ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2015, http://www.imtuoradea.ro/auo.fmte/

# RESEARCH REGARDING THE SEVERITY OF THE INJURY OF THE PEDESTRIAN'S HEAD WITH THE VEHICLE'S BONNET

**Daniel TRUSCA[1], Bogdan TOLEA, Ionut RADU[3]**
[1]University Transilvania of Brasov, truscadan@gmail.com
[21]University Transilvania of Brasov, bogdan.tzolea@gmail.com
[31]University Transilvania of Brasov, alexandru.radu@unitbv.ro

***Abstract*****—**The purpose of the paper is to determine the severity of the head injury during the collision of a vehicle's bonnet with the head of the pedestrian by using an experimental test bench. In this research were used two types of bonnets: a normal bonnet and a pop-up bonnet. Is intended to find the differences in head injuries of a vehicle equipped with a pop-up bonnet and a vehicle equipped with a standard bonnet.

***Keywords*****—** collision, experimental test, hood, injury, pedestrian

## I. INTRODUCTION

PEDESTRIANS are the road users which are the most vulnerable to serious and fatal injuries

Arregui et. al. (2010) published a study regarding the hospital data received from eight european countries which contain 10341 pedestrians with 19424 injuries.

The study reported that the traumatic brain injuries represents 26% of all injuries while overall head injuries are 33% of the total injuries [1].

The injury of the pedestrians as a consequence of the impact with a vehicle results from a primary impact in the lower limbs, and depending on the velocity, a secondary impact occurs (head injury) with the bonnet or the windshield [2]. Most of the injuries appear at the level of the head and the lower limbs. These two areas of the human body are subjected to the highest forces.

In figure 1 is presented the ratio of the pedestrian fatalities in comparison to the total fatalities due to traffic accidents [3].

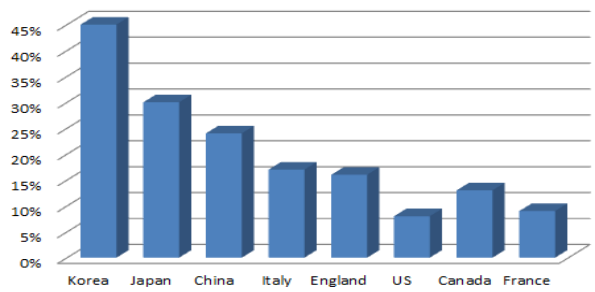

Fig. 1. Pedestrian fatalities compared with the total fatalities due to traffic accidents

The most recent elements introduced in the pedestrian safety are the pop-up hood and the airbag for the head protection. One of the most important countermeasure taken to reduce the head injuries of the pedestrians caused by the impact with a vehicle is the pop-up hood.

The pop-up hood can be classified in two types, depending on the activation time [3]:

Passive hood – when the contact of pedestrian enters in contact with the front bumper

Active hood – it is activated before the contact between the pedestrian and the front bumper takes place

Another classification of the pop-up hood is regarding the reversibility:

Reversible – can be reset after the activation (manually or automatically)

Irreversible – are for single use

A few types of the lifting systems of the pop-up hood are the following:

*1) Pyrotechnic lift system [4,[5]*

A gas generator is used to lift the hood at the detection of the impact between the bumper with the lower limbs of the pedestrian.

*2) Pyrotechnic-link lift system[6]*

A gas generator and a link mechanism lifts the hood when the impact of the pedestrian's lower limbs with the bumper is detected.

It is classified in passive and irreversible.

*3) SMA Spring lift system[7]*

The springs are released by SMA at the detection of the impact between the front bumper with the pedestrian's lower limbs, and the hood is lifted. Can be classified in passive and reversible.

Given the complexity of the collision of the vehicles phenomena which is given by a variety of factors, associated with vehicle manufacturing, the conditions of the event, physical and behavioral characteristic of the pedestrian, vehicle kinematics, vehicle dynamics, and on the other hand requires the use of experimental research results with theoretical models associated with collision.

## II. EXPERIMENTAL RESEARCH

*a) Used equipment*

The purpose of the experimental research was to determine the influence of the passive safety elements (pop-up hood), upon the head injury severity in the collision between a vehicle and a pedestrian.

