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THE RESEARCH ON DYNAMIC LOADS AND TRACTION PROPERTIES OF MILITARY VEHICLES IN THE ASPECT OF IMPROVEMENT OF THEIR STRUCTURES

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Abstract

Since the beginning of the 90's, a scientific team in the Motor Vehicle and Transport Institute of the Mechanical Department in the Military University of Technology, has been involved in the model and experimental tests of the existing structures of the military vehicles (tanks, combat infantry vehicles and wheeled armoured carriers) in the aspect of their modernization. A part of works is related to the military vehicles included in the army's equipment and the other parts are related to newly designed vehicles. In both cases issues related to the behaviour of selected assemblies and the whole vehicle, structure during threats posed by the reality of contemporary battlefield or armed symmetric or asymmetric conflicts are analysed. Selected effects of the tests and analyses will be presented mostly within the qualitative scope due to the data sensitivity.

Contemporary design of military vehicles requires involvement of various research methods and specialized calculation software. The results obtained during performed various experimental tests make a valuable basis for verification of numerical models used in design process and multi-option simulation calculations.

Keywords: *military vehicle, dynamic loads, traction, model tests, experimental tests*

1. Introduction

Military vehicles (tanks, combat infantry vehicles and wheeled armoured carriers) are the most common means of combat by the land troops. They are able to execute various combat and stabilization tasks in various geographical, terrain and weather conditions, under direct enemy's shellfire including the weapon of mass destruction. In general, the quality and usefulness of military vehicles is evaluated on the basis of the following criteria:

- firepower,
- armour (protection properties),
- mobility

The firepower is a set of factors characterizing the main armament – the gun: its calibre and the length of the barrel, rate of fire, range of absolute shot, the ability to fire various ammunition and the quality of cooperating loading systems and fire control systems.

Basic and active armour, ABC protection systems, camouflage and target recognition systems and additional systems supporting their identification make a complex protection of the crew and internal equipment of the combat vehicle against means and striking factors of the enemy's weapon.

Mobility is characterized by vehicle's ability to reach high accelerations and delays at sudden changes of direction of motion when moving on any ground. The mobility of the military vehicle depends on the following conditions: combat weight, geometrical dimensions, engine and drive system, suspension, wheeled or caterpillar chassis and other conditions. Versatile development of armour-piercing means and complexity of military actions imposes on the manufacturers of military vehicles a need to carry out intense works on efficient solutions that increase a probability of survival of people and a vehicle. Succeeding in the execution of combat tasks depend on many factors e.g. tactical situation of an armed conflict, topography etc. While from the point of view of the vehicle structure resistance and safe working conditions for the crew, variable dynamic loads during intense use have a decisive influence. Presented results make the achievements of many years of own tests (experimental and model ones), obtained during execution of various scientific-research works.

2. Tests of dynamic loads affecting military vehicles

When using military vehicles in any conditions (geographical, terrain, weather), dynamic loads resulting from various sources e.g. drive system, braking system, turning, natural and artificial terrain obstacles, uneven terrain, firing a gun, explosion of armour-piercing mines and other sources, are generated.

2.1. Experimental tests

The main purpose of performed experimental tests was to evaluate the size of dynamic loads affecting the military vehicles (Fig. 1) and their selected systems, assemblies and the crew and to obtain information about the tested object, necessary for verification of calculation models, created by the team, used in the simulation tests.

a)

b)

c)

d)

Fig. 1. Military vehicles taking part in the experimental tests: a) a tank during explosion of a model explosive under its bottom; b) a tank during the armament stabilization system tests on the military training area; c) wheeled armoured carrier during off-road driving; d) a prototype ANDERS tank during road tests

The tests on the supporting structure of the KUSZA launcher in the aspect of increasing its resistance to the operation loads (Fig. 2) make another example of the experimental tests.

a) b)

Fig. 2. Tests of the KUSZA launcher on the military training area in various conditions: a) autumn; b) winter

For the launcher motion at set speeds (v = 10-30 km/h) on the gravel road, making a representative section of the access road to the battle position, recorded values of forces in the structural nodes (frame – chassis) are typical for random enforcement and significantly lower than the values recorded for enforcements by a single unevenness. From the point of view of the crew work quality and military vehicle structure resistance, dynamic loads generated during firing from the main armament also have a significant influence (Fig. 3).

