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INVESTIGATION OF DEFORMATIONS IN THE SCENARIO OF AN IMPACT WITH A RIGID BARRIER

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Abstract: *This paper studies the deformations analysis in the scenario of an impact with a rigid barrier. The experimental test is a simulation based on traffic accidents which can occur daily. The analysis of accident is performed mainly by using PC-Crash software. The deformation energy resulted can offer important data when performing an accident reconstruction. At the end of the paper the severity of the crash can be evaluated based on accelerations obtained.*
Keywords: *crash, deformation, barrier*

1. INTRODUCTION

Every year in the world more than 1 million people die and over 20 million are severely injured in vehicle crashes based on Association for Safe International Road Travel (ASIRT, 2018) [4]. Most accidents are evaluated by technical experts with the help of computer simulations, which have financial and legal repercussions for people involved to the courthouse. Due to this fact an accident reconstruction is an important technical analysis when a vehicle crash occurs. After data analysis a key evidence from the presented report is shown by simulation results of accident reconstruction. More difficulties occurs due to eyewitnesses who have insufficient details regarding the vehicles crash scene [3]. The main aim for impact resistance structure development is to optimize the affected components which are integrated to absorb the energy during crashes. Frontal bumper is the most exposed part of vehicle during a frontal impact. The engine, axles and wheels have the purpose to limit the deformation length after a crash. When a frontal impact occurs between vehicles and rigid obstacles, it results a permanent deformation for the front of vehicle [2]. Over time, many models were developed in order to calculate or describe impact scenario. Using a time-frequency analysis during the impact, relevant values can be obtained for deformation, velocity or acceleration. The relationship between acceleration or velocity signal and front of the vehicle body distortions leads to significant values regarding the deformation process of an energy absorbing structure [7]. Current article represents a research based on experimental data obtained by using modern techniques of deformation analysis. This study is focused on the deformation behavior of vehicle which is investigated in scenario of impact at 60 km/h speed with a concrete fixed barrier.

2. TECHNICAL RESEARCH

The term of collision of vehicles depends on a variety of factors associated with the construction of motor vehicles, but also the conditions of the event. In this case, the study of vehicle kinematics and dynamics on the other hand, requires the use of experimental research results and theoretical models associated with the collision.

2.1. Objectives

The main objective of this paper represents the deformation analysis based on an experimental test of a frontal impact between a motor vehicle and a non-deformable fixed barrier. The location of experimental test is the parking lot belonging to the Research Institute of Transilvania University of Brasov. In order to achieve the purpose of the research next objectives should be stated as follows:

- Performing the frontal type collision, vehicle - concrete fixed barrier;
- Determination of the body deformations;
- Determination of deformation energy;
- Collision speed determination;
- Accelerations measurement of the vehicle during the impact.

2.2. Methodology

The methodology used for this research consists in the frontal collision test with a non-deformable fixed barrier at 60 km/h speed. For this experimental test were used a towed vehicle and a concrete rigid barrier. The test scenario is presented in Figure 1. The collision test was filmed using a high speed camera Fastec Hispec 5 capable to film up to 1000 FPS. In addition to perform the study were needed following technical items:

- Test polygon;
- Opel Astra F Caravan vehicle for impact;
- Toyota Land Cruiser towing vehicle;
- Quick release hook;
- Metal plate with rollers to guide the tow rope;
- Cable with 85 m length;
- GPS system;
- PIC DAQ device;
- Brake pedal actuator working at a pressure of 8 bar that allows the vehicle to be stopped safely;
- Remote-controlled steering system via a radio remote control module.

