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ASPECTS REGARDING THE INFLUENCE OF THE VARIATION OF FRONT-END GEOMETRICAL PARAMETERS OVER THE DEGREE OF INJURY FOR A CHILD IN A VEHICLE-PEDESTRIAN COLLISION

Adrian Ovidiu SOICA, George Radu TOGANEL, Daniel Dragos TRUSCA, Oana FALUP PECURARIU

Abstract: *The paper is aimed at the simulation and virtual reality research field, for engineering design in transportation and safety areas. This study outlines the results for the analysis of the mechanics of vehicle-pedestrian collision. It is a further investigation on the influence of the variation of front-end geometrical parameters over the degree of injury.*

Keywords: *automotive, pedestrian, impact, child, front-end geometry*

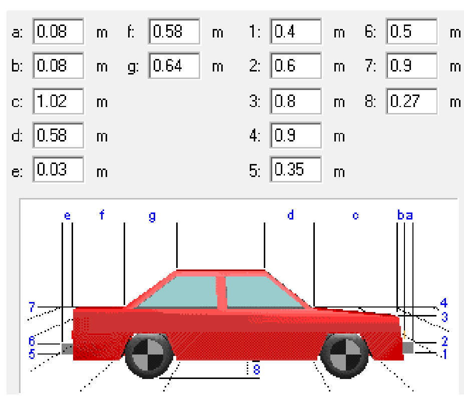


Fig. 1. Vehicle geometrical parameters example

1. INTRODUCTION

Traffic safety as well as the possibility to reduce the social costs of rehabilitation and the seriousness of injuries suffered by pedestrians present a particular complexity, being necessary to take a close approach to these issues. In 1998 in Romania at a GDP of 1141,29 USD/person and an average statistical number of 0,3018 dead persons/accident; 0,9135 persons seriously injured/accident and 0,025 slightly injured persons /accident, there results an average cost per accident in 1998: C = 14.757 USD. As related to these calculations, we can state, purely informative, that in France the material and human losses resulted from accidents in 1990 represented about 1,4% of the GNP, and in 1992 this percentage increased to 1,9%.

The statistics with regard to road traffic accidents indicate that a significant percentage of traffic victims are pedestrians and cyclists who are injured in an impact with a motor vehicle in motion. Most accidents take place in urban areas where serious or lethal injuries may occur at reduced speeds, especially in case of children.

The general desire is to diminish the seriousness of injuries by improving the frontal structures of motor vehicles. From a certain speed the aim of reducing the number of injuries is limited; yet, at speeds below about 40 km/h it is likely to significantly reduce the levels of injuries caused to pedestrians involved in frontal impacts with motor vehicles.

The data obtained from accidents are investigated by specialists and the measures to limit the reduction in accidents frequency, accidents involving pedestrians are made by car manufacturers in order to bring effective changes to the front end of the vehicle in view of reducing the seriousness of the injury dealt to the pedestrian.

The authors of the paper analyzed the regions of the body that are frequently injured as well as the component parts of the vehicles that cause these traumas.

The methods through which the accidents involving pedestrians or the rate of injuries may be reduced include:

a) Road traffic education;
b) Separation of traffic lanes;
c) Design (type) of vehicle involved in accidents;
d) The roadway where the vehicle travels in order to reduce the injury in accident.

Age distribution of pedestrians seriously injured is presented in table 1; the measures taken in order to improve their safety must consider both adults and children. Although the pedestrians less than 15 years of age represent only 20% of the total number of victims, it is noticed that the seriousness of injuries suffered by them is high, putting their life in danger.

Consequently, the present paper analyzed the collision between a vehicle and a 10 year old pedestrian, with a mass of 34,47 [kg] and an estimated height of appreciatively 1,37 [m].

Table 1

Distribution of injury cases according to age of pedestrians

Age for groups of ages	Cases involving pedestrians	
	% total	% serious injuries
0-15	20	45
15-60	30	30
Older than 60	50	25

Fig. 2. 10 year old dummy (HIII-10C)

2. INVESTIGATION OF ACCIDENTS

The accidents studied show that in 80% of the cases investigated, the first contact was with the front end of the vehicle; from which 75% were generated accelerated motions of the pedestrians' body and in 25% of the cases analyzed the pedestrians slid on the vehicle's hood, making the contact with its front corners.