Fig. 3. Combat vehicle during firing from the main armament

The experimental test results are most often presented in a form of tabular specifications or time courses of selected physical values e.g. speeds and accelerations in interesting structural nodes of a military vehicle. For example, fig. 4 presents courses of accelerations recorded in selected locations of the military vehicle body when driving on a typical deformable ground.

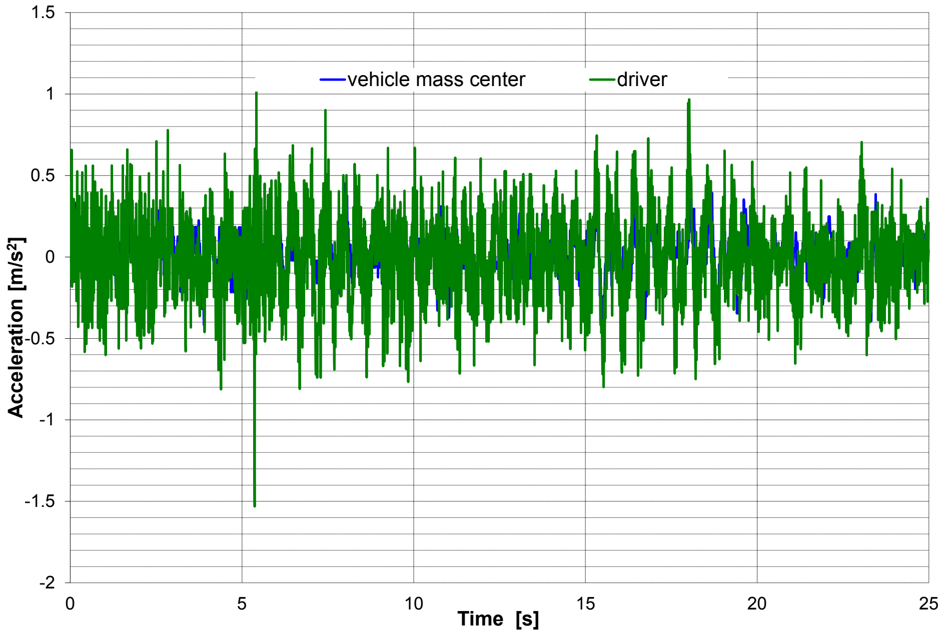


Fig. 4. Courses of accelerations recorded in selected locations of the military vehicle body when driving on deformable ground

Analysed the experimental test results, it was stated that dynamic loads affecting selected structural nodes of a tank, reach significant values even at low speeds. In battle conditions, there could be higher unevenness, which can result in significant increase of loads threatening the crew and the equipment. The values of loads mostly depend on the suspension quality and the speed of driving.

2.2. Model tests

Model tests, already at the stage of design or modernization, allow for estimating selected structural vehicle nodes or particular crewmembers in various variants of load influence: e.g. dynamic loads on the military vehicle crew or the influence of the explosive on the supporting structure of a military vehicle. The original discrete models (Fig. 5) or models prepared using the definite element method (Fig. 6) are used in the model tests.

a) b)

