SIMULATION TECHNOLOGIES SUPPORT IN CONSTRUCTION OF COMBAT AND SPECIAL VEHICLES

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Abstract
The paper is focus on usage of simulating technologies in construction of combat and special vehicles. Simulating technologies are widely spread in all of spheres of industry. These technologies offer a lot of advantages – e.g. evaluation of various vehicle configurations, simulation of various critical states of vehicle, comparison of vehicles in the same surrounding. This manner is suitable for vehicle evaluation, too. Paper consists of introduction, mathematic model description, terrain – obstacle description and simulation.

Keywords: simulation, vehicle, evaluation, obstacle. .

1 Introduction

Nowadays military ground vehicles are created in various construction manners – like different platforms itself, different mounting of weapon systems, various levels of protection, different possible power units plus engine performance, various basic characteristics like sizes and weights and mobility requirements . It is sometimes difficult to assess, to evaluate and to compare movement features and capabilities of these different vehicles. Nowadays military units operate in multinational missions, under joint command. For multinational units is very important to operate with comparable vehicles. This is the reason why we need some universal methodology and tool for vehicle evaluating.

We have done an analysis of NATO documents related to area of evaluation, testing and reliability of the vehicles. Basic documents which are focused on these issues are Allied Vehicle Testing Publications (AVTP-1) [1]. These publications were accepted in 1994 and they contain only practical information. In the section no. 3 there are defined basic possibilities of obstacles negotiation but with no any evaluation system. I believe that evaluation and setting up levels of mobility capabilities is important, because strategy and vehicle usage have changed.

Simulating technologies are widely spread in all of spheres of industry. We should focus on using of this manner for vehicle evaluation methodology too. Advantage of this methodology is that it enables not only assessment and evaluation of fixed vehicle configuration, but also enables assessment and evaluation of various modifications (e.g. chassis, main body, power units, protection systems, etc.) without necessity for real vehicle manufacturing. It will be possible to compare different vehicle types and construction ideas in same operational environment and when managing the same terrain obstacles. Simulation of various critical states and behaviour of vehicle (e.g. destruction of wheel, main body, etc.) is another benefit.

On the other hand we can find some drawbacks. The first one is input data – either insufficient or lack of them. It is essential to update current documents from this point of view too. For example we have to know basic parameters of suspension system, but input data should be the 2nd step. The 1st step is to create methodology. There are different tools for creating mathematic models all over the world and data sharing and transformation are next disadvantage.

In the next chapters there is shown an example of vehicle evaluation with simulation technologies support.

2 Mathematic model

I have created mathematic model of new designed vehicle. Our department cooperates on development of this vehicle with Department of Combat Support Management and VOP CZ, s.p.. The basic capabilities of the vehicle were set:

Maximum speed of the carrier is set up to 30 km/h. Maximum dimensions of the vehicle were determined for achieving of maximum mobility (tactical and operational) – width 1700 mm, length 2000 mm, clearance 300 mm. The carrier consists of 3 wheel axles - all-wheel drive, independent suspension of all wheels.

I have used Multibody Dynamics software ADAMS (Automatic Dynamic Analysis Mechanical Systems) of MSC.software company for creating of this model. Adams improves engineering efficiency and reduces product development costs by enabling early system-level design validation. Engineers can evaluate and manage the complex interactions between disciplines including motion, structures, actuation, and controls to better optimize product designs for performance, safety, and comfort. Along with extensive analysis capabilities, Adams is optimized for large-scale problems, taking advantage of high performance computing environments. For dynamics vehicle development and testing MSC offers module ADAMS/Car. With Adams/Car engineering teams can build and test functional virtual prototypes of complete vehicles and vehicle subsystems. Working in the Adams vehicle environment, automotive engineering teams can exercise their vehicle designs under various road conditions, performing the same tests they normally run in a test lab or on a test track, but in a fraction of time. [2]

Creating mathematic model consists of:

- 37 moving parts,
- 32 revolute joints,
- 6 translation joints.

Basic parts of the model are:

- chassis,
- axels with suspension system,
- wheels,
- terrain.

The model has 12 degrees of freedom and enables to simulate vehicle ride on define terrain defined speed. During simulation are recorded basic physical quantities (location, speed, acceleration, load…) of all parts of the model. This model enables to create other modification or states (e.g. load changes, change of center of mass, riding without wheel). Pictures of this model you can see in the next figures.

