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Comparative study of the mechanical behavior of polymer materials: between ABS and PVC

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ABSTRACT
Plastic materials play a large part in our daily lives because of their ease of installation and production costs relatively low. Thus The accelerated technological development that we live brings more and more mechanical engineers to face the problems damage of materials. However, these problems are even more serious than fatigue cracking often leads to a sudden break often cause accidents. This unfortunately happens all too frequently, due to insufficient knowledge either room service conditions or even damage parameters. This work presents new developments in the field of fracture mechanics and the objective is the evaluation of defects and thus a better estimate of the reliability of the polymeric material structures by comparing two plastics (ABS and PVC).

KEYWORDS *: Tension, polymer , damage, PVC, ABS*

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I. INTRODUCTION

The development of polymers has hardly ceased to grow and make more and more accentuated growth in our life. Leave high performance to large industries are industries diffusi, polymers are omnipresent in all aspects of our lives. Where is the pressing need to know more rigorously their properties, characteristics, and behaviors[1]. The present work is a contribution to the study of polymers used in plastics (ABS and PVC) in order to better understand the various parameters the acting [2] in the behavior of these materials and provide solutions to common problems encountered during the formatting or use by comparing these two plastics.

I.1 Industrial comparison between ABS and PVC

The **ABS** and **PVC** are used in the pipes, because they are non-toxic and resistant to abrasion. The ABS pipes are easier to install compared to PVC pipes, but also more susceptible to deformation when exposed to sunlight. SBS stands for acrylonitrile butadiene styrene and PVC means polyvinyl chloride.

Table 1 : The properties of rigid PVC and ABS materials

Name	Acrylonitrile Butadiene Styrene	Polyvinylchloride
Uses	Pipes, instruments, canoes, luggage, appliances, toys	Pipes, cable insulation, clothing, toys
Molecular formula	(C8H8 C4H6 · · C3H3N) No	(C2H3Cl) No
Properties	Strong, rigid, low cost.	Flexible but durable. low cost

The PVC and ABS pipes are resistant to most acids, bases and salts. However, they are not resistant to aromatic and chlorinated hydrocarbons. Both lines can be used above or below ground, but the ABS is more likely to deform when exposed to sunlight. For this reason, some local regulations require ABS pipes contain pigments to protect it from UV rays or be painted with latex paint . PVC is generally softer and more flexible by the addition of plasticizers. The pipes ABS are easier to install than PVC pipes like PVC pipes[3] need a purple primer before each joint is glued, and seals must then be held together for 5-1 0 seconds for the glue grabs.

I.2 use in structures

ABS is used in drain-waste-vent piping systems and sewers. It is also used as electrical insulation. PVC is also used to make tubes for systems such as wind-drain waste and for the insulation of electrical cables [4]. ABS is very high impact resistant. PVC is less resistant, it is designed to be flexible and softer than conventional plastics. However, the two plastics are resistant to chemical degradation and water.

II. THEORETICAL STUDY

II. 1 DAMAGE

All theoretical models of damage require confrontation with results from experiments, hence the need for a standardized formulation of the damage. In the literature of the damage, several authors whose Bui Quoc proposed a model of the normalized damage [5] based on the variation of the residual ultimate strength between its virgin state and critical.

II.2 Residual ultimate strength

The model of static damage is to determine the change in force which changes are due to damage. For different values of lengths of taps $_{i,}$ measures the residual ultimate forces Fur were performed on samples rigid PVC and ABS. Are generally defined residual forces as the internal forces remaining in the mechanical parts when these are not subject to any external force[6]. for plastic materials such as rigid PVC and ABS, residual efforts are mainly related to the constraints of growth and are induced by the manufacturing processes of the raw material to the finished product, and will influence the fatigue behavior and rupture. The role of these residual forces is fundamental to design a room mechanical due to our material. In recent years, studies have multiplied to understand their effects on the mechanical performance [7].

II. 1. 2. Damage calculation

The model of static damage is to determine the change in force which changes are mainly due to damage[8]. Then quantitated the damage by the variable D expressed by :

$$D = \frac{1-\frac{F_{ur}}{F_u}}{1-\frac{F_a}{F_u}} \qquad \textbf{Eq (1)}$$

Fu : The value of the ultimate strength to the undamaged original state
Fur : The value of the ultimate strength for different lengths of cracks
Fa : Force before failure

The ratio Fur/ Fu decreases when the cut length increases, it follows an exponential variation according to the equation (2) :

$$\mathbf{Fur/Fu = A{*}e^{B(a/w)}} \qquad \textbf{Eq (2)}$$

A and B are constants to be determined,

During the test, following the damage phenomenon between the blank state and the complete failure of the specimen by measuring the residual ultimate strength, this phenomenon is described by the parameter *D.*

