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RESEARCH ON WHEELED ARMOURED FIGHTING VEHICLE IN CURVILINEAR MOTION

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Abstract

The paper shall present results of simulation research studies performed using a simulation model of a vehicle in which ABS and EBS system were taken into consideration as well as hydropneumatic suspension. A decision was made to conduct the simulation studies following three tests: circumferential fixed motion; emergency braking in curvilinear motion; stepping extortion on the steering wheel. As a result of performed simulation studies, more than 30 physical quantities were recorded describing the curvilinear motion of the AFV vehicle. The following were selected for presentation in listings: motion trajectory; progress of the value of lateral and side acceleration of the vehicle centre of inertia; progress of circumferential velocity values of driving wheels (essential at braking); progress of the vehicle velocity values recorded in the vehicle's centre of inertia and in places corresponding to positions of driving wheels; and progress of the values of vertical reaction forces under the driving wheels. Catalogue of the parameters being changed for the simulation is looked up to real objects and trends occurring in the changes being introduced. Paper presents progress of the value of vertical force in different conditions and vehicle motion trajectory. It also shows general diagram of hydropneumatic suspension system in view of the vehicle and diagram of hydropneumatic suspension system.

Keywords: *ABS, EBS system, hydropneumatic suspension, AFV vehicle*

1. General Assumptions for AFV Vehicle Model with Hydropneumatic Suspension

For the AFV vehicle model, a hydropneumatic suspension model was proposed based on components used in modern trucks and passenger cars. Fig. 1 presents a diagram of the hydropneumatic suspension system with specification of key elements – responsible for performance of a function responsible for transferring dynamic vertical loads from the driving wheels axle, through hydraulic column, onto the AFV vehicle body.

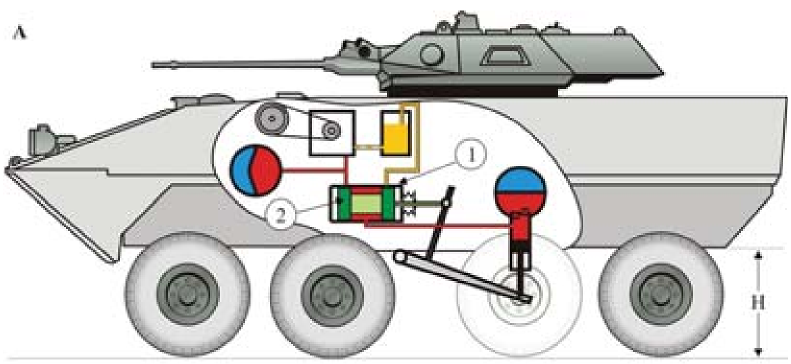

Fig. 1. General diagram of hydropneumatic suspension system in view of the vehicle

The main subassemblies of the executive system that is in charge of performance of the basic functions of the suspension include:

– hydropneumatic column,
– hydraulic cylinder,
– pneumatic resilient element,
– damper orifice,
– liquid tanks,
– feeding pump,
– vehicle body height controller,
– vehicle body height controlling valve,
– hydraulic leads (of high and low pressure).