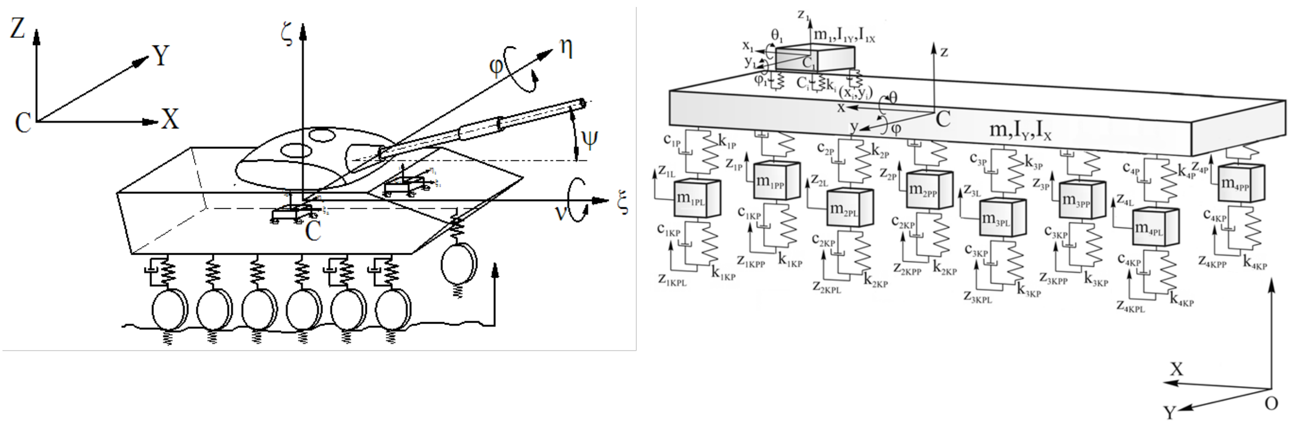
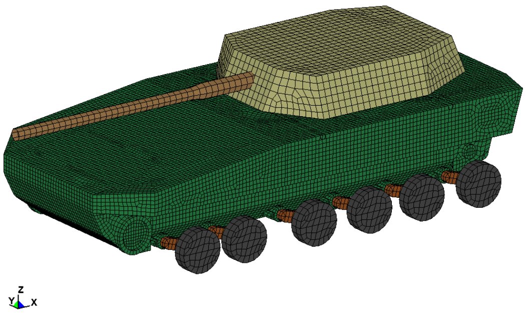
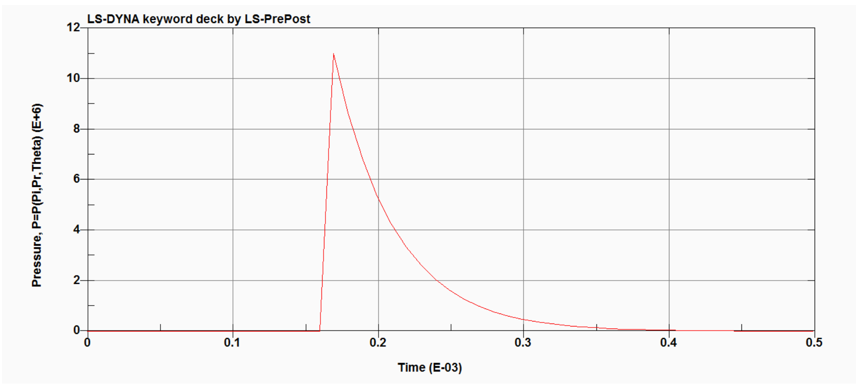


Fig. 5. Selected discrete models of the military vehicles used in the simulation tests: a) tank; b) 8x8 type wheeled vehicle



