MODEL RESEARCH ON WHEELED ARMOURED FIGHTING VEHICLE ORIENTED TO TRAFFIC SAFETY IMPROVEMENT

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Abstract

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.

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.

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

1. Data for the model

At the phase of modelling and simulation tests, the coordinate system that is related to the centre of gravity of the entire vehicle has been assumed and illustrated on Fig. 1.

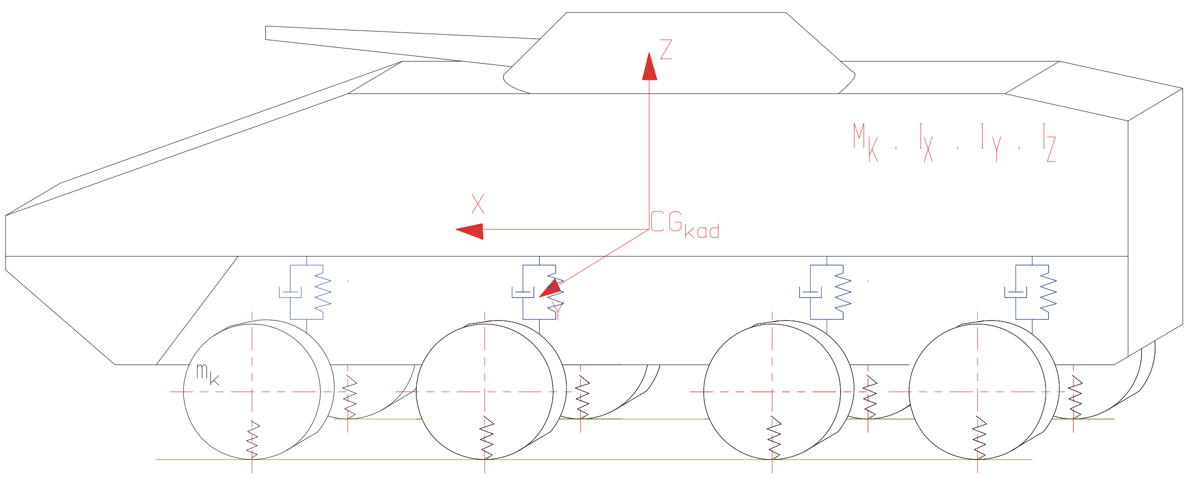

Fig. 1. Assumed system of the body coordinates and key elements of the model

The following scope of change of individual parameters has been assumed during simulation tests:

1. Change in position of the vehicle's centre of weight:
   – alongside Z axle: 200 mm (upward), -200 mm; (downward),
   – alongside X axle: 400 mm (forward), - 400 m (backward).
2. Change in the vehicle's weight and thus resulting change in value of moments of inertia of the body solid:
   – 18000 kg ($I_{X\_kad} = 16786\ [kg \cdot m^2]$, $I_{Y\_kad} = 78320\ [kg \cdot m^2]$, $I_{Z\_kad} = 80525\ [kg \cdot m^2]$.
   – 22000 kg ($I_{X\_kad} = 20500\ [kg \cdot m^2]$, $I_{Y\_kad} = 95670\ [kg \cdot m^2]$, $I_{Z\_kad} = 98365\ [kg \cdot m^2]$,
3. Increase of the suspension rigidity coefficient by 30%.
4. Decrease of the suspension rigidity coefficient by 30%.
5. Decrease of the coefficient.

The following tests have been attempted to be made for each of the above cases:

A. Driving with constant velocity of V=80 km/h with a growing angle of the steering wheel turn, following a characteristic provided on Fig. 2 – further in the paper referred to as „the turn";

B. Simulation of the steering wheel pulling, following a characteristic provided on Fig. 3 – further in the text referred to as „the puling";

C. Simulation of the traffic lane double-change manoeuvre with velocity of V=100 km/h with the steering wheel rotation function, presented on Fig. 4 – for simplification purposes further in the text referred to as „the slalom".