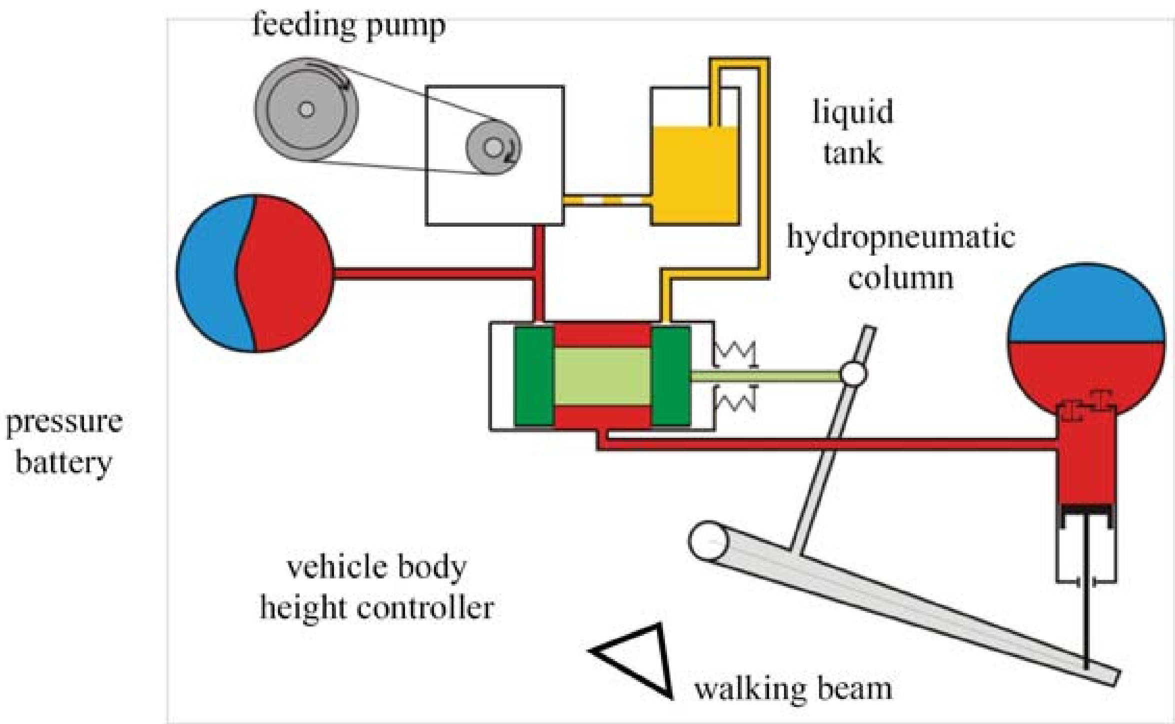

Fig .2. Diagram of hydropneumatic suspension system

2. Detailed assumptions and simplifications adopted while modelling the operational dynamics of hydropneumatic suspension

Here are essential elements that are subjects for modelling, and that influence the capabilities of hydropneumatic suspension:

– actuator, consisting of a piston fixed to driving axle (of mass m) and a hydraulic cylinder fixed to vehicle body (of mass M):

– damper orifice,

– resilient element, consisting of a tank in which working gas – nitrogen is separated from the working liquid (mineral oil) with elastic diaphragm. Thanks to its elasticity, the diaphragm can equalize pressure between two chambers.

The following was taken into consideration in the model:

– resilient capabilities of hydropneumatic suspension,

– damping capabilities of hydropneumatic suspension,

– and a possibility for its further development towards cooperation of the hydropneumatic column with high control valve controlling the height of the vehicle body position and the suspension controller algorithm (a possibility to operate in semi-automatic mode).

When building the model, the following assumptions were made:

– pressure battery was modelled as a source of indefinitely large energy of hydraulic liquid under a fixed pressure p_{ZASIL},

– friction resulting from the piston motion in the hydraulic cylinder was not taken into consideration,

– mass of the piston, piston rod and the diaphragm mass were not taken into consideration,

– operational dynamics of valves, deciding about damping capabilities (their inertia while their closing and opening was disregarded), was not taken into consideration,

– hydraulic leads were substituted by respective hydraulic resistances,

– the hydraulic leads discharge capacity coefficients were adopted as fixed,

– heat exchange with the environment has been disregarded, assuming a fixed temperature of hydraulic liquid.

Sets of equations describing capabilities of the mathematical model were presented in subsequent subsections of the statement. The numerical model was developed using the MATLAB – SIMULINK software platform.

The following was disregarded in the model:

– a phenomenon of operating liquid outflow from the suspension column as a result of leaks between the piston and the column cylinder – assuming that the link ideally sealed,

– a phenomenon of working gas loss, as a result of its permeation into the operating liquid or a loss through leakage in inlet adaptor allowing gas into spherical resilient element.

Mathematical description of the model involves making mathematical equations including:

– equations describing operation of movable elements,

– equations of liquid flow pressure losses in hydraulic elements,

– balance equations of temporary mass liquid streams (nodes equations or peripherals equations).

2.1 Progress of simulation studies

Model research studies were conducted in order to obtain information on capabilities of the AFV vehicle in curvilinear motion. The research results will be helpful in assessment of the vehicle's driving capabilities. A decision was made to perform the simulation research studies based on three tests:

– circumferential fixed motion (marked as: SPIRAL TEST OFF-RAMP),

– emergency braking in curvilinear motion (marked as: EMERGENCY BRAKING ON THE ARCH),

– stepping extortion on the steering wheel (marked as: STEPPING EXTORTION OF TURNING).

In the first test, a motion of a vehicle driving with velocity of 80 km/h was simulated by introducing linear escalation of the steering wheel's turn (with fixed velocity of 0.1 rad/s) up to a value at which one of the wheels got separated from the road. Because of the vehicle's symmetry and symmetrical steering system, trials were made for one of the steering wheel's turning directions (to the left). The simulation studies were discontinued whenever the object showed a trend to roll over sideways (i.e. the vertical reaction under any of the wheels reached the 0 value).