The surfaces which are frequently hit by pedestrians in these cases, much more severe that those minor (according to the injury scale AIS 2 or worse) were the bumper and the front edge of the hood, in many cases, serious injuries resulting from successive impacts of the head with the: hood, windshield window, windshield frame, pavilion and ground

3. PEDESTRIAN MULTIBODY MODEL

PC-Crash software has been used for simulating the impact behavior and collision mechanics.

Most simulation programs used for accident reconstruction to calculate the movement of the vehicles during and after the impact consider each vehicle as one rigid body. This simplification can be used for vehicle to vehicle collisions as well as for collisions with rigid objects. If impacts between vehicles and pedestrians have to be simulated, the pedestrians have to be modeled as a system of rigid bodies interconnected by joints.

Finite element and multi-body techniques are capable of detailed modeling of vehicle and human body characteristics as well as the complex loading patterns that occur during an impact. In 1983, van Wijk et al. used multi-body models with up to 15 segments to predict whole body kinematics and head impact velocities which correlated well with dummy experiments. Since then, the finite element model of Hardy et al. and Yang and Lovsund's multi-body model (ca 50 segments) have both been successfully used to predict detailed interactions between pedestrians and vehicles in cases where the collision configuration is well defined [6].

The pedestrian model in PC-Crash uses a multi-body system consisting of several rigid bodies to simulate the movement. The different bodies, which represent the different parts of the pedestrian like head, torso, pelvis etc., are interconnected by joints. For each body different properties like geometry, mass, contact stiffness and coefficients of friction can be specified. The geometry for each body can be specified by defining a general ellipsoid of degree n.

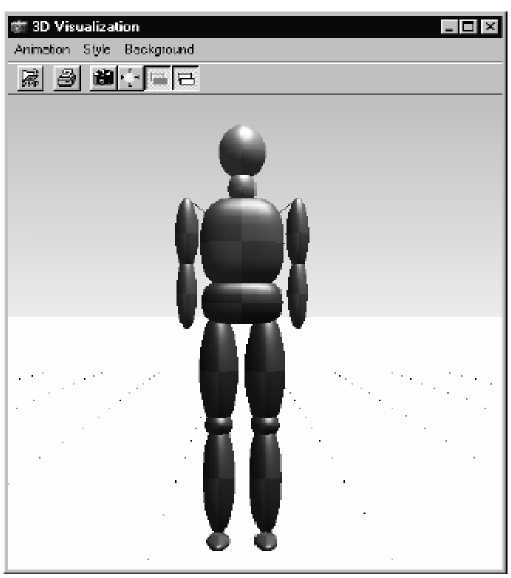
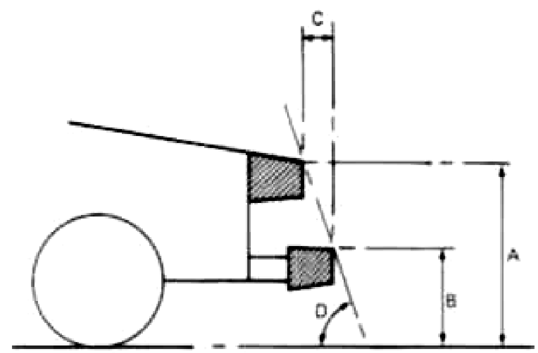


Fig. 3. PC-Crash Multi-body model [3]

4. IMPACT TESTS OF THE PEDESTRIAN DUMMY WITH THE MOTOR VEHICLE

In order to study the influence of the vehicle's front end upon the impact characteristics of the pedestrian, the complete tests led to changes and simulations in the vehicle's structure at the impact with dummies representing the child and the adult.

The motor vehicle tested at impact was designed in such a manner as to offer a variable geometry of the front edges so that the height of the bumper, the edge of the hood, the height and the depth of front bumper protuberance may be adjusted (Fig 4).



