Critical tension by injury

– a preliminary report

Jan Kovanda

Motor Vehicle Research Institute
Lihovarská 12
180 68 Praha 9
Czechoslovakia

Josef Stingl

Department of Anatomy
Charles University, 1st Medical Faculty
U nemocnice 3
128 00 Praha 2
Czechoslovakia

1. Introduction

This paper presents in short our approach to the problem of occupant injury by car crash. Both experimental methods and computer simulation were used for the study of critical forces affecting on the human body in a car crash. In our first approach the results of the real barrier test made by Motor Vehicle Research Institute were used .Fig. 1,2,3 show examples of crash of Škoda 130L with impact speed v_1=48.7 km/h. Dummies Hybrid 2 GM, 50 % were used. From car crash we obtained the values of the deceleration of the car and from dummies, some injury criteria etc. Permanent deformation of car f_{RO}=605 mm, maximal deformation f_c=833 mm, average deceleration a=11.5 g.

Driver parameters are:
head: maximal deceleration a_{max}=138 g at time t=110 ms, HIC=839 from t_1=98 ms to t_2=131 ms
chest: a_{max}=48.2 g at t=111 ms
Passenger parameters are:
head: a_{max}=65 g at t=122 ms, HIC=236 at t_1=99 ms, t_2=127 ms
chest: a_{max}=30 g at t=30 g.

To gain basic orientation data about the mechanical properties of selected parts of human body, we have measured the force-displacement characteristics of selected organs and vessels. In order to simulate the motion of the human body in a by car crash, we created planar mathematical model, which includes the necessary nonlinearities, i.e. deformation of safety belt, describing of contact forces etc. From this model we analyzed deceleration at each selected point on the dummy's body and so we are able to identify the forces affecting organs in this area. The obtained tensions are compared with the ones from human material.

2. The simulation of an occupant motion during the barrier test

As a starting point of our investigation we prepared and simplified planar model of occupant motion. For this purpose we use the longitudinal plane of symmetry of the system under study. As we are interested in global motion of the occupant, we use a standard multibody mechanical model consisting of 7 rigid bodies linked by ideal lower kinematic pairs mainly revolute ones. The position of each body is described by the coordinates of its mass centre and by an angle of instantaneous turn of a local coordinate system to a global one. In any revolute kinematic pair we consider torsion spring and damper, the torque of which depends on the relative motion in that pair. Safety belts with force-deflection behaviour taken from experiment are included. The parts of occupant's body are visualized by ellipses with the semi-axis ratio picked up in such a way that the shape of occupant's body is comparable with the projection of the real part of a man body into the plane of symmetry of the body (Fig. 4).

Dynamical behaviour of the mechanical model mentioned above is described using Lagrange's equations of the mixed type and by the equations of constraints. The equations of motion are numerically integrated using subroutine AD4, made in our institute.

This method enables to investigate the collision effects between occupant and interior of a car. The outline of interior was specified on the base of real sketch using a digitizer. By monitoring the distance between the model and interior of the car the place and time of collision could be found. The contact itself is modelled by means of a spring having nonlinear force-deflection behaviour.

Planar simulation model of an occupant's motion in a passenger car during a front barrier test was created using multibody system approach. It enables to study the influence of the main parameters on the occupant passive safety. The method of computer simulation leads to easy and cheap analysis of the phenomenon, and it gives a lot of important data for further studies.

3) Measurements of stiffness of human internal organs

Main task of this measurement was to determine approximate values of static stiffness of preselected internal human organs, which are frequently injured during car crash. These organs were selected on the basis of clinical praxis: the aorta and renal artery as examples of the largest arteries, the hepatic vein as a great vein, the splenic capsule as a cover of one of the most fragile abdominal organs, and ureter as an example of soft elastic organ.

Material was collected from the bodies destined to the anatomical dissection, which were conservated with alcohol and formalin. Four examples of each organ were measured.

