COMPARATİVE STUDY OF THE MECHANİCAL BEHAVİOUR OF THE ABS POLYMER: İNJECTİON PRESS-3D PRİNTİNG

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Abstract

Plastic processing techniques depend on the nature of the polymers and on the destination of the finished products. To improve the productivity of plastics and their performance, the industrial world has given great importance to the evolution of these transformation techniques. Our work is a comparative study of the mechanical behavior of a polymer (ABS) in two different processing techniques: press injection and 3D printing. Plastic injection uses the thermoplastic properties of the polymer, to inject it softened into a mold, in order to create a footprint of it. This technique provides the best quality for productions of large and very large series.3D printing, also called additive manufacturing or direct digital manufacturing, allows making an object by creating a numerical model and printing it in three dimensions. It opens a wide range of technical possibilities with important economic stakes. Used mainly for prototyping, its potential applications are now of interest to many sectors of activity: aeronautics, automobile, medical, ... The melt flew index of the ABS used is 22.32 g / 10 min, the mode of transformation chosen, which is the injection, is in agreement with our material. The mechanical behavior of test pieces made by the two processes is different. The stress and strain characteristics are significantly higher in the conventional injection process than in the case of 3D printing. The values of modulus of elasticity and maximum stress decrease significantly in the 3D printing process. Micrographs obtained by optical microscope and scanning electron microscope observations (MEB) of fracture facies during tensile test show a big difference in the cohesion of the material between the two processes. The results obtained show that the transformation mode has a direct influence on the mechanical characteristics of the polymer. The mechanical characteristics required of the finished product impose the mode of transformation of the polymer..

Keywords: 3D printing, Injection, polymer

1. Introduction

The conception of 3D printing, also referred to as additive manufacturing (AM), rapid prototyping (RP), or solid-freeform technology (SFF), was developed by Charles Hull. With a B.S. in engineering physics from the University of Colorado, Hull started work on fabricating plastic devices from photopolymers in the early 1980s at Ultra Violet Products in California.(1) The lengthy fabrication process (1–2 months) coupled with the high probability of design imperfections, thereby, requiring several iterations to perfect, provided Hull with the motivation to improve current methods in prototype development.[7]. A new revolutionary technology took place in 1980 in research centers and nowadays is rapidly gaining consumer acceptance, it's called Additive Manufacturing (AM) or 3 D –Printing. Fused Deposition Modelling is a method that has been patented by Stratasys, USA in 1992.[1] Through this method the material is heated and placed on a plate, layer by layer, until the part is manufactured. The material is heated slightly above the melting point and solidifies as soon as it comes out of the nozzle [1]. Every 3D model that is manufactured through the AM process follows a different step path [2 (Gibson et al. (2015)). First is the CAD model creation with the translation to STL format following. Then the 3D printed model is created by setting the manufacturing parameters. The final step is to remove any unnecessary material from the part in order to use it. Through this method the material is heated and placed on a plate, layer by layer, until the part is manufactured. The material is heated slightly above the melting point and solidifies as soon as it comes out of the nozzle. The heated material is placed on to a plate by a nozzle that is moved by a numerical controller (NC). (Gibson et al. (2015)[2]). Characteristic of the components they produce is their high strength, relatively good precision, the fact that they do not need cleaning and finishing afterwards but also the saving of raw materials, as there is no residual (Srivatsan and Sudarshan (2016) [3])

In this work a novel approach is presented on how the printing factors influence the mechanical properties of the printed part in order to obtain how parts can be manufactured (printed) to achieve improved mechanical properties. The methodology is based on an experimental procedure through which the optimum combination of manufacturing parameters and their values can be determined in order to achieve the goal. The Taguchi methodology was selected as an optimization tool towards the goal of improving the part's mechanical properties.

2. Procedure and experimental protocol

Elaboration of the samples test

Two manufacturing processes were used to develop our test specimens, plastic injection and 3D printing

2.1 . Elaboration of the samples test specimens by plastic injection

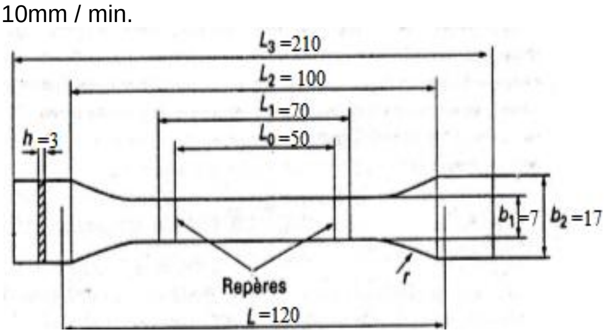
Standard tensile and resilient samples test are realized by injection process. The parameters of the injection machine are summarized in Table 1.