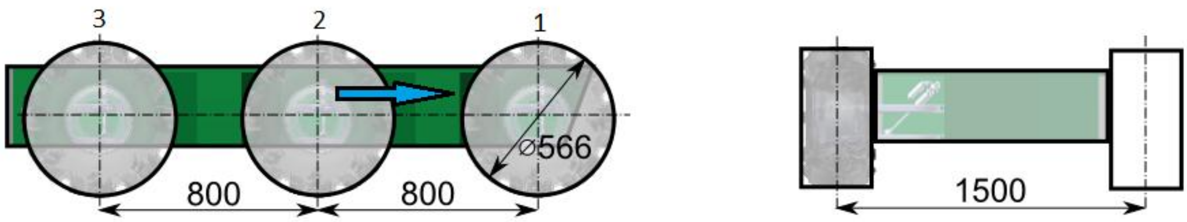

Fig. 1 *Basic parameters of the vehicle*

Model simplification:

- all parts of model are solid bodies
- all wheels have same rotation speed
- terrain is solid, without deformations

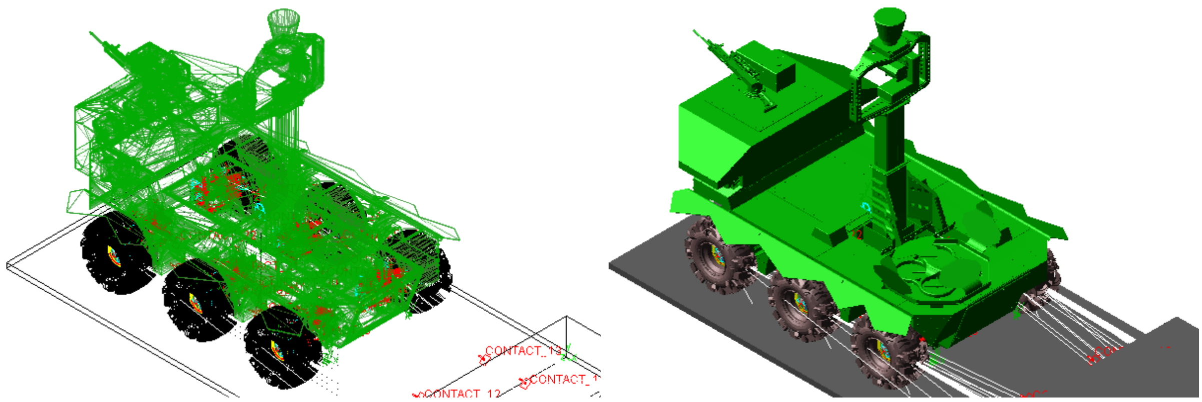

Fig. 2 *Created mathematic model of the vehicle*

3 Terrain - obstacles

I have created circuit with basic obstacles similar to circuit which is used in IDET, International Fair of Defence and Security Technology. IDET is one of the biggest shows of defence technology in Central and Eastern Europe and is being held in Brno, Czech Republic. IDET circuit was developed, manufactured and operated by Department of Combat and Special Vehicle of University of Defence Brno. This track consists of various attractive obstacles – e.g. Step obstacle, Straight-walled ditch, Wave obstacles, Special obstacles (e.g.

stairs and logs), swinging bridge, etc. IDET circuit is suitable for both light and heavy wheeled vehicles. During exhibitions were seen military vehicles, e.g. Tatra T-810, Dingo, Pandur, etc. Examples of IDET circuit you can see in the next pictures – Fig. 3.

Fig. 3 *Pictures from IDET 2011 circuit [3], [4]*

"Virtual" circuit consists of next obstacles:

Step obstacle

Theoretical high of the step is defined for all-wheel drive vehicles by formula [5]:

$$h = \left(1 \div \frac{4}{3}\right) \cdot r \tag{1}$$

where: h – high of the step (283 ÷ 377 mm); r – wheel radius (566 mm)

