MODELING PASSENGER HUMAN MODEL BEHAVIOR IN THE CASE OF REAR IMPACT

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Abstract: - Improving of the vehicle inner passive safety is a matter of utmost topical, which entails taking specific steps in order to reduce the consequences of the traffic events. The collision between two vehicles represents an elasto-plastic crash. Consequently, no results can be obtained without taking into account the conservation law impulse or of the kinematic moment, in addition, provided trajectories motor vehicles are almost parallel, methods graphic giving no satisfaction. Mathematical modeling of passenger movement during head impact may be a success "tool" in establishing mechanism of the neck injury, especially when working in parallel with experimental studies.

Key-Words: - modeling, collision, simulation, experimentation, safety, validation

1 Introduction

Vehicle safety is a phenomenon that more and more specialists who are directly involved in the motor vehicle directly in the industry vehicles or in a field complementary. The explanation lies in their desire to improve the current concept of possible safety car, but also to distinguish the design of equipment and systems performances. By forging mathematics of events is road obtained important data to help improve safety liabilities of motor vehicles. By using mathematical models human bodies are most often imprinted extensive movements. They are according to the complexity of simple mono-body models, the type mass- elastic element until three-dimensional models of the whole body. Generally they assimilate man with a crisp element linked by different types of joints, into a system with open loop.

2 Modeling rear collision between two vehicles

Modeling rear impact by a model of vibration theory involves using a mathematical model that simply consists of two masses linked with a spring for global rigidity C. The contact spring represents global rigidity two vehicles entering the collision front/rear. This model is used to theoretically determine functions of the time of speed, acceleration and deformation of the motor vehicles in front/rear centered impact.

2.1 Determining theoretical functions of the time of speed, acceleration and deformations of the motor vehicles in centered rear impact

The simplified mathematical model choice, consists of two masses linked with a spring for global rigidity C. [8]

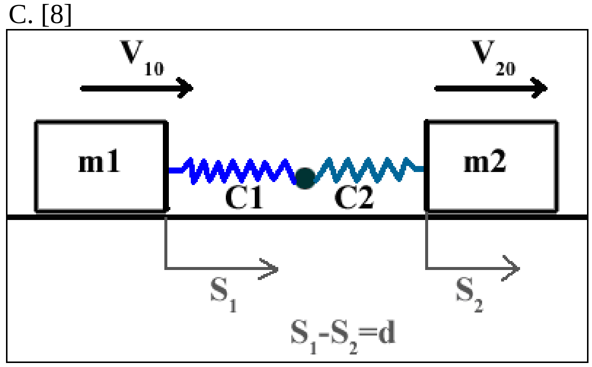

Fig.1 The scheme of crash model between two vehicles assimilated of a theory vibrations model

Noting with, index 1 the vehicle moving from behind and with 2 at the front, resulting global rigidity:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}; \tag{1}$$

Considering vehicles coming into collision that two masses coupled with one another in a spring of rigidity C equations of movement have the form:

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$$m_1 \cdot \frac{d^2 s_1}{dt^2} = -C \cdot (s_1 - s_2); \qquad (2)$$

$$m_2 \cdot \frac{d^2 s_2}{dt^2} = C \cdot (s_1 - s_2); \qquad (3)$$

The results of the equations of movement for the two vehicles are as follows:

For vehicle 1:

$$\begin{cases} s_1 = \left[v_{10} + (v_{20} - v_{10}) \cdot \dfrac{C}{m_1 \cdot \omega^2} \right] \cdot t - (v_{20} - v_{10}) \cdot \dfrac{C}{m_1 \cdot \omega^3} \cdot \sin \omega t; \\ v_1 = \dot{s}_1 = v_{10} + (v_{20} - v_{10}) \cdot \dfrac{C}{m_1 \cdot \omega^2} \cdot (1 - \cos \omega t); \qquad (4) \\ a_2 = \ddot{s}_1 = (v_{20} - v_{10}) \cdot \dfrac{C}{m_1 \cdot \omega} \cdot \sin \omega t. \end{cases}$$

For vehicle 2:

$$\begin{cases} s_2 = \dfrac{(v_{20} - v_{10})}{\omega} \cdot \sin\omega t \cdot \left(1 - \dfrac{C}{m_1 \cdot \omega^2}\right) + \left[v_{10} + (v_{20} - v_{10}) \cdot \dfrac{C}{m_1 \cdot \omega^2} \right] \cdot t; \\ v_2 = \dot{s}_2 = (v_{20} - v_{10}) \cdot \cos\omega t + v_{10} + (v_{20} - v_{10}) \cdot \dfrac{C}{m_1 \cdot \omega^2} \cdot (1 - \cos\omega t); \\ a_2 = \ddot{s}_2 = (v_{20} - v_{10}) \left(\dfrac{C}{m_1 \cdot \omega} - \omega \right) \cdot \sin\omega t. \qquad (5) \end{cases}$$

