular of the tyre envelope [3].

One of the methods of searching for an optimum solution for the designed structure consists in conducting model research with use of numerical simulations [4]. The numerical model allows for a practically unlimited number of tests for variable initial conditions. An important factor that affects the reliability of the obtained result is the correctness of the adopted parameters of the model. As far as analyses of active vibration absorption systems in the suspension of vehicles with omnidirectional wheels are concerned, the accuracy of recreating the excitation caused by irregular tyre envelope plays a major role.

The application of active vibration absorption in suspensions enables to shape the characteristics of the suspension freely, which in turn minimises the impact of the excitations caused by the contact between the wheel and the ground [5]. Due to that, a unique test site was created that serves both to determine the kinematic excitation caused by the movement of an omnidirectional wheel on the ground and to test suspensions used in mobile robotics in systems with multidirectional wheels.

2. Description of the test site

Researchers from the Department of Theoretical and Applied Mechanics of the Silesian University of Technology in Gliwice developed a test site, being the subject of a patent application, which is designated for testing suspension columns of vehicles, including those equipped with omnidirectional wheels, used in mobile robotic applications.

The previously existing methods of analysing the excitations caused by multidirectional wheels consisted in measuring the acceleration of vibrations at selected points of body elements [2] or in form of numerical simulations of model vehicle movements [6], including vehicles equipped with omnidirectional wheels. Subject literature does not provide information on specialist test sites for testing suspension columns of vehicles with multidirectional wheels. Solutions presented in publications usually refer to traditional wheels and are related, among others, to determining of motion resistance [7].

The aim of the proposed site for testing vehicle suspension columns is to measure the vibrations transmitted to the suspension column and caused by the contact between wheel and ground, depending both on the shape of the wheel and on the state of the surface on which the wheel is moving. A drawing of the proposed test site is presented in Figure 3.

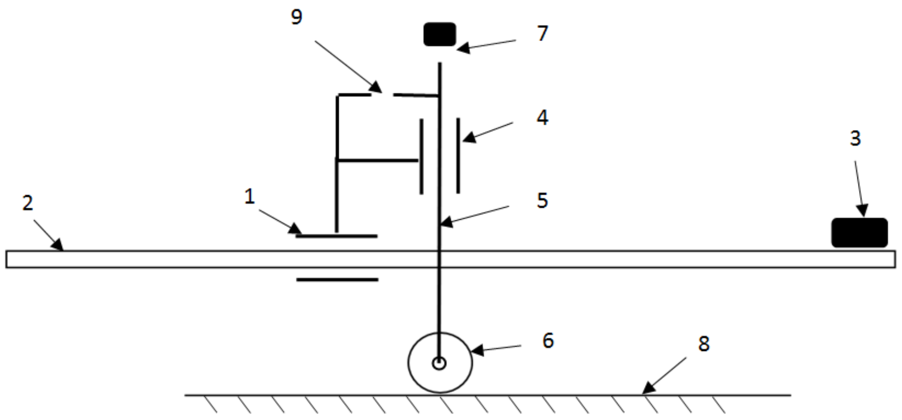

Figure. 3. Schematic designed device

The proposed device forces the movement of the suspension system (6) connected to the vertical column (5) with use of linear drive (2) that powers the trolley (1). The wheel (6) of the suspension system moves along a horizontal surface (8) that may be any material, e.g. concrete of various grain sizes (Fig. 5). The linear drive (2) is powered by an electric motor (3) coupled with the control system, which enables to set any trolley (1) movement speed at the determined characteristics of system acceleration or deceleration. The trolley (1) is linked to the vertical column (5) by a sliding connection (4), which enables it to move freely in the vertical direction under the forces caused by irregularities of the road surface (8) or irregular tyre envelope (6). The vertical displacement of the column (5) to the guide rail (1) to which the reference system is connected is measured with use of position or acceleration sensors (9). The suspension system may be loaded by adding additional weights (7).

3. Realisation of the test site

The test site was constructed based on the presented design. The drives were constructed with use of standard solutions manufactured by Item.

The electromechanical part of the test site (Fig. 4) consists of the following components: PC computer with drive control card and Matlab software (4.a), control box equipped with signal conditioning interface TTL/+24V (4.b), linear drive with a 1kW servomotor mounted at the end of guide (4.c), vertical column with installed suspension and an omnidirectional wheel (4.d).