Table 1. parameters of the injection machine

Paramètre	valeur	Paramètre	valeur
Dosage	164 mm	Opening	2 towers
Injection	2,5 s	Opening	3 towers
Mataining	1,6 s	Injection	4 towers
Cooling time	16 s	Rear ejection	4 towers
Break time	0,2 s	Front	4 towers
Injection	0,2 s	Reload speed	2 towers

2.1.1. Traction samples test

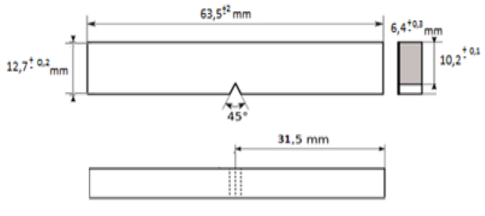
The geometry and dimensions of the tensile test pieces (Diagram 1) were carried out in accordance with the NF EN ISO 527-2 standard. The traction speed is fixed at 10mm / min.



Scheme 1 Geometry of the tensile samples test according to the NF EN ISO 527-2 standard

2.4. Resilience samples test

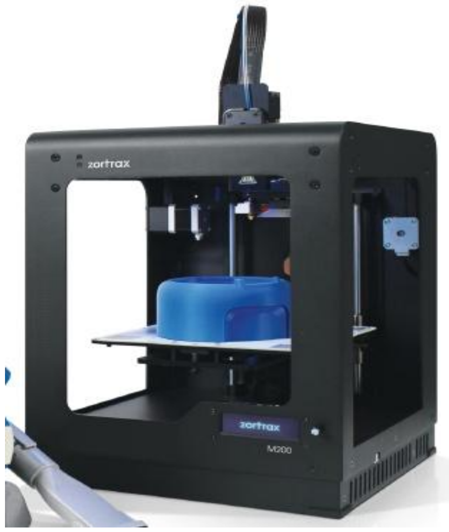
In the case of the Charpy samples test (V-notch) (Schem 2), their geometry and dimensions were carried out according to the standard NE 3.03.070 according to Method 3A. We used a ZWICK 5102 pendulum sheep according to DIN 51222



Scheme 2. Geometry and dimensions of the resilience samples test

2.1.2. Elaboration of the samples test specimens by 3D injection

We used a Zortrax M200 model printer



Printer *e 3D ZORTRAX M2000*

3. Results and observation

3.1 Stress-strain curves

Figure 1 shows the results of the tensile tests on the samples of injection procedure and 3D printer.

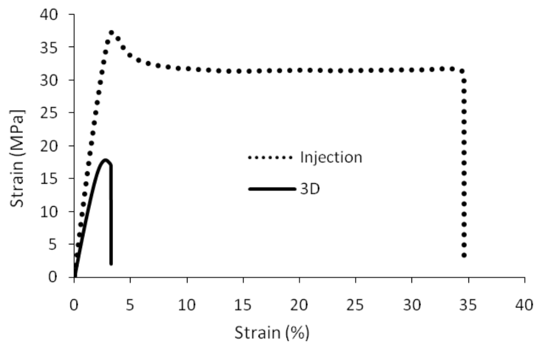


Fig. 1: Stress-strain curve of injection procedure and 3D printer

The results of tensile tests show that the mechanical characteristics of test pieces produced by injection are much larger than those obtained by 3D printing.

4.1.1. Modules of elasticity

From Figure 1, the elasticity modules for the mixtures are extracted and shown in Figure 2.
It is shown that the modulus of elasticity of specimens produced by plastic injection is much higher than that of specimens produced by 3D printing.
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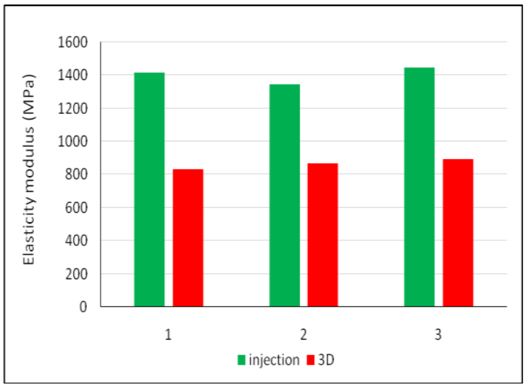

Fig. 2. Variation of the elasticity modulus of the injection procedure and 3D printer

4.1.2.Elongation at break

From Figure 1, the elongation at break he mixtures are extracted and shown in Figure 2.
It is shown that of specimens produced by plastic injection is much higher than that of specimens produced by 3D printing.