The goal of the third test was to determine the highest velocity, in rectilinear motion, for which there is a possibility to make a rapid (in time of 0.3s) turn with the steering wheel up to the value of 90°, without rolling the vehicle over (i.e. until the moment by which the vertical reaction under the wheel will have reached a value higher than 0). The analysis was made of changes in maximum absolute values of levelled lateral acceleration and the vehicle body's side roll angle before rolling the vehicle over, simulating a left-turn of the vehicle. Extortion of the steering wheel's turn was presented on Fig. 3.

3. Results of basic simulation research studies of AFV vehicle

As a result of performed simulation studies, more than 30 physical quantities were recorded describing the curvilinear motion of the AFV vehicle. The following were selected for presentation in listings:

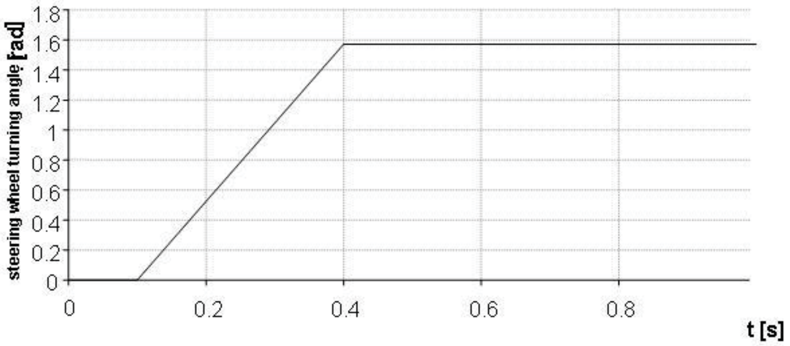

Fig. 3. Extortion of the steering wheel's turn with linear escalation period

- motion trajectory,
- progress of the value of lateral and side acceleration of the vehicle centre of inertia,
- progress of circumferential velocity values of driving wheels (essential at braking),
- progress of the vehicle velocity values recorded in the vehicle's centre of inertia and in places corresponding to driving wheels positions,
- progress of the values of vertical reaction forces under the driving wheels.

Tables 1-2 illustrate parameters for which simulation research studies were conducted and which the authors selected as being representative, and thus sufficiently „clear", to indicate certain trends in vehicle behaviour and the model possibilities.

Tab. 1. Conditions of „ circumferential fixed motion" test performance

DMC [kg]	a [m]	h_S [m]	mi0	Jx	Jy	Jz	ABS is on	Operatable UN	Vp [km/h]	uP [dcm]	W1	File Name
1	2	3	4	5	6	7	8	9	10	12	16	17
26000	2.23	1.46	0.90	16049	63414	67010	1	1	80	0.0	2	result1
31000	2.23	0.96	0.90	19135	66416	70234	1	1	80	0.0	2	result24

Tab. 2. Conditions of 'stepping extortion on the steering wheel' test performance

DMC [kg]	a [m]	h_S [m]	mi0	Jx	Jy	Jz	ABS is on	Operatable UN	Vp [km/h]	uP [dcm]	W1	File Name
1	2	3	4	5	6	7	8	9	10	13	16	17
26000	2.23	1.46	0.90	16049	63414	67010	1	1	50	0.0	2	result46
26000	2.23	1.96	0.90	16049	63414	67010	1	1	50	0.0	2	result56

The influence of selected parameters was assessed, pursuant to the catalogue of changes specified in Table 3.

Tab. 3. Catalogue of changes in the model parameters values

Parameter Name		Unit	Parameter Value	Change against Nominal Value
Vehicle Total Weight		kg	28000	+2000
			31000	+5000
The main central moment of inertia of the vehicle body solid (with a load)	against longitudinal axle	$kg{\cdot}m^2$	17172	+1123
			19135	+3086
	against lateral axle	$kg{\cdot}m^2$	64940	+1526
			66416	+3002
	against vertical axle	$kg{\cdot}m^2$	68661	+1651
			70234	+3224
Distance of the vehicle’s centre of inertia from the front axle		a [m]	2.025	-0.2
			2.125	-0.1
			2.325	+0.1
			2.425	+0.2
Height of the vehicle body’s centre of inertia over the ground		h_S[m]	0.956	–0.5
			1.156	–0.3
			1.756	+0.3
			1.956	+0.5