In order to determine the head injury severity, were performed 2 experimental tests on a test bench. The hood was fixed on the bench on vertical plane, and on the upper side of the testing bench was fixed a pendulum on which at the lower end was mounted the head-neck assembly of a dummy. On the test bench can be performed tests both with pop-up hood and with normal hood. One of the tests were performed with pop-up hood and the other one was performed with the normal hood. In Fig. 2 is presented the test bench.

Fig. 2. The test bench

The system was equipped with tri-axial accelerometers, mounted in the head of the dummy, on the pendulum bar and on the hood. In the following figure it is presented the tri-axial accelerometers and their mounting (Fig.3).

Fig. 3. Mounting of the tri-axial accelerometers

To collect data was used PIC DAQ data acquisition system, produced by DSD. This system is a platform for data acquisition, where accelerations and angular velocities can be used to describe the movement of crash tests between vehicles, braking tests and vehicle dynamic performance measurement. Has 3 sensors for measuring axial accelerations and angular velocities 8 analog input channels with 12-bit resolution and acquisition time can be up to 300 seconds at the highest sampling rate (1 kHz). Data storage is done on the memory card and can be recorded more than 500 tests.

In the Fig. 4 it is presented PIC DAQ data acquisition system, produced by DSD.

Fig. 4. PIC DAQ system

Was also used a high speed filming camera, Casio Exilim EX-F1, being able to record with 1200 (fps).

To have a good quality of the videos were used 4 spotlights. The model of the spotlights is HEPOL WL1002 having a power of 400 (W) each.

*b) Description of the two test scenarios*

*i) The first test using a normal bonnet*

The hood of the vehicle was fixed to the testing bench. The pendulum was lifted in the highest position and released for the impact to take place. The kinematics of the impact is presented in the Fig. 5.

Fig. 5. Kinematic of the impact

After the test was performed, the following diagram was obtained (Fig. 6). The peak value of the acceleration was almost 30g, g being the value of gravitational acceleration (m/s$^2$).

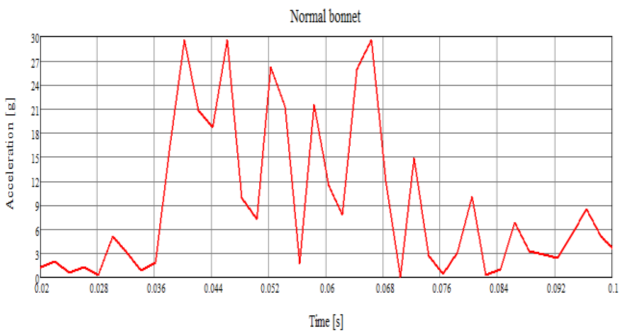


Fig. 6. Acceleration diagram

Having the acceleration of the head was possible to determine the velocity of the head at the contact with the bonnet. In the Fig.7 is shown the diagram obtained by introducing the values of the head velocity.

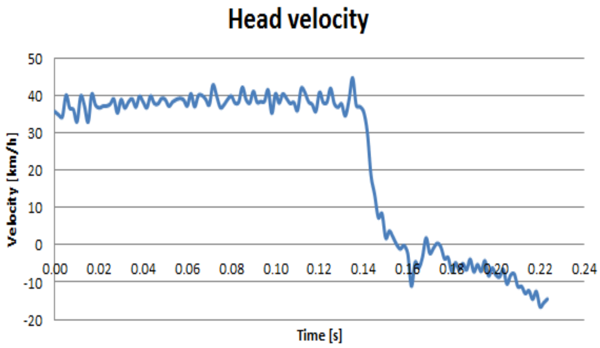


Fig. 7. Velocity diagram

As can be seen in the previous figure, the head velocity in the moment of impact was more than 40 km/h.

To determine the severity of the injury was necessary to calculate the HIC (Head Injury Criterion) value. HIC was introduced by NHTSA in 1972, and it is based on the resultant of the head acceleration in a short period of time. HIC is now a criterion in automotive industry in order to assess the injury of the pedestrians in case of a collision. This value is obtained by performing tests on the dummies [8]. Usually it is calculated in a period of 15 (ms) (HIC15) up to 36 (ms) (HIC36). It was reported a value of 1000 for HIC, where no serious injuries appear [9].

