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EXPERIMENTAL RESEARCH ON IDENTIFYING DATA FOR MODELLING SPECIAL PURPOSE VEHICLES

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Abstract

The work presents selected results of experimental research on special purpose vehicles used on military training grounds, and bench tests of their main structural elements. The results are connected mainly with identifying the main vibration parameters of those vehicles (regarding weight, resilience and damping), and with the assessment of the level of dynamic loads. The more output data experimental research provides, the more input data we have for designing models. Determined in laboratory tests, weight parameters (regarding weight and moments of inertia), coefficients of stiffness and damping, as well as selected resilience and damping characteristics, are applied in the process of creating the numerical models of assemblies, systems, and complete vehicles. The numerical models created are subject to full verification in order to minimize the differences between the real objects and their representations. The models are applied in multivariate simulation tests of the existing design solutions, upgrading them, or creating new designs. Due to a certain sensitivity of the range of special purpose vehicles, the results of experimental tests and simulation analyses presented in the work are mainly qualitative rather than quantitative.

Keywords: *special purpose vehicle, combat vehicle, loads, experimental research, modelling*

1. Introduction

Multitude of tasks to be performed, dynamic development of combat vehicles, and variety of risks under complex operating conditions, make it necessary, on almost ongoing basis, to modify the existing construction designs of special vehicles, or creating new ones. Upgrading includes introducing innovative technical and construction solutions, which determine the comfort, safety, and survivability of the vehicle and its occupants. At the same time, intensive work is performed regarding the design of new vehicles, which are equipped with modern systems and assemblies ensuring heightened protection. Before designing a new special purpose vehicle or introducing modifications, multivariate model tests are conducted, involving analysis of impact of various dynamic loads occurring during operation, e.g. due to road unevenness, shooting, IED explosions, projectile hitting etc. Fig. 1 depicts special purpose vehicles during operation under various conditions. Conducting multivariate simulation tests requires creating computational models of vehicles, generating model loads of a modern battlefield and modelling conditions of movement.

Designing numerical models of vehicles and systems used there requires information on the real object being modelled. It is necessary to identify (to know) the basic data, including material properties, parameters regarding weight, resilience, damping, geometry etc. Some of the parameters may be acquired by analysing literature or determined on the basis of experience and expert knowledge.

The key data is determined experimentally. In case of combat vehicles (tanks, infantry fighting vehicles, armoured personnel carriers, etc.), a number of technical parameters has to be taken into account, which must be in accordance with the values included in preliminary technical-tactical requirements.

a) *Truck STAR266M2 [13]*

b) *Main battle tank Merkava [14]*

c) *Wheeled armoured personal carrier Rosomak [15]*

d) *Main battle tank M1 Abrams [16]*

Fig. 1. Special purpose vehicles under complex operating conditions

The latter are highly varied but also interconnected, with regard to both construction and operation parameters, and survivability during combat missions. Generally, research and development, including a variety of experimental research (bench tests, military training ground tests etc.) are directed towards three basic features of special purpose vehicles, including: firepower, protective qualities and mobility. The above is true also for combat vehicles. In the case of transport, vehicles or those designed for other purposes, depending on the area and conditions of operation, mobility is important, whereas the protective qualities may be only a useful addition. The main purpose of the research is to obtain complete and trustworthy results, which help in assessing the qualities, as well as combat and technical value of the vehicle tested. The tests are conducted in accordance with the procedures specified in defence standards. For example, PN-V-80000:1998 standard sets out requirements regarding all the armoured military wheeled vehicles. The document specifies basic technical parameters, general requirements regarding conditions of operation, construction requirements and requirements regarding special equipment of the abovementioned vehicles. Standards [3-6] and a number of others include detailed information and guidelines regarding requirements, accuracy, method and structure of testing in accordance with the plan, with high quality maintained. In the allied armies of NATO, the tests are subject to AVTP (Allied Vehicle Testing Publications), regarding mutual acceptance of the results of the tests regarding the evaluation of mechanical military vehicles in accordance with NATO standards. The form of AVTP procedures is strictly defined and the document contains guidelines connected with the protection of classified information regarding the results of the tests. The work includes the presentation of selected results of laboratory tests involving determining the basic vibratory parameters of a special purpose vehicle (regarding weight, resilience and damping), applied in the process of creating the models of assemblies, systems and complete vehicles. The models created in the manner described above are used in multivariate simulation tests of the existing design solutions, upgrading them, or designing a new construction [1]. The main purpose of model tests [10, 11] is to determine the impact of various dynamic loads on the crew and on the frame of the combat vehicle, deformation of the bottom of the vehicle, location of the technological bases (places of installation), evaluation of active and passive protection provided by the armour, and the limits of the factors unfavourable to the lives and health of the crew (e.g. depending on the kind of threat and its destructive properties). It is worth stressing that the safety of the crew and transported troops is one of the basic requirements.