Figure 4 presents the connections between specific components. The red arrows mark the flow of energy or information, while the blue arrow marks drive transmission or the mobility of specific elements.

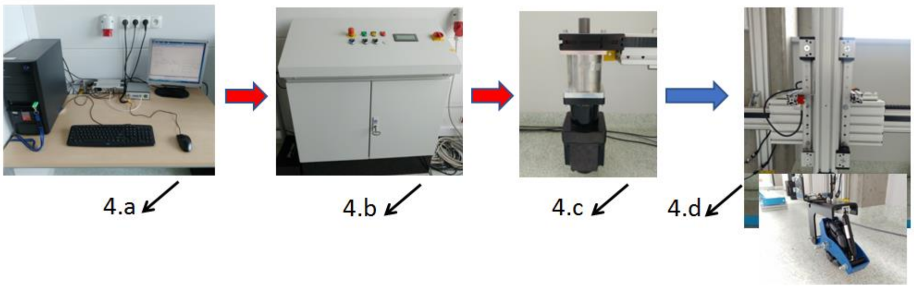

Figure 4. Flowchart of the connections between specific components of the test site

Control signals are transmitted between the computer and the control system by means of the RT-DAC4/PCI driver card connected to the signal conditioning interface. Another element that is necessary to ensure the proper functioning of the device is the control unit equipped with a servo inverter of the motor. Due to the fact that the drive uses speed control, the servo inverter acts as a regulator that controls the motor torque so as to ensure the desired rotational speed [8].Based on the movement reference unit, the signal is thus transmitted first to the control unit, which develops the settings for the drive motor.

The determination of the impact of the irregular envelope of the omnidirectional wheel consists in setting the vertical column in motion by the linear drive so that the velocity of the movement of the column with the driving (multidirectional) wheel reaches the desired value. Then, the vertical displacements of the column in relation to the trolley moving only horizontally (without vertical displacements) is measured (Fig. 5). The vertical displacements of the column are dictated both by the irregular envelope of the omnidirectional wheel and by the irregularities of the surface on which the wheel is rolling. Measurements are taken with use of a displacement sensor connected to the signal processing and recording system and the result is then archived. The possibility to set any speed of the linear drive movement enables setting the velocity of the movement of the wheel, which influences the shaping of the characteristics of the force caused by the contact between the wheel and the surface.

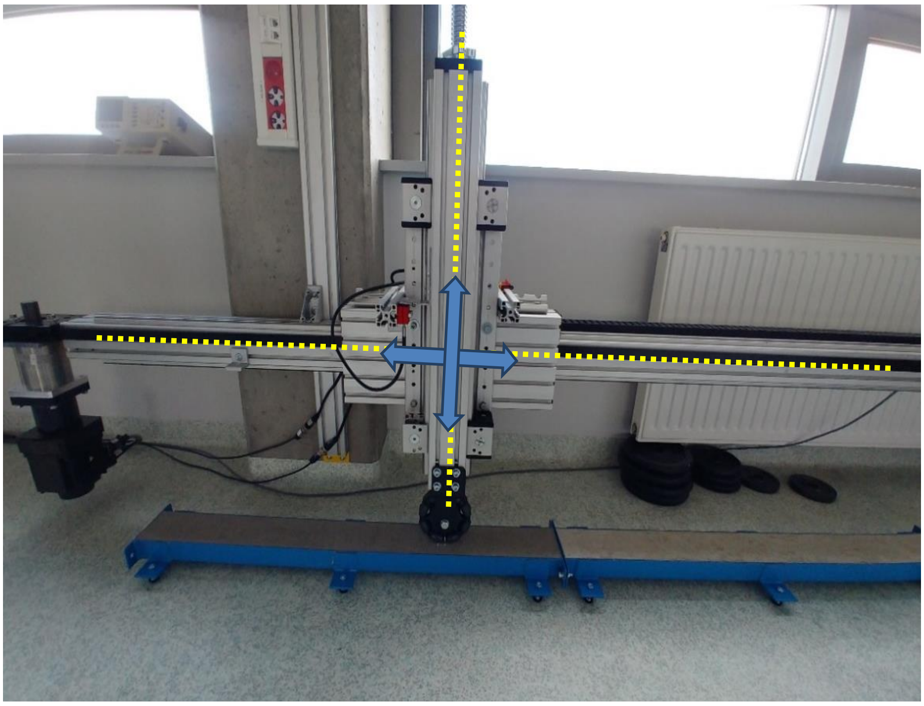

Figure 5. View of the test site.

