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Influence Of Temperature On The Mechanical Behavior Of ABS.

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--***ABSTRACT***--

The purpose of this article is to investigate the influence of temperature on the mechanical behavior of acrylonitrile Butadiene Styrene from a wide range of uniaxial tensile tests conducted from room temperature in the laboratory (22 ° C) to at 180 ° C, near the melting temperature (195 ° C). Knowledge of the mechanical behavior is essential to predict the life of the components in order to avoid any sudden interruption of service. In this context, our study aims to predict the life span and know the limits that must not be exceeded, namely the identification of the three stages of damage: initiation, progression and sudden acceleration. The estimation of the degree of damage by the model of static damage leads to the theoretical identification of the three stages of damage evolution. Subsequently, a theoretical re-evaluation of the level of damage was carried out by a judicious adaptation of the theoretical model proposed in the unified theory of damage. Theoretical and experimental results showed a good agreement..

KEYWORDS;- *Damage, Mechanical behavior, Polymer, Reliability, sudden rupture, Temperature, Tensile tests.,*

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I. INTRODUCTION

The mechanical behavior of polymers is characterized by a very large apparent diversity. Indeed, for the same conditions of use, and from a technological point of view, we can find polymers that are either rigid fragile, ductile or rubbery [1]. They are linked in a remarkable way to the temperature; one must not deny its influence on the physical characteristics during the study of behavior of the polymers [2], more precisely when it is about the study of the processes shaping [3] that require a large amount of heat and mechanical effort.

It should be noted, however, that the behavior of polymers is strongly related to a temperature margin called glass transition temperature Tg, below which the configuration of macromolecular chains is largely immobile [4]. It is in the transition zone between the vitreous state and the rubbery state that the temperature dependence manifests itself more dramatically. This dependence is all the more remarkable as the dependence over time for viscoelastic materials. The macromolecular chains then tend to move more freely as the temperature increases, especially from 195 ° C which significantly affects the performance of the polymers.

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 polybutadiene emulsion.

The geometry and dimensions of the specimen used are given in Fig.1 according to ASTM D638-03[5].

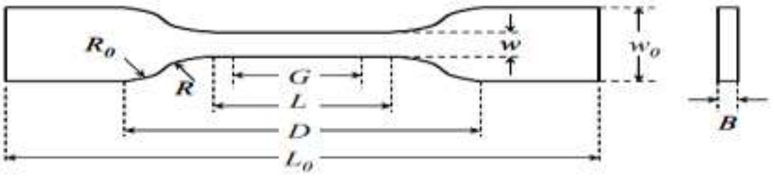

Fig. 1. Dimensions of the specimens according to ASTM D638-03 [5]

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

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

Fig.2 shows the evolution of the stress applied to the specimens (MPa) as a function of the deformation ε (%). The general appearance of this curve has shown ductile behavior.

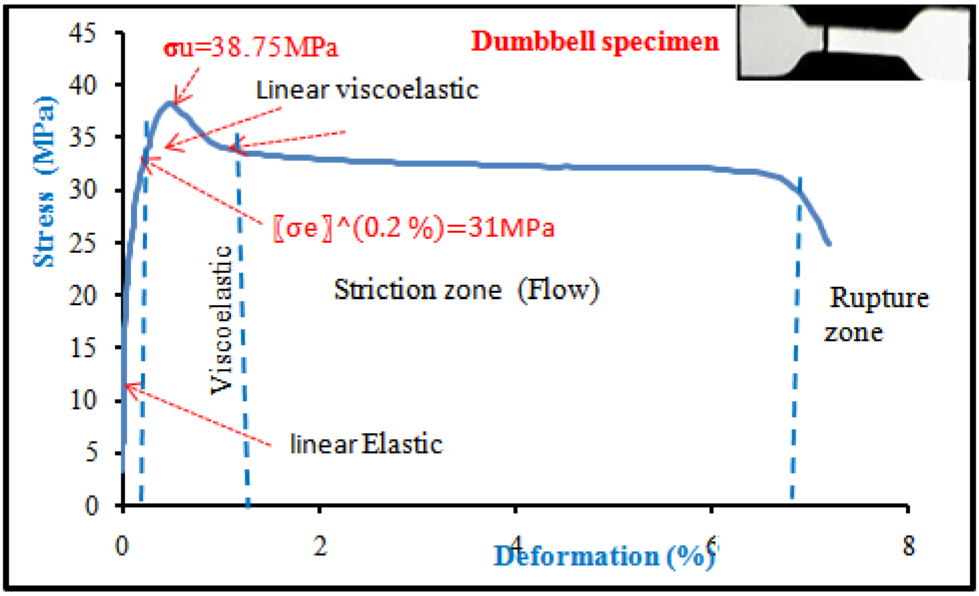

Fig. 2. Tensile curve stress-Deformation Dumbbell specimen

We note from Fig. 2 that the curve has 4 zones. Each of these zones reveals a particular mechanical behavior of the material (ABS) during the tensile test.

