EXPERIMENTAL VERIFICATION OF THE MODEL ASSIGNED FOR WHEELED ARMOURED FIGHTING VEHICLE TESTING

Przemysław Siminski, Maciej Zajac

Military Institute of Armour and Automotive Technology
Okuniewska 1, 05-070 Sulejowek, Poland
tel.+48 22 6811204, fax: +48 22 6811073
e-mail: psiminski@tlen.pl

Abstract

Experimental research studies of vehicles are of high cognitive importance. However, they are expensive, time-consuming and sometimes dangerous, especially when they refer to edge safety parameters of a vehicle motion. Their scope can be limited if researchers conducting the studies have at their disposal a mathematical model of the vehicle motion and dynamics and a simulation program allowing for carrying out research in „virtual space." A start-up of the simulation process requires gathering a relevant and require amount of data. If the simulation research studies that have been conducted are used for experimental verification, it is essential to obtain them to carry out a „package" of a series of experiments and a detailed design documentation analysis. Such a proceeding has been conducted with reference to research and development project of Ministry of Science and Higher Education (MNiSzW) No. R0000502. As part of its implementation, a model has inter alia been constructed using a multi-body-system class of software. The model has also gone through its experimental verification process basing on a test of a double change of traffic lane recommended by ISO standards. The developed model allows for changing the values of a specific parameter in „Parameters" options – in the main window of the model.

Keywords: *simulation tests, multi body systems, AFV*

1. Introduction

Development of the 8-wheeled military vehicle computer model allows for motion simulation in various terrain conditions, as well as it serves assessment of selected dynamic parameters at specified extortions.

Out of a number of the currently available professional software programs for dynamic and kinematic analysis of multi body systems, such as e.g.: DADS, ADAMS, SIMPACK, MEDYNA or NEWEUL, the DADS program has been used for modelling the wheeled vehicle.

In the first phase, the model data (inter alia position of the main and local coordinate systems, geometrical dimensions, inertial and weight parameters, and also damping and elastic characteristics) is entered and presented in a form of a group of elements using the graphic interface DADSModel. As the next step, the system of differential equations that describe motion of the model is generated, using the second type of Lagrange equation. Then, position, velocity and accelerations of individual elements of the system are determined as well as their mutual interaction (forces, moments).

The modelling results may be presented in a form of time processes of selected quantities, or by using computer animation illustrating behaviour of the entire system from any point of view.

The model that has been developed in DADS program is saved in *.def file that stores four types of basic information:

- DADS model elements, such as: coordinate systems, solids, constraints, forces and limitations,
- information about appearance and environment – colour of environment, observation point and angle of the model, etc.,

– information about animation hierarchy – which elements of geometry are assigned to which solids,
– sizes of geometrical figures.

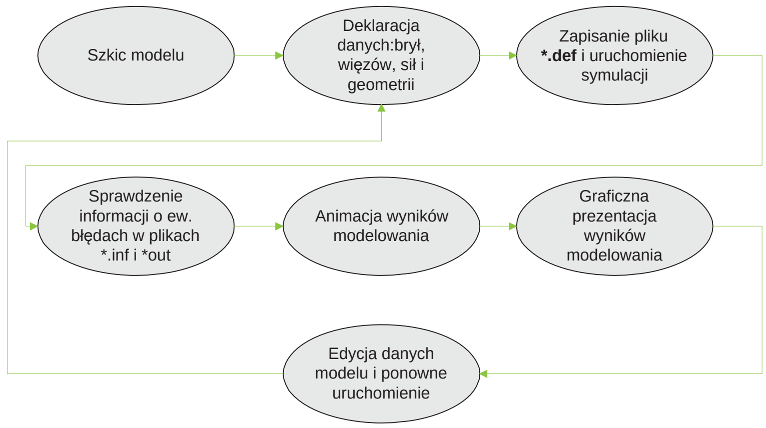

Fig. 1. Modelling phases in DADS program

2. Data for the model

In the model verification phase, those results were used which had been obtained while testing traffic lane double change and moving round the circle at various driving velocities. Velocities, obtained during real measurements, and angular positions of the steering wheel were fed to the model.