Due to the kind of analysed military vehicles (or their models), the presented results of conducted bench tests, military training ground tests, and measurements of important parameters, serving as input data for modelling, are mainly qualitative rather than quantitative.

Special purpose vehicles are operated in untypical and very complex load conditions, including meteorological, geographical, and connected with the features of the terrain, as shown in Fig. 1. The area of a military conflict or of some mission activities, its variety and the pressure of constant threat – all of this poses for the crew of the military vehicle a complicated, multi-criteria problem of its survivability on the modern battlefield (or place of a conflict). Military vehicles are expected to meet complex and varied conditions. For example, the preliminary tactical-technical requirements for universal container bodies for specialist bodywork include the following decision areas: general construction requirements; operation; technology; safety; transport vulnerability; storage; simplicity of operation and repairing; ergonomics and technical aesthetics; reliability; vehicle lifetime and environmental resistance; radio-electronic protection; compatibility and interchangeability; camouflage effectiveness; technical and economical requirements; kinds of protection; materials and completing products; maintenance, packing and marking; special requirements; requirements regarding the manner of designing and production, as well as provisions of non-disclosure and manner of testing, implementing and manufacturing; guaranty; commissioning and implementation etc. The scope of requirements presented above is similar for the whole category of military vehicles and it includes complex requirements to be met under a variety of operating conditions.

2. Experimental research

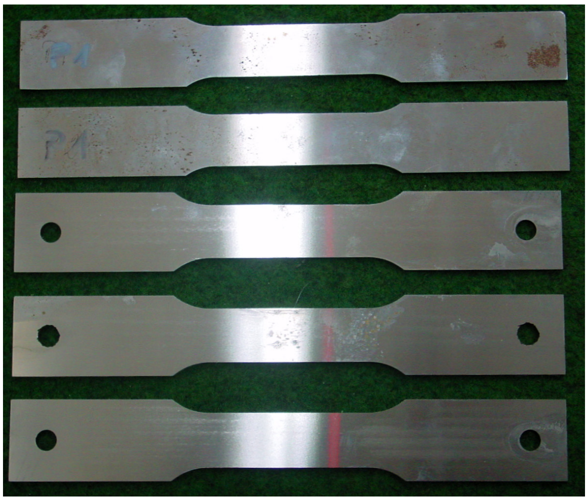
2.1. Bench tests

Bench tests can be conducted both on mobile and stationary benches. An example of a mobile testing bench are scales presented in Fig. 2, used for measuring the load distribution for each of the wheels, and therefore for each of the axles of the vehicle. This data is very important for meeting the requirements of the law regarding traffic and moving through different kinds of terrain.