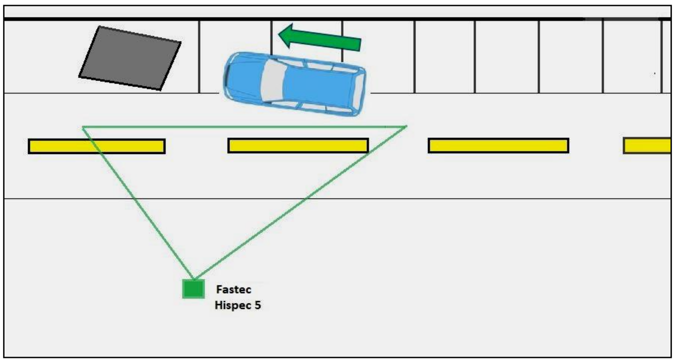

Figure 1: Test scenario

To obtain the deceleration of the vehicle, the formula can be used to differentiate the velocity obtained by GPS system [6]:

$$a = \frac{dv}{dt} \tag{1}$$

2.3. Results

The deformation analysis was performed by using PC-Crash software. Figure 2 shows the distribution of the points C1-C11 across the bumper width. Static crush measurements were performed by calculating the difference between the pre-crash and post-crash measurements relative to a reference point [1]. The crush values of post-collision measurements are indicated in Table 1.

Figure 2: Post-collision vehicle static crush measurements

Table 1: Post-collision measurements

C1 [m]	C2 [m]	C3 [m]	C4 [m]	C5 [m]	C6 [m]	C7 [m]	C8 [m]	C9 [m]	C10 [m]	C11 [m]
0	0,412	0,436	0,459	0,458	0,445	0,433	0,411	0,365	0,290	0,012

Using the available data the average crush depth could be calculated for each test, using the formula:

$$C_{Ave} = \frac{\frac{C_1}{2} + \sum_{i=2}^{n-1} C_i + \frac{C_n}{2}}{n-1} \qquad (2)$$

Based on values presented in Table 1, the average crush depth value which results is 0,372 m.
The deformation energy shown in Figure 3 is calculated by using PC crash software.