The stiffness of individual samples was tested with the help of a one axle deformation test. Measurements were plotted as force-deformation characteristic and maximal forces were identified. In addition the maximal tension was computed. From the passive safety point of view is not allowed to overstep value of critical tension c_k. This tension was defined from static maximal tension c_s using coefficient of safety and coefficient of dynamic stroke. Results shows Tab. 1.

	c_s
Aorta	1.68 MPa
Vena hepatica	2.04 MPa
Renal artery	2.20 MPa
Spleen	6.80×10^{-2} MPa
Ureter	10.20 MPa

Tab. 1 - Results of measurements

The obtained values can be orientationally compared with the results of the measurements of the stiffness of individual layers of the abdominal wall, performed on unfixed human cadaverous material (Tab. 2). The measurements were carried out on the Instron Model 1185 in the same way as mentioned by the first group of human samples In both tables they are demonstrated the average values, the differences of measurements were ± 20%.

	c_s
Musculus obl.int.abd. + m.transv.abd.	0.39 MPa
Fascia transversalis	1.26 MPa
Fascia abd. spf.	1.80 MPa
Peritonaeum	1.95 MPa
Skin	7.35 MPa
Aponeurosis m.obl.ext.abd.	11.30 MPa

Tab. 2 - Results of measurements

On the basis of comparison of both files of results we may conclude that the obtained values are quantitatively comparable, although the measuring procedures were done independently and on samples of different provenience.

It is evident that our results of the stiffness measurement of the above mentioned organs are of orientational character only. Nevertheless, even in this form they brought us the basic objective information about some physical properties of human organs.

Comparison of the results of measured physical properties of biological preparates with the values obtained from the mathematical simulation is very important for the estimation of degree of correlation between the model and the real process.

By the simulation of the load of the human body due to barrier crash test, in which the injury could not arise, we can by this way easily estimate whether the obtained results do not exceed the biological value.

At least we can conclude that if critical tension is greater than real actual tension caused by car crash, we can suppose, on the basis of simple consideration or on the basis of finite element method, good chance to survive.

4. Conclusion

The subject of this paper is to show one approach of dynamic of occupant motion during car barrier crash. The computer model was adapted to meet multibody system analysis. The orientation measurements of force-deformation characteristics of certain human organs are presented. The connection of modelling and measurements enables better estimating of the influence of changes in car design from risk of injury point of view.