4. Exemplary research results based on test SPIRAL TEST OFF-RAMP

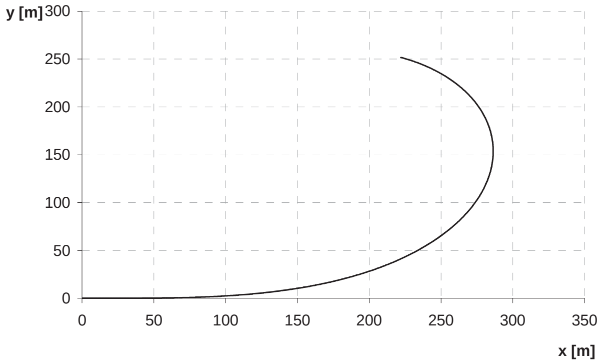

Fig. 4. Vehicle motion trajectory, data based on variant No. 1

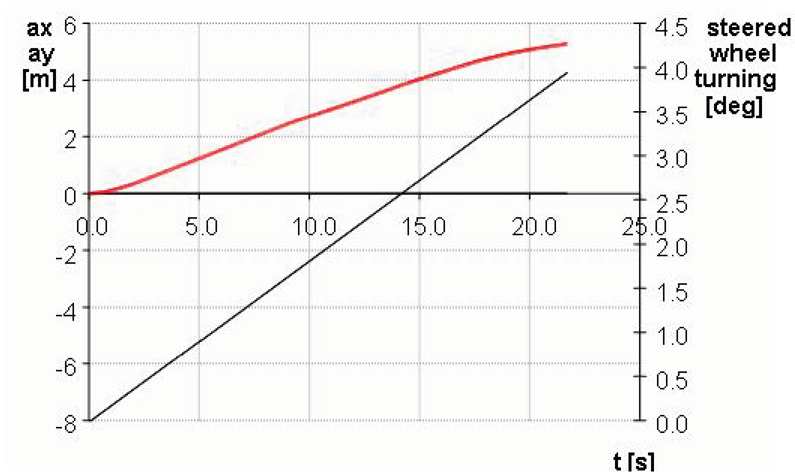

Fig. 5. Progress of the value of lateral acceleration a_x, side acceleration a_y and steered wheels turning angle, data based on variant No. 1

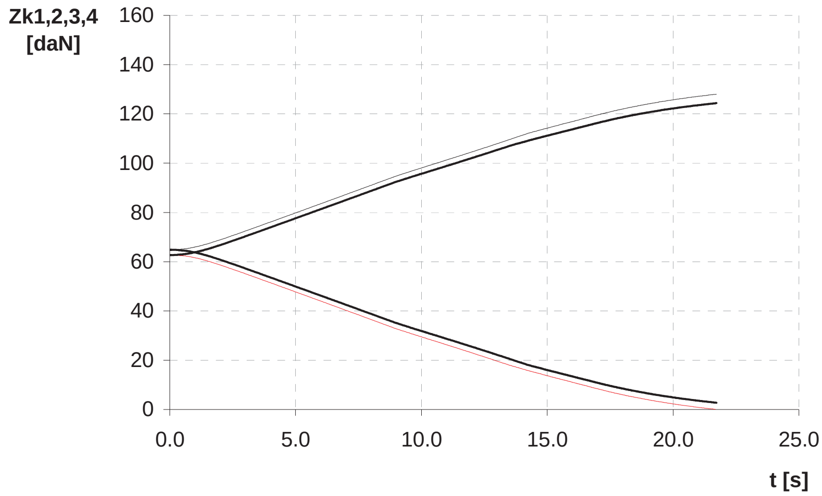

Fig. 6. Progress of the value of vertical force pressed by vehicle wheels on the road, data based on variant No. 1

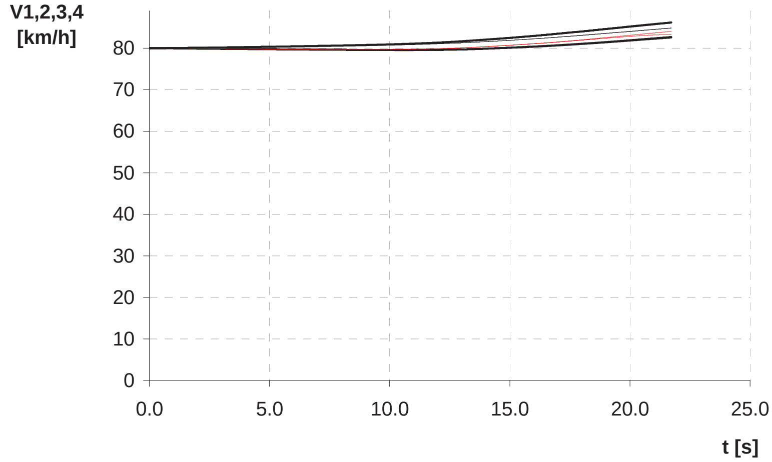

Fig. 7. Progress of longitudinal velocity value of the vehicle and circumferential velocity of its wheels data based on variant No. 1