Fig. 2. Weight distribution testing for STAR 266M2 vehicle with special body

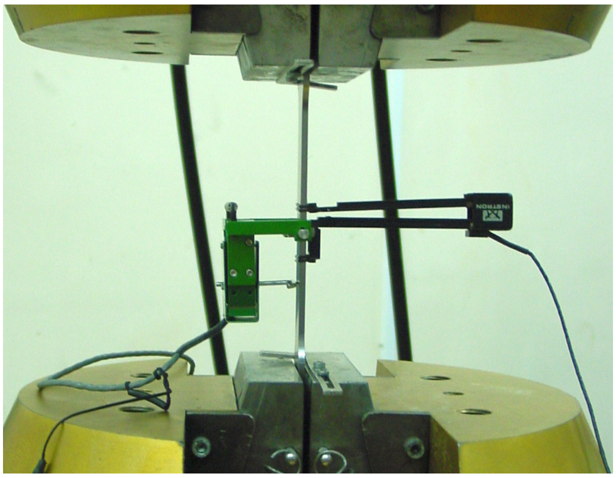
Universal endurance-testing machines, e.g. Instron, are used to determine the parameters describing the qualities of construction materials used in the existing vehicles, or materials selected for construction elements of the designed vehicles. Fig. 3 shows photographs of the samples of steel materials taken before the tests, an exemplary sample after the test (after breaking), manner of assembling in the holding elements of the machine, and the chart of the results of pullout test.

Resilient elements and damping suspensions are very important elements in vehicle construction, in particular in the case of military vehicles, designed for hard terrain conditions, ensuring proper safety and comfort of transport. Therefore, it is important to know the properties of these elements. The data is acquired from bench tests. Fig. 4 presents the fragments of multi-variant tests of pneumatic bellows, and Fig. 5 shows the characteristics allowing for determining the parameters interesting from the point of view of modelling. Fig. 6 presents a photograph from the tests and acquired characteristics of double-acting telescopic hydraulic shock absorber.

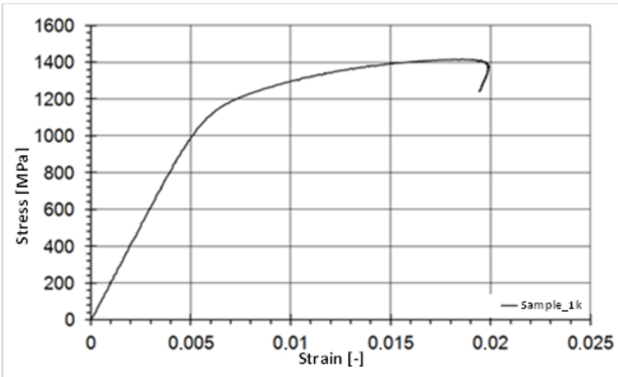


a) Alloy steel samples before the test

b) One of the samples after the tests



c) A sample installed in the holding elements of the testing machine



d) Pull-out chart for Sample_1k

Fig. 3. Testing the qualities of construction materials

Elastomer is one of the most interesting construction materials with regard to resilience and damping qualities, especially with regard to energy absorption. Fig. 7 presents a photograph from the multi-variant bench tests at the strength-testing machine, and one of the characteristics acquired at the enforcement frequency.

