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Study of the Mechanical Behavior of a Thermoplastic Material under Uni-Axial Loading: Application to Acrylonitrile Butadiene Styrene (ABS)

A.Lamarti[1], A.Naguib[2], A.Hachim[2], Kh. El Had[2], M.Elghorba[1]
1(Laboratory of Control and Mechanical Characterization of Materials and of Structures, National School of electrical and mechanical, Hassan II University, BP 8118 Oasis, Road El Jadida, Casablanca, Morocco).
[2] (Higher Institute of Maritime Studies, Department of Machinery, 7 km Road El Jadida, Hassan II University, BP 8118 Oasis Casablanca, Morocco).
Corresponding Author: A.Lamarti

Abstract: *Acrylonitrile Butadiene Styrene (ABS) has undergone considerable industrial development because of all of these properties: good heat resistance, high impact resistance, rigidity, and its dimensional stability. The combination of the three monomers which constitute it of chemical and physical different properties, makes it possible to have a material of interest with good performances. The disordered nature of macromolecular chains makes it difficult to understand the mechanisms of deformations and damage on the microscopic scale and the resulting descriptive models are generally complex and difficult to apply. Nevertheless, plastics specialists must provide answers about the durability of their products under certain conditions of solicitation. For this purpose, we studied the mechanical behavior of an amorphous polymer, Acrylonitrile Butadiene Styrene (ABS), by means of uni-axial tensile tests on pierced test pieces with different notch lengths ranging from 1 to 7 mm. The proposed approach consists in analyzing the evolution of the global geometry of the strain curves obtained by considering the zones and the characteristic points of these curves and also taking into account the effect of the mechanical behavior of the polymers, especially the ABS.*

Keywords: *ABS, Characterization, Damage, Polymer, Rupture.*

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I. Introduction

Amorphous thermoplastic materials are of great interest because of their important industrial applications. This importance is reflected in numerous works concerning their mechanical responses [1]. However, if one considers only their mechanical properties, their behavior is complex and constitutes a major obstacle, as the potential users encounter difficulties in taking account of them during the sizing and optimization stages. This difficulty is related to the particular structure of the amorphous polymers [2]. The disordered nature of macromolecular chains makes it difficult to understand the mechanisms of deformations and damage on the microscopic scale and the resulting descriptive models are generally complex and difficult to apply. Nevertheless, plastics specialists must provide answers about the durability of their products for certain conditions of solicitation. Acrylonitrile Butadiene Styrene (ABS) has undergone considerable industrial development because of all of these properties: good heat resistance, high impact strength and rigidity, dimensional stability and design ability [3]. The combination of the three monomers which constitute it of different chemical and physical properties, makes it possible to have a material of interest with good performances [4]. The disordered nature of macromolecular chains makes it difficult to understand the mechanisms of deformations and damage on the microscopic scale and the resulting descriptive models are generally complex and difficult to apply. Nevertheless, plastics specialists must provide answers about the durability of their products for certain conditions of solicitation. Our work consists in studying the mechanical behavior of the ABS subjected to a uni-axial loading. In the first stage we carried out an experimental study to characterize the mechanical behavior and in the second part we considered the damage by creating a notch in 3 mm diameter pierced test pieces and notch lengths ranging from 1 to 14 mm.

II. Experimental method

In this work, we will describe the polymer studied, the morphology of the test pieces as well as the experimental technique allowing the measurement of the stresses-deformations during the mechanical stress.

2.1 Studied material

The polymer used in this work is Acrylonitrile Butadiene Styrene (ABS), it is an amorphous polymer produced by emulsification or bulk polymerization of acrylonitrile and styrene in the presence of polybutadiene (Figure.1).

Acrylonitrile 	**Butadiene** 	**Styrene** 
Ensures the stiffness and the thermal resistance	Makes the product harder and more elastic even at low temperatures	Gives to the ABS a good transformability

Fig.1: The chemical nature and physical properties of ABS.

2.2 Operational method

The experiment consists in subjecting ABS test pieces pierced with a hole of diameter Ø = 3mm and simply notched with different length of notches to static tests.

