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Analysis of Polymer Behavior (ABS) Under Mechanical Solicitation Based on Statistical Models

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ABSTRACT

Amorphous thermoplastic polymers require a great interest thanks to their important industrial applications. This importance is reflected in many studies about their mechanical responses. Acrylonitrile butadiene styrene (ABS) has seen significant industrial development as a result of its proprieties: good heat resistance, high impact resistance, rigidity, and its dimensional stability. The combination of the three monomers that constitute it from different chemical and physical proprieties, provides a material of interest with higher performance.
This work consists in studying the mechanical behavior of ABS subjected to uni-axial loading, using a statistical study based on two methods: Student distribution and Weibull distribution.

Keywords: *ABS; Polymers; Statistics, Student; Weibull.*

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I. INTRODUCTION

Polymers have undergone a remarkable historical development and their use has been imposed in our civilization over the past few decades by gradually dethroning most of the secular materials. These polymer materials have always been distinguished by their simple and inexpensive shaping, their versatility, their lightness, their chemical stability but despite their massive use in everyday life as well as in advanced technologies, these materials remain in general very misunderstood which requires a thorough knowledge of their chemical, physical, rheological and in particular mechanical properties [1].
Among these polymers, Acrylonitrile butadiene styrene (ABS) has seen significant industrial development as a result of its proprieties: good heat resistance, high impact resistance, rigidity, and its dimensional stability [2]. The combination of the three monomers that constitute it from different chemical and physical proprieties provides a material of interest with higher performance [3].
This study is based on the control of the mechanical behavior of the "ABS" polymer, in order to optimize and enhance the mechanical properties of this polymer, another aspect of the characterization that was taken into account is the statistic study. Through this work, we're going to mainly look at the statistic tests of STUDENT distribution and WEIBULL distribution.

II. BEHAVIOR ANALYSIS OF PIERCED AND SIMPLY NOTCHED SPECIMENS ON STATISTICAL MODELS

2.1 Student distribution for notched specimens

The tensile tests were carried out on two batches of 17 test pieces pierced and simply notched at "a=7mm and a=14mm". Table 1 shows the average values of the maximum stresses obtained for the notched test pieces.

Table 1: Average values of maximum stress for ABS test specimens

	a=7mm	a=14mm
Average	20,19	4,81
Standard deviation	0,15	0,12

Student's law allows to determine a confidence interval in which the maximum stress limit values have 90 chances of 100 to frame the average distribution of the tensile tests [4].

We have:

$$P\left[-t(\alpha; n-1); \alpha \leq \frac{X-\mu}{S/\sqrt{n}} \leq +t(\alpha; n-1); \alpha\right] = 1-\alpha \qquad (1)$$

Which defines limits in probability of the true average "μ" :

$$P\left[X - t(\alpha;\mu); \alpha * \frac{S}{\sqrt{n}} \leq \mu \leq X + t(\alpha;\mu); \alpha * \frac{S}{\sqrt{n}}\right] = 1-\alpha \qquad (2)$$

With:
X: The average.
S: The standard deviation.
n : The number of samples.
t(α ;μ) : The value given by Student table.
α : The risk threshold.

In order to determine the confidence interval by calculating upper and lower limits of the rupture stress's true average, we apply the relation (2) to the results from static tensile tests. We obtain confidence intervals that correspond to the two cases:

- Confidence interval: Notched test specimens at "a = 7mm".

$$\mu = 20{,}19 \pm 1{,}746 \times \frac{0{,}157}{\sqrt{17}}$$ Then μ= [20,13 ; 20,26]

- Confidence interval: Notched test specimens at "a = 14 mm".

$$\mu = 4{,}81 \pm 1{,}746 \times \frac{0{,}126}{\sqrt{17}}$$ Then μ= [4,76 ; 4,87]

2.2 .Weibull distribution for notched specimens

The probability of survival of the specimens subjected to tensile stress, under mechanical stress, could be modeled according to the following Weibull distribution [5]:

$$P_s = e^{-\left(\frac{\sigma}{\sigma_0}\right)^m} \qquad (3)$$

With:
Ps : Probability of Survival.
σ : The applied constraint.
σ0 : The scale parameter.
m : The Weibull modulus (dimensionless).

