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Influence of Test Time on the Mechanical Behaviour of Acrylonitrile Butadiene Styrene "ABS"

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Abstract:- In this article we are interested in the study of the mechanical behaviour of an amorphous polymer, acrylonitrile butadiene styrene "ABS", and this by uniaxial tensile tests on rectangular specimens containing a combined defect: test pieces pierced with a simple notch and other breakthroughs with double notch. The proposed approach consists in developing a method to calculate the evolution of the damage over the life of the materials that can be used to predict quantitatively the risk of sudden rupture in a room. To do this, we will use the method of evaluation of damage by the method of the variation of time of the tensile test. The damage calculation by the method of the variation of time was compared to the unified theory for different load levels. The correlation between the two methods was found for a loading level of 1.68.

***Keywords**:- Damage, Mechanical behaviour, Polymer, Reliability, sudden rupture.*

I. INTRODUCTION

The mechanical behaviour of polymers is characterized by a very large apparent diversity. Indeed, for the same conditions of use, and from a technological point of view, one can find polymers either rigid, fragile, ductile or rubbery [1]. Polymers require great interest for their many industrial applications. This interest is reflected in many works on their mechanical responses [2]. Acrylonitrile butadiene styrene (ABS) is one of those polymers that has undergone significant industrial development, due to its properties (good heat resistance, high impact resistance and rigidity, and dimensional stability) [3]. But there are several mechanisms of degradation of these materials including: Reduction of the surface of the material by wear, corrosion or abrasion; rupture of materials by cracking; Tired….

For this purpose, the precise prediction of the life time of ABS materials is an important economic and strategic issue in the industrial field. However, the life of the ABS is mainly related to the mechanical characteristics of the polymer material. Indeed, during the installation of the materials in the building site, these are often subjected to accidental shocks such as the falling of the rollers, a bad handling by the hammers of the construction machines, etc ... It becomes important for the engineers appreciate its ability to withstand the sudden spread of a crack. Therefore, it requires conducting in-depth studies on the mechanical behaviour of this material.

The objective of our research is to predict the damage of an ABS material according to its fraction of life which is defined as the length of the crack divided by the width of the specimen. resistance is observed at with increasing fraction of life. In this paper, we will use the difference in test time between the types of defects studied in the material as a criterion for defining the damage.

II. MATERIAL & EXPERIMENTAL METHODS

The material used in this work is Acrylonitrile Butadiene Styrene (ABS). The latter is an amorphous polymer produced by emulsification or mass polymerization of acrylonitrile and styrene in the presence of poly butadiene emulsion.

For the characterization of the damage of the material, series of tests were carried out on rectangular specimens, on smooth rectangular specimens (without defect), in order to characterize the material and to give a scale of comparison, likewise to study the Combined defect effect another series of tests was performed on rectangular test pieces with a single notch and holes with double notches with diameters ranging from 2 mm to 30 mm and a pitch of 3 mm and with a fixed notch of 1 mm, in order to highlight the influence of combined defects on the behaviour of the specimens, note that the tests were conducted according to ASTM 882-02 [6] and ASTM D 5766 M [5].

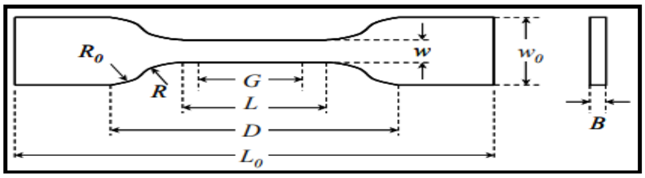

Fig 1:- Dimensions of the specimens according to ASTM D638-03 [4]

Symbol	Description	Size (mm)
L0	Total length	75
D	Initial distance between jaws	42
L	Length of the calibrated part	25
G	Length between landmarks	20
W	Width of the calibrated part	4
R	Small radius of curvature	8
W0	Widths at the ends	14
B	Thickness	2

