Stanisław **TOMASZEWSKI**

MOTION ANALYSIS OF A TRACKED VEHICLE

Abstract. The article describes a method of modelling the movements of a vehicle in the SolidWorks environment. Driving a vehicle on a test track with model bumps at various speeds is presented and capabilities are described for determining road wheel load, determining the frequency of vertical and angular vibration of the vehicle, as well as of displacements and forces generated during movement and acting on the individual components of the hull.

Keywords: suspension, hull, tracks, road wheels, traction system.

1. INTRODUCTION

Motion analysis was carried out on a hull suspended on 12 wheels (6 wheels each side). Each wheel transfers forces via suspension arm and a spring and damper onto the hull, keeping it at a certain height above the ground. Springs are supplemented with dampers which enable smooth movement of the vehicle.

Fig. 1 shows the side view of the hull under analysis.

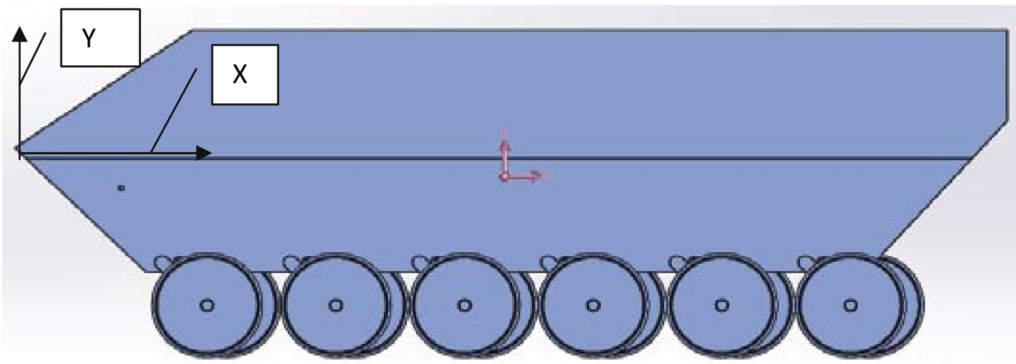

Fig. 1. Computational model of the hull (Z axis perpendicular to the drawing plane)

The hull is described by the following quantities:

Mass = 36541.98 kg

Centre of mass: (mm)

X = 3066.80

Y = -184.32

Z = 0.01

Stanisław TOMASZEWSKI - Ośrodek Badawczo – Rozwojowy Urządzeń Mechanicznych OBRUM sp. z o.o., Gliwice

Principal axes of inertia and principal moments of inertia: (kg*mm^2).

Derived in the centre of gravity.

Ix = (1.00, 0.00, 0.00)	Px = 46255484278.97
Iy = (0.00, 0.00, -1.00)	Py = 131823858709.67
Iz = (0.00, 1.00, 0.00)	Pz = 160122052090.31

Number of wheels	- 12
Wheel diameter	- 690 mm
Suspension arm	- 400 mm
Stiffness of wheel suspension	-488000.00 N·mm/°
Damping coefficient	- 30000.00 N·mm/(°/s)

2. VERTICAL AND ANGULAR VIBRATION OF A VEHICLE

When a vehicle is dropped from a certain height to the ground, an interaction occurs between the force of gravity of the vehicle and the restoring forces of the vehicle's suspension, which causes vertical vibration of the hull.

Fig. 2 shows a graph of the displacements and accelerations generated by vibration. Blue colour represents displacements, red colour represents accelerations of a point at the front edge of the hull. Before being dropped to the ground, that point is positioned 1900 mm above the ground.

The period of natural vibration read from the graph is 0.9 second. It is assumed in this case that there is no damping (free vibration).

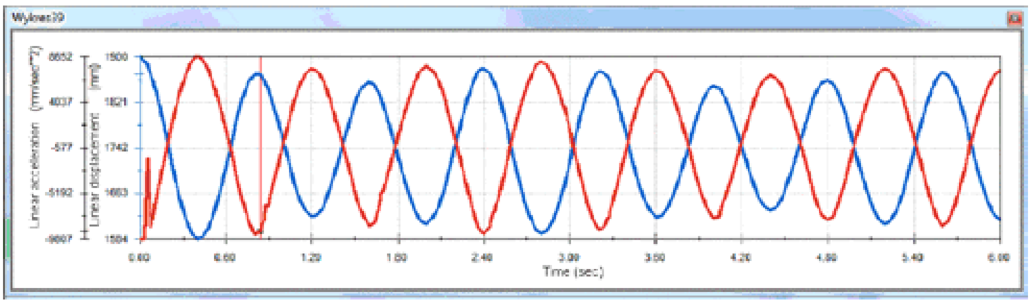

Fig. 2. Displacements and accelerations of the hull

To illustrate the displacements occurring during vibration, Fig. 3 shows the hull in two positions (lowermost position - 269.6 mm, and highest position - 554.33 mm from the ground).