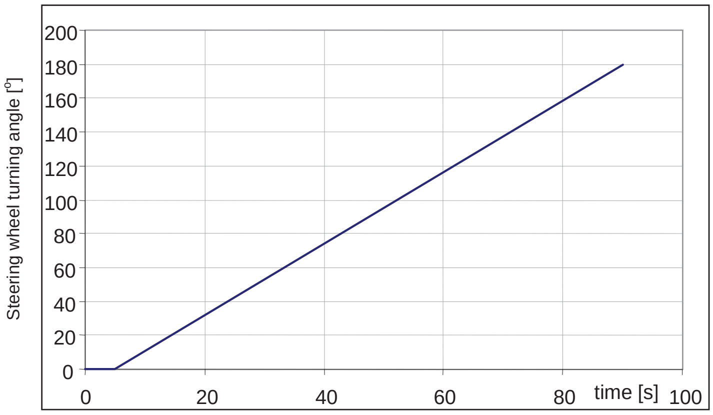

Fig. 2. The steering wheel turning angle in time function for soft turning manoeuvre with constant velocity

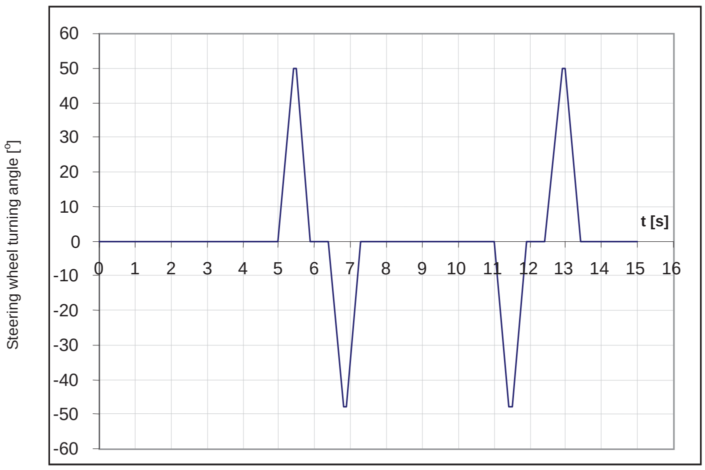

Fig. 3. The steering wheel turning angle in time function for the steering wheel pulling manoeuvre

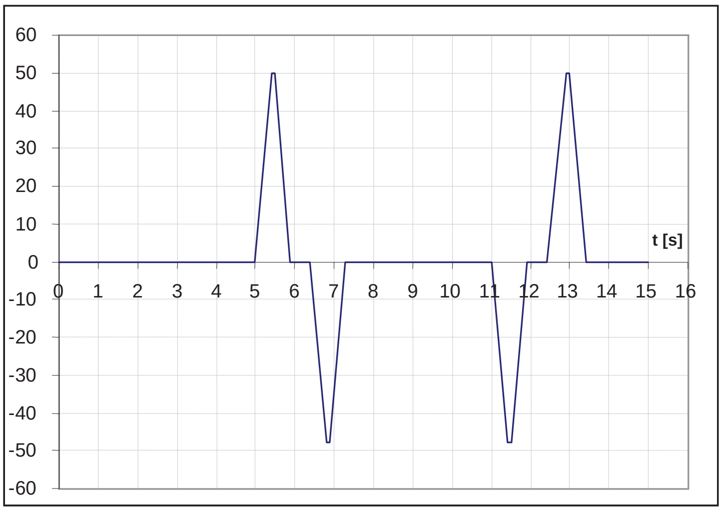

Fig. 4. The steering wheel turning angle in time function for traffic lane double-change manoeuvre (the slalom)

2. Simulation tests results

As a result of simulation tests that have been conducted, the whole series of data has been generated related to dynamics of the tested vehicle. The diagrams that are presented further on in the paper mostly focus on determining an influence that parameters being changed have on driving stability, during manoeuvres defined above, and expressed by value of radiant force in tires, lateral acceleration defined in the vehicle weight centre, and position of the vehicle on X-Y plane.

2.1. Influence of a change in position of the vehicle's centre of gravity

On Fig. 5, values have been presented of vertical forces affecting on individual wheels of the vehicle in variants of the vehicle's weight centre transposition. Time moments in which the force value declines to zero means no contact of tyre with the ground – i.e. „separation" of the wheel from the ground.