A: heght for the bonnet leading edge referenceline
B: height for the upper bumper reference line
C: frontal bumper advance
D: angle for the upper bumper reference line

Fig. 4. Vehicle with variable geometry

The tests with the front end of the vehicles showed the impossibility of an effective protection for pedestrians at an impact speed of 40 km/h because at high speed dummies were frequently thrown into the air, generating a serious impact of the head with the windshield, rolling on the ground, this being one of the most frequent causes of lethal injury.

Dummies were frequently deteriorated at high speed, representing particular injuries at the lower part of the leg, at the knee, at the upper part of the femur, at pelvis, head and neck. Deteriorations occurred especially when the lower part of the leg was crashed by the bumper or the pelvis was crashed by the upper edge of the hood and the front vertical part.

Tests showed that significant reductions in the seriousness of the impact may be obtained through:

- Setting the units of energy absorption on the hood edge and on the bumper in order to limit the impact force to legs and pelvis as far as the adults are concerned and to limit the impact force to legs and thorax as far as the children are concerned.
- Adjusting the form of the vehicles' front end in order to limit the head rotation and to make the head hit the hood after the thorax hits the windshield.

Table 2

Crash tests

Test no.	C [mm] B [mm] (* see figure 4)	Maximum acceleration head [g]	Maximum speed head [m/s]	Maximum acceleration thorax [g]	Maximum speed thorax [m/s]	Maximum acceleration neck [g]	Maximum speed neck [m/s]
1	C=60 B=570	71	9,9	11,4	8,4	16,3	8,5
2	C=70 B=570	46,3	9,87	23,1	9,3	24,8	9,33
3	C=50 B=570	58,5	9,74	16,3	7,78	17,4	7,75
4	C=80 B=570	52,2	9,30	20,9	8,41	32,8	8,48
5	C=80 B=450	55,1	8,94	19,4	7,45	17,2	7,43
6	C=80 B=650	47,4	9,14	27,3	7,64	19,3	7,67
7	C=70 B=450	65,6	9,12	20,4	7,08	15,9	7,09
8	C=70 B=650	52,4	9,55	10,5	7,48	13,6	7,53
9	C=60 B=450	65,1	9,74	18,2	7,22	14,4	7,20
10	C=60 B=650	46,6	8,84	13,36	7,41	19,75	7,44
11	C=50 B=450	50,4	9,73	17,68	7,65	18,44	7,63
12	C=50 B=650	44,1	8,90	27,3	7,35	19,01	7,39

In the present paper the authors considered that the impact point between the motor vehicle and the child pedestrian was the same in all cases analyzed, geometrical parameters of the vehicle's front end being different. Subsequent researches should approach the cases in which the impact pint on the vehicle modifies concomitantly with the variation of geometrical factors. The speed at which simulations were conducted was the same, 30 km/h, in order to avoid the above-described phenomenon, i.e. throwing the pedestrian into the air and pedestrian falling on soil as secondary impact. There were recorded the speeds and accelerations of the pedestrian's thorax, neck and head. The height of the front edge of the hood was the standard one, i.e. 700 mm from the ground level in all cases analyzed.

The head speed varies within the narrow limits 8,84 – 9,9 m/s, more pronounced being the speed variation of the thorax impact with the hood 7,08-9,3 m/s. As the height of the bumper increases, the impact speed of the thorax with the hood increases. For the standard configuration and for the configuration with the bumper set at a greater height there is noticed an increase of the impact speed with the hood as the bumper advance increases. An opposite tendency is noticed if the height of bumper setting is under the standard configuration.

Increasing the height of bumper setting implies the decrease in the maximum level of head accelerations. The minimum value of head accelerations was reached for a bumper height of 650 mm and bumper advance of 50 mm. Yet, in this case the value of thorax accelerations increased, which means that at the beginning the pedestrian hits the hood with the thorax more severely than in other cases, he/she takes the impact energy on thorax and at the impact of the head with the windshield he/she takes less energy, figures 5 through 8.

It is to mention that the time interval when the impact of the head with the hood takes place ranges from 0,16 to 0,21 seconds from the impact of the bumper with the dummy's leg.