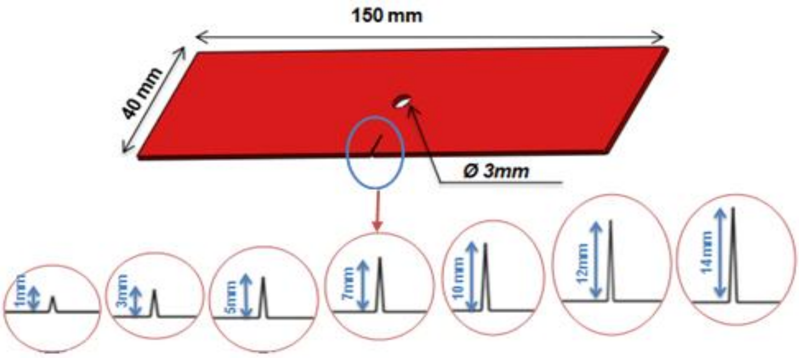

Fig. 2: pierced ABS test piece of 3mm diameter prepared according to ASTM D5766M [5].

2.3 Experimental apparatus

ABS tensile tests are carried out on a Zwick Roell universal tensile machine with a maximum loading capacity of 2.5 KN (Figure 3), which allowed us to obtain more precision given nature of the test material, and the geometry of the test pieces which have a small thickness. The tests were carried out at a uniform speed of 1 mm / min with controlled displacement.

Fig. 3: The «Zwick-Roell» tensile machine.

III. Analysis of the results of the mechanical characterization of ABS test pieces

The analyzes and discussions of the results presented in this work are exclusively relative to the static tests carried out on the test pieces cut from the plates, whose dimensional characteristics are shown in figure 2. First, we determined the mechanical properties of the material studied, and then we used the equations of linear elastic rupture mechanics (MLER) for a more in-depth analysis. For this work, we used flat rectangular specimens of small thickness. Mechanical tensile tests on standardized blank test pieces taken in dumbbell

shapes represent the evolution of stress as a function of the deformation from which we determined the different phases of behavior of the material during the test until reaching breaking point.
The curve represents the stress variation as a function of the strain, for blank ABS test pieces cut according to ASTM D882-02[6].

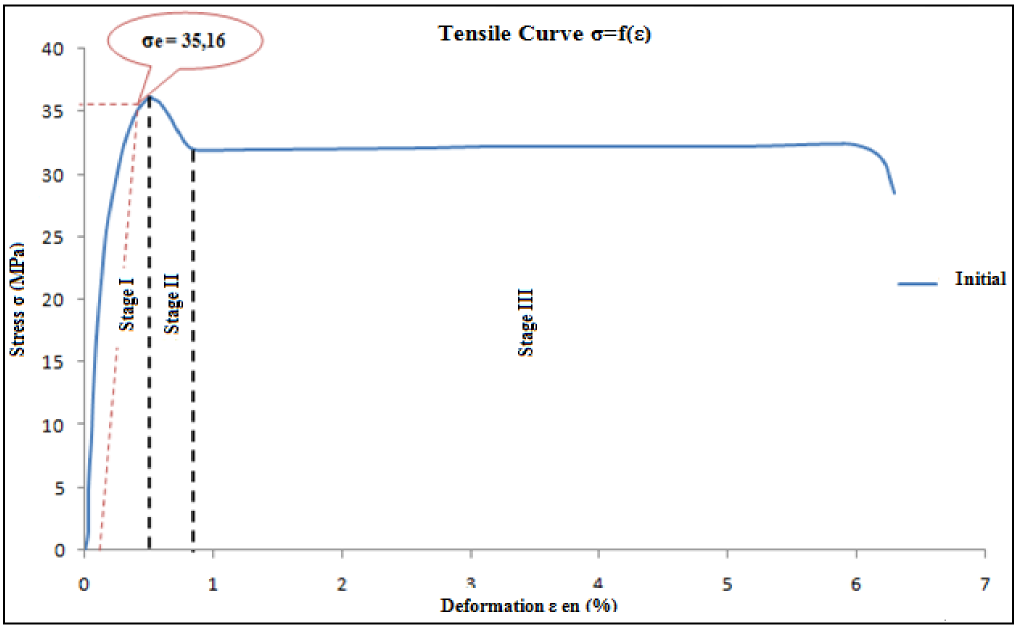

Fig. 4: Tensile stress-strain curve of blank test pieces.

From the obtained results, we note that the values vary in a significant way as the stresses increase. The curve of figure 4 breaks down into three zones:

Stage 1:

It presents the elastic zone in which the material returns to its original shape and allows us to extract the various intrinsic parameters of the ABS, such as: Young's modulus, 0.2% elastic limit, ultimate stress and Breaking stress, table 1 groups together these various parameters.

Table 1: The mechanical characterization of the ABS test pieces.