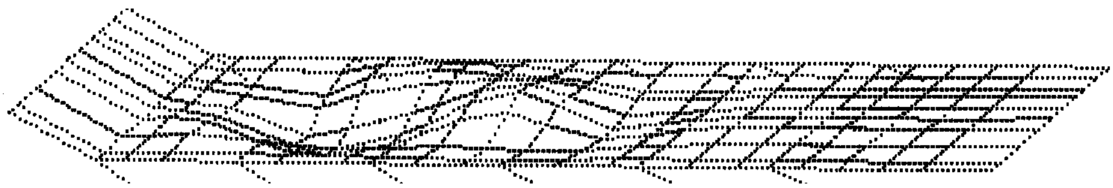
Object model



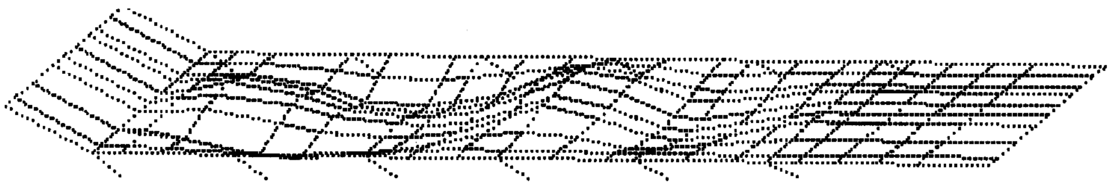
Model load

Fig. 6. FEM models for the impact load analysis

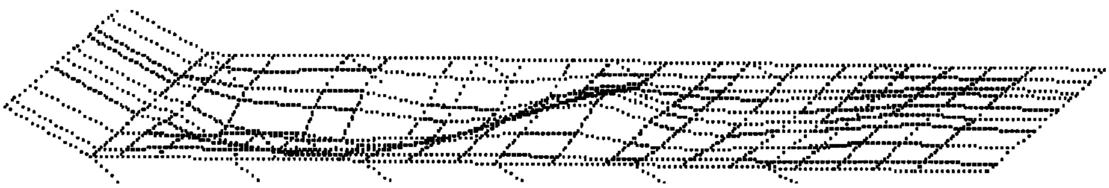
The above issues are solved by means of the original calculation software developed by the team as well as commercial numerical calculation software (systems). Examples of model test results are presented on figures 7-13. Fig. 7 shows a course of deformation of the body bottom plate in the time function, caused by a non-contact explosion.