Maximum amplitude are to be determined by the time compression t_c when

$$\omega \cdot t_c = \frac{\pi}{2}; \qquad (6)$$

$$\sin \omega t = 1; \qquad (7)$$

The relationship with pulsation (rhytmic variation) during compression caused result global rigidity C:

$$\Rightarrow \quad C = \frac{\omega^2 \cdot m_1 \cdot m_2}{m_1 + m_2}; \qquad (6)$$

$$\Rightarrow \quad C_{1,2} = C \cdot \frac{d}{d_{1,2}}; \qquad (7)$$

and $$EES = d_{st} \cdot \sqrt{\frac{1.1 \cdot C}{m_{tot}}}; \qquad (8)$$

$$d_1 = d_{st1} + 0.1 \cdot d_{st1} = 1.1 \cdot d_{st1}; \qquad (9)$$

$$d_2 = 1.1 \cdot d_{st2}; \qquad (10)$$

Where:

$s_{1,2}$ – distance covered of the vehicle 1 and 2, during the phase of compression;

C – The coefficient of global rigidity, $C_{1,2}$ – Vehicle rigidity coefficient 1 and 2

d – Global deformation, $d_{1,2}$ – deformation (d_{st} + d_{din}) during compression time of vehicle 1 and 2; d_{st} – static deformation; d_{din} –dynamic deformation;

d – Dynamic deformation is higher than the approximately 10 percent static deformation measured after impact.

EES- Equivalent Energy Speed.

2.2 Front-rear collision modeling between two vehicles using dedicated software

For the simulation of two motor vehicles impact made used the PC-Crash application. [5] In order to determine acceleration variations of vehicle occupant head and torso level, in correlation with pusher vehicle speed, the researchers simulated the collision between two vehicles; the speed of the pusher vehicle ranged from 15km/h to 70 km/h and a human model was located in driver's seat in the pushed vehicle.

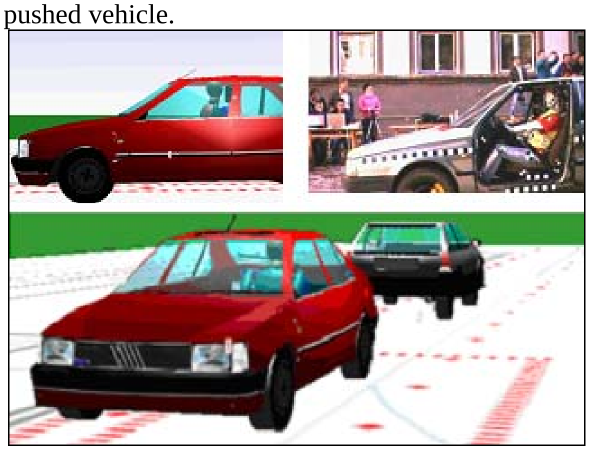

Fig. 2 Images of vehicle pushed, obtained from the PC-Crash and simulation video evidence of the experiment

In the simulation program of have been inserted two vehicles corresponding models of cars used in experimental phase.

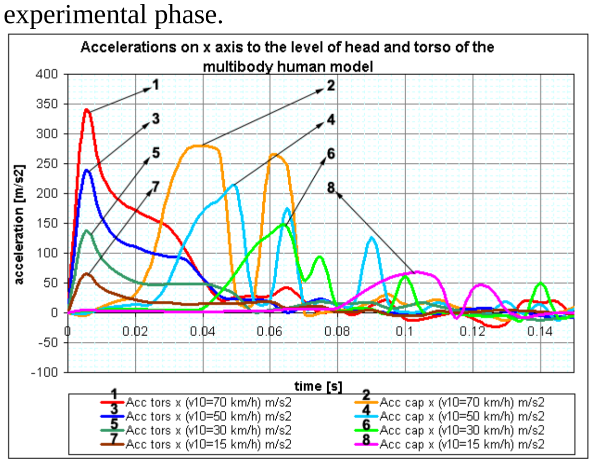

Fig.3 The curve of the acceleration on x axis determined for multi-body system term varying speed v_{10} of pusher vehicle [8]

Modeling rear impact between two motor vehicles, shows that during the appearance of peak of the head acceleration, varies at t_1= 0.035 s for v_{10}= 70 km/h of pusher vehicle, up to t_2=0.105 s for v_{10}= 15 km/h of pusher vehicle.