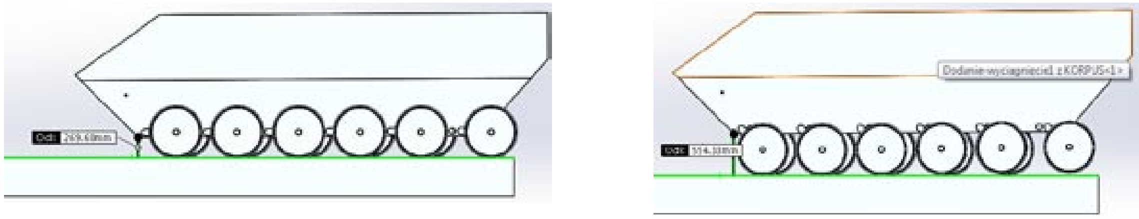

Fig. 3. The hull in two positions

In the second case the vehicle was dropped from the same height, after one and a half second a force of 50,000 N was applied onto the front edge, and that force was removed after 0.7 second. A graph illustrating the displacements (blue) and accelerations of the front edge (red) is shown in Fig. 3. The graph presents the composition of vertical and angular vibration.

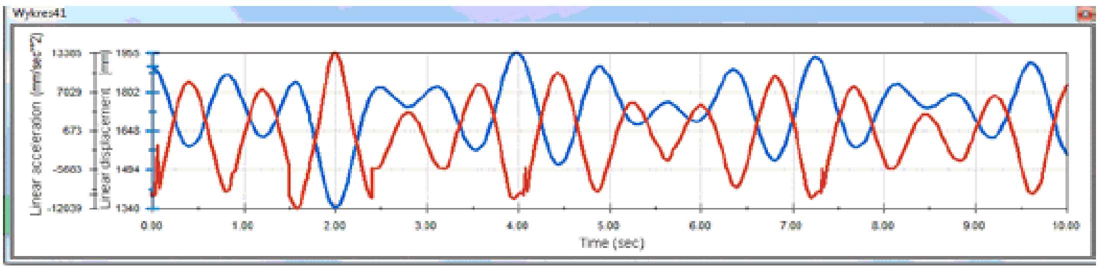

Fig. 4. Displacements and accelerations of the hull

These vibrations are illustrated in Fig. 5, where the hull is shown in two positions (lowermost position after two seconds and highest position after four seconds).

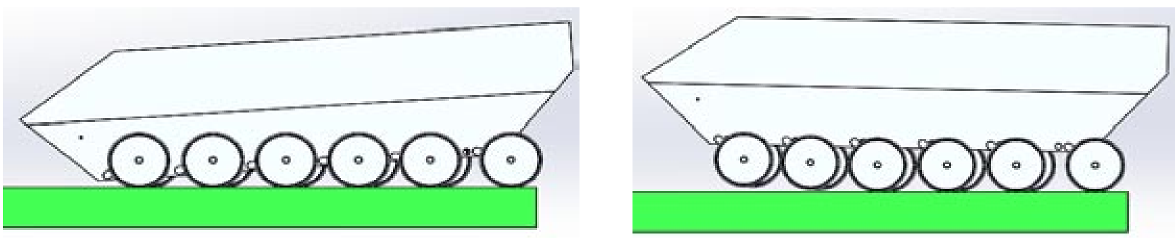

Fig. 5. The hull in two positions

3. VERTICAL AND ANGULAR VIBRATION WITH DAMPING

In this case the vehicle was dropped from the same height of 1900 mm, and after the extinction of vibration of the hull after 3.5 seconds a force of 50,000 N was applied onto the front edge, and that force was removed after 0.7 second.

A graph of the displacements and accelerations of the front edge of the hull is shown in Fig. 6.

The graph shows that after being dropped to the ground, the hull stabilises after two seconds, and the period of vertical vibration is 0.8 second.

The second phase of the graph, after 3.5 seconds, shows angular vibration generated by tilting the vehicle with a force of 50,000 N.

Under the action of the vertical force the front edge attains the lowermost position and, starting from the fourth second, the hull makes angular oscillations with a period of 1.2 second. After 8 seconds the hull is in the rest position.