In order to verify whether the data obtained from the results of the experimental tests on the specimens follow the Weibull law, we draw the points having as their coordinates (lnσ ; ln(ln(1/Ps))).For the two cases (a=7mm et a=14mm) such as [6]:

$$\ln\left(\ln\left(\frac{1}{P_s}\right)\right) = m(\ln\sigma - \ln\sigma_0) \qquad (4)$$

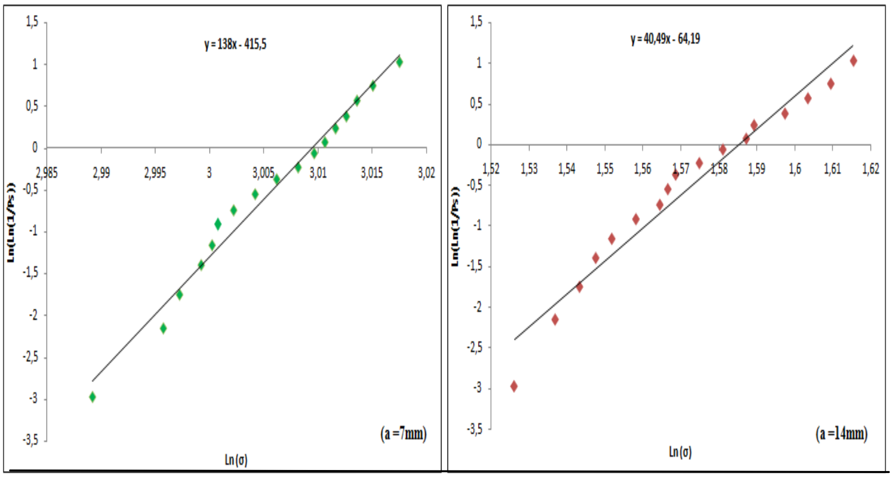

Fig .1: Trend of the Ln curve (Ln (1 / Ps)) as a function of Ln (σ) for pierced and notched specimens (a= 7mm and a= 14mm).

The scatter of points is rectilinear for the two cases of the test pieces with different notch length. Table 2 summarizes the values of the Weibull parameters determined for the drilled and notched specimens.

Table 2: Weibull parameters

Weibull parameters	a=7mm	a=14mm
m	138,07	40,49
σ0	20,27	4,88

The probability of survival Ps and the probability of failure for the notched specimens (a=7mm and a=14mm) are illustrated in Figure 2.