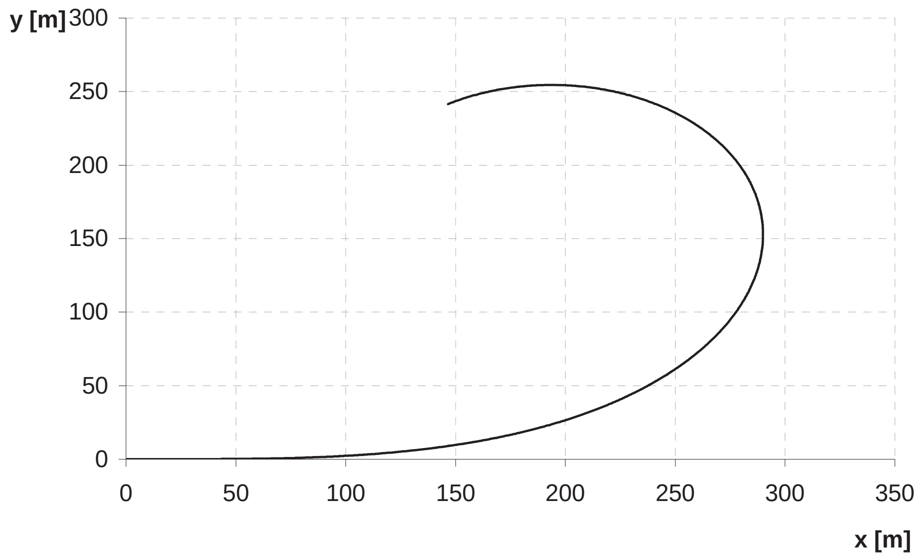

Fig. 8. Vehicle motion trajectory, data based on variant No. 24

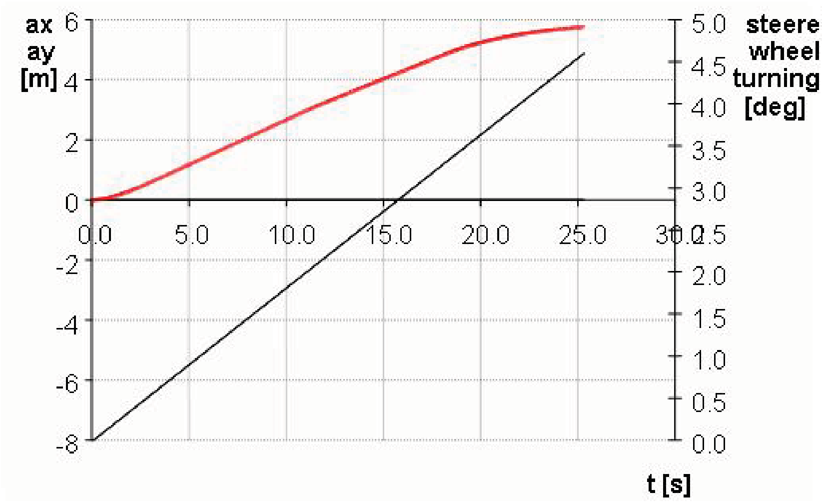

Fig. 9. Progress of the value of longitudinal acceleration a_x, side acceleration a_y and steered wheels turning angle, data based on variant No. 24

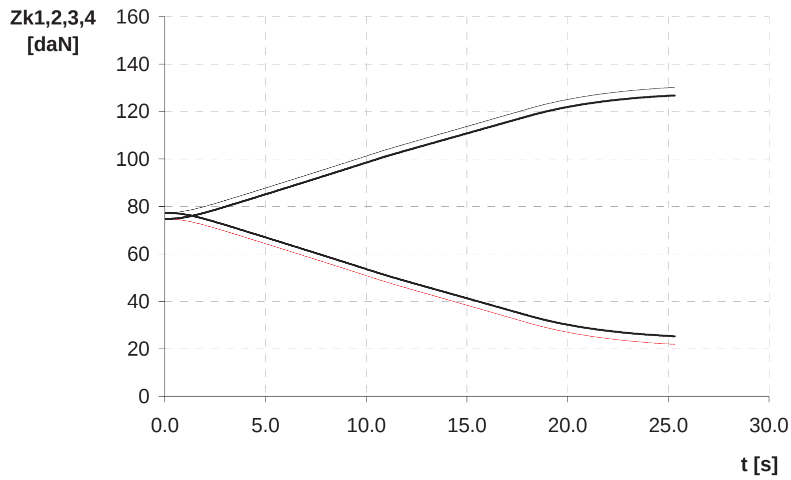

Fig. 10. Progress of the value of vertical force pressed by vehicle wheels on the road, data based on variant No. 24

