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The concept of the application of modelling and simulation to simplify and reduce the cost of durability tests of vehicles and their components

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Abstract. The paper deals with durability tests of road vehicle components. They may be performed in a real work environment or in the laboratory. New or modified structures of vehicles and their components should and are tested in an accelerated manner in real or simulated conditions, corresponding to the anticipated conditions of use. The work presents the concept of using modelling and simulation to determine the inputs during the tests of the car's structural components (assemblies, subassemblies, and parts), without the need to test the entire vehicle. The author proposes the use of physical and mathematical models of vehicles to determine the excitations affecting the assembly, subassembly, or element of interest during the research tests of the entire vehicle. This approach reduces the dimensionality of the experimental research and limits its scope to the structural node of interest, which in turn reduces the costs. The next, more extensive publication will present an exemplary application of the presented concept.

Keywords. durability tests, laboratory tests, modelling, simulation, costs reduction, vehicle

1. Introduction

New or modified structures of vehicles and their components should and are tested in an accelerated manner in real or simulated conditions, corresponding to the anticipated conditions of use [2, 4, 5, 14, 16, 17, 20, 21, 22, 23]. Granting a product of different types (e.g. a safety certificate) requires an appropriate cycle of tests to confirm their suitability under the target operating conditions [20]. Durability tests of the structure and validation tests of the prototype are also important [2, 4, 5, 14, 16, 17, 20, 21, 22, 23]. Tests in real conditions (traction or field) are very long-lasting, expensive, and the most dangerous. Simulation tests on simulation stand significantly accelerate the product testing process; it also becomes repetitive [16, 17]. Manufacturers of vehicle structural components (assemblies, subassemblies, and parts) are mainly interested in testing their products; fewer other elements of the vehicle structure - this is the domain of activity of the final vehicle manufacturer (OEM) [5, 22, 23].

The author presents a proposal for the use of modelling and simulation to determine the test conditions for structural components (assemblies, subassemblies, and parts), without the need to test the entire vehicle. The construction of a mathematical model of the car's motion under representative operating

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conditions allows for simulation tests in the frequency and/or time domain [3, 6, 7, 8, 9, 10, 11, 15, 18, 19], leading to the determination of load time courses selected items. They can be used in the research of the vehicle structure nodes of interest to us: axle axles, wheel hubs, tires, elastic and damping suspension elements, couplings of vehicle assemblies (saddle - kingpin, towing hook - trailer drawbar towing hitch). The anticipated benefit is the limitation of the scope of research to the structural node of interest to us, which reduces the "dimensionality" of the research process and its costs.

2. Examples of stands for the simulation of operational loads of vehicles and their construction nodes

Simulation tests of vehicles, their assemblies, and components have been conducted for several dozen years all over the world [2, 4, 16, 17]. In Poland, the leading role (for many years) is played by the Automotive Industry Institute (currently Łukasiewicz - Automotive Industry Institute), both in the field of research methodology [16, 17] and practical applications [16, 17, 20]. In recent years, even private manufacturers of the automotive sector have built research centres and applied the methodology of durability testing and validation of prototypes [22, 23]. For this purpose, the available production offer of advanced test stands and devices together with control software (for example [14, 21]) is used.
However, methods of the most accurate reflection of the real load conditions of vehicles and their design nodes are still sought, allowing the accelerated and possibly low-cost checking of the tested structures.

3. Methods of conducting bench simulation tests of operational loads of vehicles and their construction nodes

It is worth quoting the words of the work, the authors of which have conducted simulation tests for many years [17]: "Laboratory test-band research gives better possibilities and, at the same time, the possibility of evaluating the vehicle in a relatively short time. (...). Generally, bench tests are poor in input signals and are also artificially shaped; However, they provide much greater possibilities of measuring output signals, both in terms of their number and type; moreover, they have a very important feature: repeatability of tests". The same authors note that each experimental research can be regarded as a certain simulation of real events, only its accuracy, scope, and purpose for which it is carried out differ.
Simulation test stands are built for various tests, both in terms of their purpose and completeness of the vehicle. There are stands for whole cars (fully equipped), partially disassembled (not fully equipped), individual assemblies, as well as selected parts of the vehicle.
The experimental simulation (on laboratory stands) is carried out (Fig. 1) in two variants [17]:

- in variant 1 (*simulation based on input signals*), the signals controlling the vibrators of the stand are predetermined, e.g. based on measurements of geometric unevenness of the road surface that we want to recreate;
- in variant 2 (*simulation based on output signals*), external inputs are introduced in such a way as to obtain the compliance of the values measured in the vehicle at the station and on the road (during previous measurements under imposed conditions).