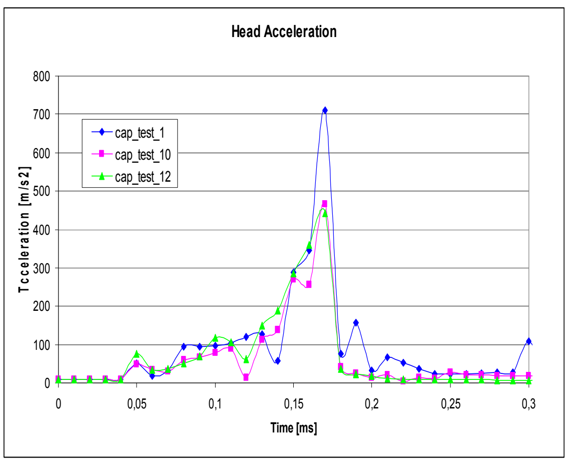


Fig. 5. Head acceleration

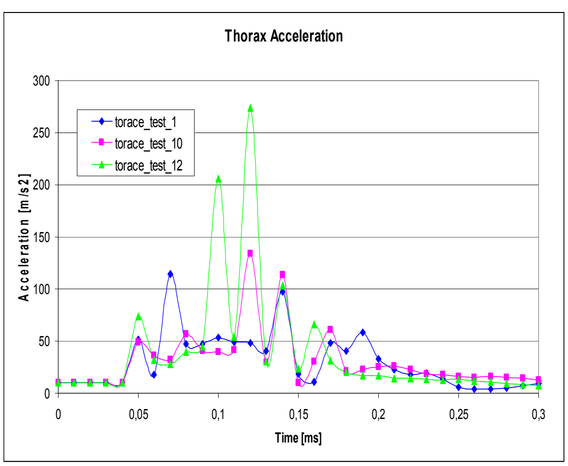


Fig. 6. Thorax acceleration

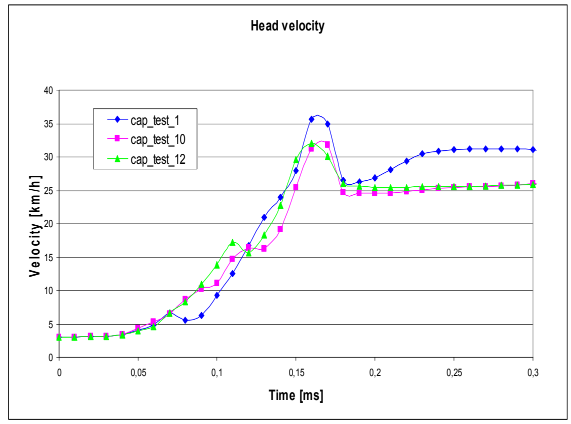


Fig. 7. Head velocity

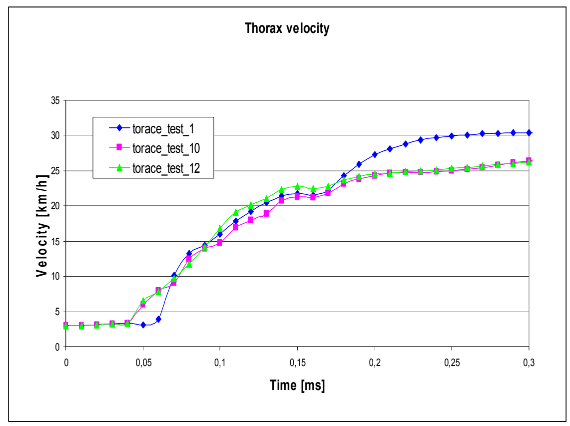


Fig. 8. Thorax velocity

4. CONCLUSION

The test shows the influence of the geometrical parameters for different vehicle frontal shape types. Different values and numbers for maximal values for the different body parts evolved clearly illustrate the difference of influence each shape type has on the car-pedestrian impact.

The figures 5 through 8 show the evolution for head and thorax acceleration and velocity. It can be seen that slight modifications in the geometrical structure of the vehicle have an influence over the vehicle-pedestrian impact, influence that varies from slight to profound.

A special importance is presented by the variation in time of head accelerations, the cases from tests 10 and 12 being more favorable for the pedestrians as they do not present sudden increases.

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