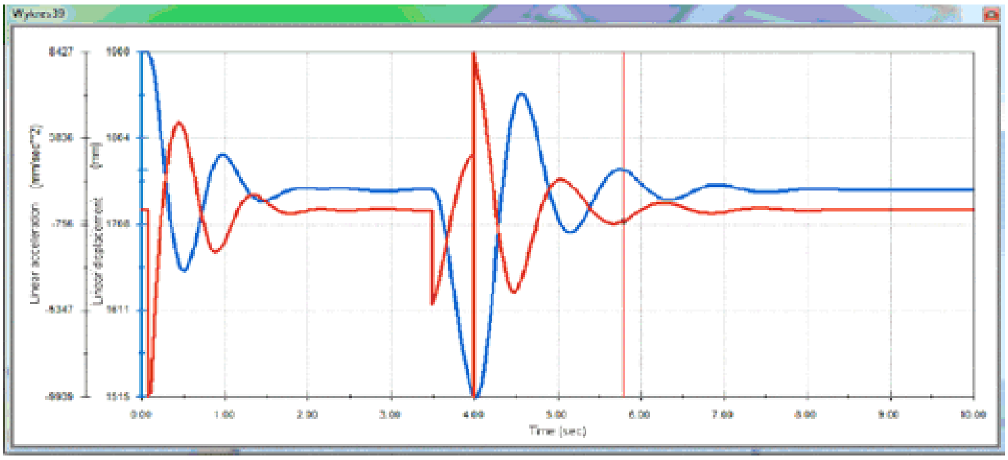

Fig. 6. Displacements (blue) and accelerations (red) of the hull

After the vehicle has driven past the obstacles, graphs of forces acting between the wheels and the ground are plotted. These graphs enable determination of the load exerted on every wheel at any moment of the test.

Fig. 7 shows examples of the graphs of force plotted for the first and sixth left wheels, and Fig. 8 shows graphs of force plotted for the first and sixth right wheels when the vehicle is driven over an obstacle.

By reading the values of forces acting in the 3rd or 9th second from the graphs in Figs. 7 and 8 we can determine the static loads generated in these wheels.

The hull in the rest position is shown in Fig. 9.

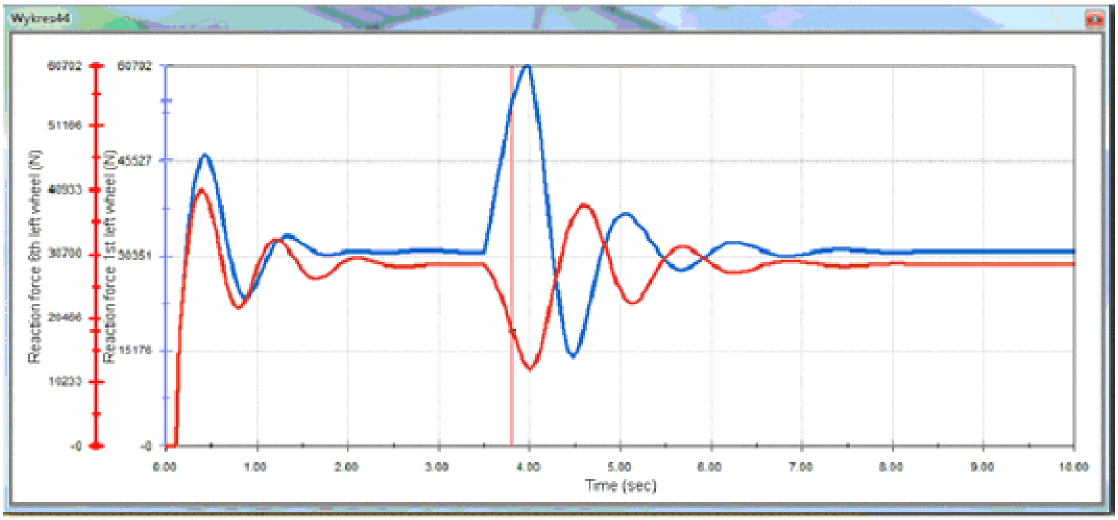

Fig. 7. Wheel loads on the left side (1st wheel - blue) and accelerations of the hull (6th wheel - red)