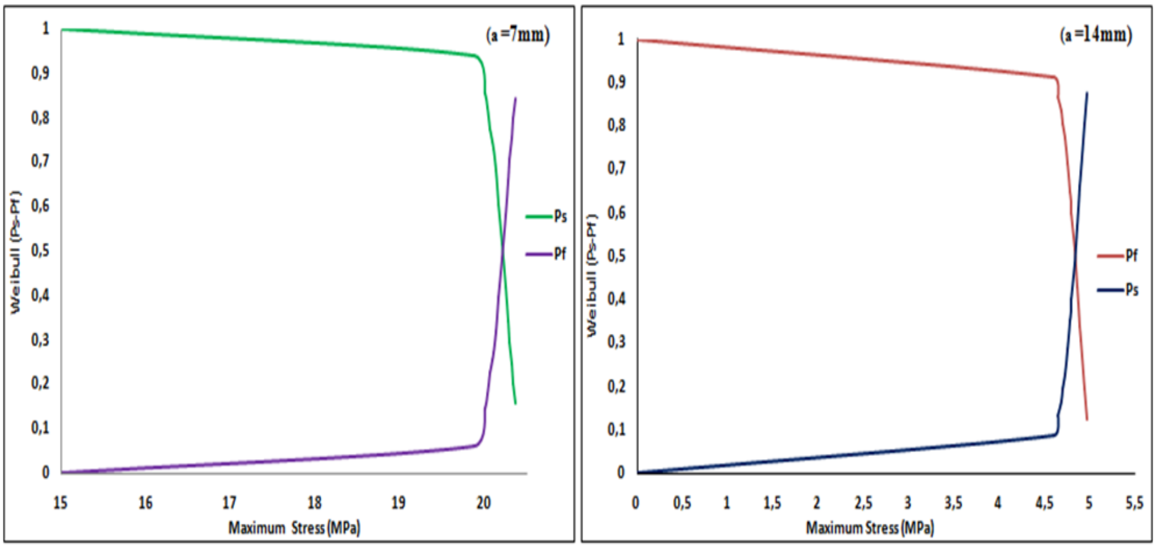

Fig .2: Survival Probability - Failure probabilityCurve for cuts a = 7mm and a = 14mm.

2.3 Superposition of probability of survival- failure probability curves for pierced and simply notched test pieces (a = 7mm, a = 14mm).

The superposition of the set of curves obtained is shown in Figure 3.

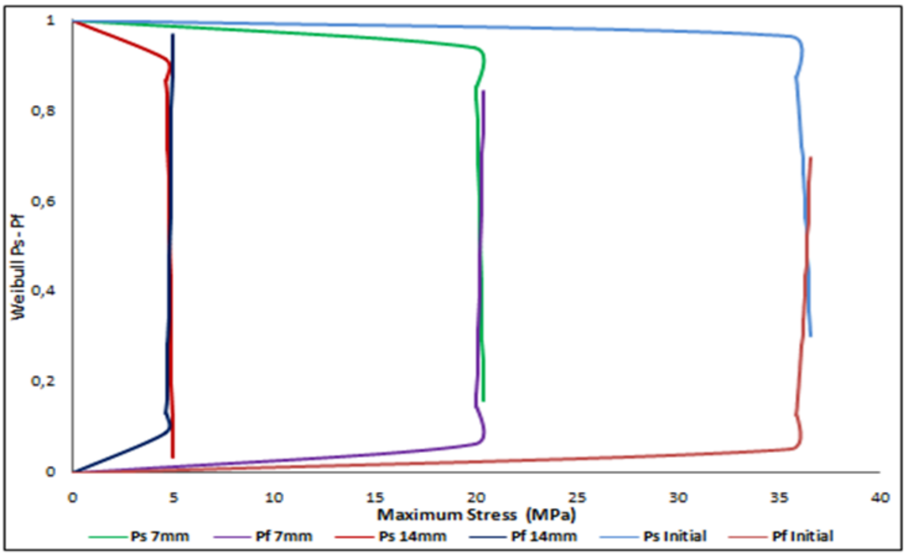

Fig .3: Superposition of survival and failure probability curves of maximum stress for pierced and notched specimens.

According to Figure 3, we found a decrease in the reliability of the test specimens, which corresponds to 58% for the notched specimens at (a = 7 mm) and 10% for the specimens at (a = 14 mm). Which allowed us to observe the notch effect on the behavior of the polymer.

III. CONCLUSION

The behavior of the polymer is directly related to that of their fundamental constituent, which is the microstructure. For this purpose, tensile tests were carried out on rectangular specimens, drilled and simply notched, for the purpose of reliable mechanical characterization and a statistical study for a better understanding of the material.

The Student distribution allowed us to determine the confidence intervals for the blank tests pieces, and the pierced and notched specimens at (a = 7mm and a = 14mm).

The study of the Weibull law allows us to plot the failure curves for pierced and simply notched specimens at different notch lengths (a = 7mm and a = 14mm), and consequently to understand the effects of the length notched on the lifetime of the ABS polymer.

A great reduction in reliability has been noticed, in the case of notched specimens at a = 14mm, so at this stage the damage becomes very important and uncontrollable.

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