The verification involved an assessment of the obtained lateral accelerations values, measured in the driver's seat, against values being received from the model.

Fig. 1 presents the process of the steering wheel yaw angle function in time function while performing three subsequent traffic lane double-change manoeuvres at velocity of V=85km/h („LOS85JP.res", „LOS85JP2.res", and „LOS85LTC.res" files). The initial values of the angle, ranging around the size of 150°-170°, are most likely to result from the fact that recording of the aforementioned process was started at the moment when the vehicle was already moving and they effect from a relative position of the vehicle against the intended driving trajectory.

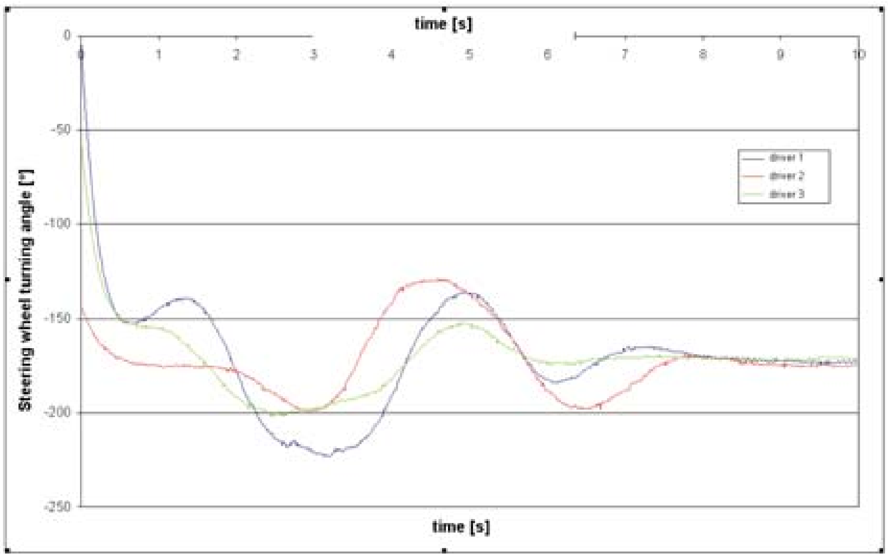

Fig. 2. Process of measured yaws of the steering wheel

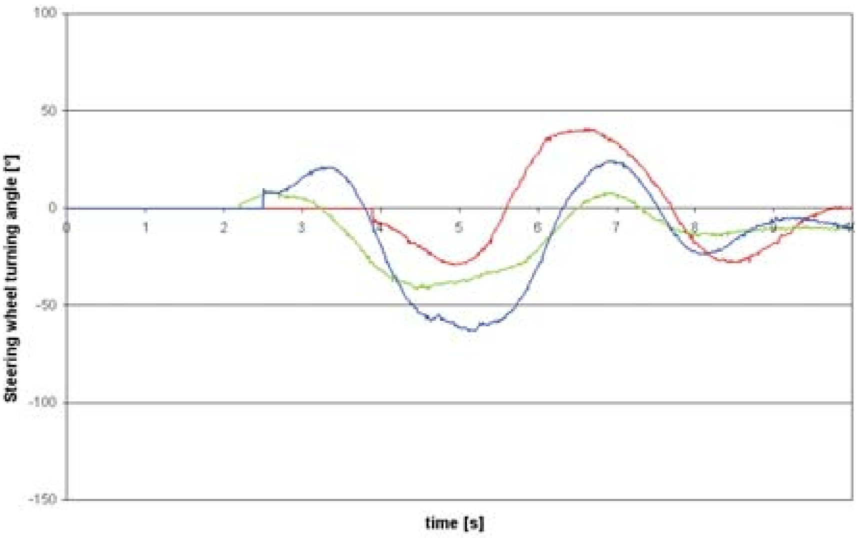

Fig. 3. Process of the steering wheel extortions assumed in the model

Adopting the extortion on the steering wheel, presented on Fig. 2, and simulating a drive with velocity of 85 km/h, the centre of gravity's lateral acceleration values were analysed and compared.