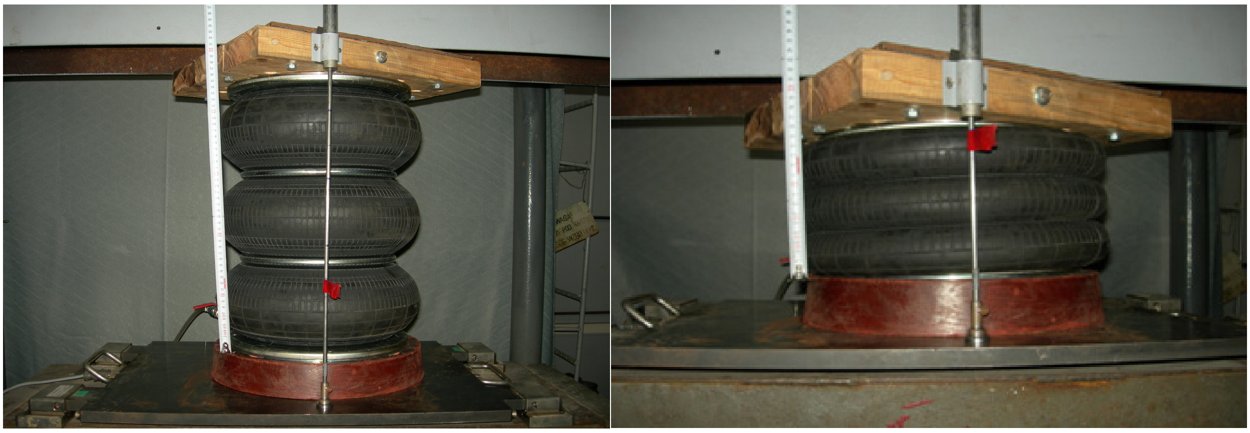
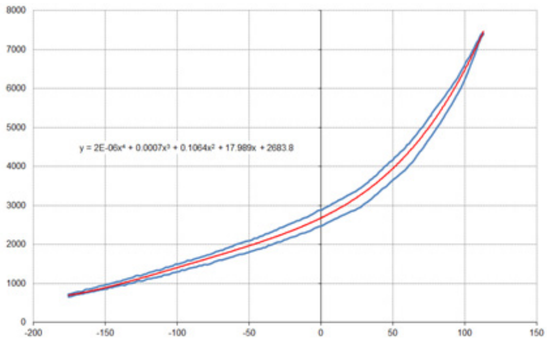
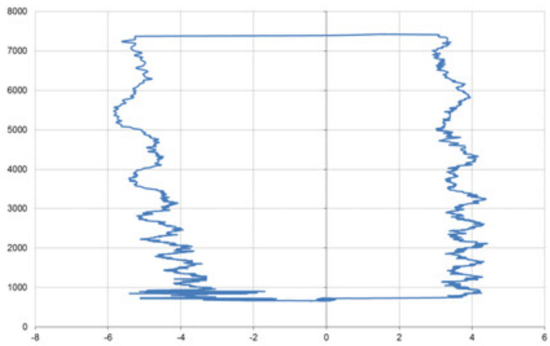


Fig. 4. Tests of the pneumatic shock absorber (pneumatic bellows): a) location of the maximum operating length, b) location of the minimum operating length