Straight-walled ditch

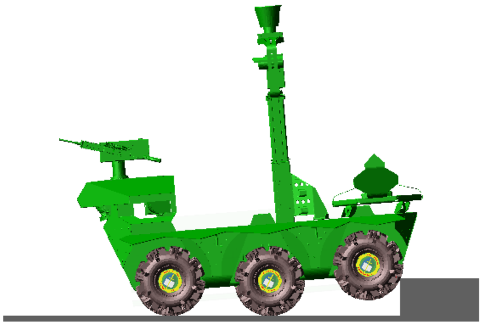

Fig. 3 *Step obstacle – height 300 mm*

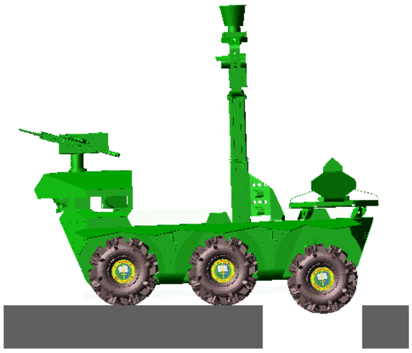

Fig. 4 *Staight-walled ditches – width 800 mm*

Vehicle capability (for vehicles with two and tree axles) of overcoming of straight-walled ditches is limited by sticking of wheels in the trench. Maximal trench width is defined by formula [5]:

$$a = \frac{3}{2} \cdot r \tag{2}$$

where: a –width of the trench (425 mm); r – wheel radius

Vehicles with three axles can overcome this obstacle by appropriate technique of driving. It is necessary to speed up in front of trench – inertial force works against vehicle overturning. In this case vehicle is theoretically able to overcome obstacle define by [5]:

$$a = \left(\frac{3}{2} \cdot r\right) + L \tag{3}$$

where: a –width of the trench; r – wheel radius; L – wheelbase

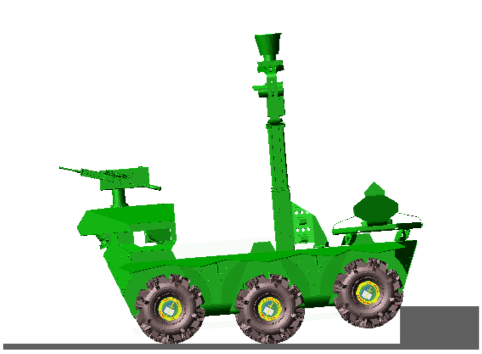

Fig. 3 Step obstacle – height 300 mm

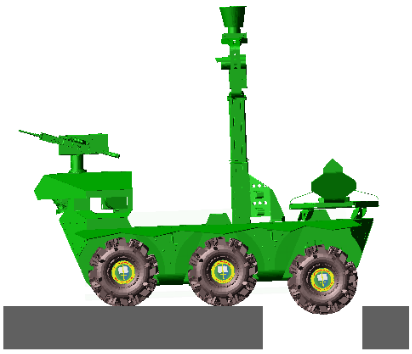

Fig. 4 Staight-walled ditches – width 800 mm

Wave obstacles

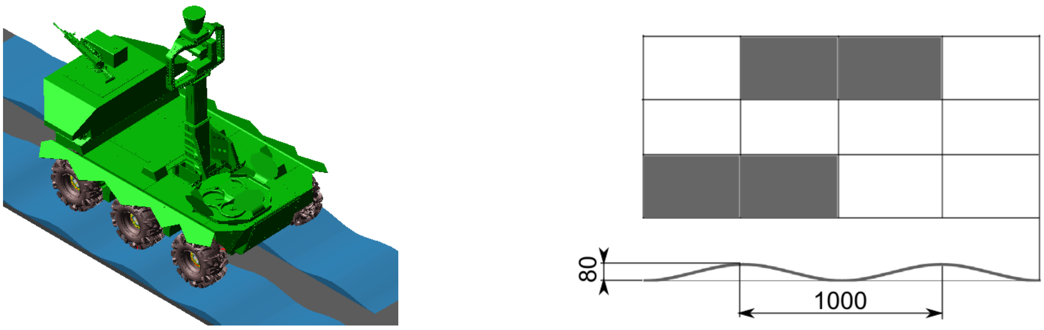

Fig. 5 Wave obstacles – small bumps

Effect of bumpy terrain on general vehicle vibration, vibration of a crew and axles stress can be tested on these wave obstacles.

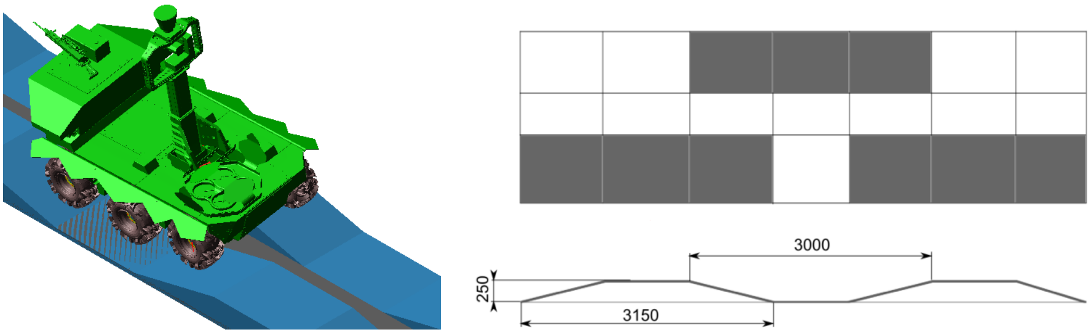

Fig. 6 Wave obstacles – hight bumps

In the mathematic model were used two types of wave obstacles:

- small bumps (height 80 mm, length 1000 mm) – Fig. 5
- high bumps (height 250 mm, length 3150 mm) – Fig. 6

General arrangement of these obstacles is show in the pictures – Fig. 5 and Fig. 6.

Special obstacles - Stairs and logs

Usage of these special obstacles can be very important, because they simulate crossing through a heavy terrain, especially logs. Not only capability of negotiating these obstacles but also vehicle vibration and stress are essential parameters for vehicle evaluation. Arrangement of special obstacles you can find in the pictures – Fig. 7 and Fig. 8.

Fig. 7 *Stairs obstacle*

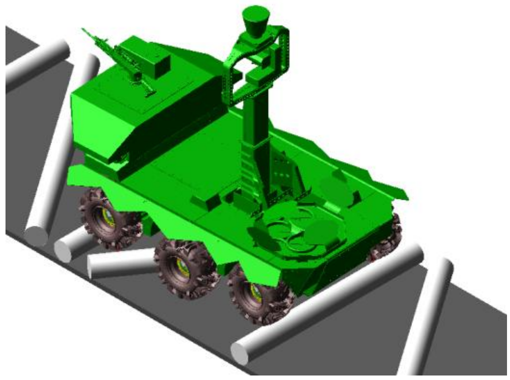

Fig. 8 *Log obstacle – log diameter 200 mm*

4 Simulations - outcomes

Simulations were focused on model ability to overcome defined obstacles with various speed. During simulations were recorded basic physical parameters of the basic vehicle parts. Some outputs are presented in the next graphs (Fig. 9, Fig. 10) – position, velocity and acceleration of selected parts.

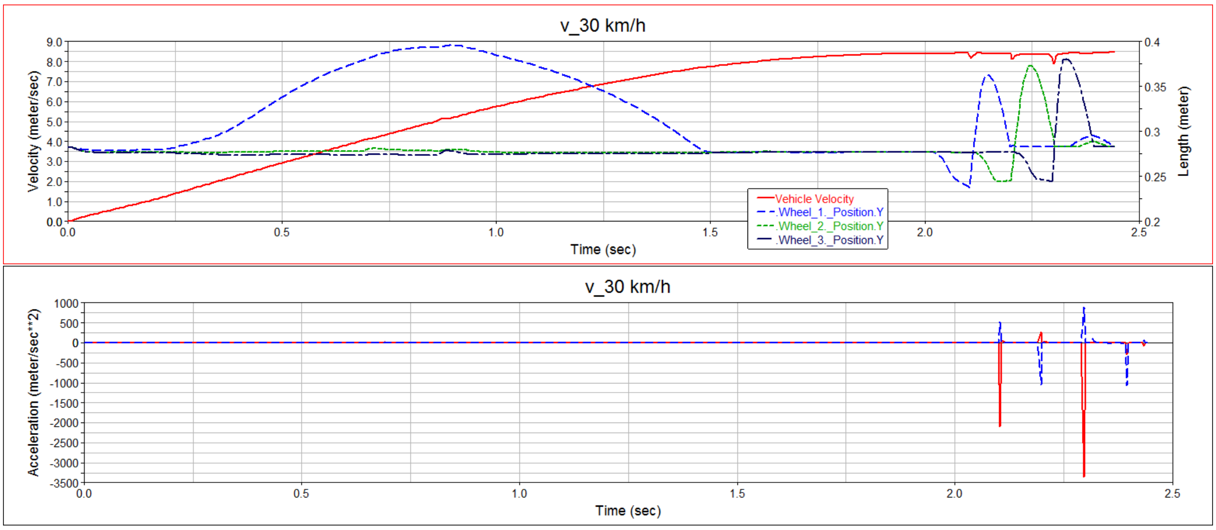

Fig. 9 *Staight-walled ditch – speed 30 km/h, upper graph - red line – vehicle speed, blue line – Y position of 1st wheels, green line - Y position of 2nd wheels, black line - Y position of 3rd wheels; lower graph – red line – chassis accleration in X axis, blue line – chassis accleration in Y axis*

Vehicle is not capable to overcome the Straight-walled ditch in range of small speed. Possibility of overcoming obstacle by appropriate technique of driving was proved by simulation. By the simulations was set the minimal speed for overcoming the trench - 8 km/h. In the next graphs you can find some simulations outcomes (speed, acceleration and chassis vertical CM position).