References

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Fig. 1
Frontal Car Crash

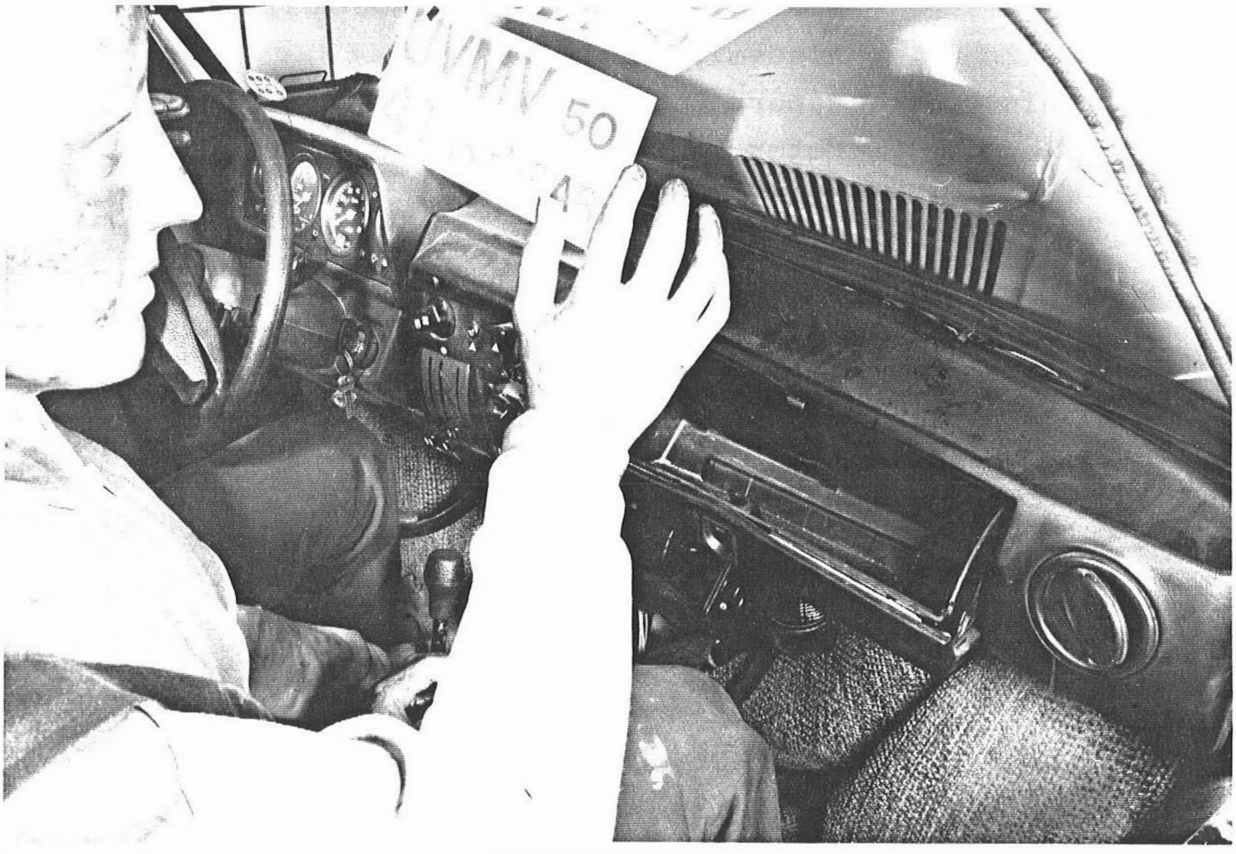

Fig. 2
Frontal Car Crash