Diagrams 4 and 5 illustrate the values generated from measurements and simulation tests.

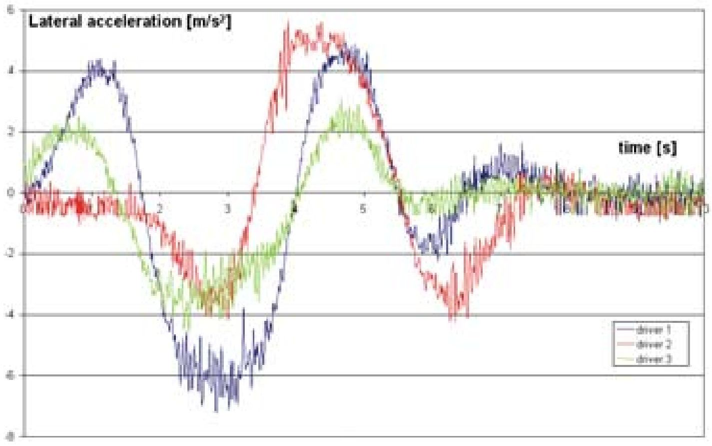

Fig. 4. Process of lateral accelerations obtained while individual forays

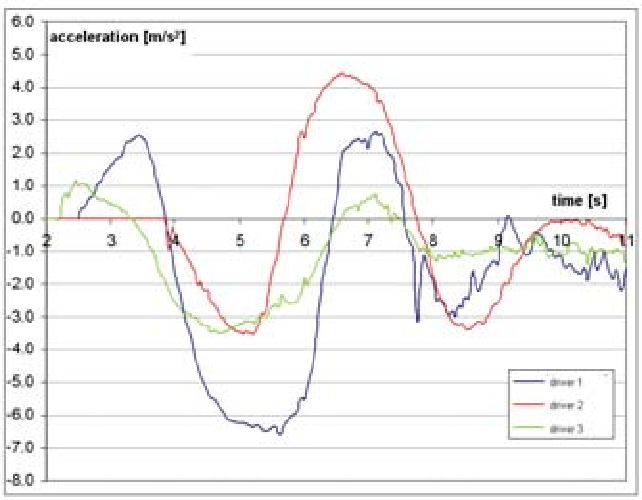

Fig. 5. Process of lateral accelerations obtained in the computer model

In order to become certain that the developed model is reliable, the lateral accelerations generated while driving around the circle with constant velocity were compared in the next phase of the verification. The results are presented on Fig. 6 and 7.

a) b)

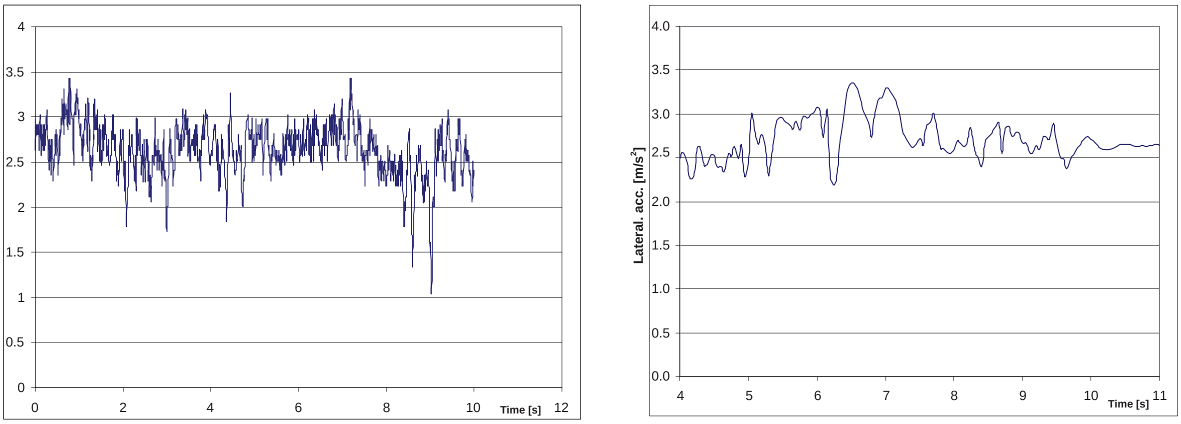

Fig. 6. Right turn V=30 km/h („pr30.res"file): a) experiment, b) simulation

a) b)