The authors of the work [17] draw attention to the fact that in variant 1 there is a risk of distorting the output signals of the forcing devices if the conditions of the input (on the stand) on the vehicle differ significantly from the actual ones. The most frequently quoted example is the lack of rotation of road wheels during bench tests, which significantly changes the dynamic properties of the pneumatic wheel. It is worth noting, however, that in modern stands, forcing a rotating wheel is introduced. However, this significantly increases the cost of the stand and the test itself.
For similar reasons, in variant 2, the input signals are distorted, because the compliance of the selected signal during bench tests and in road conditions is important.

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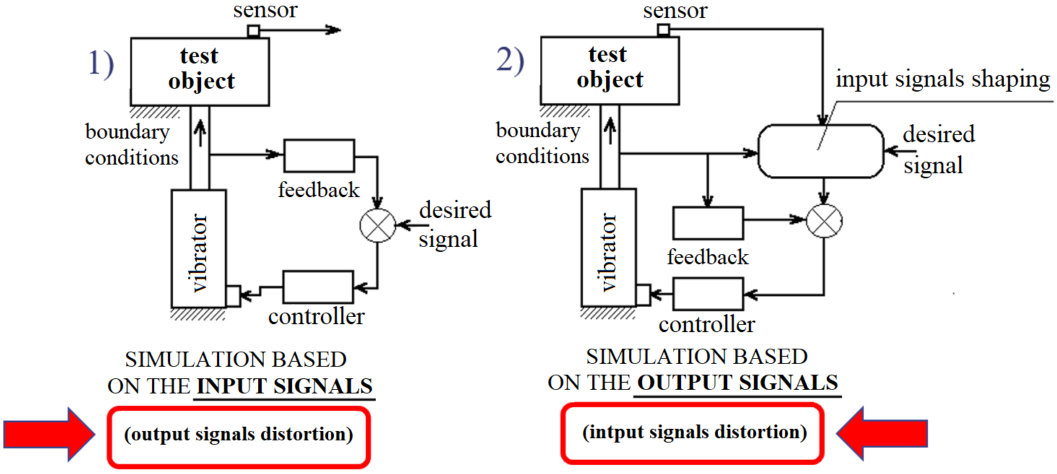

Figure 1. Variants of research in the experimental simulation (the figure was prepared based on Fig. 7.9 in the paper [17]).

4. The essence of the proposed method

A digital simulation will be used - on a computer, using a mathematical model of a real object, along with models of inputs and outputs. It is carried out in variant 1 (*simulation on the basis of input signals*) - with the use of input signal (excitation) models. These are road unevenness, aerodynamic effects of air, internal forces (driving and braking torques, turning angles of the road wheels), resulting from the activity of the vehicle driver.

The mathematical model/simulation model of the vehicle includes the model of the structural node of interest with the model of inputs and outputs (Figs. 2 and 3). Assuming an excitation representative for the operating conditions of the object, we use this model to determine the excitation acting on the vehicle structure node of interest to us. This extortion can be used in the experimental simulation of loads of the structural node on a laboratory stand, which reduces the "dimensionality" of the test process and their costs.

The determined time courses of loads (corresponding to representative conditions of their operation) can be used in the tests of the vehicle design nodes of interest: wheel axles, wheel hubs, tires, elastic and damping elements of suspensions, couplings of vehicle assemblies (saddle - kingpin, towing hook - hitch tow bar of the trailer).

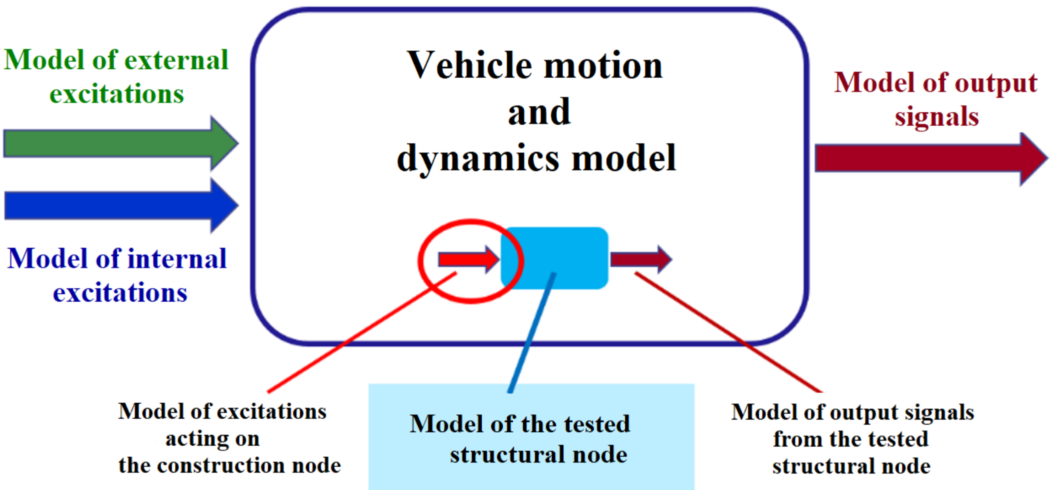

Figure 2. Determining the excitation acting on the selected vehicle structure node.