t_1



t_2

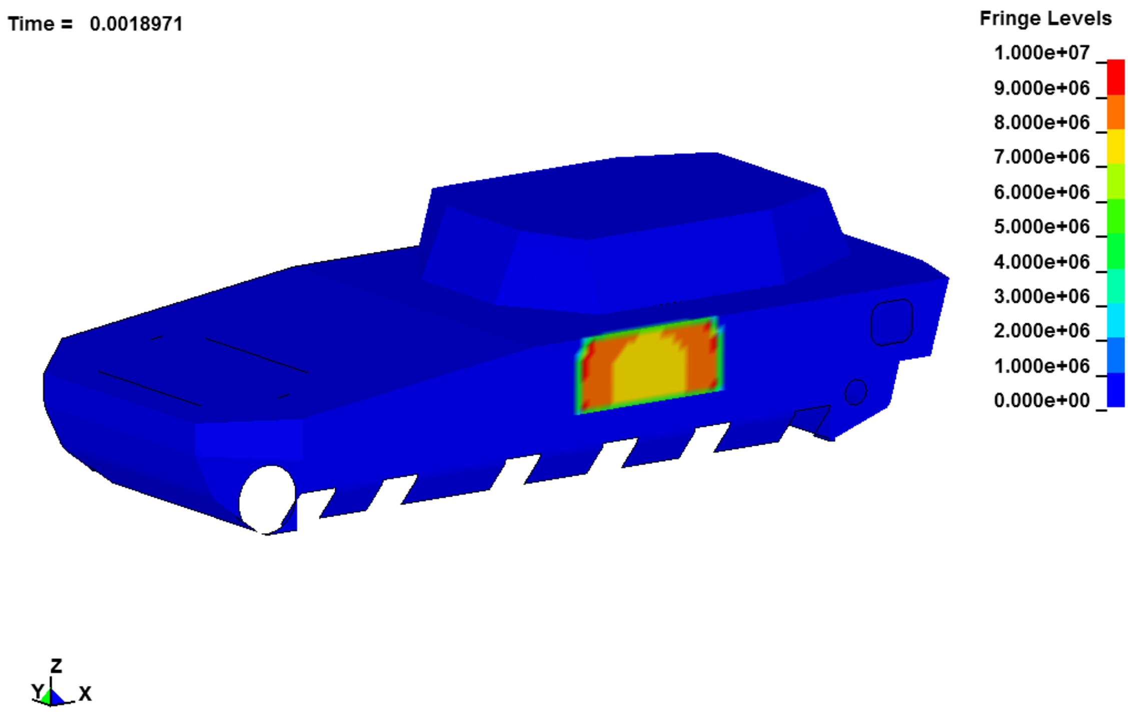


t_3

Fig. 7. Deformations of the vehicle bottom in various time, for $t_1 > t_2 > t_3$

Fig. 8 presents variations of stresses in the bodies of the military vehicles caused by various impulse impacts. Explosives are very often detonated under a vehicle bottom.

a)



b)

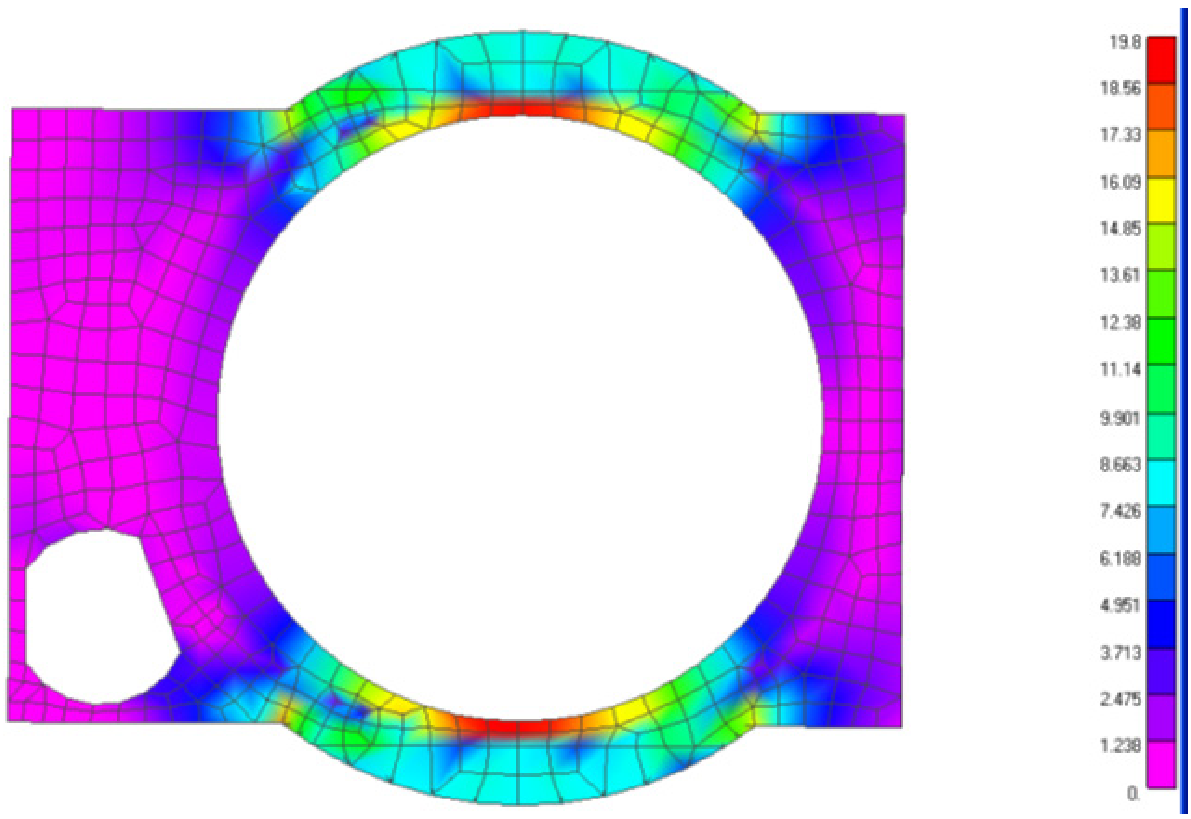


Fig. 8. Changes of stresses in the military vehicle bodies caused by: a) explosion of a side explosive, b) when firing a 105 mm calibre gun to the right side