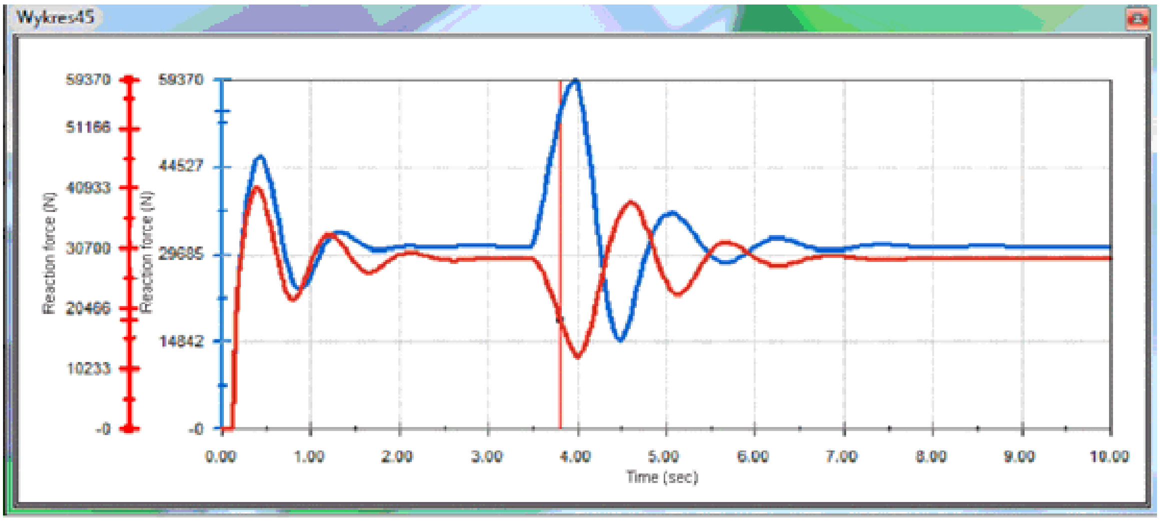

Fig. 8. Wheel loads on the right side (1st wheel - blue) and accelerations of the hull (6th wheel - red)

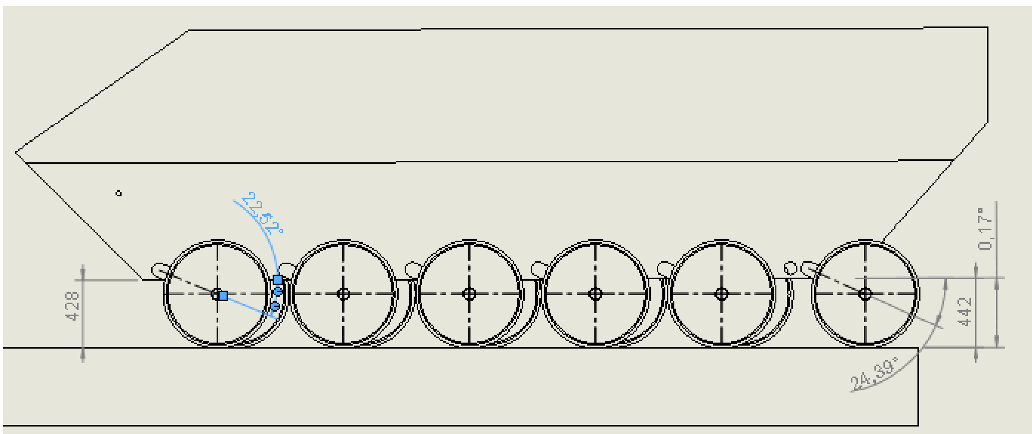

Fig. 9. Side view of the hull in the rest position

4. DRIVING OVER OBSTACLES AT 60 km/h

For the purpose of this research a model of a test track shown in Fig. 10 was developed. The test track includes two bumps indicated in Fig. 10. The distance between the bumps is twice the contact length of the track (caterpillar) and ground. The vehicle is driven on this test track at a speed of 60 km/h.

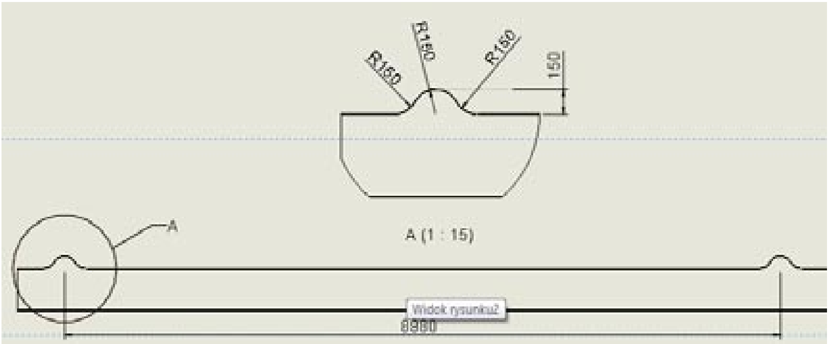

Fig. 10. Obstacle dimensions

Fig. 11 shows the model of the hull just before reaching the first bump and a graph of the accelerations of the front edge of the vehicle driving over the obstacle.