3 NUMERICAL SOLUTIONS FOR MATHEMATICAL MODEL OF REAR COLLISION

For the numerical solving of the mathematical model have been introduced values masses vehicles used in the experimental, the speeds of impact and the compression times determined by the experiment.

In order to define the experimental tests the following situations were considered as representative for the impact of two vehicles [7]:

- A vehicle is stationary, no speed recorded V_{20}=0;
- Test1: Pusher vehicle speed V_{10}=18.46 km/h;
- Test2: Pusher vehicle speed V_{10}=26.4 km/h.

The vehicles speeds has resulted by integration of the acceleration measured on x axis with Datalogger device. Knowing the fall in the pusher vehicle speed and its growth for the pushed vehicle, they can find compression time per these overlapping curves. Knowing the decrease of the pusher vehicle speed and its growth for the pushed vehicle, they can find compression time through by these overlapping curves.[8]

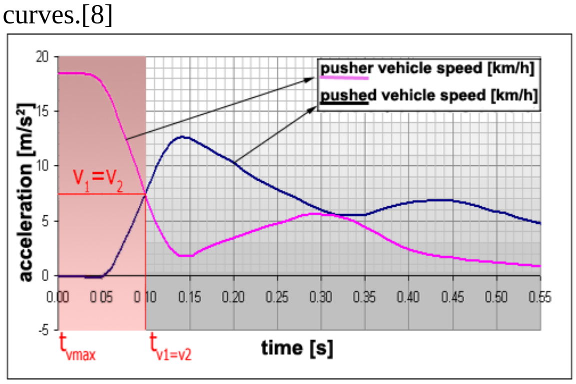

Fig. 4 Determining compression time for v_{10}=18, 46 km/h => t_c=-0.37+0.10=0.063s

By analyzing decreasing and increasing speeds of those two motor vehicles, can be determined the compression time, in to the range of time between t_{vmax} and t_{v1}=t_{v2}.

Where t_{vmax} is the time when v_{10} begin to decrease, and $t_{v1=v2}$ is time when the speeds of those two vehicles are equal.

The time t_c=0.045…0.075s is obtaining from diagrams measurements:

$$v_{10} = 14...70 km/h;$$

$$v_{20} = 0 km/h;$$

$$m_{1(mveh1+moccupant)} = 948 kg;$$

$$m_{2(mveh2+moccupant)} = 1253 kg;$$

$$He\ asks: d_{st1} = ?\, d_{st2} = ?$$

Using the compression time it has been determined pulse system of bodies connected by springs treated stiffness like, and thus the coefficient of stiffness in depending of the compression time and determining static alteration resulting on two vehicles involved in conflict.

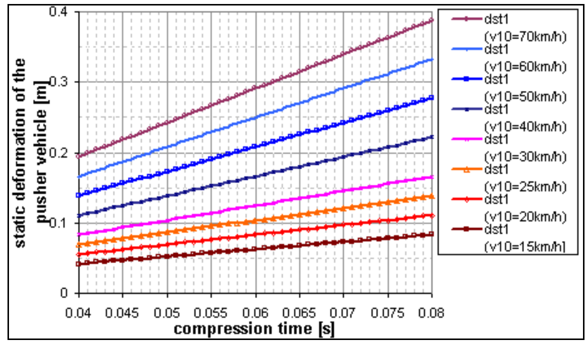

Fig. 5 The change in the static deformation pusher vehicle depending of the stiffness coefficient

Space covered by vehicle and overall deformation during compression depends on value coefficient rigidity, and the compression time.

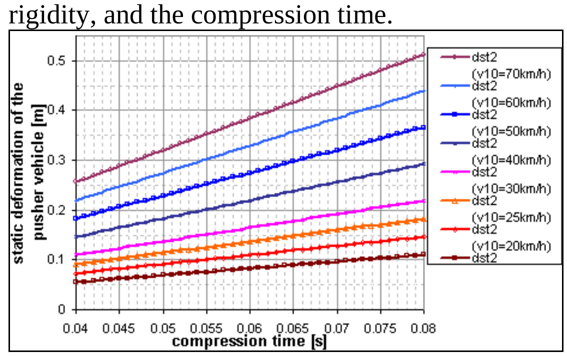

Fig. 6 The change in the static deformation pushed vehicle depending of the stiffness coefficient

During the compression phase when the speeds of the two vehicles are equal, motor vehicles deformations are elastic, so that dynamic deformations differs with about 10 percent from the static ones measured after the compression phase..[8]

4 Conclusion

By comparing the experimentally and mathematically obtained data the researchers were able to determine:

- Uncertainty between the parameters determined by simulation using specialized applications and the values experimentally measured.
- Uncertainty between the model of vibration theory and experiment.

