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MECHANICAL TESTING OF THE COMPOSITE MATERIALS BASED ON POLYPROPYLENE AND ITS APPLICATION IN AUTOMOTIVE PARTS

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Abstract: *The paper shows some advantages of the composite materials based on polypropylene for applications in the automotive field. Then, tensile test is applied to some specimens made of such a composite material. The stress-strain* $(\sigma-\varepsilon)$ *curves are shown. After statistically processing of the experimental results, these were used for analysis and simulation of the mechanical behavior of a front bumper under the impact with a stone. It is known that the bumper is only a component part of the bumper system of an automotive and it is located in front of the energy absorber and bumper beam.*
Keywords: *polypropylene, composite, tensile test, simulation*

1. INTRODUCTION

The bumper considered in this study is only a part of the front bumper system whose components are: bumper; energy absorber; bumper beam; bumper mounting bracket. It is known that the front bumper system is designed to protect the vehicle's safety systems in low-speed impacts by absorbing kinetic energy during a collision. On the other hand, the role is to reduce pedestrian injuries in very light accidents.
In the last years, there was a lot of material combination used to manufacture the automotive bumper: a combination of polycarbonate and acrylonitrile butadiene styrene called PC/ABS [1,8]; glass fibre reinforced polypropylene [5]; glass fibre reinforced plastics [2]; thermoplastic olefin elastomers denoted with TPO [4].
There are some works [5,6] that focused on material selection for the bumper taking into account the required properties of this material. Another paper [7] focused on the analysis of a bumper with capacity of energy release.
The bumper analyzed in this paper is made of thermoplastic olefin elastomers (TPO). It is presented some mechanical properties of the material used to manufacture the bumper of a car. These properties were determinate in tensile test. Then, the tensile properties together with the stress-strain $(\sigma-\varepsilon)$ curve are used to describe the material behavior in numerical modeling of the bumper.

2. WORKING METHOD

2.1. Mechanical testing of the material

The first of all, tensile specimens were cut from a flat surface of a front automotive bumper. A number of ten specimens were prepared according to the European standard [9] for tensile testing of plastics or reinforced plastics. The dimensions of the cross-section of each specimen were accurately measured before mechanical testing. Then, the dimensions were considered as input data in the software program of the machine.
The testing equipment used for tensile test consists of a hydraulic power supply. The maximum force capacity is ±15 kN. During the tensile tests, the speed of loading was 1.5 mm/min. according with [9].
The testing equipment allowed us to record pairs of values (force F and elongation Δl of the specimen) in form of files having 200-300 lines. Therefore, the average values of the following quantities could be computed:

Young's modulus E in tensile test; tensile stress σ_{max} at maximum load; tensile strain ε at max. load; maximum tensile strain ε_{max}.

Experimental results recorded during tensile tests of the specimens, may be graphically drawn by using $\sigma - \varepsilon$ curves (Figure 1). Herein, only five curves recorded in case of 5 specimens are shown. It may be noted that Young's modulus E was computed for data points located on the linear portion of the $\sigma - \varepsilon$ curve in case of each specimen tested. In Figure 1 it may be observed the nonlinear behavior of the material for values of strains greater than 0.01 to 0.015.

Finally, the experimental data were statistically processed and the average values of the tensile properties are shown in the Table 1.