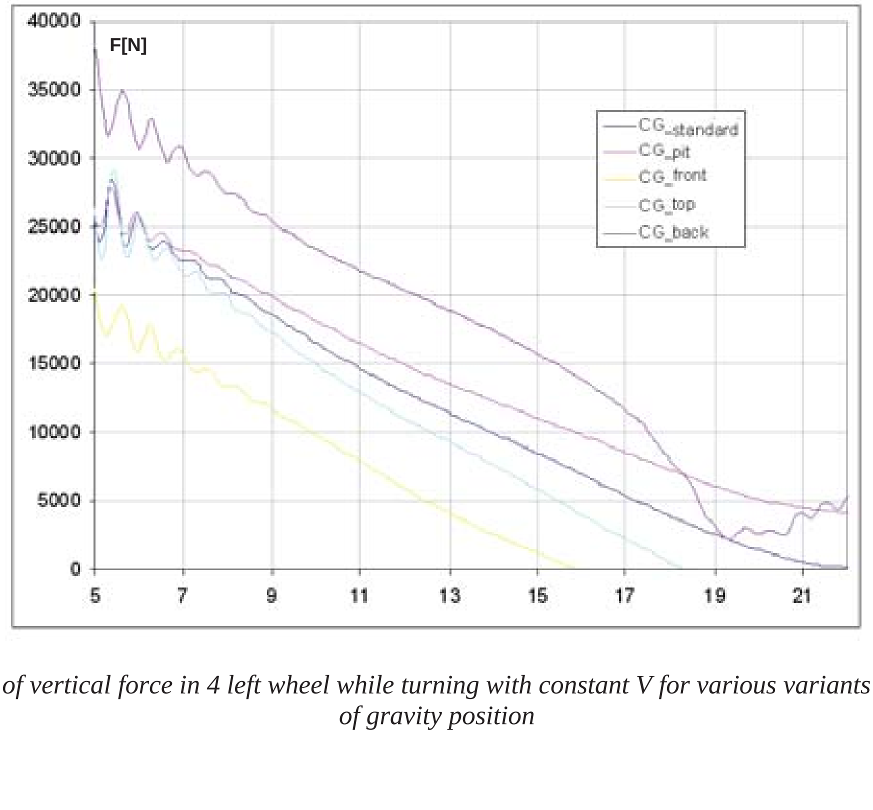

Fig. 5. Value of vertical force in 4 left wheel while turning with constant V for various variants of the centre of gravity position

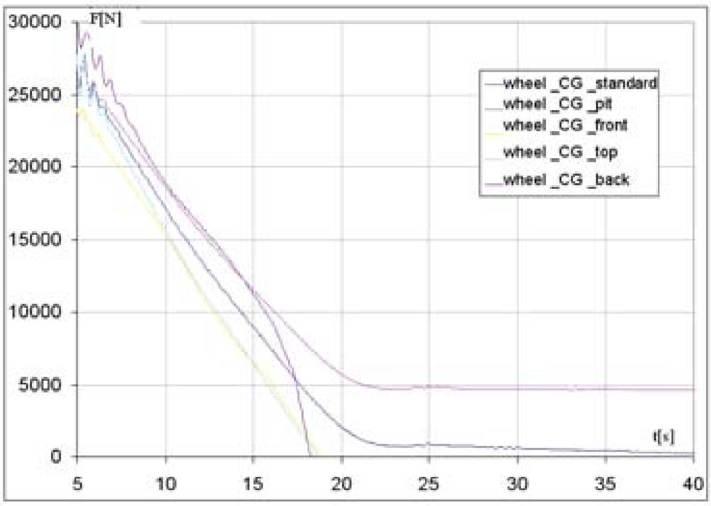

Fig. 6. Value of vertical force (F) in 3 left wheel while turning with constant V for various variants of the centre of gravity position

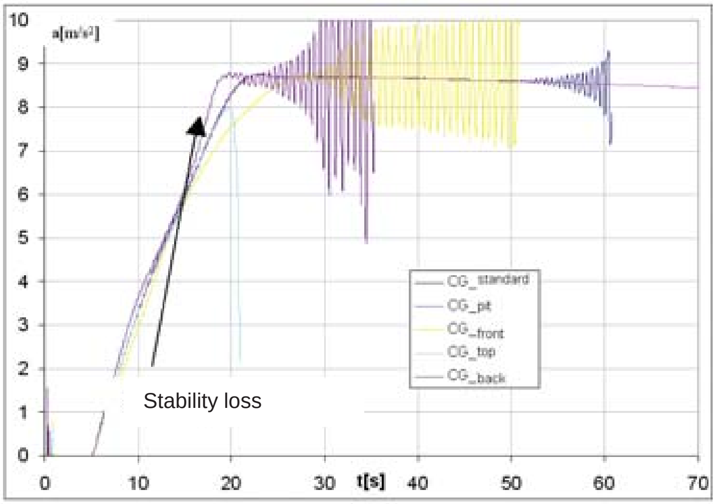

Fig. 7. Value of lateral acceleration for standard AFV (KTO) vs. time for various positions of the centre of gravity (CG) while turning with constant V