Table 1. The dimensions of the dumbbell specimen for the tensile test

➢ *Experimental procedure*

The tensile tests in ABS are carried out on a universal traction machine, type "Zwick Roell", with a maximum loading capacity of 2.5 KN (Figure 2), which allowed us to obtain more precision in our tests, considering the nature of the test material, and the geometry of the specimens which

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have a small thickness. Tests were performed at a steady speed of 1mm / min with controlled displacement

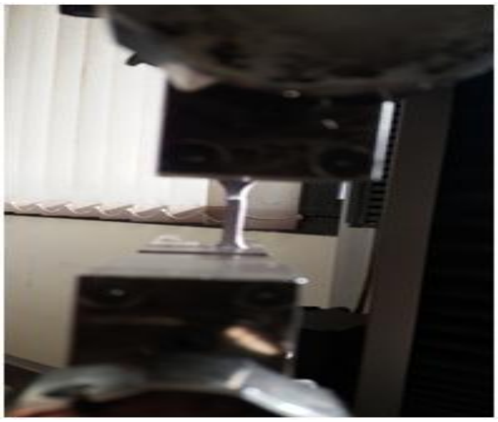

Fig 2. The Zwick Roell Traction Machine

➢ *Mechanical characteristics are summarized in the Table 2:*

Young's modulus	Poisson's ratio	Elastic limit	Ultimate stress
E=2.08 GPa	ν=0,3	σe=31MPa	σu= 38MPa

Table 2. The mechanical characteristics of ABS

III. RESULTS AND DISCUSSION

During the mechanical tests of the simply and doubly notched specimens, we noticed that the behaviour of the specimens and the test time change from one specimen to another. The program of the machine used displays the running time of the mechanical tests for each specimen until the total damage. Figures 3and 4 shows the evolution of the test time as a function of notch lengths for all test specimens used and figure 5 shows the comparison between the test time of the perforated test pieces with a single notch and the perforated test pieces with a double notch.

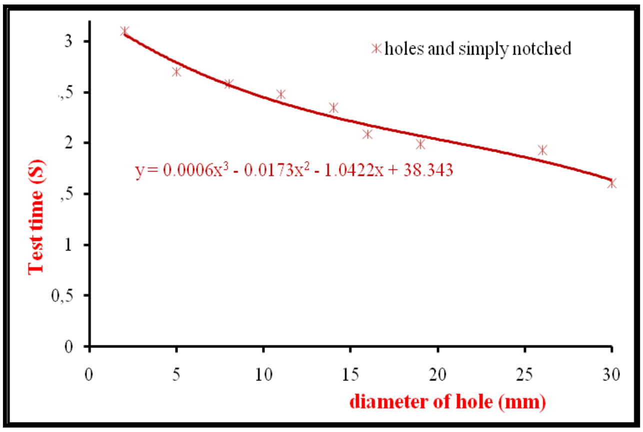

Fig 3:- The evolution of time of tensile test for perforated specimens and simply notched

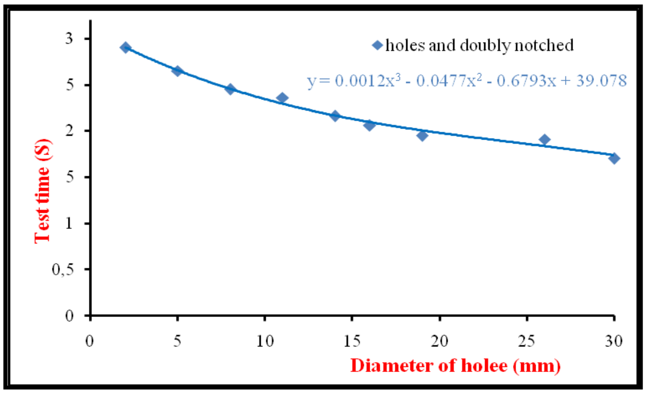

Fig 4:- The evolution of time of tensile test for perforated specimens and doubly notched