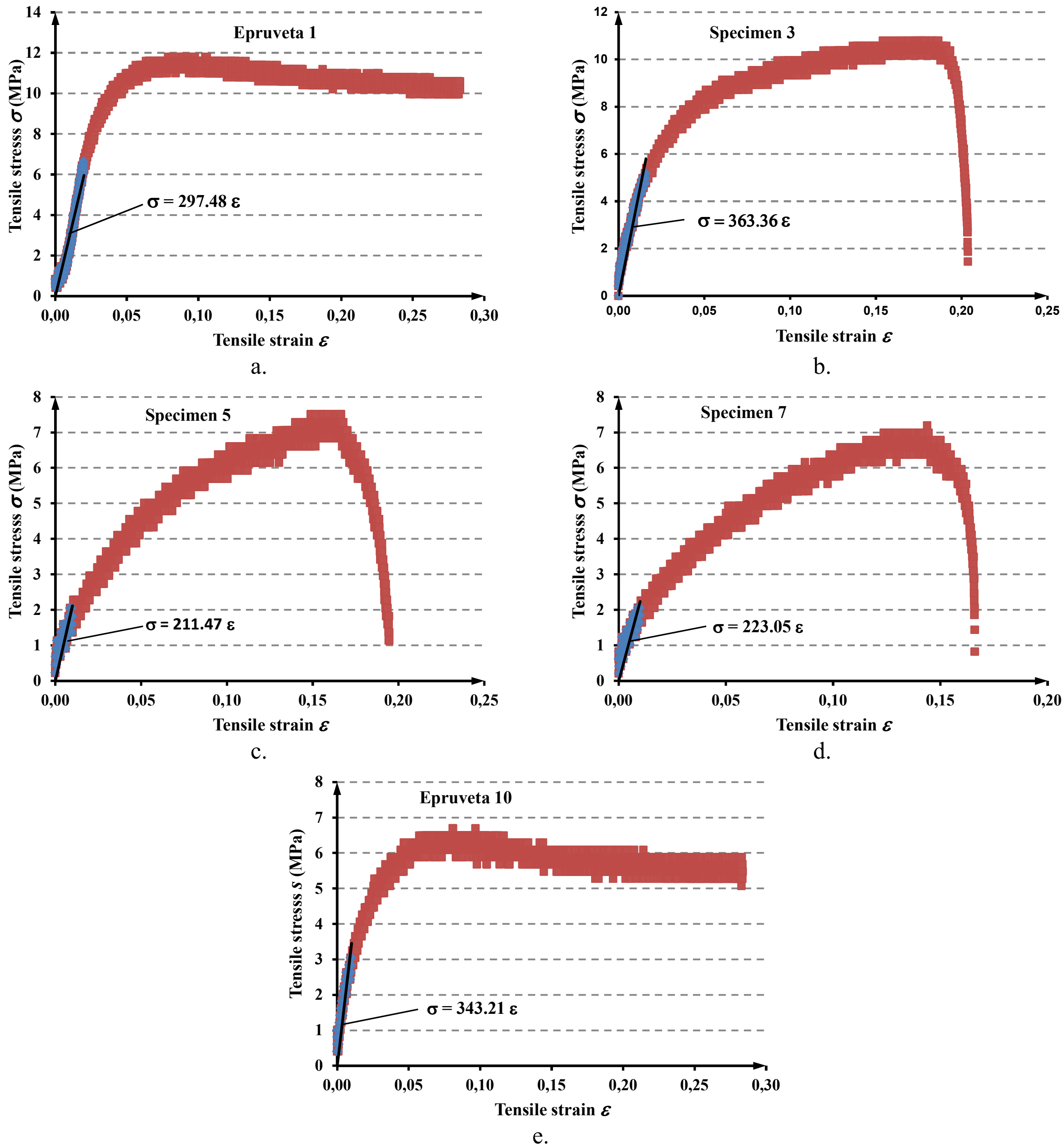

Figure 1: Some of stress-strain $(\sigma - \varepsilon)$ curves recorded in tensile test in case of the material tested

Table 1: Mechanical properties determinate in tensile test in case of the material of the bumper fascia

Specimen	Young's modulus E (MPa)	Max. Force F (N)	Tensile stress σ at max. load (MPa)	Tensile strain ε at max. load [%]	Max.tensile strain ε_{max} [%]
Average value of the mechanical property	287.714	359.08	8.8	13.98	22.62

2.2. Numerical simulation of the mechanical behavior of the bumper

In the second part of the paper, the experimental results obtained in tensile test are applied to the numerical model of the front bumper to describe the mechanical behavior of the material.
The material of the bumper is TPO that is homogeneous and isotropic from macroscopically point of view. Taking into account the mechanical behavior in tensile test, the elastic portion of the $\sigma - \varepsilon$ curve will be described by the following properties : Young's modulus *E*=287.7 MPa; Poison's ratio $\nu = 0.26$. Plastic domain of stress-strain $(\sigma - \varepsilon)$ curve is described by using the coordinates of the points corresponding to this portion. For modeling was used the stress-strain $(\sigma - \varepsilon)$ curve showed in Figure 1, a, obtained in case of the first tensile specimen tested.

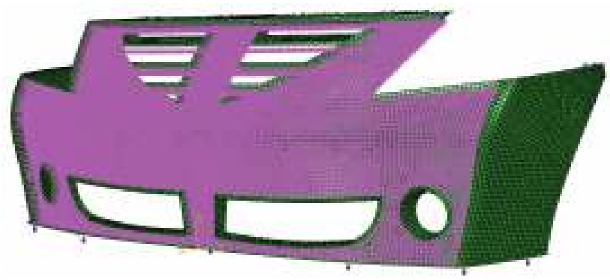

Figure 2: Numerical model for the 1st Scheme of loading (uniform pressure)

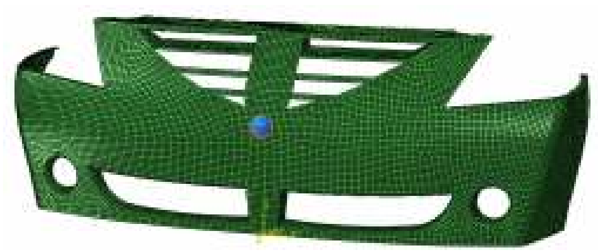

Figure 3: Numerical model for the 2nd Scheme of loading (impact with a steel ball)

Two schemes of loading are considered to analyse the mechanical behavior of the bumper. In the first scheme of loading (Figure 2), the bumper subjected to an uniformly pressure $p = 10^{-3}\ N/mm$ and it is fixed at the holes used for mounting on both bumper beam and car body. In the second scheme of loading (Figure 3) the impact with a steel ball is analyzed. The diameter of the steel ball is equal to 25 mm. The last scheme of loading is analogous with the impact with a stone. It was chosen this way because the defining of the steel is easier. The low-speed impact was considered, the speed of the steel ball being equal to 2 m/s. It was considered that the steel ball hints perpendicular on the front bumper, parallel to Ox axis.