Zone 1 (linear): this is the reversible elastic deformation of the material due to the amorphous phase.

Zone 2: the force decreases, it is the beginning of the constriction which corresponds to a heterogeneous deformation of the material

Zone 3 : increase of the zone of constriction along the specimen until stabilization.

Zone4: the stretching force increases, the deformation again becomes homogeneous thanks to a structural hardening linked to the orientation of the macromolecular chains in the direction of stretching and the increase of the fibrillar fraction of the material until rupture

The results shown in Fig. 2 enabled us to determine the mechanical properties of the studied material.

Among these properties, we have the elastic limit, the modulus of elasticity and the breaking stress which have been given in Table 2.

Tableau 2. The mechanical characteristics of ABS

Young's modulus	Poisson's ratio	Elastic limit	Ultimate stress
E=2.08 GPa	ν =0,3	σe=31MPa	σu= 38.75MPa

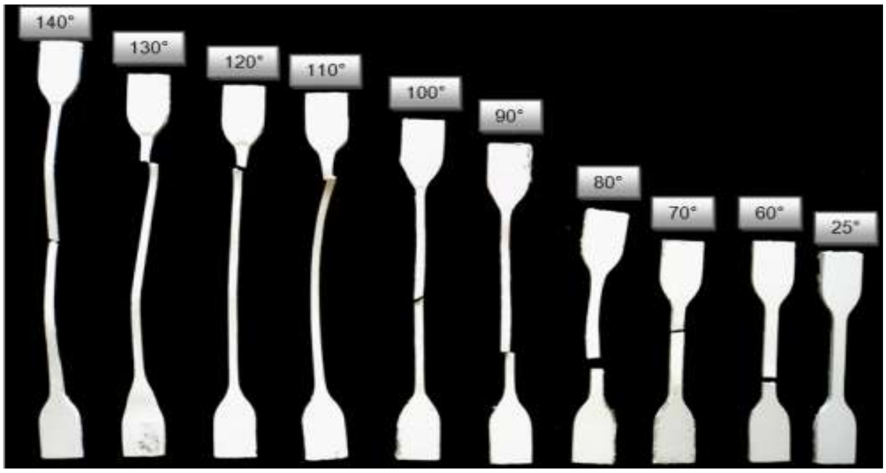

Fig. 3. **Test specimens subjected to tensile tests as a function of temperature [6]**

III. RESULT VIEW

Temperature effect on the mechanical behavior for ABS

To take account of the influence of temperature on the mechanical characteristics of the ABS, especially the Elongation, several series of tests were carried out on dumbbell specimens in a temperature range from 25°C.(Laboratory temperature) Up to170°C through the glass transition temperature T=110 °C.
Fig. 4 shows the evolution of elongation (mm) as a function of temperature (°C).

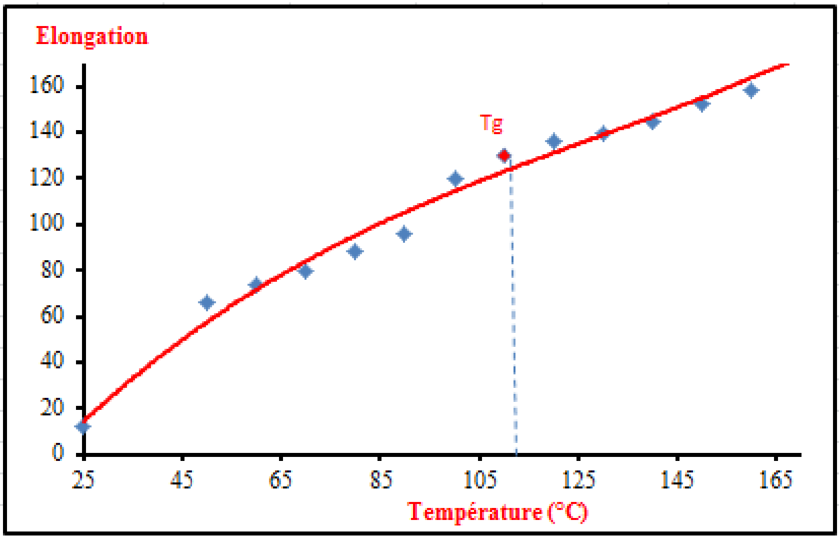

Fig. 4. **Evolution of the elongation modulus according to the temperature.**

We found the existence of two zones: The zone I which corresponds to the temperature which is situated between the temperature of laboratory Ta = 25 ° C and the glass transition temperature Tg = 110 ° C corresponding to a rigid state (vitreous) ie that the molecules of the amorphous part are deformable (industrial zone). Zone II is above the vitreous temperature can correspond to a state of transition in which the chain movements become possible in the now amorphous zones, and allowing larger and easier deformations: the mechanical properties fall in this phase, that is to say, the mechanical behavior of the polymers is affected it is a shaping zone.