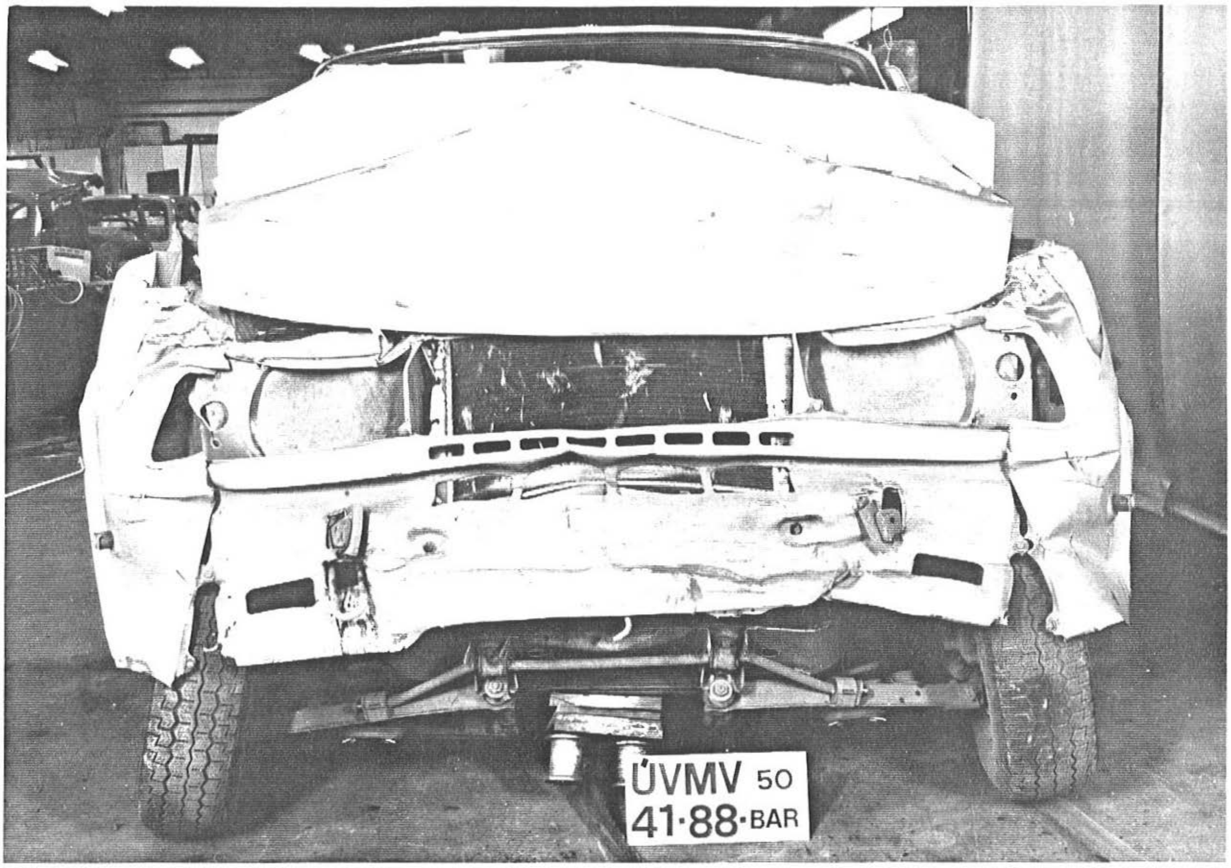

Fig. 3
Frontal Car Crash

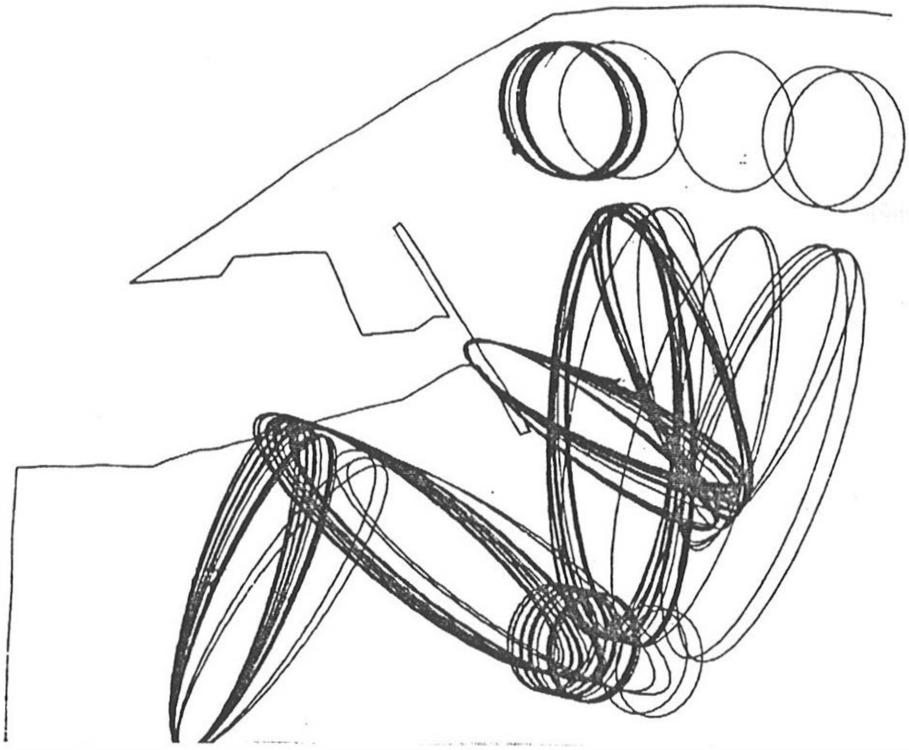

Fig. 4
Simulation of occupant motion