The researchers compared the variations of the dummy's torso and head acceleration (in the experimentally test), as well as the accelerations of the multi-body in the simulation conducted by PC-Crash. Consequently, there have been compared the theoretically determined values of deformation at the end of compression, i.e. the dynamic deformation, and the experimentally determined values, i.e. remanent deformation; the first two tests considered a difference of 10 percent between the dynamic and static deformation.

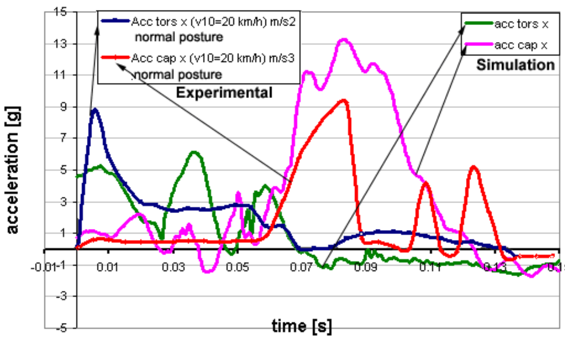

Fig. 7 The curve of the acceleration on x axis in simulation and experimental determinations for v_{10} = 19.44 km/h of pusher vehicle

A comparison between the two diagrams shows an accurate calculation of the parameters that stress the dummy's components. In terms of quality a distinction between experiment and simulation is also noticed. This distinction is particularly caused by the seat rigidity. The simulation could not consider all the characteristics of rigidity of the seat. The experiment shows an oscillation of torso acceleration in the first 50 ms in time.

During the simulation this variation is partly damped. For a speed of the pusher vehicle of 20 km/h, the maximum head acceleration is 10 g on simulation and 13 g on the experiment, the difference is explained by rigidity links between bodies, the multi-body system of the occupant.

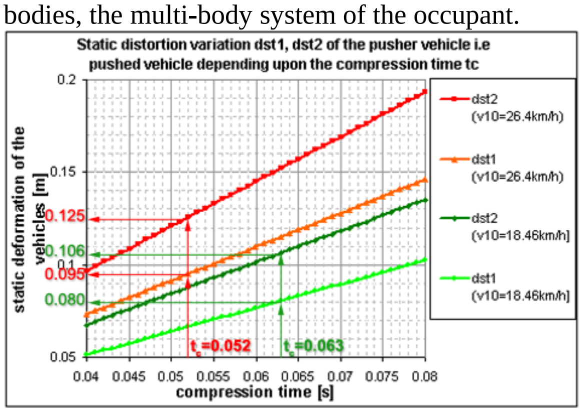

Fig. 8 The determination of vehicles static deformations from the theoretical model diagram of vibration theory

Therefore, for the compression time t_c = 0.063 s and a speed of the pusher vehicle of 18.47 km/h there was determined a calculated value of the static deformation of 0.106 m, and after the first test there has been measured a deformation of the pusher vehicle driven by 0.10 m. For the pusher vehicle, the deformation measured after the first test was 0.08 m, which corresponds to the value calculated by the mathematical formula (see Table 1.).

Table 1. Comparing the theoretical and experimental results

Speed/ Compression time	Theoretical determination d [m]; v[km/h]	Experimental determination d [m]; v[km/h]
v_{10}=18.46km/h tc=0.063 s	d_{1st}= 0.080	d_{1st}= 0.080
	d_{2st}= 0.1064	d_{2st}= 0.100
	$v_1=v_2$=7.95	$v_1=v_2$=7.5
v_{10}=26.4km/h tc=0.052 s	d_{1st}= 0.0950	d_{1st}= 0.082
	d_{2st}= 0.1256	d_{2st}= 0.100
	$v_1=v_2$=11.37	$v_1=v_2$=12.00

The differences noticed in table 1, between the theoretically and experimentally determined values, during test 2, at a speed v_{10} of 26.4 km/h, are due to the fact that the vehicles involved have suffered deformations and throughout the test 1 as well, which led to the modification over the rigidity coefficient. However, the values compared during the test 2 provides the possibility to validate the mathematical model because the differences do not exceed the rate of error by 10%.[8]

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