We have:

- $a_i/w = 0 \rightarrow$ Fur = Fu $\rightarrow$ D=0
- ai/w = 1 $\rightarrow$ Fur = Fa $\rightarrow$ D = 1

In terms of constraint expression (1) becomes

$$D_{Exp} = \frac{1-\frac{\sigma_{ur}}{\sigma_u}}{1-\frac{\sigma^*_{ur}}{\sigma_u}} \quad \Rightarrow \quad D_{Exp} = \frac{\sigma_{ur}-\sigma_u}{\sigma^*_{ur}-\sigma_u} \quad \text{wit} \qquad \textbf{Eq (3)}$$

σu : The ultimate stress in undamaged original state
σur : The ultimate stress for different lengths of cracks
σur * : Strain before failure

III. EXPERIMENTAL PROTOCOL

III. 1 Test tube and test device :

We take a dumbbell configuration goal is to determine the mechanical properties of ABS materials studied and rigid PVC.

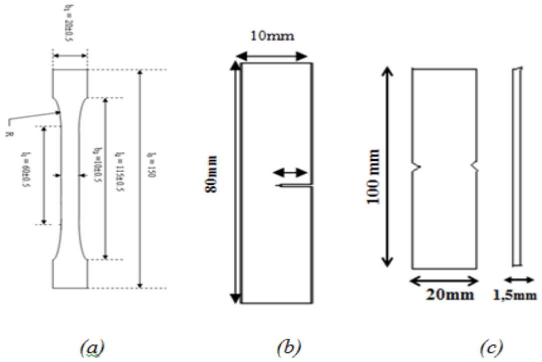

Figure 1: *the standardized dimensions of test s s used traction in sound condition (a) and notched B) PVC Rigid c) ABS*

All tensile tests for the type of specimen (a), were carried out quickly sse constant strain. The test consists of subjecting the specimen to a tensile force until fracture to determine the following mechanical properties:

- Tensile elastic limit: σ_e
- Rupture strength : σ_R
- Maximum resistance or tension : σ_M, maximum stress measured on the traction curve.
- Deformation tensile elastic limit : ε_E
- Strain to failure in tension : ε_R
- Deformation corresponding to the maximum resistance σ_M : ε_M
- Tensile modulus, Young's modulus E (MPA) **[MASSA, 1995].**

To highlight the influence of the notch on the behavior of specimens ABS, a series of tests was carried out on the characterization of damage on two rectangular sample groups of ABS in the base of ASTM 882 -02 [15] and ASTM D 766m [16]. the first test is to smooth rectangular specimens (without defects) for the mechanical characterization, and the second is on rectangular test specimens with notches double length of 1mm to 7mm. All the experimental tests were carried out under a controlled displacement and the following figure shows the implementation of the tensile test. For PVC material, the specimens used are free weights and flat test pieces they consist mainly of polyvinyl chloride (PVC rigid) .They come from the same casting. The specimens were collected in rectangular shape from rigid PVC pipes in the sense longitudinal**.** We adopt a configuration SENT (Single Edge Notched Tension) with notches of different lengths as $0.2 \leq a/w \leq 0.6$, such that the notch has a length and W is the width of the specimen.

IV. RESULTS

After to be treated curves are engineering produced by the traction machine, and after the statistical analysis of the results, we can draw the following average curve :