Determination of static damage.

The static damage model consists in determining the evolution of elongation according to the fraction of life

$$\beta = \frac{L_i - L_0}{L_f - L_0} = \frac{\Delta L}{L}$$

The damage is determined by the variable D:
With: L0 : Initial elongation
Li : Instant lengthening

Lf : Final elongation

The static damage model consists in determining the evolution of the elongation, the variations of which are essentially due to the damage.
Residual temperatures [7] are generally defined as the internal forces that remain in mechanical parts when they are not subjected to any external forces.
During the test, we followed the phenomenon of damage between the virgin state and the complete rupture of the test piece by the measurement of the variations of temperatures, this phenomenon is quantified by the parameter damage (D).

$$D = \frac{1 - \frac{T_{ur}}{T_U}}{1 - \frac{T_a}{T_U}} \qquad (1)\ ;[8]$$

With:
Tu: Value of the maximum temperature (deterioration of material)
Tur: Value of different temperatures
Ta: room temperature

Evolution of static damage
Static damage as a function of fraction of life is represented by the curve in figure 5, which corresponds to the deterioration of the ABS with the increase of the temperature (figure 5) With the following conditions:

In the initial state: β=0→ Lur = Lu → D = 0
In the final state: β=1 → Lur = La →D = 1

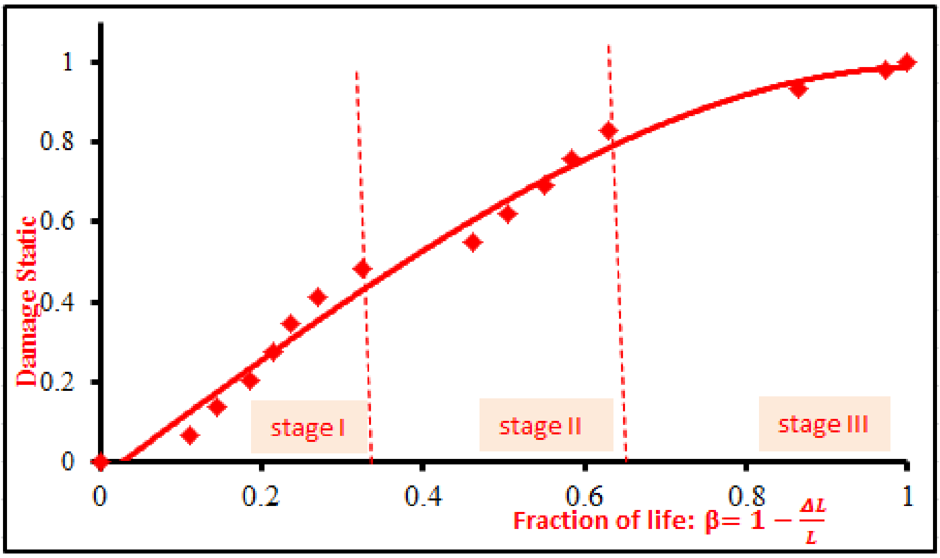

Fig. 5. Evolution of the static damage depending on the life fraction β

From Figure 5 We notice that the increase of the damage signifies the increase of the static tensile strength loss, this loss evolves with the increase of the temperature.
We distinguish three zones, zone 1 which corresponds to the initiation of the damage, zone 2 which corresponds to the critical damage and zone 3 which corresponds to the brutal damage. Indeed; . It is very interesting to be able to correlate the process of damage to the three stages of damage. By observing the damage curves of Figure.5, we can note the following characteristics.

- At the initiation of the damage, the end of the stage I or the life fraction β = 1-ΔT / T = 35%, the damage increases in a linear and progressive way
- In the slow propagation zone, the stage П which is in the interval of β =1- ΔT / T = [35%, 70%] the damage rapidly evolves to 0. 8.
- At the moment of the sudden propagation (stage Ш), the life fraction β> 70% for D = 0.8, the damage accelerates very markedly.

Finally, beyond these two intervals, the damage increases in a brutal way.