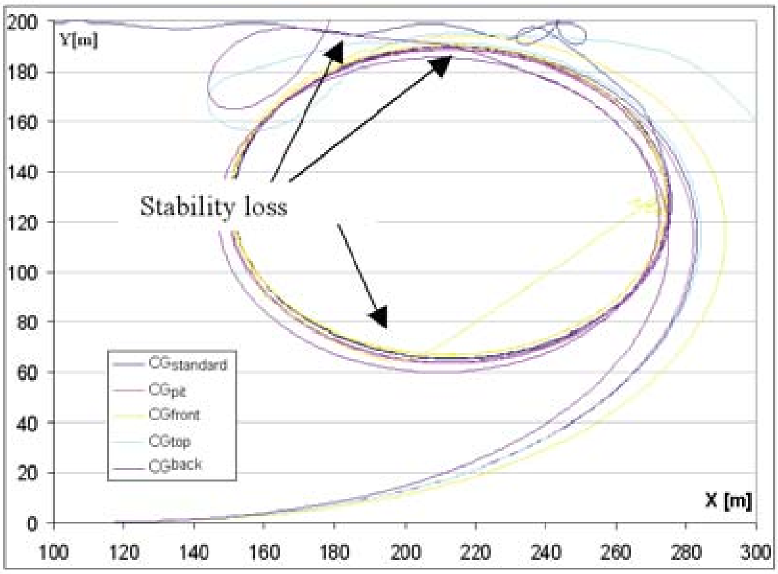

Fig. 8. The vehicle motion trajectory while soft turning manoeuvre with constant velocity for various CG position

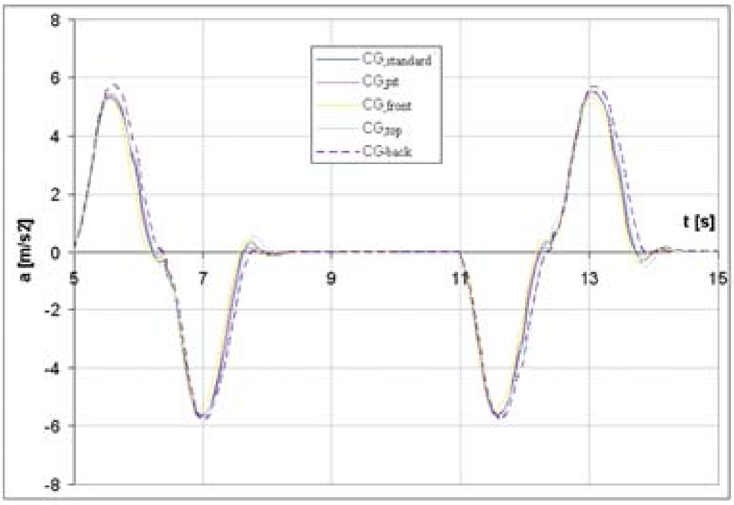

Fig. 9. Value of lateral acceleration (a) while the slalom manoeuvre for various positions of the centre of gravity

2.2. Influence of change in vehicle weight

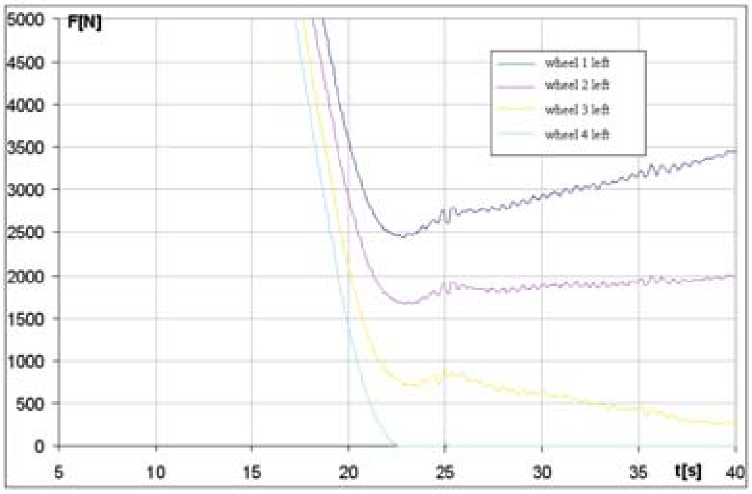

Fig. 10. Value of vertical forces vs. time in individual wheels of the left side of the vehicle for standard AFV (KTO) while the turning manoeuvre with constant velocity