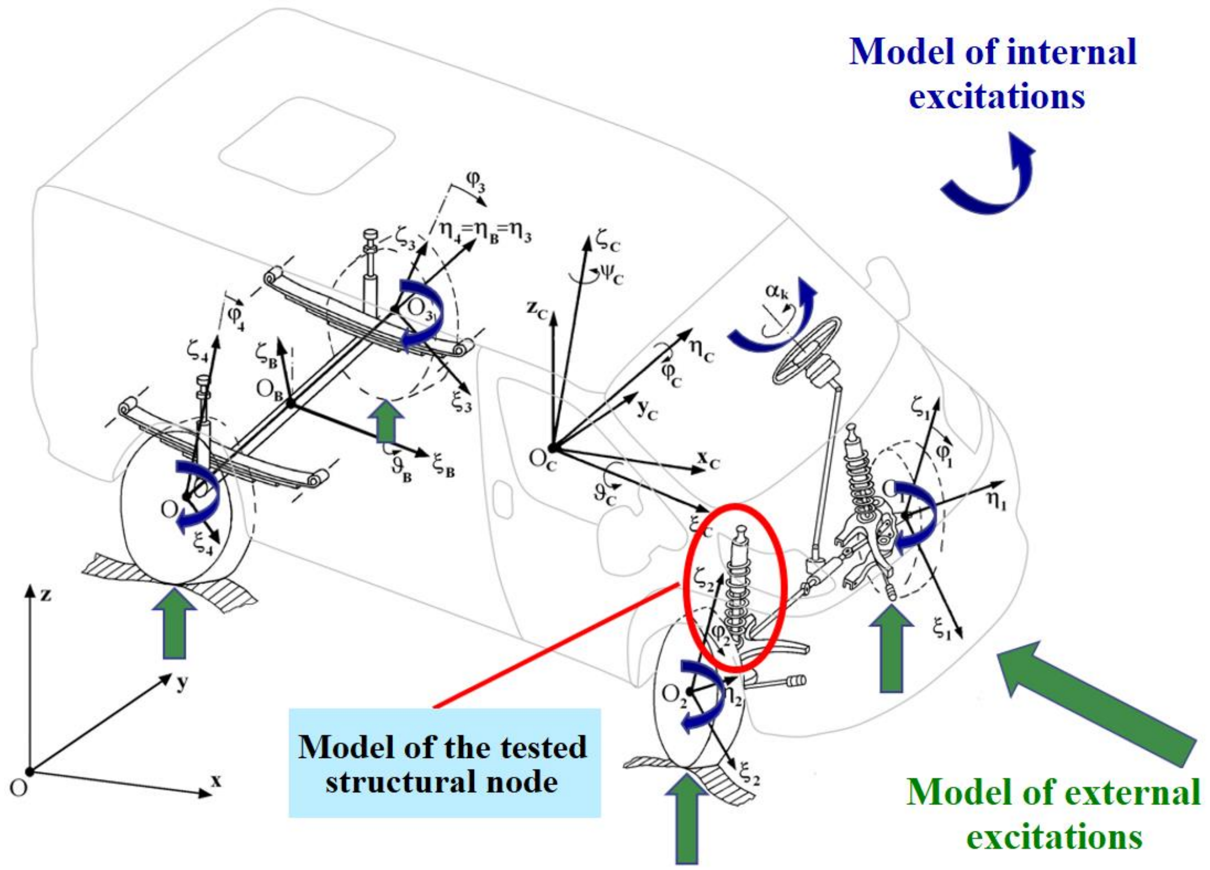

Figure 3. Determining the excitation acting on a selected construction node of the vehicle, using a digital simulation of working processes accompanying the vehicle movement (the own drawing presented in the paper was used [10]).

5. Examples of simulation models of motion, and dynamics of road vehicles

Models of this type have been used for several dozen years in the study of motion, and vehicle dynamics. They are widely presented in monographs [1, 4, 6, 7, 9, 12, 13, 19].

The author has built many own, original models and simulation programs, described in the works [8, 9, 10, 11]. They can be used to determine the input acting on a selected vehicle structure node, as schematically shown in Fig. 3, in the case of the elastic and damping element (coil spring and hydraulic damper) of the front wheel suspension of a passenger car.

6. Recapitulation

The presented concept of the use of modelling and simulation to determine the input during tests of structural components of a car requires verification for example applications. The author expects to present a much more extensive publication in the future, containing such an example - the use of a road vehicle simulation model in the study of the construction node. The physical and mathematical model of the vehicle under consideration will be described.