Relationship Damage-Reliability

The reliability R is a statistical parameter, which follows the evolution of the deterioration of the material. It varies in the opposite direction of the damage, so the relationship between these two parameters is written as follows:R (β) + D (β) = 1 [9]

Figure6. Illustrates the variation of the reliability and the damage according to the fraction of life β.

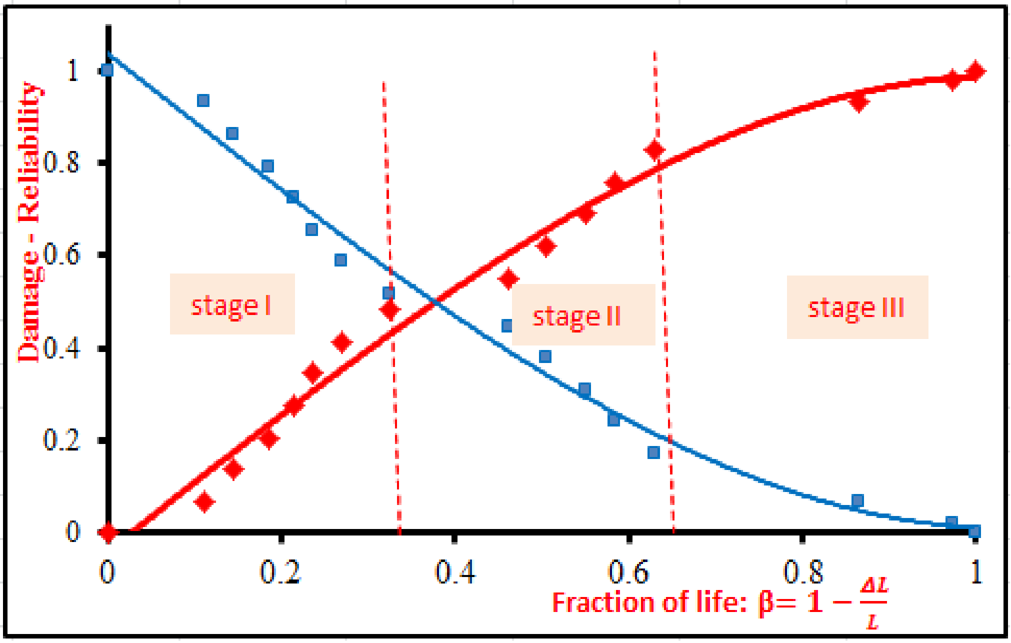

Fig. 6. Superposition of static curves Damage - Reliability depending on the life fraction

The increase in damage is necessarily accompanied by the decrease in reliability (Figure 6). At the beginning, we have the zone of initiation of the damage (stage I), with 50%. The specimens begin to lose their internal strength and the ABS material begins to degrade, this is the propagation of damage, designated by the zone of progressive damage (stage II). At 80% of the damage (20% reliability) the Acrylonitrile Butadiene Styrene (ABS) specimens subjected to tensile stress start the area of abrupt damage which corresponds to a critical temperature of 70 ° C. At this stage III the material becomes unstable.

Unified damage

By correlation to the expression of the unified damage proposed by Bui-Quoc, a relationship describing the evolution of the damage depending on the fraction of life and elongation is given by the next equation: $D_{th} = \frac{\beta}{\beta+(1-\beta)\left[\frac{\gamma-(\gamma/\gamma_u)^m}{\gamma-1}\right]}$ (2)

Where: $\beta = 1 - \frac{\Delta L}{L}$, $\gamma = \frac{Tur}{Ta}$ and $\gamma u = \frac{Tu}{Ta}$

The variation of the damage as a function of β with γ as a parameter is illustrated in FIG. 7. Each curve is associated with a loading level.

The damage by unified theory, calculated from relation (2) as a function of the fraction of life β, is carried by three curves in Figure 7.