Stiffness characteristics of the bellows for static pressure p_s=0.4 MPa



Damping characteristics of the bellows for static pressure p_s=0.4 MPa

Fig. 5. Characteristics chart for pneumatic bellows

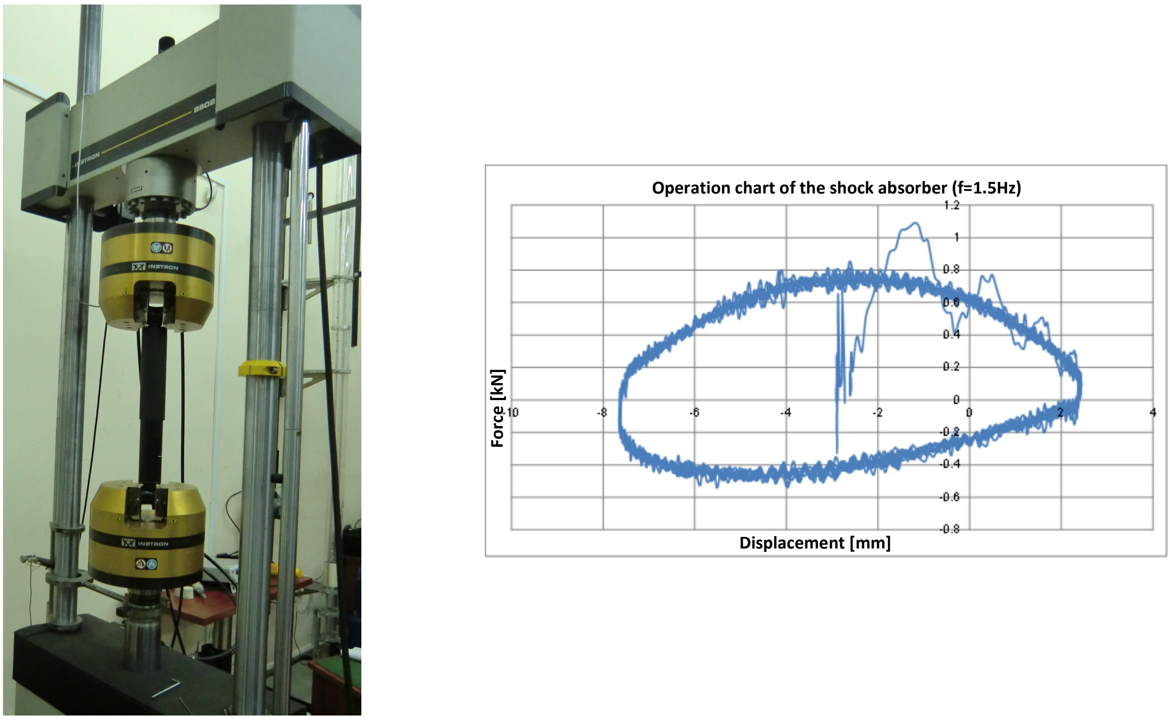
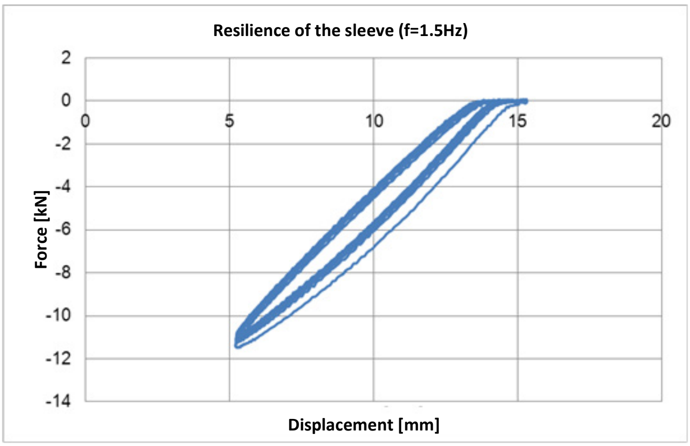


Fig. 6. Tests of the double-action hydraulic shock absorber: a) shock absorber at the bench, b) operation chart of the shock absorber

a)



b)

Fig. 7. Tests of the elastomer bushing: a) bushing at the bench, b) resilience characteristic of the bushing

2.2. Road tests and military training ground tests

The results of experimental research conducted on the road and on military training ground for military and special purpose vehicles, which were used to design their computer models, are presented in Fig. 8. The results of this type of experimental research and their thorough analysis allow for determining the parameters responsible for the dynamic qualities of the vehicles and for verifying the models being designed.