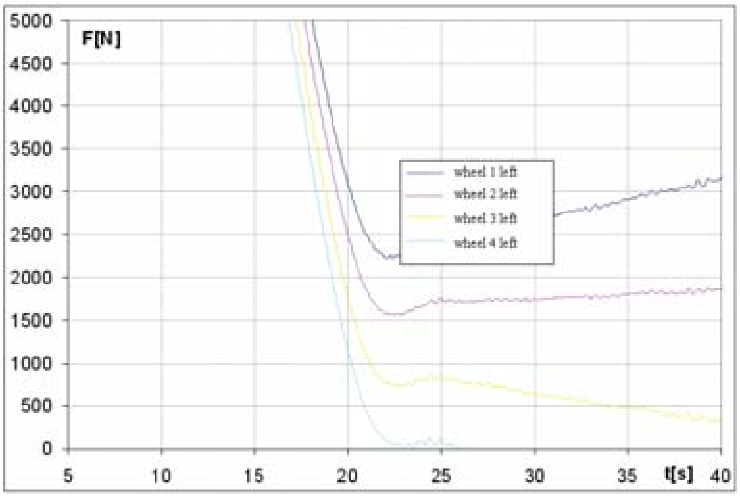

Fig. 11. Value of vertical forces vs. time in individual wheels of the left side of the vehicle for the reduced-weight AFV (KTO) while the turning manoeuvre with constant velocity

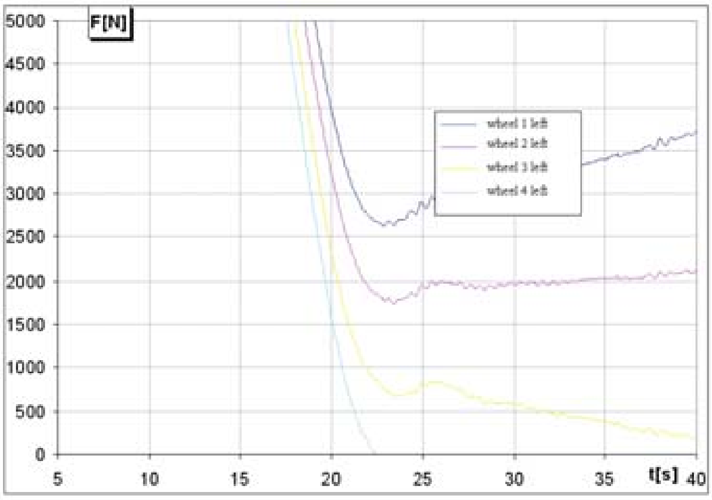

Fig. 12. Value of vertical forces vs. time in individual wheels of the left side of the vehicle for the increased-weight AFV (KTO) while the turning manoeuvre with constant velocity

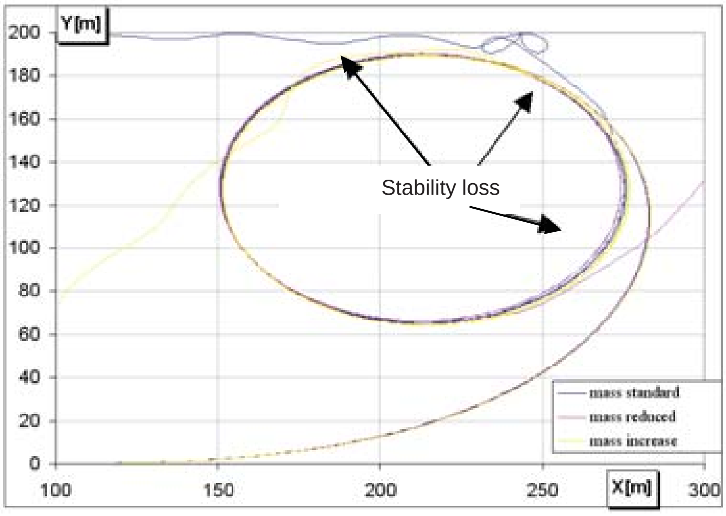

Fig. 13. The vehicle motion trajectory while soft turning manoeuvre with constant velocity for different values of vehicle mas

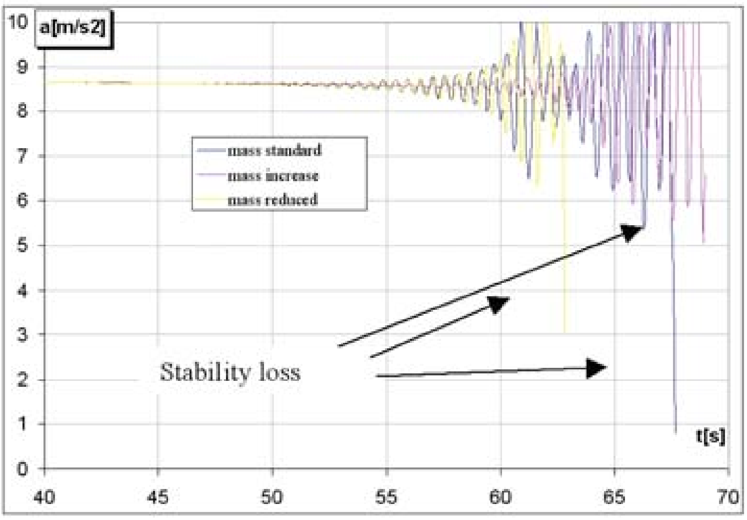

Fig. 14. The lateral acceleration vs. time for different values of vehicle mass while the turning manoeuvre with constant velocity