Young's modulus (GPa)	elastic limit $\sigma e_{0,2}$ (MPa)	ultimate stress σ_u (MPa)
2,8	35,16	36,14

Stage 2:

In this zone, we find the maximum value of the stress (36.14 MPa) with a slight decrease to a value where the curve stabilizes.

Stage 3:

From this zone, the stress remains constant with time, and the strain increases, it is the viscoelastic part. This part represents the zone of necking beyond which the test piece breaks completely.

IV. Analysis of the results of the tensile tests of the notched test pieces

Figure 5 shows the evolution of the stresses / strains for different lengths of notches. The results obtained on the notched test pieces show an identical evolution, we have also observed that the importance of the ductility of the material gives it a non-linear behavior. In this evolution, two parts are distinguished. The first part of figure.5 corresponds to the total Yielding of the ligament, the second part corresponds to the characterization of the stable propagation of the crack to a total rupture of the piece. The plot of the stress / strain curves shows two parts: a linear part, then a continuous distance from the actual curve to the ideal stress / strains. This non-linearity is due mainly to a high plastic deformation at the end of the crack and to a possible slow propagation of the crack. As a result, the crack tends to spread suddenly at very low intensity. The following curves (fig.5) show the variation of the stresses as a function of the deformations for the pierced ABS test pieces of diameter Ø=3mm, with different notch lengths ranging from 1 to 14 mm.

4.1 Notch effect on the material

The following curves (Figure. 5) show the variation of the stresses as a function of the deformations for the pierced ABS test pieces of diameter Ø = 3 mm, with different notch lengths ranging from 1 to 14 mm.

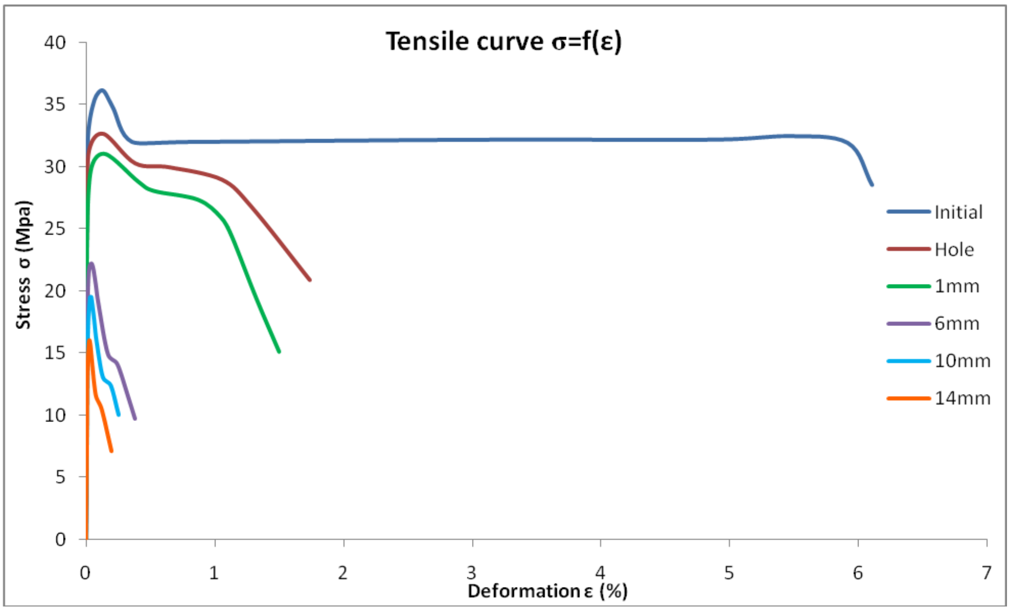

Fig. 5: Tensile stress-strain curve of notched test pieces

The evolution of the curve gives an increasing and then decreasing appearance with an apparent discrepancy between the different values as a function of the length of the notch. By comparing the results of the blank curve versus those damaged, we find a decrease in viscoelasticity when the notch length increases. These results show that the stress at the notch increases (the size of the defects increase), the viscoelasticity decreases and the material tends to weaken.

V. Conclusion

This study concentrated on the mechanical behavior of the Acrylonitrile Butadiene Styrene (ABS) plastic material, using rectangular pierced holes punched and simply notched from 1 to 14mm, subjected to tensile stresses. The geometry of the test pieces studied is proposed by ASTM D882-02. After determining the properties and mechanical characteristics, the influence of the variation of the notch length on the course of the test was studied and the results showed that its influence is remarkable, increasing the notch length, the material stress increases the decreased viscoelasticity and the material tends to weaken.

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