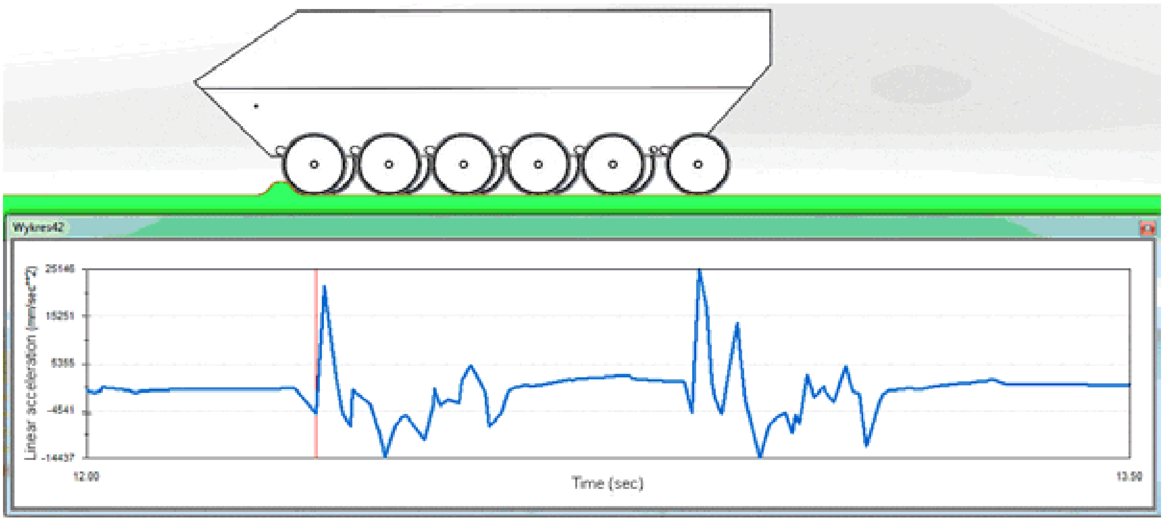

Fig. 11. Graph of the acceleration of the front edge of the hull (vehicle shown just before reaching the obstacle, maximum acceleration 25.146 m/s^2)

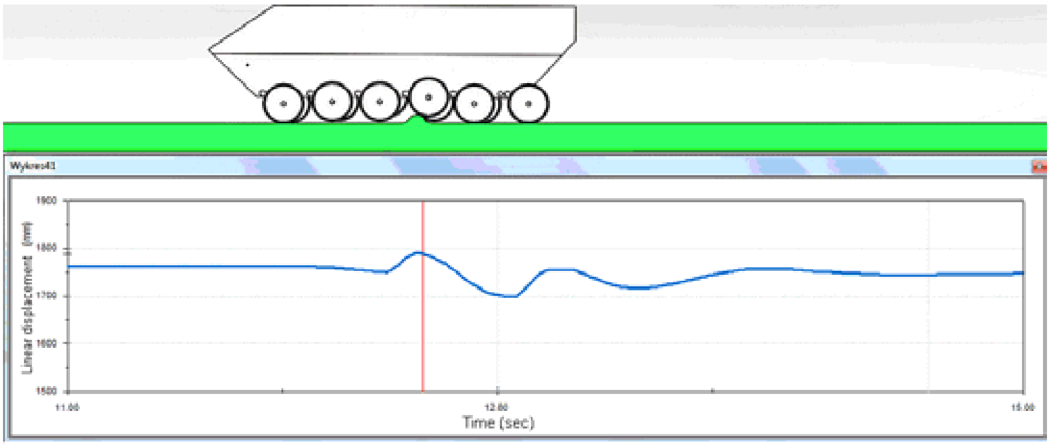

Fig. 12. Graph of the displacement of the front edge of the hull (vehicle shown when the 4th wheel is over the bump)