In this experimental test, the interval used was the one where the peak values of the acceleration were obtained. In this interval, were calculated different HIC values, at different time steps. The two most important values obtained were the values of HIC15 and HIC36.

The formula used to determine the HIC values is presented in (1).

$$HIC15_1 = \max_{t1,t2}[(t_2 - t_1)(\frac{1}{t_2 - t_2}\int_{t1}^{t2} a(t)dt)^{2.5}] \qquad (1)$$

where:

$t_2$ – final value of the time (s)

$t_1$ – initial value of the time (s)

a(t) – the resulting head acceleration (g)

After performing the calculation for (1) a HIC value of 14,192 was obtained.

The time interval limits $\Delta t = t_2 - t_1$ has to be smaller or equal than 0,015 (s) or 0,036 (s).

The obtained HIC result is a low value, and the pedestrian should not be in danger in case of an impact. It has to be taken into consideration that in this test, the mass of the pendulum is not corresponding with the mass of the pedestrian. A pedestrian has a mass greater than the used pendulum, and the mass distribution is completely different. Due to the greater mass, the moments of inertia are higher in case of an impact, and also the mean value of the head acceleration is higher.

*ii) The second test using a pop-up bonnet*

On the bench were mounted two small pistons to simulate the active bonnet, and the procedure used in the first test was repeated, by lifting the pendulum to the highest position, and released to impact the pop-up bonnet.

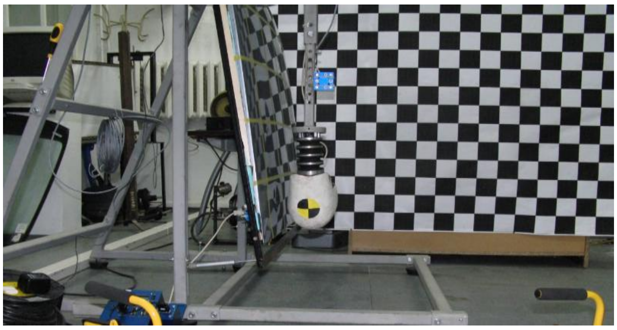

Fig. 8. The rest position of the pendulum after the impact

In the experiment were obtained similar values of head accelerations, but the duration of the impact was different. In this case, the duration of the peak value of the acceleration is shorter than in the previous case. The reason of this phenomenon is that the piston which acts like a spring pushes the assembly away from the bonnet when the piston is completely compressed.

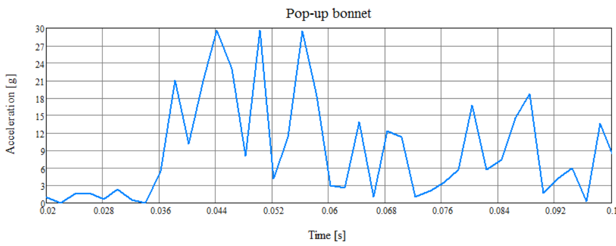


Fig. 9. Head acceleration diagram

In this case, the velocity in the moment of impact is the same with first case due to the fact that the initial conditions were not changed. The pendulum was positioned at the same height, and it was released under its own weight. The velocity in the moment of impact was approximately 40 (km/h).

To be accurate regarding the obtained HIC value for the second test, the pendulum was positioned to enter in contact in the same area of the bonnet like in the first case. Therefore will be used the same critical area for the pedestrian’s head.

In the following figure it is shown the position of the pendulum in the moment of the impact with the pop-up bonnet (Fig. 10).

Fig. 10. The impact location

In order to determine the HIC value in the second case was chosen the time interval where the contact between the head-neck assembly and the pop-up bonnet took place. Also in this interval, the peak value of the acceleration was reached.

To compute the HIC values, was created a Mathcad sheet, where input values were introduced. Were used two matrices, one corresponding to the selected time and one corresponding to head acceleration. These values were downloaded from the PIC DAQ device. The next step was to find the transposition of both matrices. After this calculation, Mathcad was able to create the acceleration diagrams presented above.