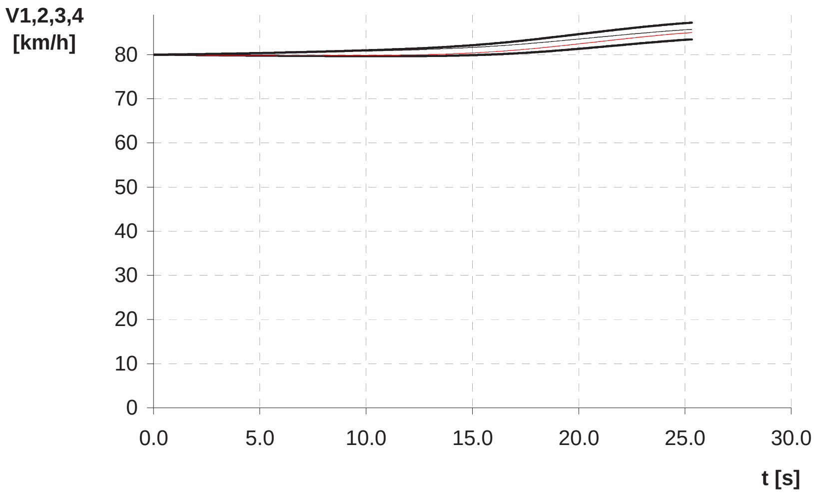

Fig. 11. Progress of longitudinal velocity value of the vehicle and circumferential velocity of its wheels data based on variant No. 24

5. Exemplary research results based on test STEPPING EXTORTION OF TURNING

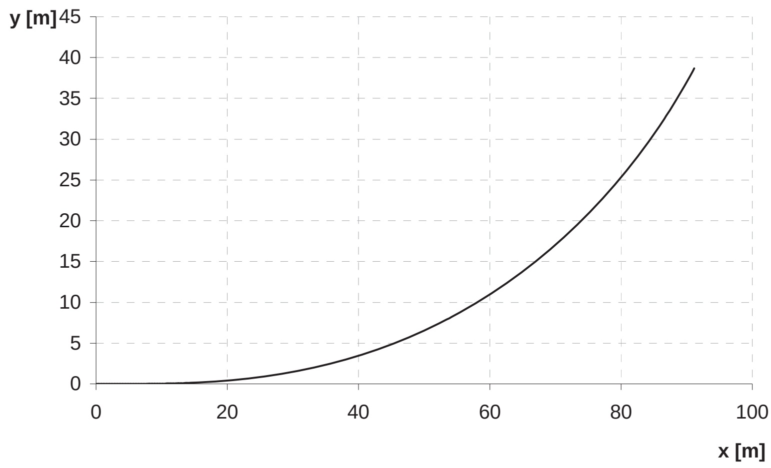

Fig. 12. Vehicle motion trajectory, data based on variant No. 46

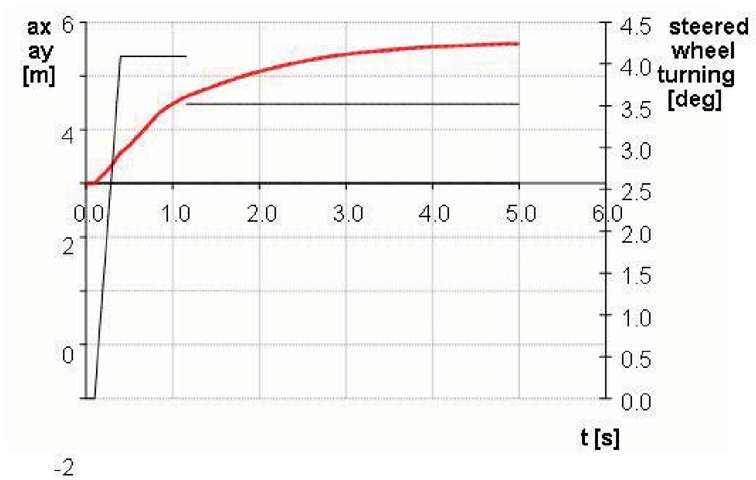

Fig. 13. Progress of the value of longitudinal acceleration a_x, side acceleration a_y and steered wheels turning angle, data based on variant No. 46