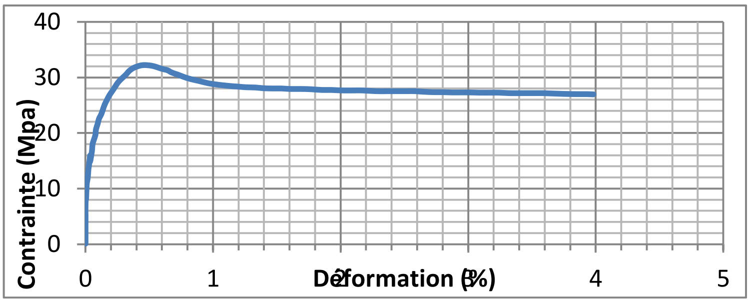

Figure 2 : *courbe de la contrainte-déformation pour l'ABS*

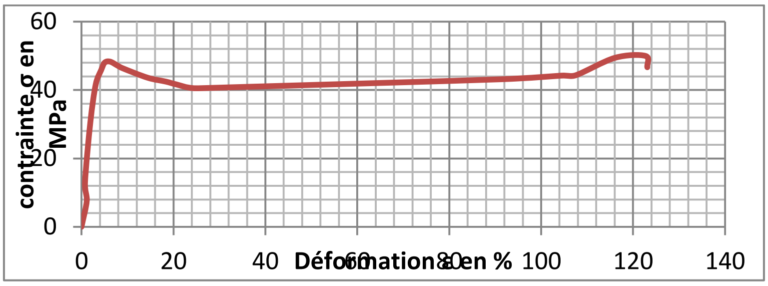

Figure 3 : *courbe de la contrainte-déformation pour le PVC*

The results of the tensile tests reported in FIG show the evolution of the stress-strain curve up to failure for the two polymers (ABS and PVC), the reproducibility of the test was as good a result of various tests made, and allows the detection of the typical behavior of a large deformation polymers ; the early trials, although there is proportionality between the applied force and elongation, this is the area of the elastic deformation, this quasi-linear region allows us to obtain the Young's modulus and the determination of the elastic limit and the following table gives the various values obtained from the tensile curves.

Table 2 : The mechanical properties of rigid PVC and ABS materials

Mechanical properties	**ABS**	**PVC**
E modulus (GPa)	2	2.72
Ultimate stress (MPa)	34	50
Elastic constraint (0.2%) (MPa)	30	44

The value of 34 MPa (ABS) and 50MPa (PVC) has a limit value of the stress beyond which more linear proportionality was observed between the applied force and the elongation, the material begins to plastically deform a permanently ; is the intrinsic softening zone corresponding to the start of the non-linear distortion (This softening the plastic flow threshold is mainly due to the change of the microscopic structure of the material), this deformation is continued with an increase in stress to a final value, after which it drops to where it stabilizes and remains constant with increasing elongation, the plastic deformation is localized on a white line at the center of the sample in a region which is called curing zone.

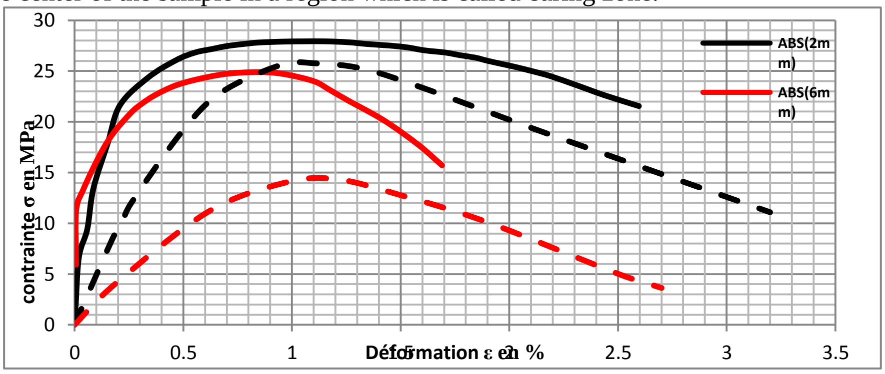

Figure 4 : *Evolution of the stress-strain curve for both ABS and PVC materials in two different cuts (2mm and 6mm)*

The degradation of the mechanical properties always proves remarkable ; the elastic stress, ultimate stress, the tensile strength and the elongation take increasingly decreasing values with increasing the diameter of the hole, there is no longer a constraint stabilization zone, or a high elongation, the rupture often precedes a local plasticizing and a sharp break afterwards. The evaluation of the experimental damage based on the loss of material resistance **[BUI, 1986],** leads to discriminate the residual tensile mechanical characteristics according to their ability to relate the damage caused by the impact. Indeed, the experimental damage Bui Quoc **[BUI, 1986]** is based on a residual mechanical characteristic reflecting the strength loss or degradation of the material.