Fig. 9 presents the effects of explosion of the explosive (*MW*) under the supporting structure of a vehicle for the following relation $MW_a < MW_b$.

a)

b)

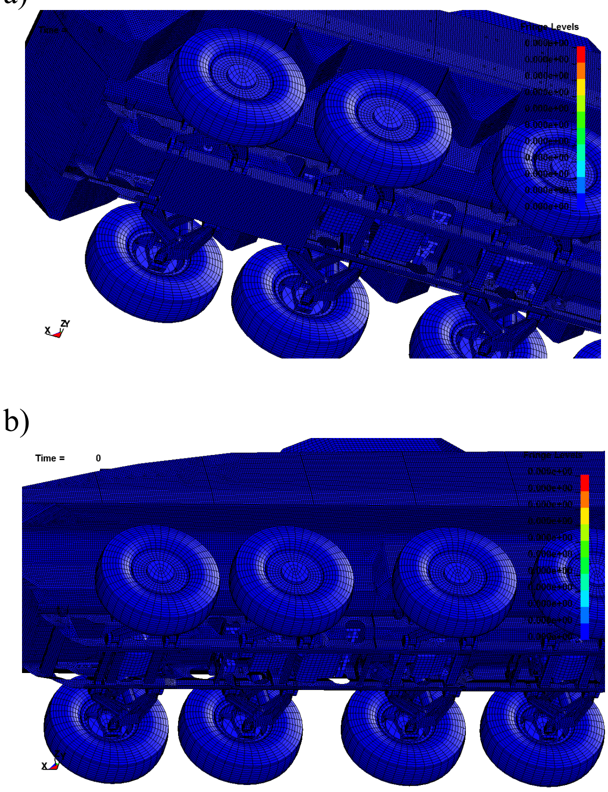


Fig. 9. Explosion of a mine under the supporting structure of KTO for various MW explosive weights, while $MW_a < MW_b$

The use of military vehicles to destroy or remove various road obstacles (barriers) makes an important problem when combatting terrorist attacks. An example of such situation is shown on fig. 10.

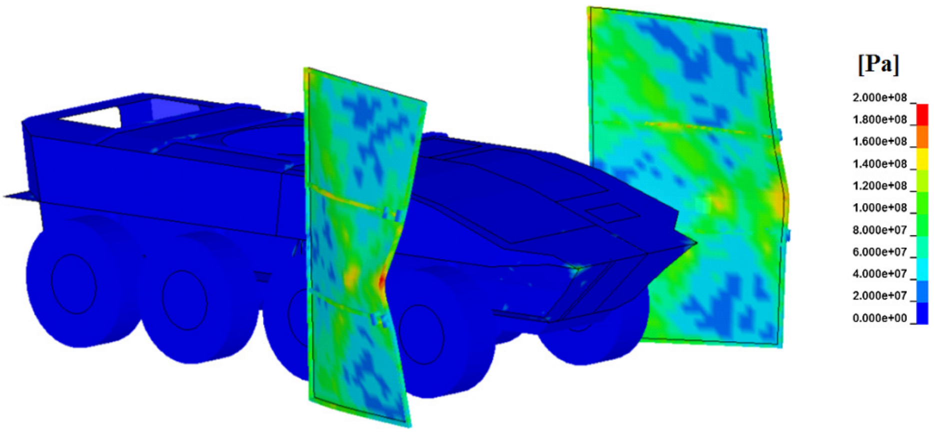


Fig. 10. A model of collision of a wheeled armoured carrier and the gate (ramming)

Depending on the gate resistance parameters and vehicle motion parameters, during ramming, occurring short-time accelerations affecting the crew can amount to app. 8-10 g and higher. In case of improper protection of the crew members, there is a high danger of exposure to various head, limb or torso injuries.