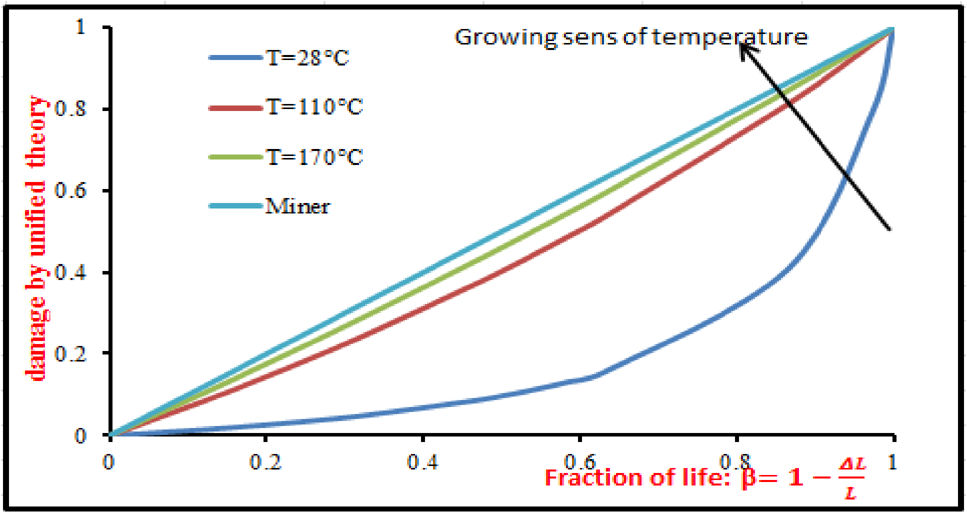

Fig. 7. **Represents the damage as a function of the fraction of life, according to the unified theory.**

From the different curves, which represent the damage according to the unified theory for each temperature studied, it can be seen that gaits relative to different temperature levels are superimposed in the order of T (the upper curve is the one with the highest temperature level). The last curve relating to the last temperature .T = 28 ° C presents a significant difference from other loads.as the temperature increases, the curve of the damage approaches the bisector which corresponds to the damage of Miner. We deduce that Miner's law presents more security since the damage remains underestimated by the computation of damage of the law of the unified theory. Miner's law is more critical with respect to the various damages related to the unified theory. Hence the use of the damage defined by the law of Miner in most works dealing with the damage of the structures.

Static damage and unified damage comparison:

Figure 8 shows the correlation between the damage calculated from equation (2) of static damage and that of the equation (3) of the unified theory, without forgetting the linear rule of Miner.

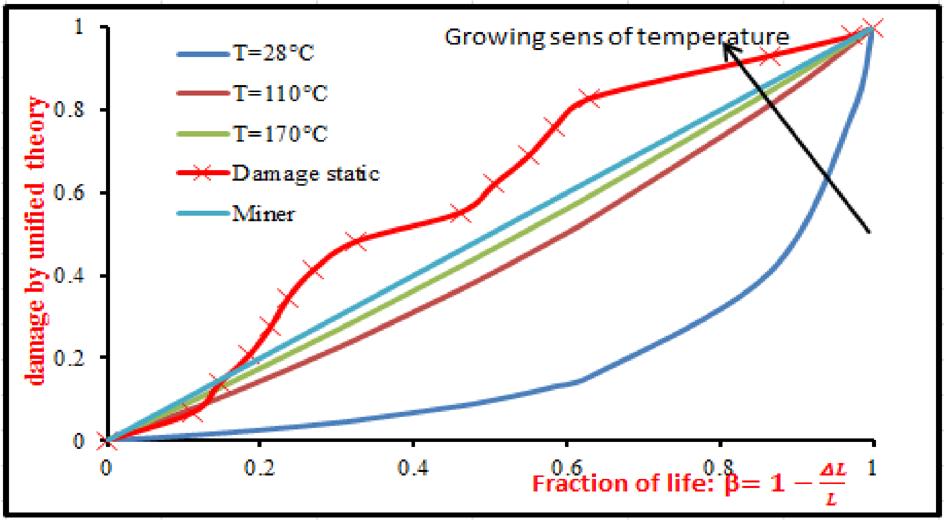

Fig. 8. **Characteristic curves representing the comparison between the static damage and the unified theory according to the fraction of life**

In Figure 8 it is found that the static damage is considered the most critical in relation to all forms of damage presented.

IV. CONCLUSION

The aim of this work was to characterize the thermal and mechanical behavior of a thermoplastic flat wafer. It was felt that the uniaxial tensile test was the most practical and accurate approach to the actual state of deformation during actual loading, this technique was used to describe damage to thermal elongation. and coupled mechanics.

The unified theory of damage has been used to provide a more comprehensive damage model that can more accurately describe the damage state of the material.

We used unified theory, which is formulated in a macroscopic approach to damage. We first redefined the different parameters of the model according to our type of tensile load. Thus reformulated, the validity of this one is implemented during a comparative study between the theoretical predictions and the experimental measurements. We have seen that the theoretical predictions are more or less close to the experimental results.
This comparative study revealed that the predictions of our theoretical model of damage and flow are not significant for low loads. On the other hand, for large loads, the theoretical predictions are closer to those obtained by experimental measurements.

The results showed the feasibility of the applied damage approach, the proposed approach involves intrinsic parameters of the material (its elongation model, its temperature), which allows a rigorous description of the damaging condition of the materials.

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