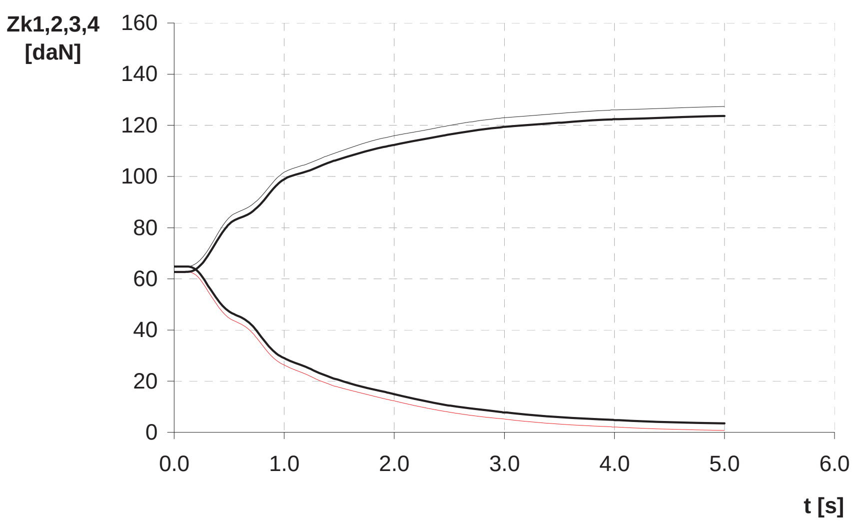

Fig. 14. Progress of the value of vertical force pressed by vehicle wheels on the road, data based on variant No. 46

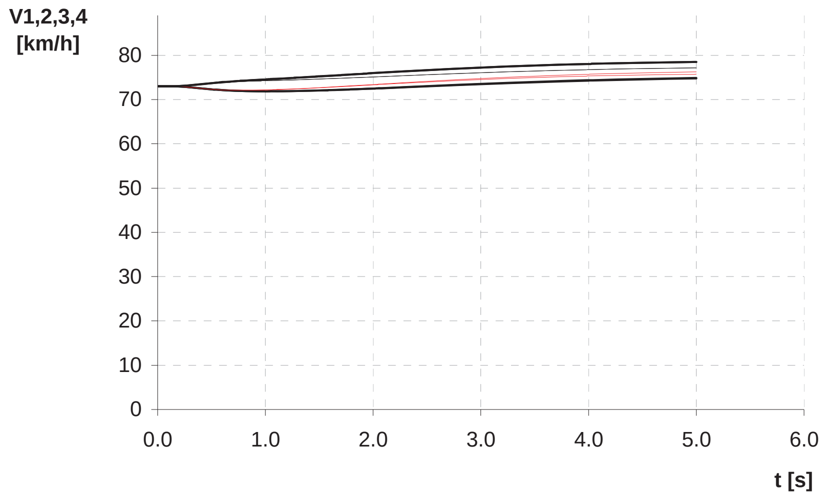

Fig. 15. Progress of longitudinal velocity value of the vehicle and circumferential velocity of its wheels data based on variant No. 46