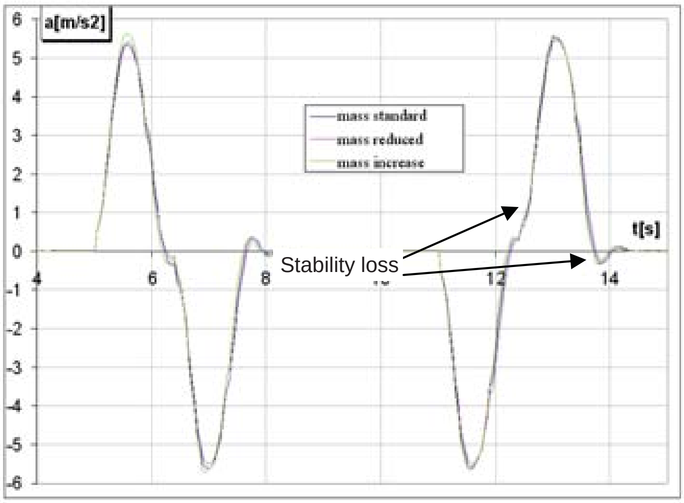

Fig. 15.The lateral acceleration vs. time while the „slalom" manoeuvre for different values of vehicle mass

2.3. Influence of a change in the suspension rigidity coefficient

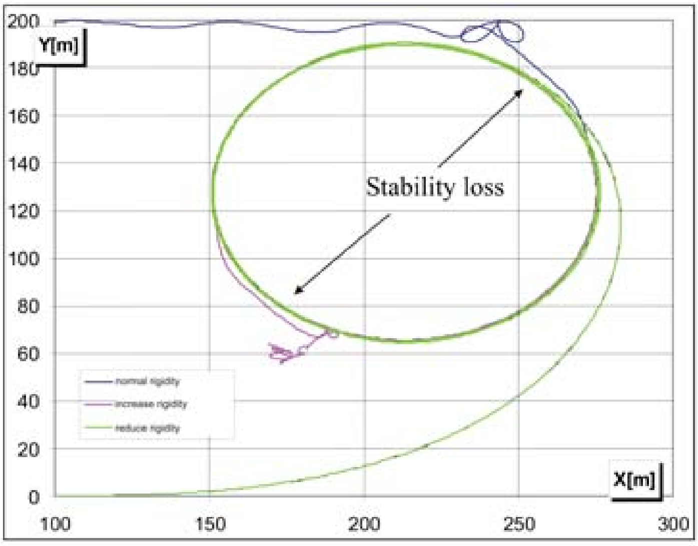

Fig. 16.The vehicle motion trajectory for different values of the suspension rigidity coefficient

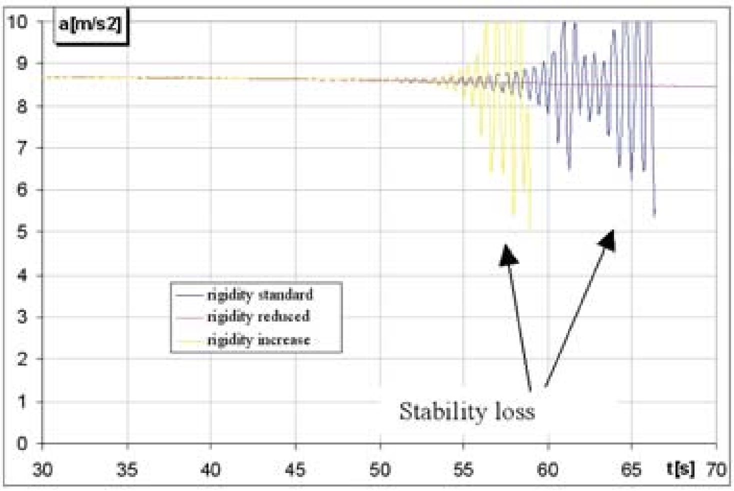

Fig. 17. The value of side acceleration vs. time while the turning manoeuvre with constant velocity for different values of suspension rigidity coefficient