Next set of simulations was focused on possibility to overcome the trench diagonally (constant low speed). Minimal angle from transverse axle of vehicle was found 10° and maximal angle from transverse axle of vehicle was found 60°. Outcomes from simulations are shown in the next figures.

The mathematic model was added by “active suspension system” – spring length was changed during the movement. Spring length was changed by predefined function. Usage of this system decreased vehicle overturning and increased the model ability to overcome the trench.

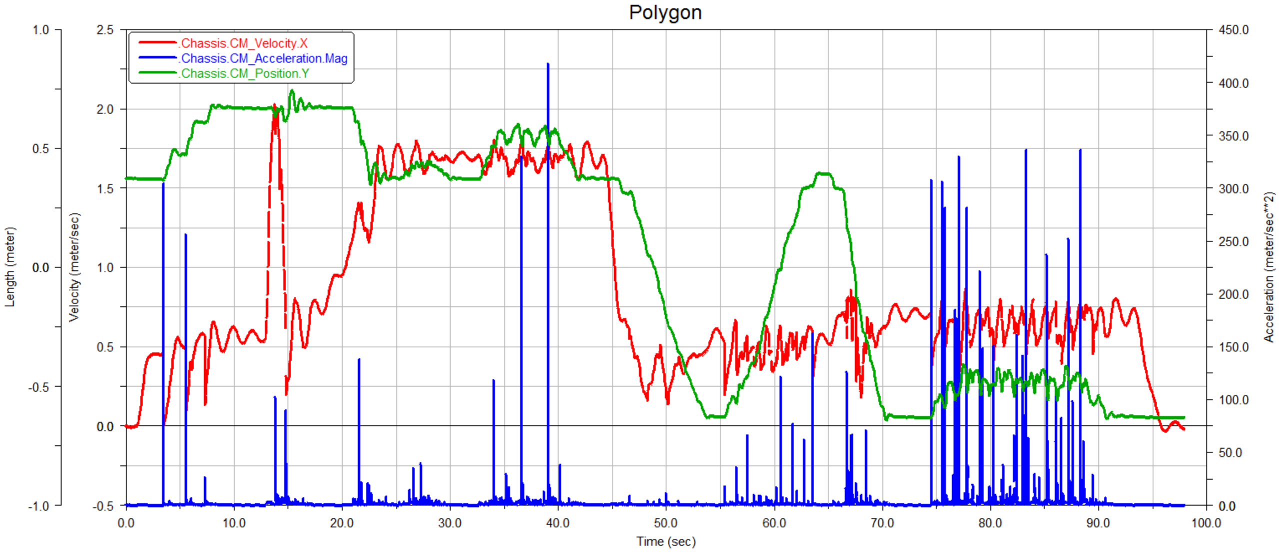

Fig. 10 Ride through the whole circuit– red line – chassis velocity, blue line – chassis acceleration, green line – chassis vertical CM position

5 Conclusion

Simulating technologies offer a lot of advantages – e.g. evaluation of various vehicle configurations, simulation of various critical states of vehicle, comparison of vehicles in the same surrounding.

Desired width (800 mm) is bigger than theoretical rate (425 mm) – vehicle is not capable to overcome the obstacle. This statement was proved by simulation. Capability to overcome this obstacle depends on driver skills and character of a terrain, because it is essential to speed up in front of trench – inertial force works against vehicle overturning. Possibility of overcoming obstacle by this manner was proved by simulation.

Created analysis and simulation are basic inputs for next development of the vehicle. If it is necessary to achieve overcoming the staight-wallted ditches in any case, the vehicle construction has to be changed – use some active system (active suspension system or active change of position of center of mass), change wheel radius, wheelbase. Possibility of overcoming defined obstacles is limited at this vehicle configuration.

Usage of simulating technologies can be suitable for vehicle evaluating, yet for their usage must be done some changes, because input data and their transformation and sharing can be drawbacks of this tool. It is essential to focus on methodology creating and its implementation to the current NATO documents related to area of evaluation, testing and reliability of the vehicles.

Acknowledgement

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