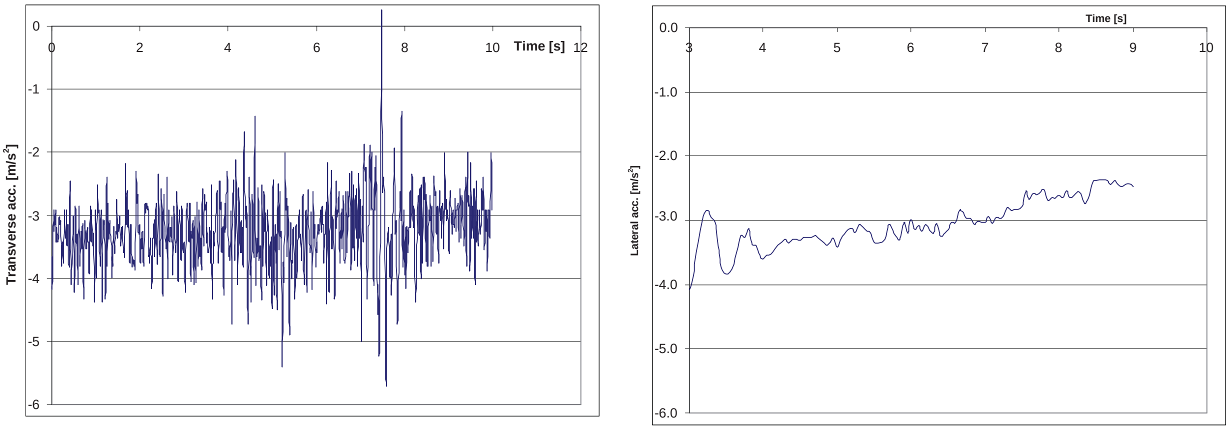

Fig. 7. Left turn V=30 km/h („le30.res"file): a) experiment, b) simulation

Basing on the generated results, it was found that the obtained processes of accelerations may constitute a foundation of a statement that the model operates properly and reflects the real object with satisfactory accuracy.

By verifying the model, the authors of this paper were considering overall results of simulation research and tests at military training field. The above-presented processes are the compromise between matches of the model's different parameters that may have affected the obtained processes, thus gaining a high degree of compliance in a single simulation – while the results generated in the next simulation were not that fully satisfactory.

Moreover, it has been found when analysing the results obtained in the verification phase that certain discrepancies in the results may effect from occurrence of the steering wheel plays in the real object, which is not included in the computer model.

2.1. Nominal model of the vehicle

While modelling of the wheeled armoured type of vehicle (KTO), general characteristics were used and determined on the real vehicle, namely: the Medical Rescue vehicle, developed on the chassis of armoured vehicle presently serving in Polish Armed Forces (SZ RP).

The basic elements of the vehicle as mechanical system are as follows: rigid body placed on the frame, engine with power transmission system, and driving system consisting of 8 road wheels with independent suspension in a form of upper and bottom spring as well as gas-hydraulic shock-absorber.

The vehicle total weight is 22 000 kg.

2.2. Physical model of the vehicle

In the development process of the physical model, a focus was on those features of the vehicle that have key influence on the performance of dynamic processes and the transfer of loads among elements of the vehicle [2]. In this phase, the vehicle was replaced with equivalent system of solids and material points, its shapes were simplified, hardly significant influences were disregarded, homogeneity of material was assumed, and deformabilities of elements (weights) were omitted [1,3].