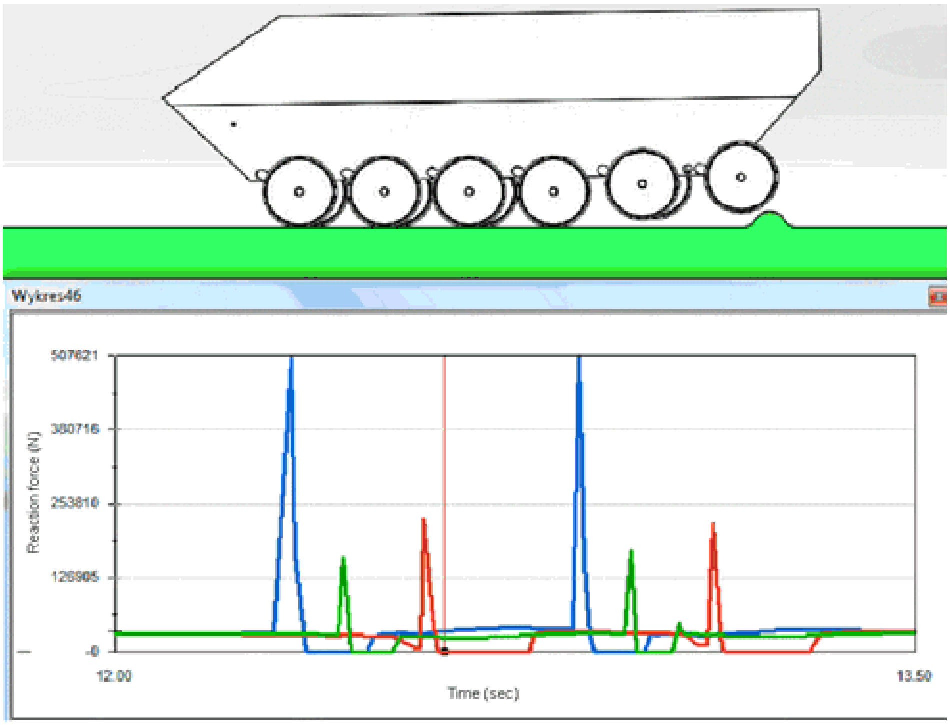

Fig. 13. Wheel loads on the left side of the hull (1st wheel - blue, 3rd wheel - green, 6th wheel - red)

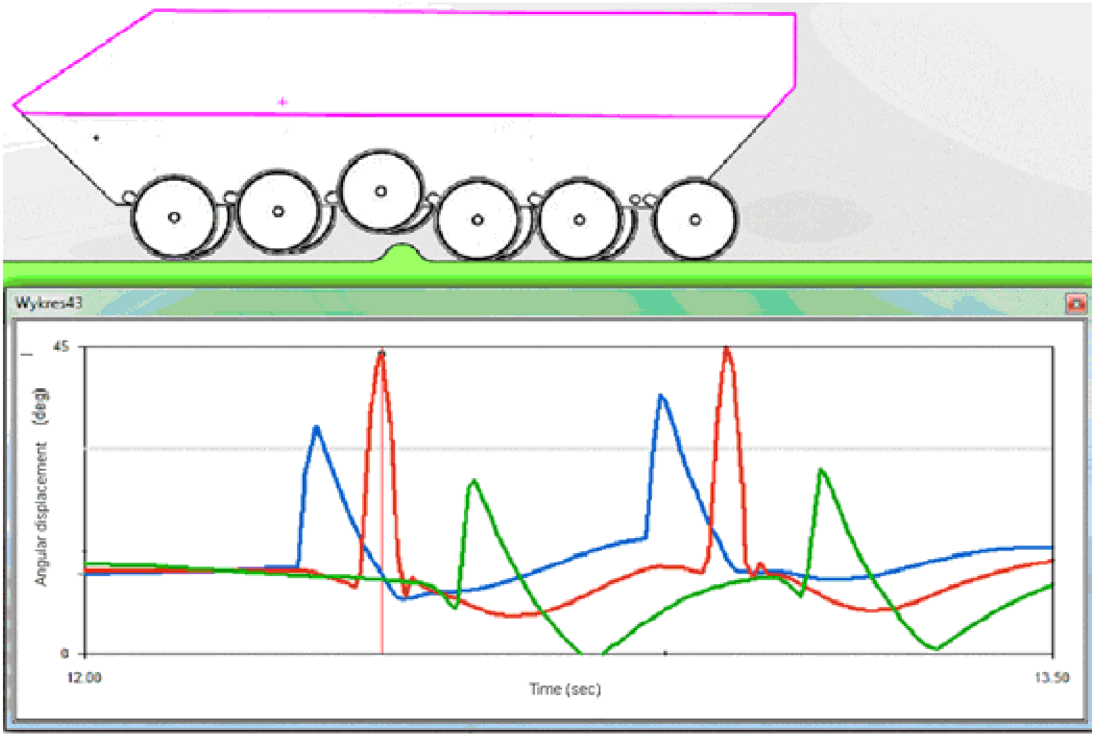

Fig. 14. Angular displacements of the suspension arms on the left side (1st wheel - blue, 3rd wheel - red, 6th wheel - green)

5. DRIVING OVER OBSTACLES AT 30 km/h

For the purpose of this research a model of a test track shown in Fig. 10 was developed. The test track includes several bumps indicated in Fig. 15. The vehicle is driven on this test track at a speed of 30 km/h. The distance between the bumps is comparable with the contact length of the track (caterpillar) and ground.