References

[1] Arczyński S 1993 *Mechanika ruchu samochodu* (Warszawa: WNT)
[2] Azrulhisham E (et al.) 2011 *Application of road simulator service loads in automotive component durability assessment.* (The Open Industrial & Manufacturing Engineering Journal vol 4) pp 1–7
[3] Dukkipati R (et al.) 2008 *Road vehicle dynamics* (Warrendale: SAE International USA)

[4] Gierulski W 1991 *Kształtowanie drgań w stanowiskowych badaniach symulacyjnych* (Kielce: Zeszyty Naukowe Politechniki Świętokrzyskiej Mechanika 46) PL ISSN 0239-4979
[5] Kaczor M and Januszka M 2019 *Optymalizacja konstrukcji naczep z zastosowaniem symulatora drogi MTS* (Mechanik No 1/2019) pp 52-54 (DOI: https://doi.org/10.17814/mechanik.2019.1.10)
[6] Kamiński E and Pokorski J 1983 *Teoria samochodu Dynamika zawieszeń i układów napędowych pojazdów samochodowych* (Warszawa: WKŁ)
[7] Kasprzyk T and Prochowski L 1990 *Teoria samochodu Obciążenia dynamiczne zawieszeń* (Warszawa: WKŁ)
[8] Lozia Z 1990 *Analiza wpływu podatnego zamocowania haka holowniczego na dynamikę zestawu samochód - przyczepa w ruchu prostoliniowym ze stałą prędkością* V Konferencja Naukowa Instytutu Transportu Politechniki Warszawskiej "Nauka i praktyka w transporcie". Warszawa, 19-21.09.1990 Materiały pp 116-123
[9] Lozia Z 1998 *Analiza ruchu samochodu dwuosiowego na tle modelowania jego dynamiki*. (Warszawa: Prace Naukowe Politechniki Warszawskiej. Transport Zeszyt 41)
[10] Lozia Z 2015 *Examples of authorial models for the simulation of motor vehicle motion and dynamics* (Warszawa: Zeszyty Naukowe Instytutu Pojazdów PW vol 04 No 4) pp 9-27
[11] Lozia Z 2016 *The use of a linear quarter-car model to optimize the damping in a passive automotive suspension system – a follow-on from many authors' works of the recent 40 years* (Warsaw: The Archives of Automotive Engineering – Archiwum Motoryzacji vol 71(1)) pp 39-71 http://dx.doi.org/10.14669/AM.VOL71.ART3
[12] Mitschke M 1977 *Teoria samochodu Dynamika samochodu* (Warszawa: WKŁ)
[13] Mitschke M 1989 *Dynamika samochodu Drgania* (Warszawa: WKŁ)
[14] *MTS Model 320 Tire-Coupled Road Simulators Versatile repeatable road simulation for the full range of vehicle sizes and application* (MTS booklet available as: https://www.mts.com/cs/groups/public/documents/library/ dev_002219.pdf) (Google attempt: 2020-02-1).
[15] Osiecki J W 1994 *Dynamika maszyn* (Warszawa: Wojskowa Akademia Techniczna)
[16] Osiecki J W 2004 *Badania pojazdów samochodowych i ich zespołów na stanowiskach badawczych* (Kielce: Politechnika Świętokrzyska Specjalne zagadnienia mechaniki i sterowania) ISBN 83-88906-16-x pp 19-49
[17] Osiecki J W Gromadowski T and Stępiński B 2006 *Badania pojazdów samochodowych i ich zespołów na symulacyjnych stanowiskach badawczych* (Radom: Wydawnictwo Instytutu Technologii Eksploatacji – PIB) ISBN 83-7204-510-0
[18] Osiński Z 1978 *Teoria drgań* (Warszawa: PWN)
[19] Prochowski L 2005 *Pojazdy samochodowe Mechanika ruchu* (Warszawa: WKŁ)
[20] Homepage Łukasiewicz PIMOT. Laboratorium BLY: https://pimot.lukasiewicz.gov.pl/index.php?option=com_content&view=article&id=40&Itemid=222 (Google attempt: 2022-03-07)
[21] Homepage MTS: https://www.mts.com/home/ oraz https://test.mts.com/industries/automotive (Google attempt: 2022-03-07)
[22] Homepage firmy Wielton: https://wielton.com.pl/ oraz https://wieltongroup.com/innowacyjnosc/ (Google attempt: 2022-03-07)
[23] Homepage 40ton.net (motoryzacja dla profesjonalistów): https://40ton.net/zobacz-jak-dziala-i-do-czego-sluzy-centrum-badawczo-rozwojowe-firmy-wielton-otwarte-wczoraj-w-wieluniu/ (Google attempt: 2022-03-07)