In this second case, the same formula was used to determine HIC value.

$$HIC15_2 = \max_{t1,t2}[(t_2 - t_1)(\frac{1}{t_2 - t_2}\int_{t1}^{t2} a(t)dt)^{2.5}] \quad (2)$$

where:

$t_2$ – final value of the time (s)

$t_1$ – initial value of the time (s)

a(t) – the resulting head acceleration (g)

$\Delta t = t_2 - t_1 \leq 0{,}015$ or $0{,}036$ (s)

After substituting the values and performing the computation, was obtained a HIC value of 7,229.

In this case the HIC value is smaller than in the first case because of the two pistons which have the purpose to simulate the pop-up bonnet. It can be seen that the value is almost half of the first test value. As in the first case, when interpreting this value as being not dangerous for the pedestrian, has to be taken into account that for this second test was used a pendulum which has a lower mass than the human body.

## III. CONCLUSIONS

By performing these tests we are capable to asses not only the severity of the injury of the pedestrian but also the influence of the pop-up bonnet in case of an impact.

Analyzing the data and making the computations were obtained HIC values for both tests. The value for the second test was smaller than the value obtained in the first test although the peak accelerations for both of the tests were almost the same. This fact is leading us to a first conclusion that the most important parameter in case of an accident is not the peak value of the acceleration but the duration of the acceleration. Therefore a shorter amount of time when the pedestrian is subjected to acceleration will lead to a smaller chance of a serious injury (Fig. 11).

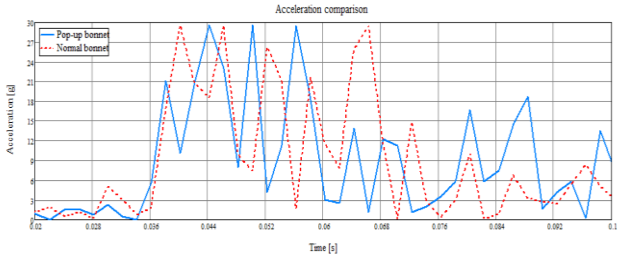


Fig. 11. Acceleration comparison

In the second case the active bonnet decreased the amount of time when the head was subjected to accelerations, obtaining almost half of the HIC value from the first test.

This research leads to the fact that the pop-up bonnets are useful in case of an accident by reducing the risk of an injury in the critical areas of the frontal part by increasing the free space above the engine.

## REFERENCES

[1] Tarko, A., Azam M. S. “Pedestrian injury analysis with consideration of the selectivity bias in linked police-hospital data.”, *Accident Analysis & Prevention*, 43(5), pp. 1689-1695, 2011.

[2] B. Romero, A. Lenard, “Source of head injury for pedestrians and pedal cyclists Striking vehicle or road?”. *Accident Analysis & Prevention*, 50, pp. 1140-1150, 2013

[3] Xu, D., Zhu, X., Miao, Q., Ma, Z., & Wu, B. “The research of reversible pop-up Hood for pedestrian protection” *Vehicular Electronics and Safety (ICVES)*, IEEE International Conference pp. 42-47, July 2010

[4] R.Fredriksson, Y. Haland, J. Yang. “Evaluation of a New Pedestrian Head Injury Protection System with a Sensor in the Bumper and Lifting the Bonnet's Rear Part”, *17th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*, pp. 131, 2001

[5] K. Bae Lee, H. Jo Jung, H. Bae, “The study on developing active hood lift system”. *SAE* pp.07- 0198

[6] Z. Xu, Z.You “Design and analysis of hood lifting device”, *11 th forma of mechanism and machine design*, Taiwan, China, 2008

[7] Brian M. Bames, Diann E. Brei. “Shape Memory Alloy Resetable Spring Lift for Pedestrian Protection”. *Proc. Of 2008 SPIE*,Vol. 6930 693005

[8] McHenry, Brian G. "Head injury criterion and the ATB." *ATB Users' Group*, pp.5-8, 2004

[9] H. Burg, A. Moser, *Handbook of Accident Reconstruction*, 2013.