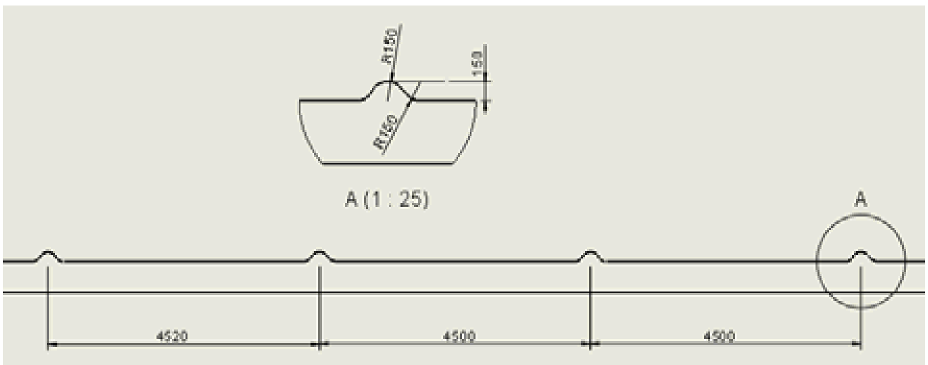

Fig. 15. Obstacle dimensions

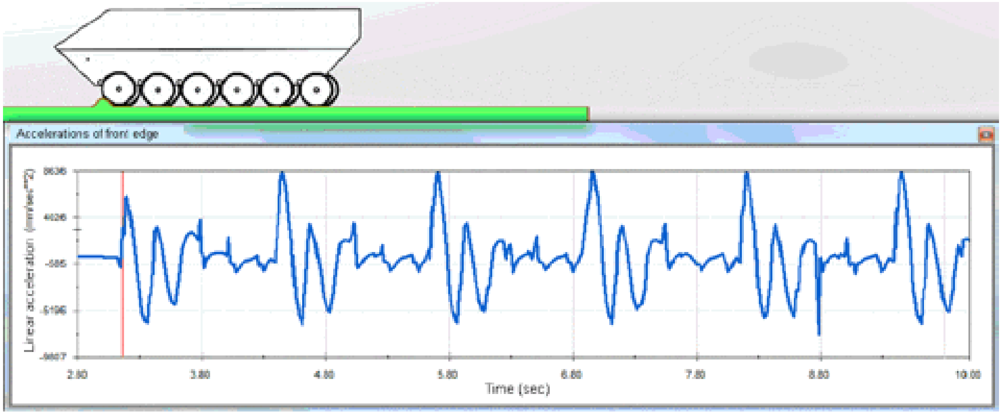

Fig. 16. Graph of the acceleration of the front edge of the hull (vehicle shown just before reaching the obstacle)

Fig. 17. Graph of the displacement of the front edge of the hull (vehicle shown just before reaching the 2nd bump)

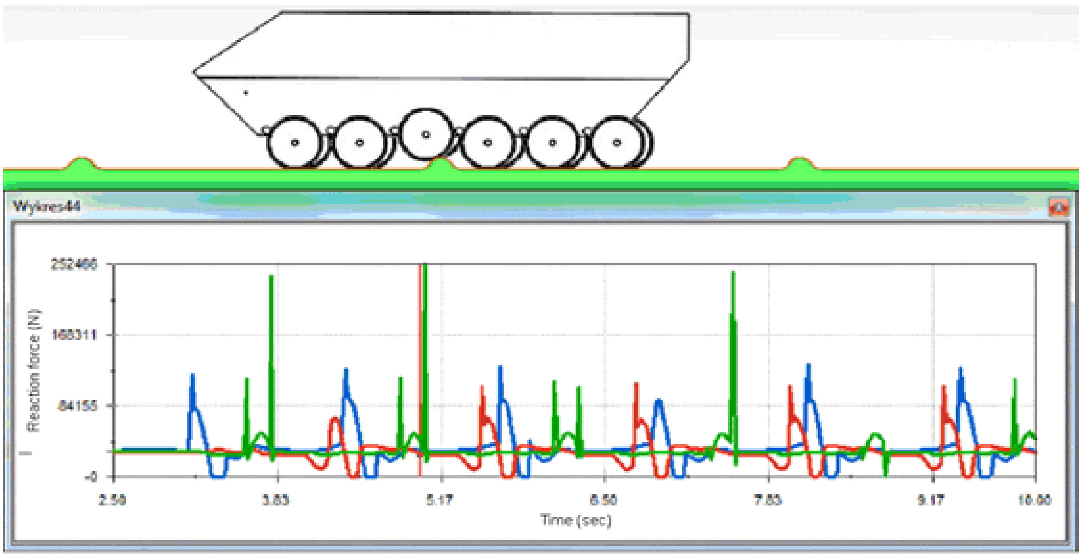

Fig. 18. Wheel loads on the left side (1st wheel - blue, 3rd wheel - green, 6th wheel - red)