Other examples included development of a 30-feet container of increased resistance, designed as a mobile laboratory for environmental sampling and biological threat identification (Fig. 11).

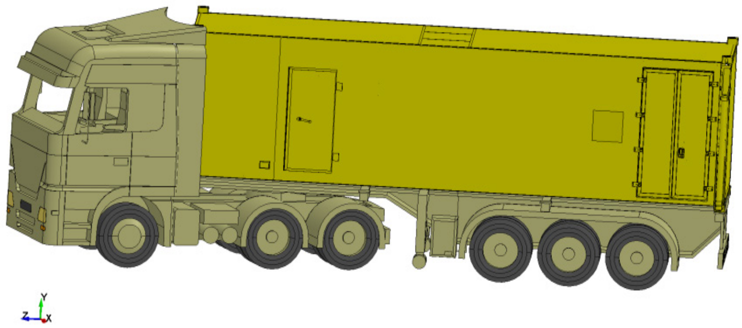
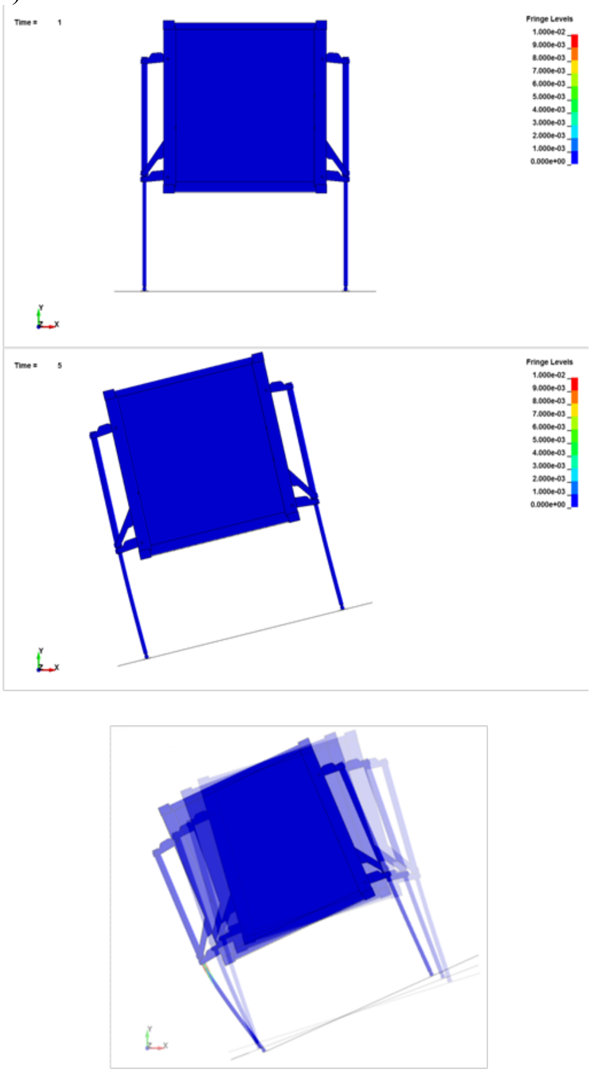


Fig. 11. Transport unit designed for transporting the laboratory-container, variant

Selected fragment of transverse container stability tests is presented on fig. 12.

a)



b)

Fig. 12. Transverse stability test of the laboratory-container: a) in simulation tests; b) experimental tests

Obtained results allowed for making resistance evaluation of selected structural nodes, loss of stability and checking the container during loading (unloading) manoeuvres on/from a trailer using autonomous hydraulic cylinders.