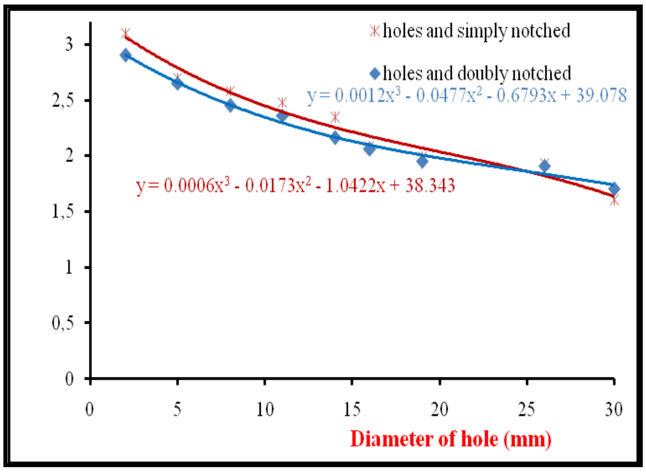

Fig 5:- Comparison of the evolution of test time between perforated specimens, simply notched and perforated test specimens, double notched according to the diameter of the hole

These curves show the values obtained from cumulated test time for each type of defect studied, because for each fraction of life (β), the total time is the superposition of the times calculated at each diameter. It can be seen that when the diameter of the hole is increased, the rupture time of the test piece decreases, in fact the more the defect propagates at the level of the material, the more the stress increases and loses its plasticity, this highlights the decreased plastic energy.

A. Damage calculation

The static damage model consists in determining the evolution of time of the static test whose variations are due essentially to

$$\beta = \frac{a}{w}$$

the damage according to the fraction of life The damage is determined by the variable D:

With:

a: the default length
W: the width of the test piece

During the test, we followed the phenomenon of damage between the virgin state and the complete rupture of the specimen by the measurement of residual ultimate stresses, this phenomenon is quantified by the parameter damage (D), the formula indicating the loss of residual resistance with the test time (1) can be developed as:

$$D = \frac{1 - \frac{T_{ur}}{T_u}}{1 - \frac{T_a}{T_u}} \quad (1)$$

Such as

Tur: the ultimate residual time for the damaged material

Tu: the ultimate time for tensile test for virgin material

Ta: the time applied for tensile test just before the break

The boundary conditions are presented below

- In the initial state ⇨ βu = 0 ⇨ Tur = Tu ⇨ D = 0
- In the final state ⇨ βu = 1 ⇨ Tur = Ta ⇨ D = 1

The variation of the damage as a function of the fraction of useful life βu for the test-pieces with a single notch and the test-pieces with a double notch is illustrated by the two figures below

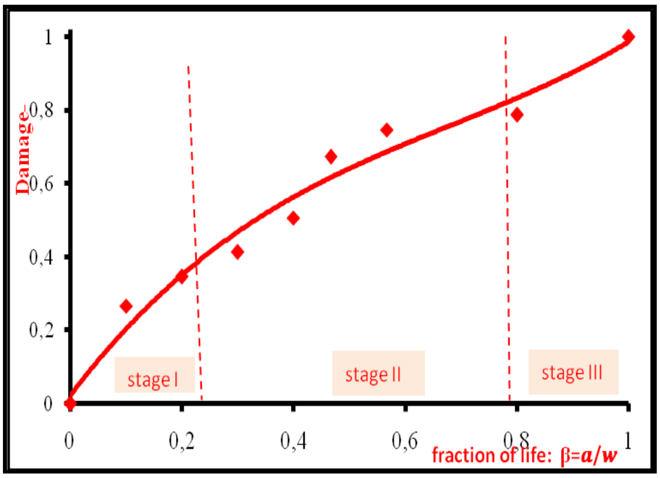

Fig 6:- Evolution of the damage as a function of the fraction of life for perforated and simply notched specimens