The following assumptions were made when developing the physical model of the vehicle:

– the vehicle consists of the hull, eight road wheels (of which each is able to make turns), upper and bottom springs,
– changes in weights of individual solids, effecting e.g. from fuel consumption, are small, which allows for assuming them as being constant,
– the body is a rigid solid of the known weight and weight moments of inertia,
– elastic and damping elements are zero-mass elements,
– the vehicle makes small vibrations around static balance position,
– constraints imposed on the system are holonomic, scleronomic, and bilateral,
– translocation velocity of the vehicle is constant.

The coordinate system related to the centre of gravity of the entire vehicle, illustrated on Fig. 8, was assumed while modelling.

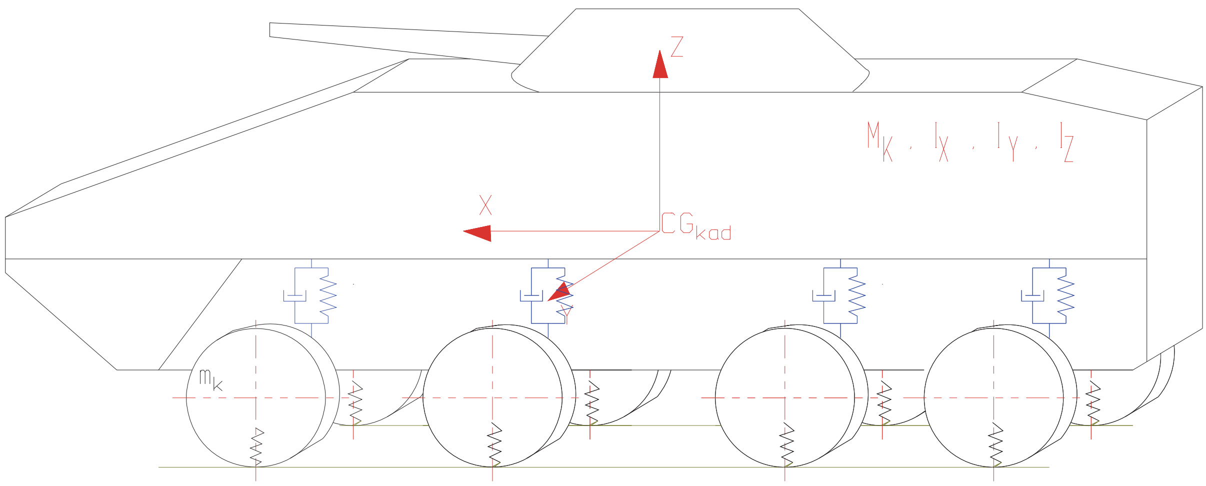

Fig. 8. Assumed system of the body coordinates and key elements of the model

2.3. Simulation model of the vehicle

The following preliminary assumptions have been adopted for vehicle modelling:

– body weight:	20161 kg,
– wheel weight	233 kg,
– total vehicle weight	22025 kg,
– wheel track:	2444 mm,
– wheel base 1_2	1402 mm,

– wheel base 2_3 1701 mm,
– wheel base 3_4 1451 mm,
– wheel static radius 650 mm,
– spring length ` 500 mm,
– shock absorber's elasticity coefficient 957000 N/m,
– environment resistance coefficient 0.015,
– traction coefficient 0.8,
– height of position of centre of weight over road surface 1238 mm,
– tire radial rigidity 887 000N/m,
– lateral resistance of tires for sideway drifting 430000 N/m.

All the aforementioned quantities have been parameterised in the developed model.

For modelling purposes, the solids-related local coordinate systems have been adopted and used to define respective moments of inertia, which reached e.g. for the body:

$$I_{X\_kadł} = 18748{,}37\ [kg \cdot m^2],$$

$$I_{Y\_kadł} = 87422{,}77\ [kg \cdot m^2],$$

$$I_{Z\_kadł} = 89842{,}27\ [kg \cdot m^2].$$

The elastic-absorbing elements, included in the vehicle model, were gas-hydraulic shock-absorbers with fixed elasticity coefficient and of absorption characteristic illustrated on Fig. 9.