The system for measuring excitations caused by the suspension with an omnidirectional wheel (Fig. 6) consists of Philtec RC171 optical sensor with power supply unit (6.b), measuring tip and a reflector made from a steel bracket (6.a). The Philtec RC 171 sensor was connected with the Traveler 1 measuring device by ESAM with a cable and plug (6.c). The measurement is recorded on a PC-class computer in real time (6.c). It is also possible to view the readings of the sensor in real time.

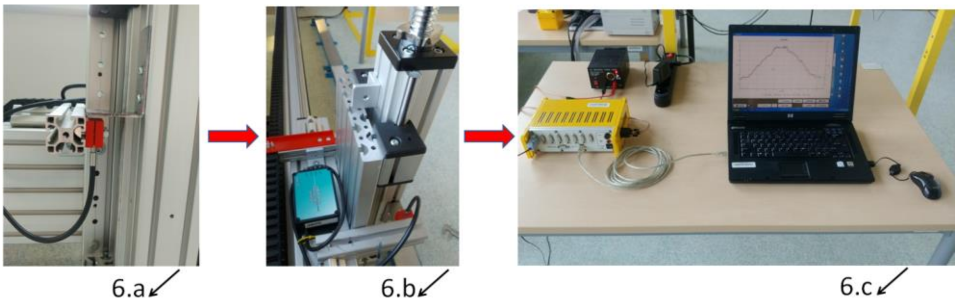

Figure 6. Flow chart of the connections between individual elements of the measurement site.

4. Results

The developed design was the basis for constructing the test site described in Section 3. In order to verify proper functioning of the site, pilot tests were conducted with only the wheel (Fig. 5) and the suspension containing an omnidirectional wheel mounted on the vertical column (Fig. 7).

Figure 7. View of the vertical column with the suspension attached

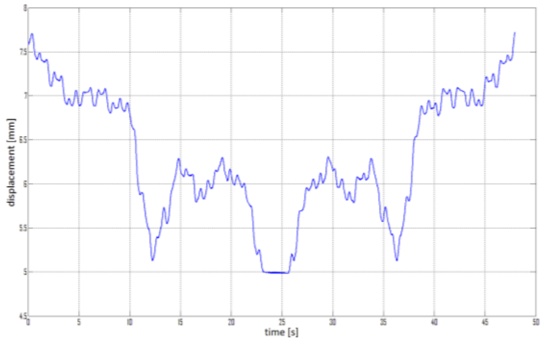

Figure 8. Course of the measured displacement of the column while driving

The test was conducted in quasi-static conditions, at very low velocity of the system – 0.01 m/s. Figure 8 shows one of the recorded drives. The measurement shown here was presented in the domain of time and it shows the recorded vertical displacement of the column during the movement of the system from the starting point to the end and back. The result are twin courses, which proves that the conducted measurements were correct. Sudden dips in the recorded measurement are caused by the indentations in the floor surface, and the descending trend of displacements (in the first phase of movement) – by the fact that the floor was not levelled. The presented results demonstrate that, apart from the irregular tyre envelope, the condition of the surface on which the wheel rolls also affects the dynamics of the suspension with omnidirectional wheels.

The recorded signal shows the excitations caused by the movement of the omnidirectional wheel, which allows us to claim that the designed test site enables testing the efficiency of the suspension structure (Fig. 8). Efficiency tests may be conducted by means of comparing the obtained courses with the courses recorded for an omnidirectional wheel mounted directly on the column (Fig. 5). The proposed test site, apart from numerical modelling methods, may be used in the search for an optimum structural form of an omnidirectional wheel or of the connected suspension system.

4. Conclusions

The article presents a test site for determining the dynamic interactions caused by the irregular envelope of an omnidirectional wheel. The obtained courses and their analyses will be discussed in further papers.

Acknowledgments

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