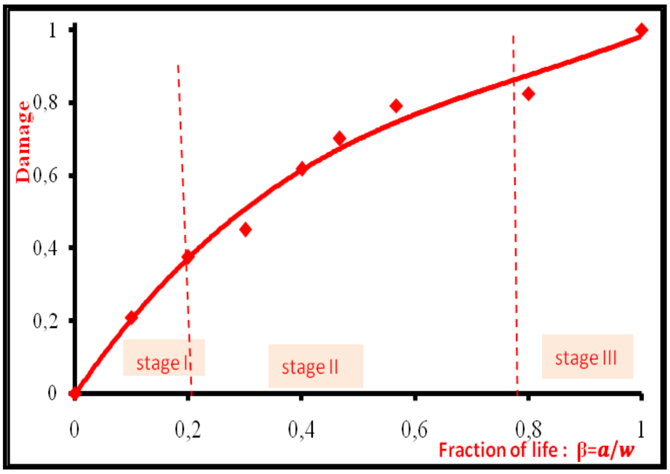

Fig 7:- Evolution of the damage as a function of the fraction of life for perforated and doubly notched specimens

Figures 6 and 7 show the evolution of the damage in the specimens with a single notch and the perforated specimens with double notch with a defect length ranging from 3mm to 31mm which is a linear variation. At the beginning of the curve, we see negligible damage levels, and as the fault length increases, the damage accelerates to a maximum value of 0.98. Or the first slice of the curve which represents the initiation zone characterizes the highest mechanical properties of the material until the last breaking point represents a degradation. This approach is proposed by analogy with the theory of cumulative damage proposed by Gatts [7] Bui Quoc-by [8] to show the evolution of damage in an ABS structure.

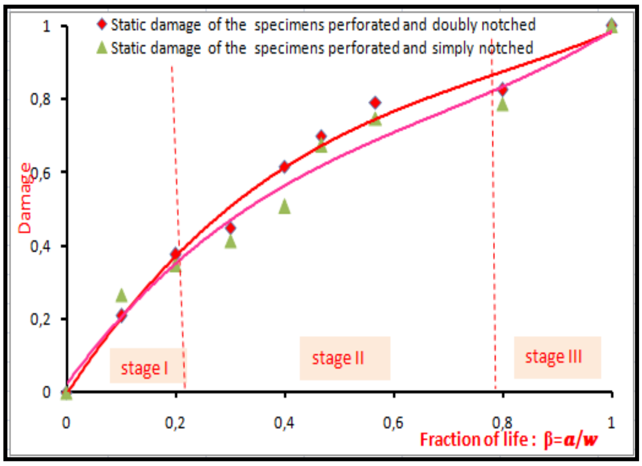

Fig 8:- Comparison between the damage evolution of the perforated specimen with single notch and the perforated specimen with double notch is according to the fraction of life.

The process of damage (Figure 8) is schematized by a concave curve which means that the damage accelerates towards the end of the life of the material, and the rupture will take place at D = 1. Increasing the damage means increasing the static tensile strength loss of the ABS specimens. This loss evolves as the notch length becomes larger. This is a damage with appreciable irreversible deformations, which reduces the ultimate strength of the material. On the other hand, we note that the curve of the damage of the test-tube perforated and doubly notched is above that of the test-tube and simply notched during the first two stages, this reflects the rapid evolution of the level of damage to the perforated test piece with a double notch compared to that which is perforated with a simple notch. From the critical fraction of life βc which announces the beginning of stage III almost all the curves are confused, it is about the unstable phase. The damage becomes uncontrollable, the test pieces can at any moment manifest a sudden break.

Comparing stage I, which represents the zone of the so-called elastic damage it is the safe zone where the advanced defect can be controlled, of the test pieces studied. Note that that of the simple notch is less critical compared to the double notch.

In the light of these observations, we can say that the doubly-notched test-tube is the most fragile. This mainly comes down to the distribution of the stresses at the test-tubes, where a high concentration of stresses at the notches of the pierced and doubly-cut test piece is noted. whereas, for example, for the perforated and simply notched specimen, this concentration is localized only in one part. Therefore, and in our case the most tolerable combined defect is the hole with single notch when it has a longer life.