The steering wheel leverage has been taken into consideration in the model, excluding the steering system plays (Fig. 10).

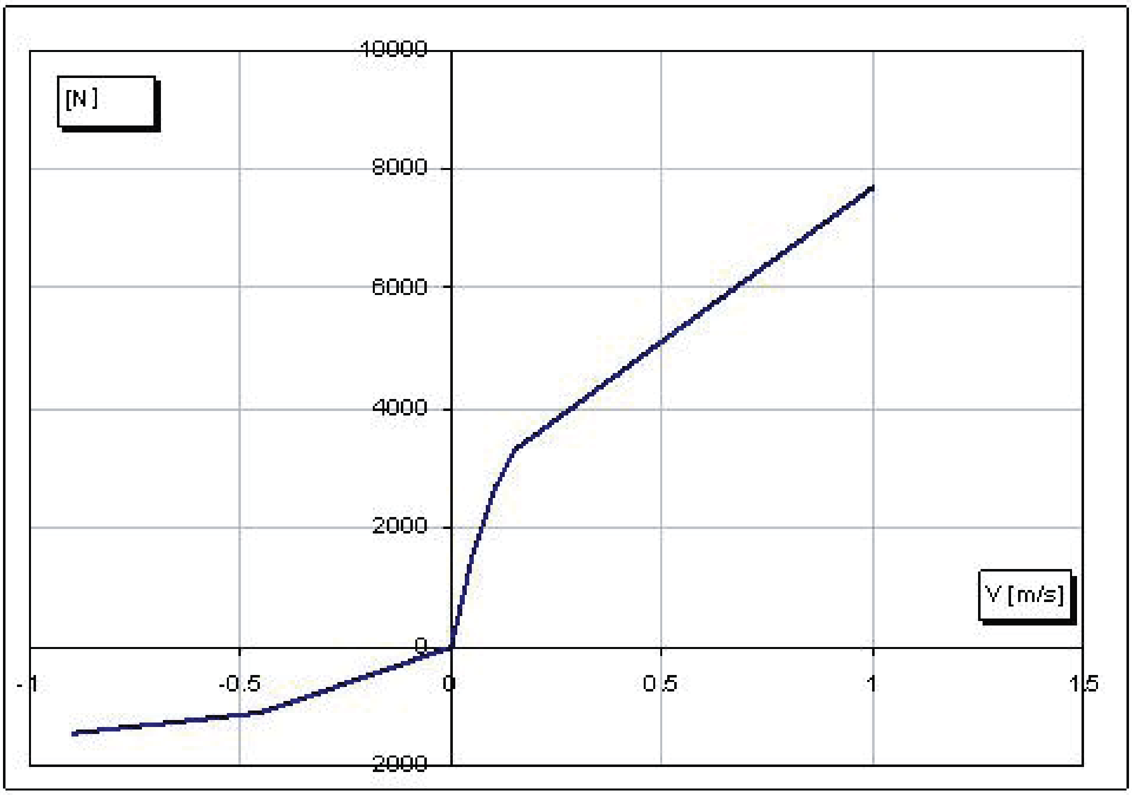

Fig. 9. Absorption characteristic of gas-hydraulic shock absorber

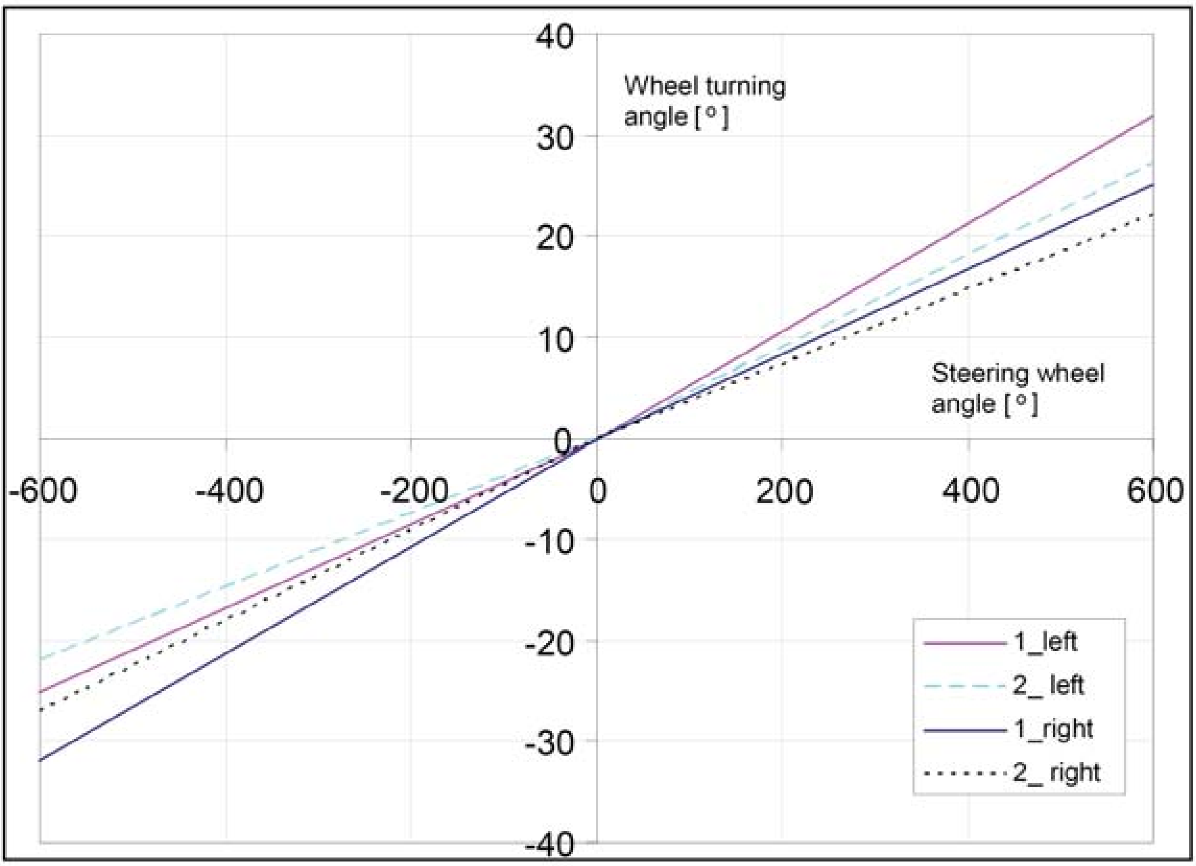

Fig. 10. Assumed characteristic of the steering system

Characteristics of the above-mentioned elements have been determined in experimental way by the WITPiS research team (the steering system characteristic) as well as they have been assumed a priori in order to make a preliminary verification (rigidity and absorption characteristics) and they may be a subject to adjustments in further phases of the research study.

2.4. Constraints, limitations, and extortions of the model

A total of 9 solids have been differentiated in the model, including:

- body: having a possibility of relocations alongside 3 axles and rotations around them;
- 4 turning wheels (1^{st} and 2^{nd} axle), having a possibility of vertical relocations and angular transpositions against the body
- 4 wheels of the third and fourth axle, having a possibility of vertical relocations with a simultaneous possibility of making turns (during further preliminary verification, the aforementioned wheels will not make angular transpositions against the body);

Extortions have been taken into consideration in the model:

- in a form of torque applied to the front axle, and aiming to move the vehicle at provided velocity;
- in a form of angular transposition of the first and the second axle wheels against the body, and aiming to cause the turning manoeuvre.

On Fig. 11, a zoomed view of the wheel suspension model has been presented (together with visible upper and bottom springs), developed in the DADS program along with marked characteristic coordinate systems.