3. Traction property tests

The analysis of traction properties of the military (and other) vehicles is carried out already at design stage. A vehicle traction characteristic is prepared for predefined parameters of the drive system and selected source of drive (engine). Considering traffic and road conditions, the summarized drags are defined that decide on a possibility of reaching the maximum (minimum) speeds of driving in various conditions, the maximum accelerations when speeding up, crossing hills of various inclination angles etc. In case of modernized vehicles that require mobility improvement, the easiest structural intervention is to replace the drive unit – increase the engine horsepower. However, already at the modernization concept stage, the assemblies of the power transmission systems should be checked for resistance. Fig. 13 presents an example of caterpillar vehicle run characteristics set for two engines with different parameters.

After analytical check of obtained results, further verification is carried out during the tests on the military training area.

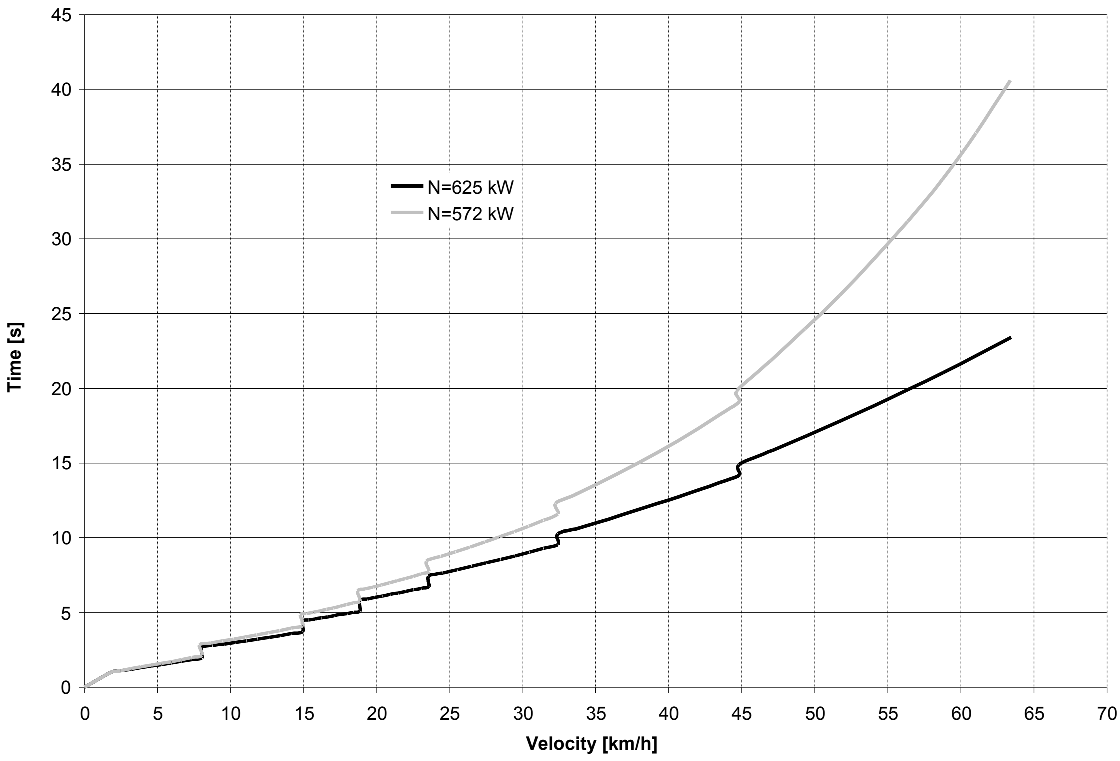


Fig. 13. Caterpillar vehicle running characteristics

4. Final conclusions

Contemporary design of military vehicles requires involvement of various research methods and specialized calculation software. However, in each case multi-option experimental tests should be carried out that will verify and allow for removing weak structural nodes of design or modernization.

The results obtained during performed various experimental tests make a valuable basis for verification of numerical models used in design process and multi-option simulation calculations.

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