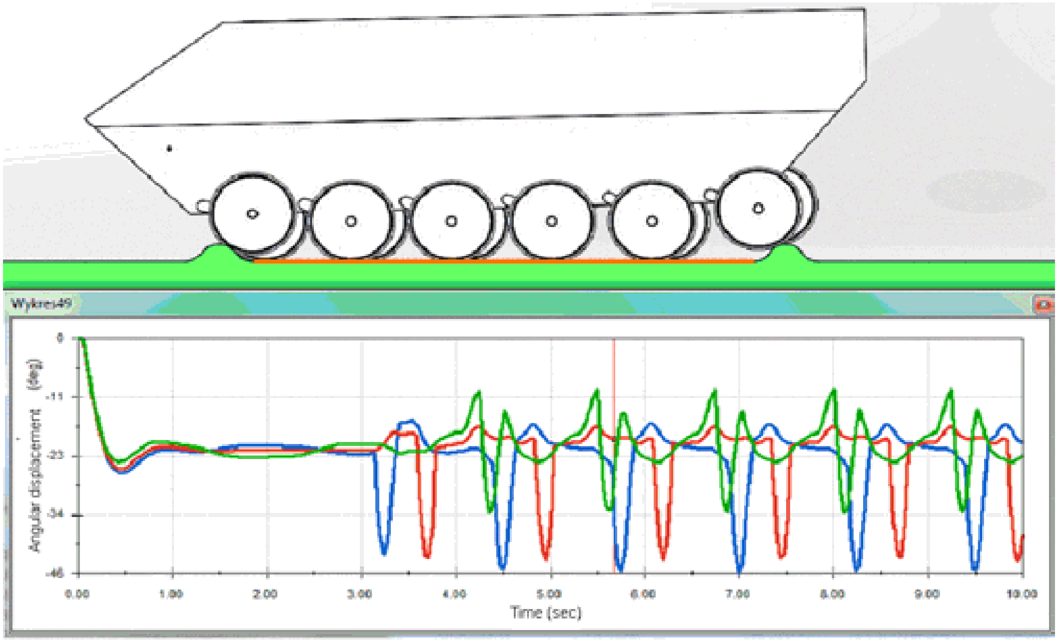

Fig. 19. Angular displacements of the suspension arms on the left side (1st wheel - blue, 3rd wheel - red, 6th wheel - green)

6. SUMMARY AND CONCLUSIONS

Using SolidWorks Motion, at the design stage it is possible to carry out comparative studies of suspension systems characterised by various parameters of stiffness and damping. Comparison of the values of accelerations and of other quantities helps optimise the characteristics of a suspension system.

By varying the characteristics of elasticity and damping, by changing the initial settings of suspension arms and their arrangement in the hull it is possible to alter the movement characteristics of a vehicle passing over obstacles.

Results can be presented in graphs, movies displaying a vehicle passing over obstacles can be recorded, and also data on the loads generated during the movement of the vehicle can be exported to perform strength calculations of individual elements of the suspension and of the hull.

The motion analyses of the vehicle driving at a speed of 60 km/h on a test track with two bumps 150 mm in height and spaced apart by a distance equal to twice the contact length of the track (caterpillar) and ground have shown that maximum acceleration was 25.146 m/s^2 (it should be less than 3 g [3]).

7. REFERENCES

[1] Burdziński Z.: Teoria ruchu pojazdu gąsienicowego. Warsaw, Wydawnictwo Komunikacji i Łączności WKiŁ, 1972.
[2] Kamiński E., Pokorski J.: Dynamika zawieszeń i układów napędowych pojazdów samochodowych. Warsaw, Wydawnictwo Komunikacji i Łączności WKiŁ, 1982.
[3] Tału K. A.: Konstrukcja i obliczanie czołgów. Moscow 1963.

Results of the State security and defence project titled "Direct Fire Support Vehicle (WWB)" financed by NCBiR (National Centre for Research and Development) as part of competition no. 4/2013 (Contract no. DOBR-BI04/017/13411/2013) were used in this paper.