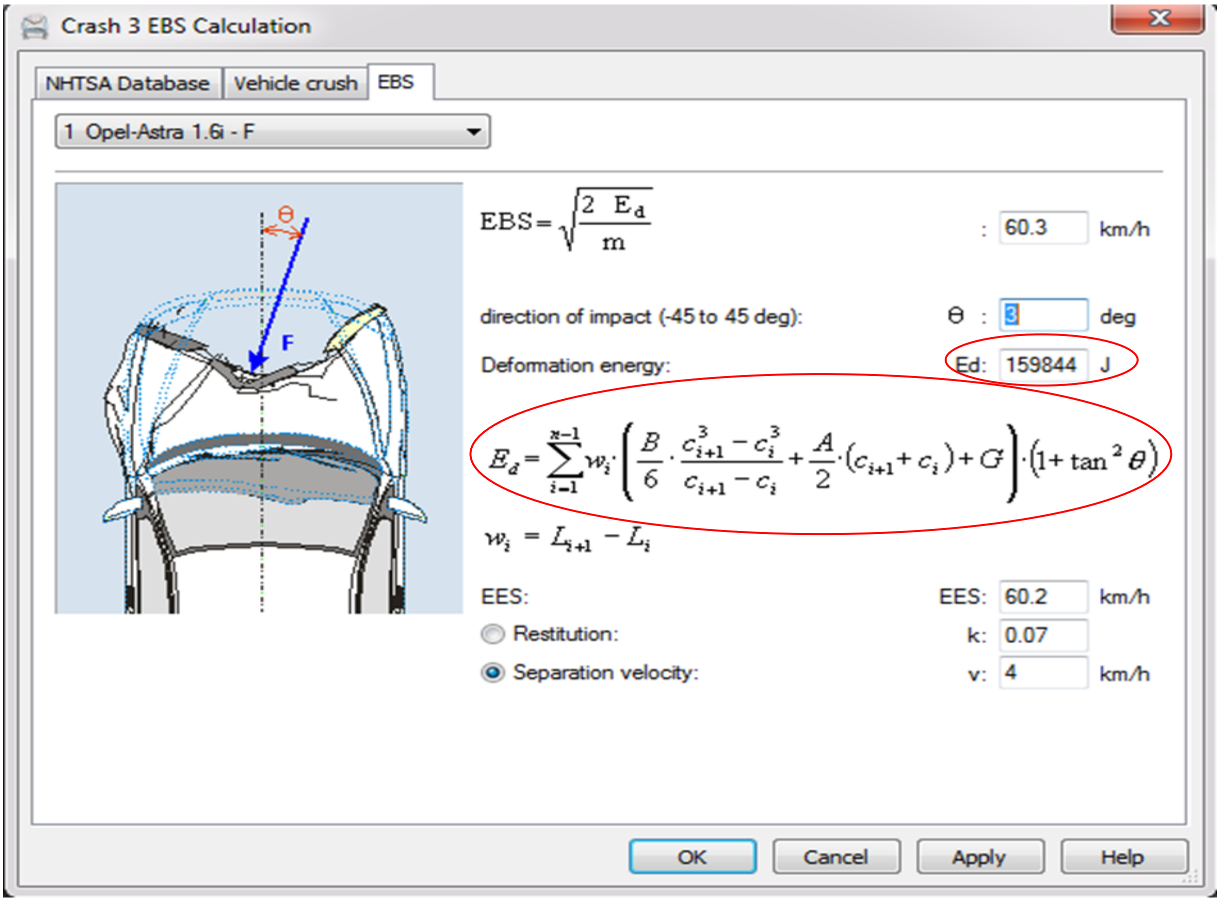

Figure 3: Deformation energy calculated in PC Crash software

where:
Ed - deformation energy (J);
A, B, G – stiffness constants;
Ci, Ci+1 – the deformation measured at point i and point i+1 (m);
Li, Li+1 – the rate of the measuring station from point i, and point i+1 (m);
Θ – angle between the longitudinal axis of the vehicle and the direction of the main impact force (degree);
k – coefficient of restitution;
v – vehicle separation velocity difference.

The deformation energy of 159844 J represents the permanent deformation during the impact. The dynamic deformation of vehicle frontal side achieves the maximum value at the impulse point during compression. Afterwards, during the comeback stage, the deformation magnitude is decreased to the static deformation value. In this case, the Equivalent Barrier Speed (EBS) value for damaged vehicle Opel Astra F is 60.3 km/h, while the Energy Equivalent Speed (EES) resulted is 60.2 km/h. The EES value is lower, but very close to the EBS value. It can be seen that EBS and EES parameters represent equivalents factors of energy dissipated on vehicle deformation (neglecting the braking or skidding circumstances). Therefore EES is the velocity at which an

impact against a rigid, non-deformable barrier should be performed to get only plastic deformation, while EBS speed additionally takes into consideration elastic deformation. It is the elastic part that was included in G factor in deformation energy equation Ed. Therefore the EBS is higher than EES [5].
The relevant data have been provided by cameras and with the help of Tracker, Origin Pro and Microsoft Excel software, the accelerations obtained after vehicle velocities differentiation were processed. Using the formula 1, a variation of acceleration during the impact is shown in Figure 4.