3. RESULTS

The figures 4 and 5 show some results obtained by analysis with finite elements.in case of the first scheme of loading:

- equivalent normal stress σ (Misses) in the bumper due to the action of the uniform pressure (Figure 4);
- total displacement in the bumper (Figure 4).

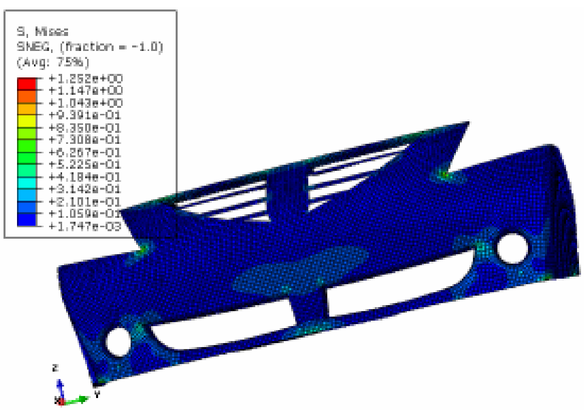

Figure 4: Distribution of the equivalent stress σ in the bumper due to the action of the uniform pressure

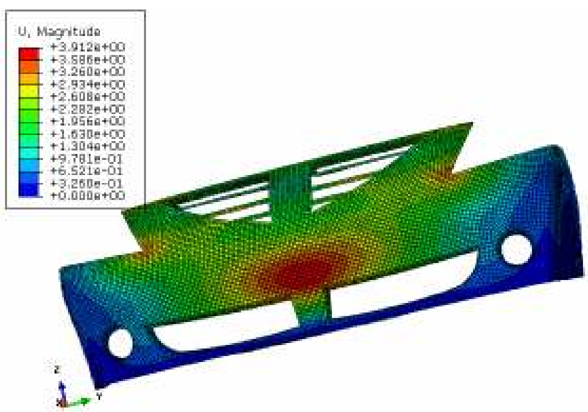

Figure 5: Distribution of the total displacement in the bumper due to the action of the uniform pressure

It may remark that the maximum value of the resultant normal stress σ (Misses) is 1.252 MPa which does not exceed the average value $\sigma_{max} = 8.8\,MPa$ of the stress recorded at maximum load (see the forth column of the Table 1). On the other hand, the maximum value of the total displacement is equal to 3.912 mm corresponding to the plastic portion of $\sigma - \varepsilon$ curve.

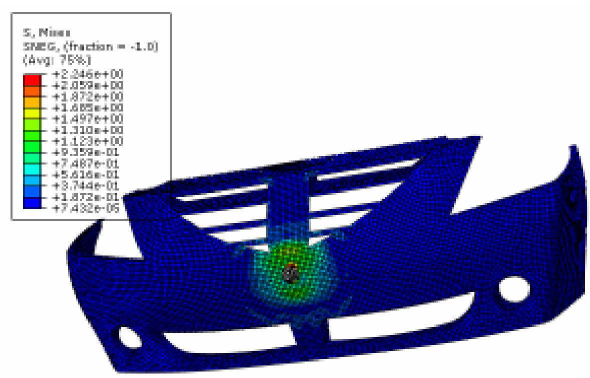

Figure 6: Distribution of the equivalent stress σ in the bumper due to the impact with a steel ball

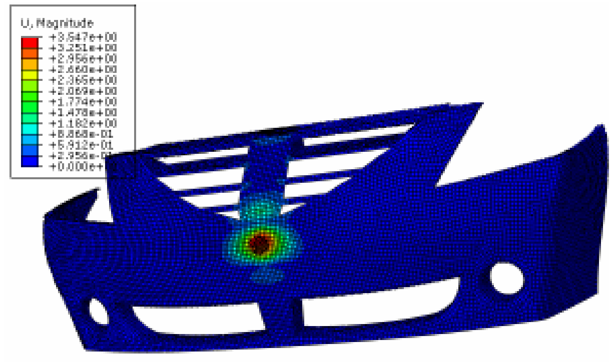

Figure 7: Distribution of the total displacement in the bumper due to the impact with a steel ball

Figures 6 and 7 show the results obtained in case of the second scheme of loading that involved a dynamically analysis of the bumper in impact loading. In this case, the maximum value of the resultant normal stress σ (Misses) is 2.246 MPa which does not exceed again the average value $\sigma_{max} = 8.8\,MPa$ recorded in tensile tests.

4. CONCLUSIONS

In this paper, it was highlighted the behavior in tensile test concerning to the material thermoplastic olefin elastomers (TPO). The using of the real stress-strain $(\sigma - \varepsilon)$ curve to model the front bumper lead to the conclusion that the maximum resultant normal stress σ (Misses) does not exceed the average limit stress 8.8MPa allowed for the material tested (Table 1).
These are only preliminary results because in reality the bumper is included in the bumper system that contains the energy absorber part. To be closer the real behavior, in the futer the entire bumper system should be considered.

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