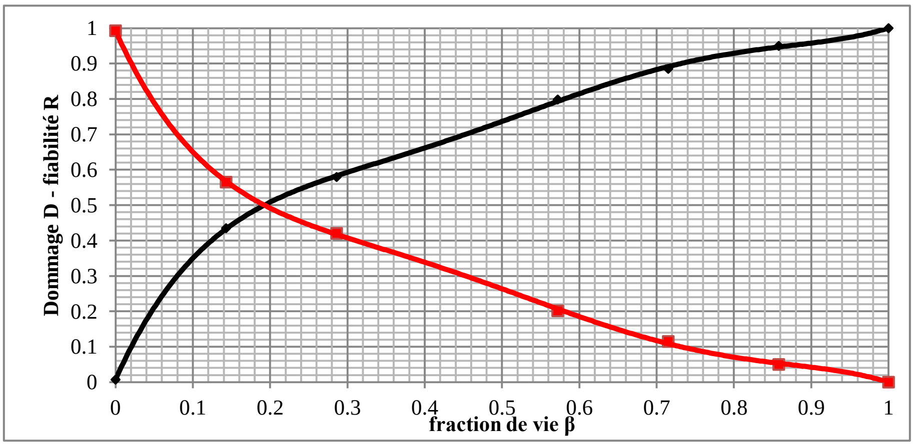

***Figure* 5 :** *Evolution of the damage and reliability based on the fraction of life for ABS*

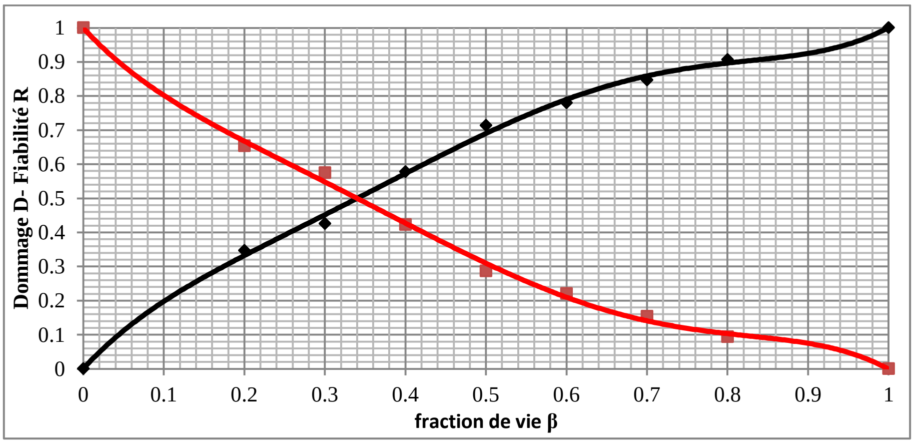

***Figure 6* :** *Evolution of the damage and reliability based on the fraction of life for PVC*

Table 3*: Summary of the different stages of the damage for both ABS and PVC materials*

	ABS	**PVC**
Stage I	• β_{I} (0, 0.2) • D_{I} (0, 0.5)	• β_{I} (0, 0.2) • $_{I}D$ (0, 0.34)
Stage II	• β_{II} (0.2, 0.86) • D_{II} (0.5, 0.94)	• β_{II} (0.2; 0.8) • D_{II} (0.34; 0.9)
Stage III	• β_{III} (0.86: 1) • D_{III} (0.94: 1)	• β_{III} (0.8, 1) • D_{III} (0.9, 1)

It is very interesting to be able to correlate the damage process and the three stages described above in the summary table .In observing the damage curves in figure for us to identify the following features for ABS

- When initiating LPs ofissures, the end of I stadium or the fraction of life β = 0% for D = 0 and β = 20% D = 0.5, damage is almost linear
- N the slow propagation area, the Π stage which is within the range of β = [20%, 86%] D = [0.5, 0.94], the endommagem ent increases in a progressive manner .
- A t the time of the sudden spread (stage Ш), the fraction of life β> 86% D = 0.94, the damage accelerates very marked way.

The same reasoning applies to the curves in figure for PVC .In fact, no notice us :

- Stade I : Corresponding to a value of β = 20% for D = 0.34, an increase of the damage is remarkable
- Stade II : Is between 20% and $\beta = \beta$ = 80% damage values for D = 0.34 and D = 0.9, and the damage in this area is changing rapidly
- Stade III : The damage increases to a critical value followed by the rupture of the specimen.

It is clear that the different phases appear similar to the propagation of a crack, wherein the step 1, Phase 2 and Phase 3 correspond to the initiation, propagation and fracture of the crack. The only difference is that priming of a crack corresponds on average to 60% of the damage **[Ghorba 1990],** whereas here the Phase 1 occupies 20% of the damage.

V. CONCLUSION

The aim of our work is to better understand the mechanical behavior of different polymers used in industry (ABS and PVC) and know the acting parameters on the behavior of these materials to provide solutions to common problems encountered during the implementation form or use.

Uniaxial tensile technique was used given the simplicity of its coming into realization, and the reliability of its results ; the values for the Young's modulus are E = 2 GPa for ABS and E = 2.7 GPa for PVC, the ultimate stress value of : $_U \sigma$ = 34MPa for ABS and σ_u = 50MPa for PVC. As for damage testing, defect geometry the influence was studied. Tensile tests at break on standard specimens with different cuts for each of the two materials.

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