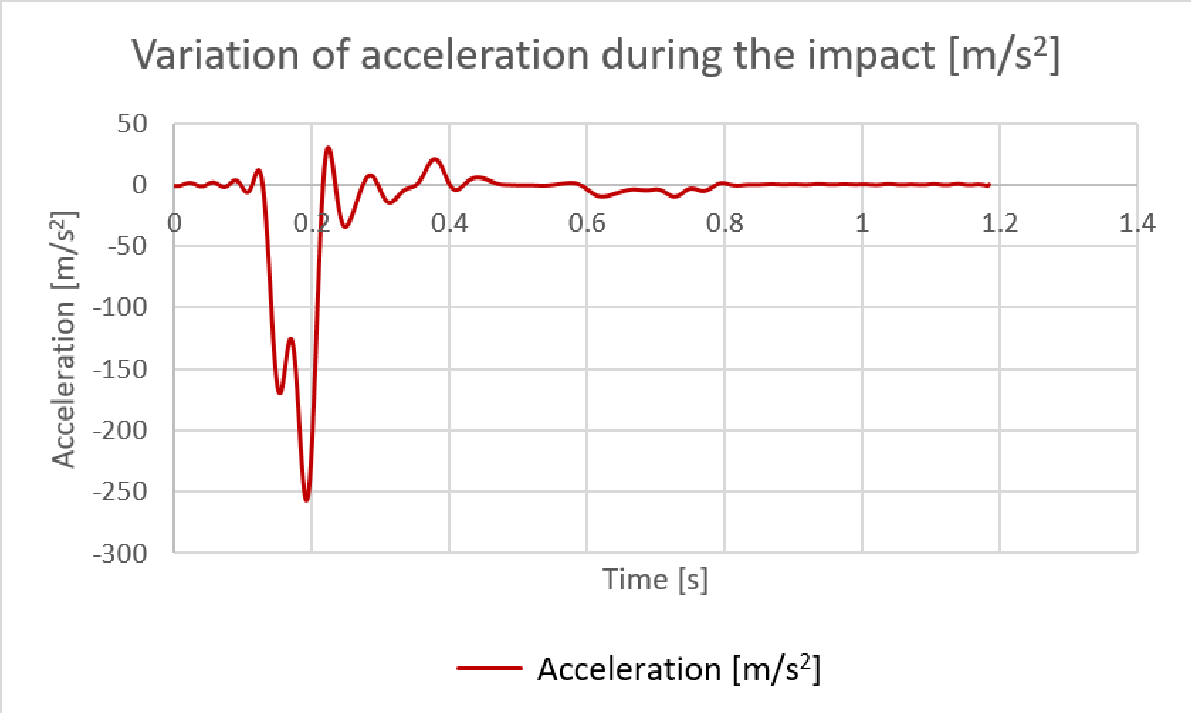

Figure 4: Acceleration change of the vehicle during the impact with a concrete barrier

During the impact it results a maximum deceleration value of -255 m/s^2.

3. CONCLUSIONS

The experimental research was performed by creating simulations of the scenario where the traffic accidents occur.
It can be concluded that the maximum crush measurement of vehicle after the impact is 0,459 m and the deceleration obtained is -255 m/s^2. The deformation of vehicle is permanent and it results also from the kinetic energy consumed by the components of vehicle.
The variation of acceleration during a collision is the most common criteria to evaluate the impact severity.

REFERENCES

[1] Barbat S., Li X. Analysis of the Proposed Frontal Oblique Crash Test, In The 25th International Technical Conference on the Enhanced Safety of Vehicles, Paper (No. 17-0130), Detroit, 2017;
[2] Bosch R. Automotive handbook, Automotive Equipment Business Sector, Department for Technical Information, 3rd Edition, Stuttgart, 1993;
[3] Kostek R., Aleksandrowicz P. Study of vehicle crashes into a rigid barrier, Transactions of the Canadian Society for Mechanical Engineering, (0), 1-9, 2019;
[4] Molan A. M., Rezapour M., & Ksaibati K. Investigating the relationship between crash severity, traffic barrier type, and vehicle type in crashes involving traffic barrier, Journal of traffic and transportation engineering (English edition), 7(1), 125-136, 2020;
[5] Papić Z., Bogdanović V., Štetin G. & Saulić N. Estimation of EES values by vehicle 3-D modelling, Vehicle Vozila i, 27, 2018;
[6] Radu A. I., Trusca D. & Toganel G. Influence of tire pressure on the braking distance when driving on snow and asphalt, IOP Conference Series: Materials Science and Engineering, Vol. 444, No. 7, p. 072013, 2018;

[7] Wei Z., Robbersmyr K. G. & Karimi H. R. Data-based modeling and estimation of vehicle crash processes in frontal fixed-barrier crashes, Journal of the Franklin Institute, 354(12), 4896-4912, 2017.