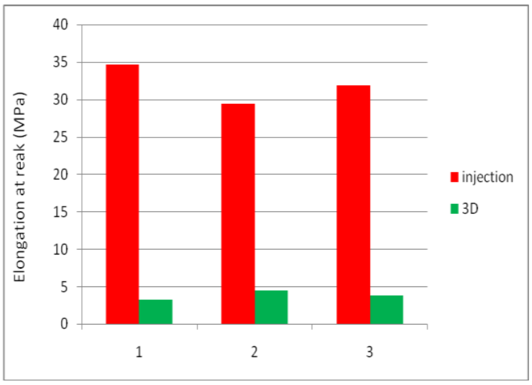

Fig. 3: Variation of the elongation at break of of the injection procedure and 3D printer

4.1.3. Elastic limit stress

From Figure 1, the maximum elastic stress for the mixtures are extracted and shown in Figure4.
It is shown that maximum elastic stress by plastic injection is much higher than that of specimens produced by 3D printing.

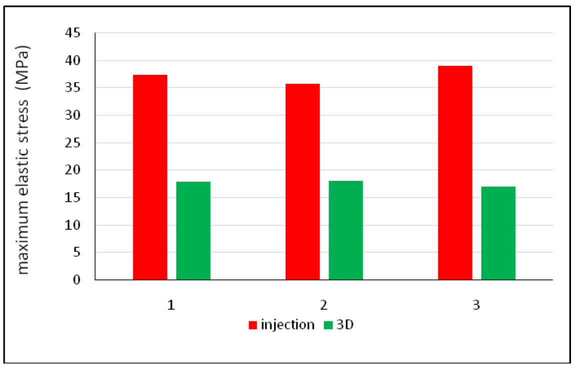

Fig 4.: Variation of the maximum stress . of the injection procedure and 3D printer

4.1.4. Resilience

Fig. 5 shows that the resilience of the test pieces obtained by plastic injection is 50% greater than that obtained by 3D printing.

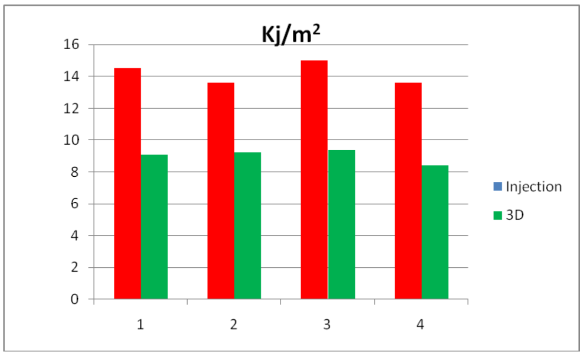

Fig 5.: . Variation of the résilence of the injection procedure and 3D printer

4.2. Morphological characterization

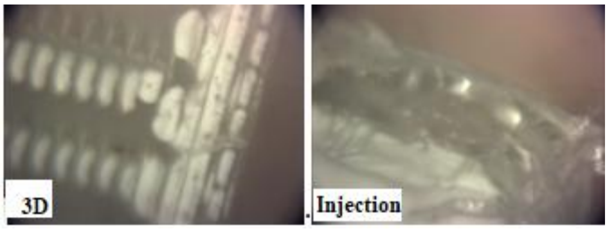

Fig. 6: Morphologies of the breaking facies by flexion of of the injection procedure and 3D printer

Figure 6 shows the fracture facies of *facies by flexion of* of the injection procedure and 3D printer
We note the presence of porosities in the 3D samples Which justify the reduction of the mechanical characteristics compared to the plastic injection

4. Conclusion

The results obtained show that the transformation mode has a direct influence on the mechanical and thermal characteristics of ABS. The choice of the best implementation procedure depends on the destination of the finished products.

The ABS tensile test pieces obtained by two different transformation modes, namely plastic injection and 3D printing, had different behavior during the break; the plastic injected ABS gives it mechanical properties of deformation and resistance to the specifications. 3D printing makes the fragile

material its resistance decreases as well as its deformation.
The cooling of the injected test piece is continuous, from the outside of the specimen to its core, there is a cohesion of the material which implies a homogeneous mechanical behavior, and a ductile rupture characterized by the elongation of the fracture facies material as shown in FIG. 6 (injection)
The weakening of ABS specimens produced by 3D printing is the discontinuous cooling of the different layers of the material; indeed the material in the 3D printing cools down layer after layer which creates a discontinuity in this cooling and consequently a bad cohesion of the material. This appears clear in FIG. 6 (printing) where a failure of the traction test piece in the form of teeth separated by dark areas is observed as if it were two different materials and not a single material. which is the ABS; the cooling of the ABS layers by this second process renders the inhomogeneous material filled with porosities and thus defects.

References

[1] V.D. Sagiasa,b,*, K.I. Giannakopoulosa, C. Stergiou. Mechanical properties of 3D printed polymer specimens , Structural Integrity Procedia 00 (2016) 000–0

[2] B H Feng[1,2], W W Cai[1], P E Zhou[1], J X Luo[2,3], H F He[2,3] and L F Peng[1]
Design and implementation of three-dimensional model for medical image of bone defect

[3] 3D printing technique applied to rapid casting, Elena Bassoli and Andrea Gatto Rapid Prototyping Journal, Vol. 10 No. 5, pp. 281-7.