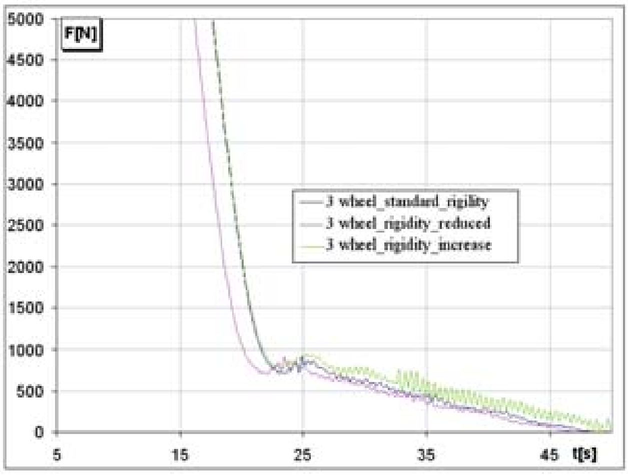

Fig. 18. Value of vertical loads of third left-side road wheels vs. time while turning with a constant velocity for various values of the rigidity coefficient

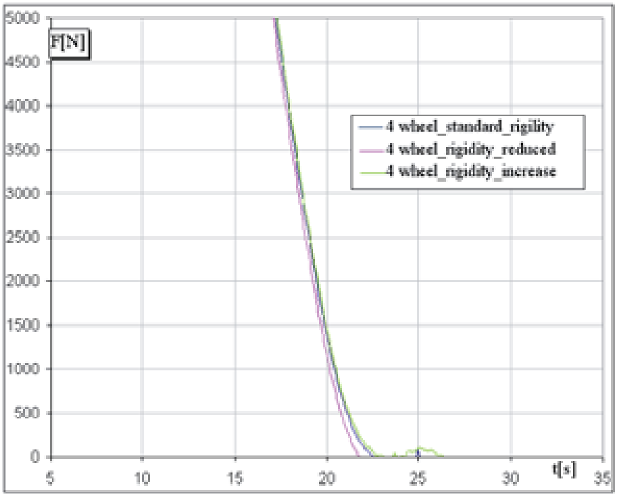

Fig. 19. Value of vertical loads of fourth left-side road wheels vs. time for various values of the rigidity coefficient while turning with a constant velocity

Additionally, and due to the fact that analysis of the computer animation has indicated that the vehicle with reduced rigidity coefficient has not lost its stability (as it happened for standard and increased rigidity), vertical forces in all wheels of the left side (being relieved while the turning manoeuvre) of the vehicle have been presented.

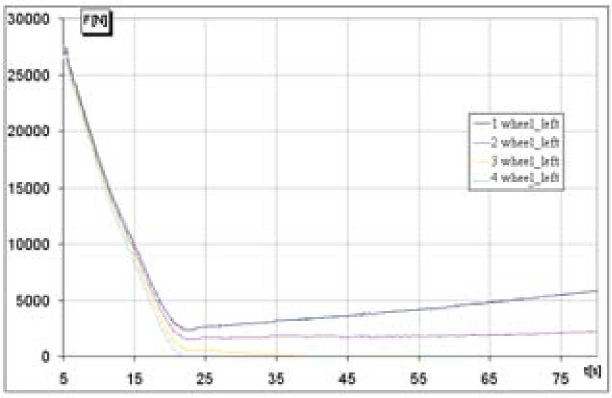

Fig. 20. Value of vertical loads of all left-side wheels for AFV (KTO) with reduced rigidity coefficient vs. time while turning with constant velocity

Based on data included on Fig. 20, a statement can be made that 3rd and 4th wheels have lost their contact with the ground (respectively in 38 second and 21 second of the simulation), but 1st and 2nd left-side wheels are constantly in contact with the ground.

2.4. Influence of a change in vehicle velocity

Also, a variant of the traffic lane double-change manoeuvre made by a vehicle moving with velocity of 120 km/h and 140 km/h was assumed during simulation tests. The value of the lateral acceleration of the vehicle's centre of gravity has been illustrated on Fig. 21.