a) medium tank during military training ground tests, impacted by an explosion

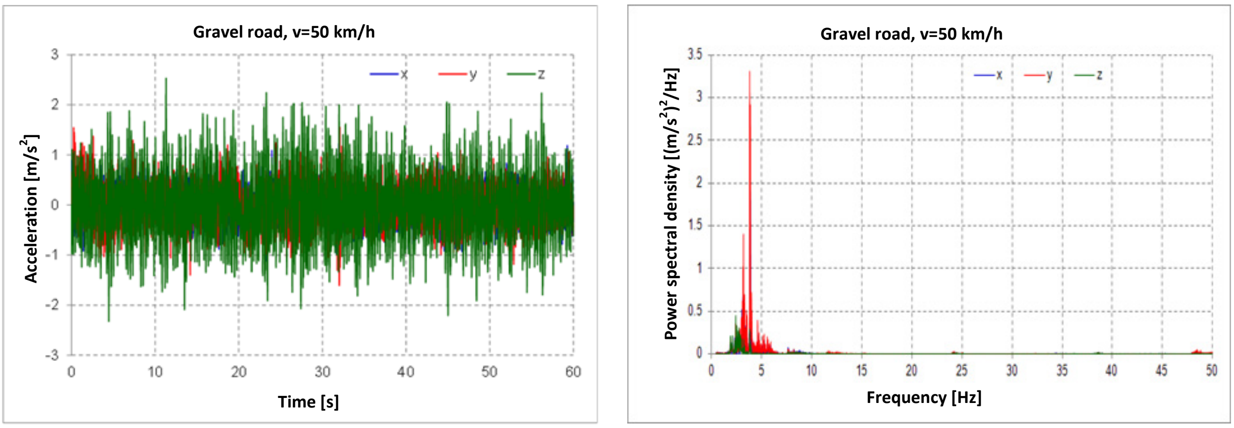
b) Anders tank firing

c) transport assembly during road tests

d) special purpose vehicle during field test

Fig. 8. Military and special purpose vehicles during road tests

Figure 9 presents exemplary courses of vertical acceleration over time and a chart of spectral density of vibrations during the road tests of one of the special purpose vehicles.

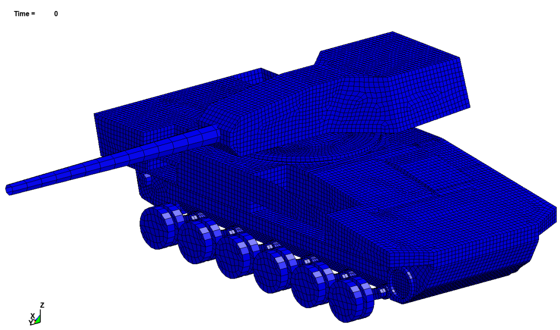


a) changes in acceleration over time *b) spectral density chart of the accelerations*

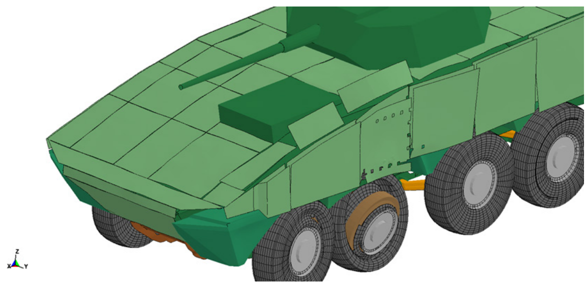
Fig. 9. Selected results of the experimental research on a special purpose vehicle

3. Summary and conclusions

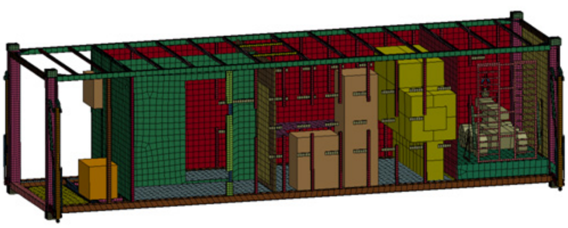
Presented above selected results of the measurements (including geometry and shape), experimental bench tests, road tests, and military training ground tests, and the analysis of the results, served as a basis for designing models of military and special purpose vehicles. As a result, the acquired models are reliable and they highly correspond with the real objects. Some of the models are presented in Fig. 10.



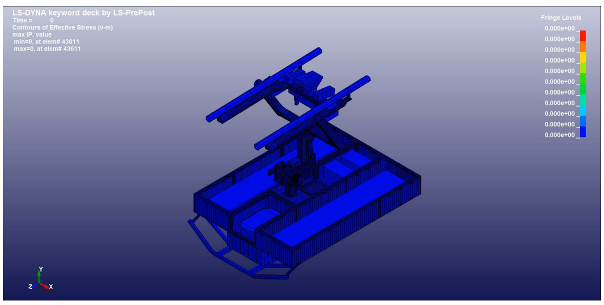
Anders Tank model



Model of Rosomak armoured transporter



Special container model



Model Launcher Crossbow

Fig. 10. Selected vehicle numerical models

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