B. Quantification of damage by unified theory

As a method to evaluate the damage taking into account the loading level, the unified theory developed by T. Bui Qu'oc and al [8] établis a relationship between damage and the loading level. Here, replacing loads by the residual energy, normalized damage is thus written as:

$$D_{th} = \frac{\beta}{\beta + (1-\beta)\left[\dfrac{\gamma - \left(\dfrac{\gamma}{\gamma_u}\right)^m}{\gamma - 1}\right]}$$

Where : $\beta = \dfrac{a}{w}$, $\gamma = \dfrac{T_{ur}}{T_0}$ $\dfrac{L_{ur}}{L_0}$ and $\gamma_u = \dfrac{T_u}{T_0}$

the constant m is a material parameter, with m = 1 for the amorphous polymers [9].

The variation of the lesion of the unified theory and that of the linear rule of Miner as a function of the fraction of life β for the test pieces with a single notch and the test pieces with a double notch are presented respectively in the figures.9 and 10

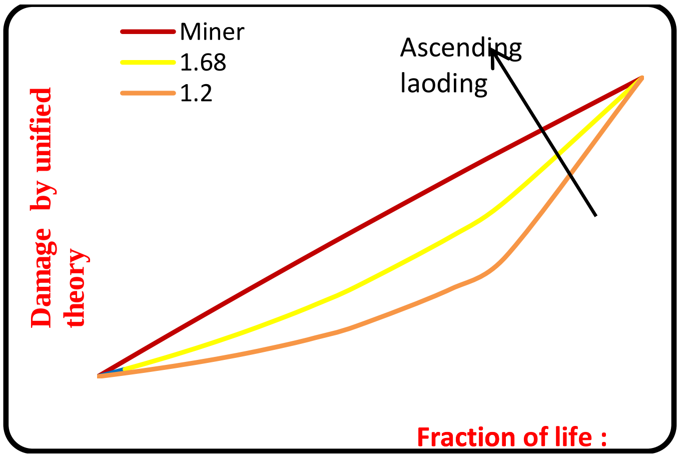

Fig 9. Evolution of Damage by unified theory and Miner law of the test specimens with simply notch according to the fraction of life.

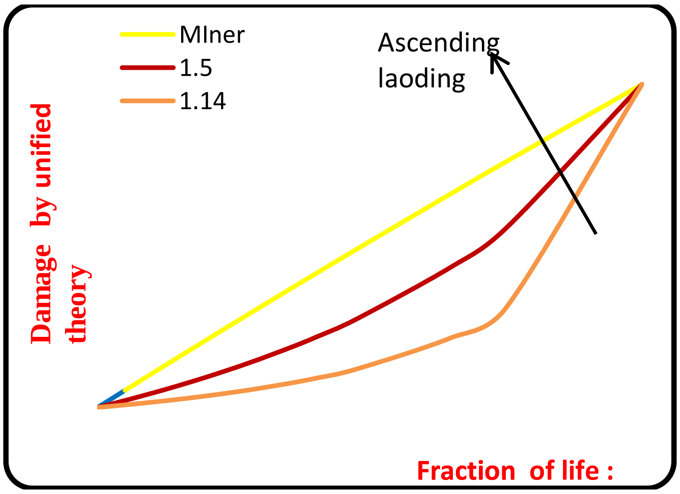

Fig 10. Evolution of Damage by unified theory and Miner law of the test specimens with double notch according to β.

From this diagram, we can note that the limits of damage stages are similar to those obtained by the experimental static method. With the unified theory, the curves approach the bisectrix as the loading level increases. The bisectrix represents Miner damage with is calculated regardless of the loading.

IV. CONCLUSION

The evolution of the damage of an ABS structure according to the fraction of the life was determined in this research. A new method of calculating damage using the time of each test has been developed. Different levels of damage have been identified. The boot damage step ends for a fraction of life of the order of 20%. Then it enters the step of progressive damage where an intervention for predictive maintenance is required. The limit of this step is of the order of 70% then we enter the fraction of life of brutal damage. The residual damage calculation was compared to the unified theory for different load levels. The correlation between the two methods was found for a loading level of 1.68. In conclusion, we have proved that the theoretical and experimental results show a good agreement.

This preliminary work is a necessary step to completely reach our objectives and develop other tools to simulate the structures of phenomena of microstructural degradation ABS.

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