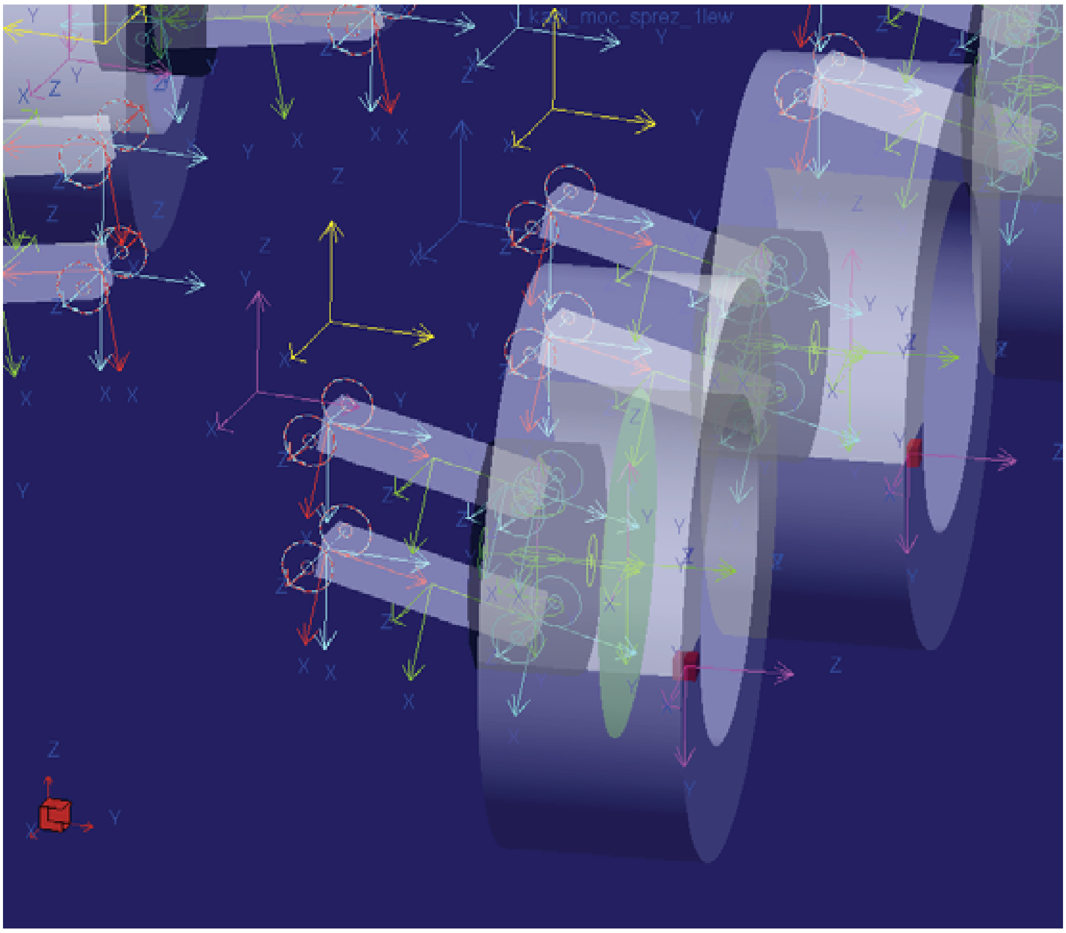

Fig. 11. View of AFV wheel suspension modelled in DADS program

3. Summary

The developed simulation model of the vehicle has been significantly parameterised, which means that it allows for changing the values of a specific parameter in „*Parameters*" options – in the main window of the model.

The result of performed preliminary computer simulations, basing on the above-mentioned simplifying assumptions, indicates that the model reflects a real object to a certain extent; nevertheless it requires further works with respect to a more complete verification in the aspect of specific values that are obtained through measurements, which shall be continued in further phases of the scientific work.

Additionally, a computer visualisation of the vehicle motion has been made in a form of *.avi files for purposes of „media" imaging and also easier assessment of the results.

References

[1] Borkowski, W., Konopka, S., Prochowski, L., *Dynamika maszyn*, WNT, Warsaw, 1996.
[2] Canzon, R. H., *Dynamika układów fizycznych*, WNT, Warsaw, 1973.
[3] Żółtowski, B., *Badania dynamiki maszyn*, Wyd. Markar-BZ, Bydgoszcz, 2002.