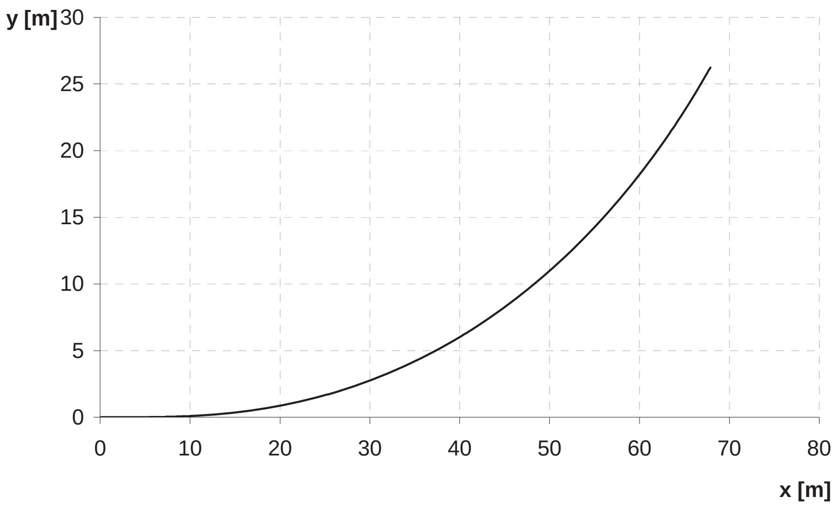

Fig. 16. Vehicle motion trajectory, data based on variant No. 56

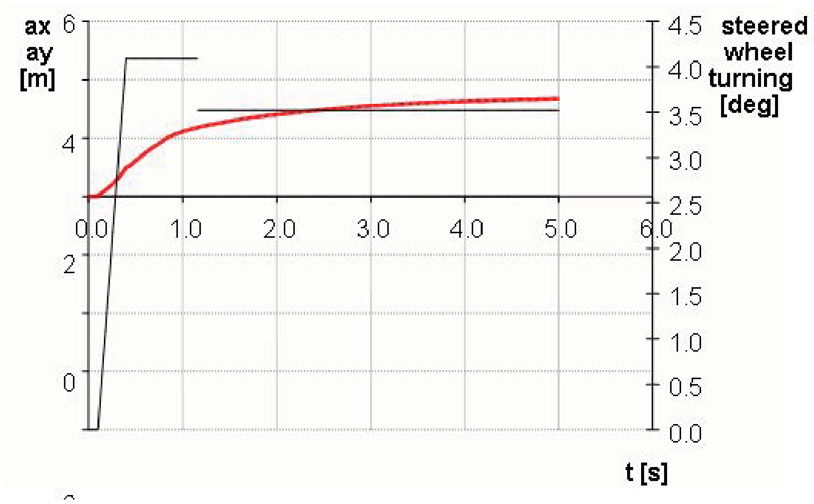

Fig. 17. Progress of the value of lateral acceleration a_x, side acceleration a_y and steered wheels turning angle, data based on variant No. 56

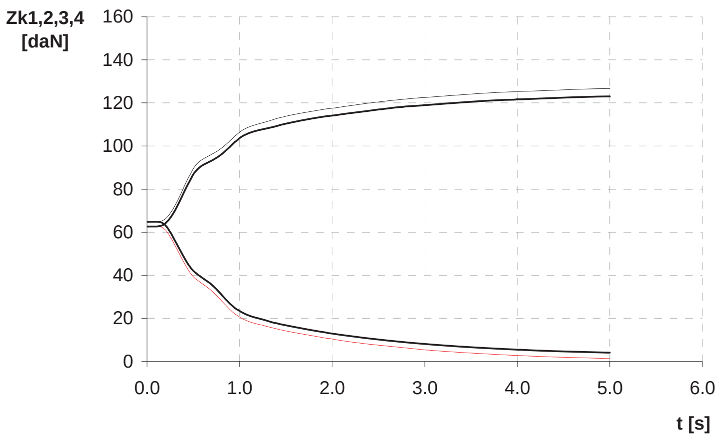

Fig. 18. Progress of the value of vertical force pressed by vehicle wheels on the road, data based on variant No. 56

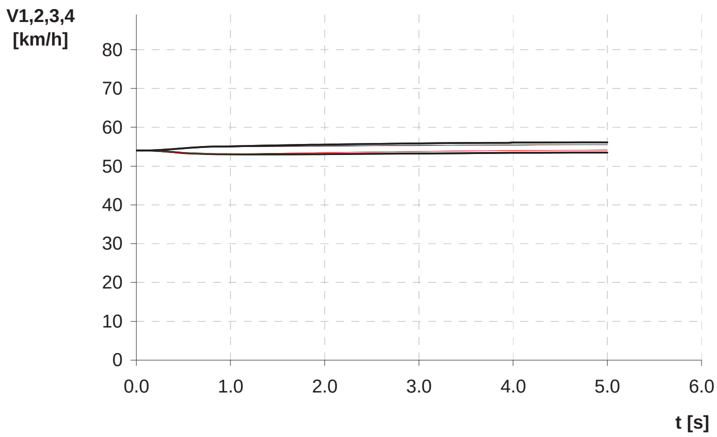

Fig. 19. Progress of longitudinal velocity value of the vehicle and circumferential velocity of its wheels data based on variant No. 56

6. Summary

The results that have been presented in the paper are very selective and basically demonstrate the idea of performed simulation research studies. However, the simulation studies were conducted to a much wider extent and in the way sufficiently allowing for defining influence on vehicle's behaviour in curvilinear motion, impact of the weight and location of the centre of inertia, and parameters that are most often changed whenever modernisation works are performed on the vehicle. It is worth stressing that a catalogue of the parameters being changed is looked up to real objects and trends occurring in the changes being introduced. The tests of emergency braking while turning have allowed for determining the influence of the ABS system. As the number of wheeled armoured fighting vehicles used buy our armed forces keeps growing, it becomes more crucial to define influence of the aforementioned selected designing parameters on their traffic safety. Detailed analysis along with its effecting conclusions both for users and the designing of this type of vehicles shall be presented in a separate publication.

References

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