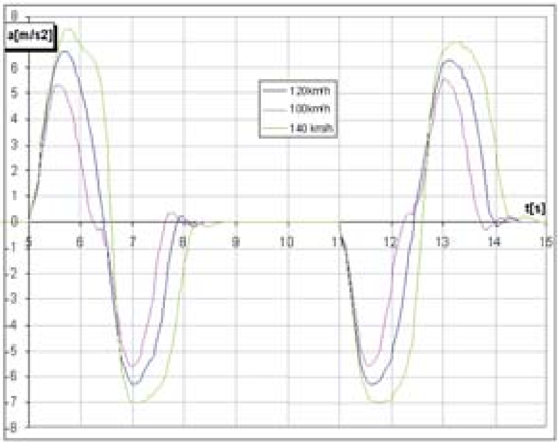

Fig. 21. Value of lateral acceleration vs. time while the traffic lane double-change manoeuvre with driving velocity of 100 km/h, 120 km/ and 140 km/h

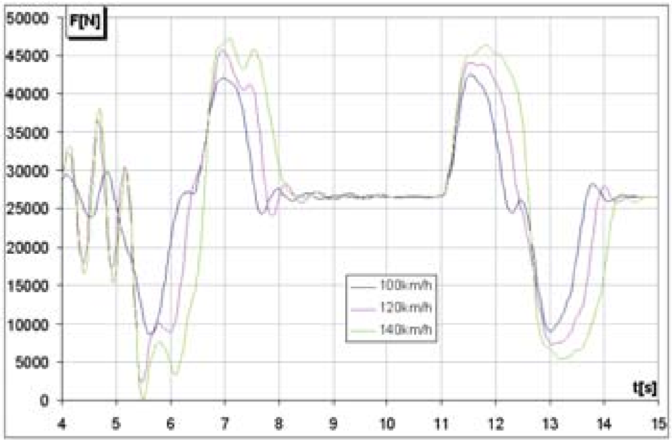

Fig. 22. Value of vertical loads of 4 wheels vs. time while the traffic lane double-change manoeuvre at various driving velocities

3. Analysis of obtained results

Basing on the results of review and simulation tests that have been performed, included in chapter 3 and 4, the following statements can be made:

1. the developed model and its characteristics reflect a real object with accuracy that allows for conducting further simulation tests;
2. transposition of the vehicle's centre of gravity alongside of Z axle by 200 mm worsened dynamic parameters of the vehicle through loss of its stability while the turning manoeuvre already in 20th second of the simulation (all wheels lost their contact with the ground).
3. the most favourable variant of the centre-of-gravity position was its transposition downward by 200 mm (while the manoeuvre of turning the 3rd and 4th left-side wheels lost their contact, but the vehicle did not roll over).
4. transposition of the vehicle's centre of gravity alongside longitudinal axle affected the change of the vehicle's turning radius (forward transposition – increased the turning radius, backward transposition – reduced it, Fig. 8).
5. the change of the vehicle's centre-of-gravity position practically had no impact on the value of the lateral acceleration while the traffic lane double-change manoeuvre (Fig. 9).
6. increase in the vehicle weight (and thus effecting change of inertia characteristics) caused earlier loss of stability while the turning manoeuvre (Fig. 13) – the reduction of weight caused reverse trend. The change in weight practically did not affect the value of lateral accelerations while the traffic lane double-change manoeuvre (Fig. 16).
7. the data, included on Fig. 22, indicates that reduction of the suspension rigidity coefficient definitely improved a possibility to perform the turning manoeuvre with constant velocity. Despite that 3rd and 4th wheels lost their contact with the ground, the vehicle was moving

around the circle with constant value of lateral acceleration. The vehicle with standard and increased rigidity coefficient lost its stability respectively in 67th and 59th second of the simulation.

8. while simulating the performance of the traffic lane double-change manoeuvre at velocities of 120 km/h and 140 km/h the vehicle was found to behave in a stable way. Values of vertical loads on road wheels indicate that none of the wheels have lost contact with the ground. Taking the maximum velocity of the vehicle (~110 km/h) into consideration, a statement can be made that that vehicle has a large reserve allowing for making safe manoeuvres on the road at high velocities.

4. Conclusions

The individual parameters values that were assumed for vehicle modelling and the process of characteristics allowed for developing a model with maximum possible reflection of reality.

The results obtained from simulation tests, for the assumed extortions, have proved a certain influence of the change in individual parameters on the vehicle's motion safety, but the results are not very spectacular. This rather indicates that the current design of the vehicle is good enough so that a specific scope of changes in selected characteristics (which may occur during standard exploitation – e.g. a change in load and thus effecting change in position of the centre of gravity or adjustment of the hydro-pneumatic suspension rigidity) are fully allowable without the worsening of traction parameters and safety conditions.

Nevertheless, a more precise definition of the suspension characteristic (and mostly the rigidity characteristic) is proposed in any possible further studies, basing on assessment of the results that are included binary files of individual simulations as well as by watching animations of individual drives.

References

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