



COMPARATIVE ANALYSIS OF THREE POLYMERS: ABS, PMMA, AND ABS/15%PMMA BILAYER IN THREE-POINT BENDING

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ABSTRACT

An experimental study aimed at exploring the mechanical characteristics of amorphous thermoplastic polymers, namely acrylonitrile butadiene styrene (ABS), polymethyl methacrylate (PMMA) and ABS/15% PMMA bilayer sheet was carried out. These polymers are manufactured by the extrusion and co-extrusion process intended for engineering applications. Experiments were carried out in three-point bending at room temperature. The results indicate that ABS exhibits up to 12% higher ductility than ABS/15% PMMA bilayer, with PMMA tending to become more brittle with a high flexural strength of 125 MPa.

Keywords: ABS, PMMA, ABS/15%PMMA, bending, polymer.

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1. INTRODUCTION

The ABS polymer, short for acrylonitrile-butadiene-styrene, stands out as a well-established and widely employed amorphous thermoplastic. Its extensive study and application are attributed to its impressive impact resistance and ductility. In contrast, poly methyl methacrylate (PMMA) represents an amorphous and brittle polymer with notable mechanical properties. Demonstrating resilience against brittleness, particularly when its surface is scratched, PMMA also exhibits resistance to chemical properties. Both ABS and PMMA find common usage in various engineering applications. ABS/PMMA, whether employed as a composite blend [1], [2] or in a multilayer form [3], [4], offers versatility for use in different processes. The ABS and PMMA polymers find application in the industrial domain [5], such as the automotive [6] and sanitary [3]. Like several other flexural testing techniques, the 3-point

bending test follows a similar principle: applying a load to analyse the relationship between load and material elongation. This method, also known as the 3-point bending test, assesses the force necessary to bend a beam under conditions where load is applied at three points [7]. various research studies have explored the mechanical properties of ABS subjected to three-point bending, investigating diverse manufacturing processes like injection moulding, 3D printing, extrusion, and fused deposition [7]–[11]. The findings indicate that ABS polymer showcases significant ductility in contrast to PMMA, which exhibits notable flexural strength but tends to undergo brittle fracture [12].

The focus of this study is to compare the three-point bending behaviour of extruded ABS, PMMA and ABS/PMMA bilayer polymer sheets used in the thermoforming process. These experimental tests were performed at room temperature.

2. Experimental method

2.1. Material

ABS with PMMA is a bilayer polymer produced commercially by coextrusion, designed for engineering applications in the thermoforming process due to its ability to resist scratches and impacts. ABS-15% PMMA composite is a commercial product used by the sanitary materials company Miliana (Algeria). In addition, ABS and PMMA sheets represent other commercial polymers manufactured by the extrusion process.

2.2. Method

Three-point bending tests were carried out using a Zwick universal testing machine with a 15 KN load cell. a pair of supports was made from tool steel (fig. 2). the span between the lower l supports was set at 64 mm and the loading speed was 3 mm/min, three-point bending specimens were prepared and produced according to iso 178 [13] with a total length of 80 mm, a width of 10 mm and a thickness of 4 mm.



Fig.1. Three-point bending specimen mounted on custom-made supports during test.

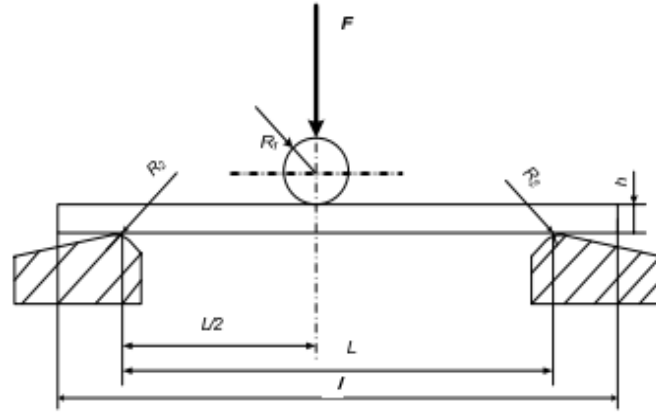


Fig.1. Test set-up according to ISO 178 [13]

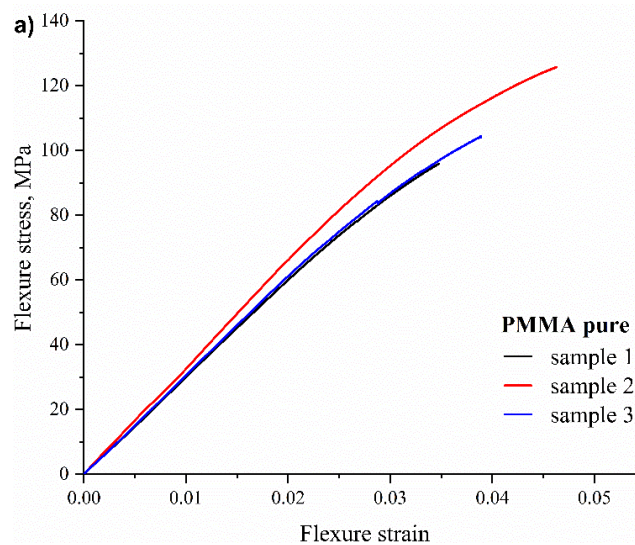
3. RESULTS AND DISCUSSION

The load-displacement (deflection) curves obtained during bending were transformed into stress-strain curves using the following equations for bending stress (σ_f) and strain (ϵ_f) [13].

$$\sigma_f = \frac{3Fl}{2bh^2} \quad (1) \quad \epsilon_f = \frac{6hd}{l^2} \quad (2)$$

where **h** and **B** are the thickness and width of the specimen, **F** is the force, **d** is the displacement (deflection) at midspan.

Stress-strain curves showing three-point bending behavior for various polymers, including PMMA, ABS and the ABS/PMMA bilayer, are shown in Figure 3. PMMA exhibits high strength, with brittle fracture behavior at room temperature and minimum deformation after yield. ABS, on the contrary, shows weaker behavior than PMMA, with high elongation at break, a sign of ductility. On the other hand, the ABS/PMMA bilayer exhibits stress levels close to those of PMMA and strain levels similar to those of ABS. The ductility of this polymer is attributed to the presence of butadiene in the ABS polymer, rendering both ABS pure and ABS/15% PMMA highly flexible, butadiene becomes like a rubbery component in ABS.. [14].



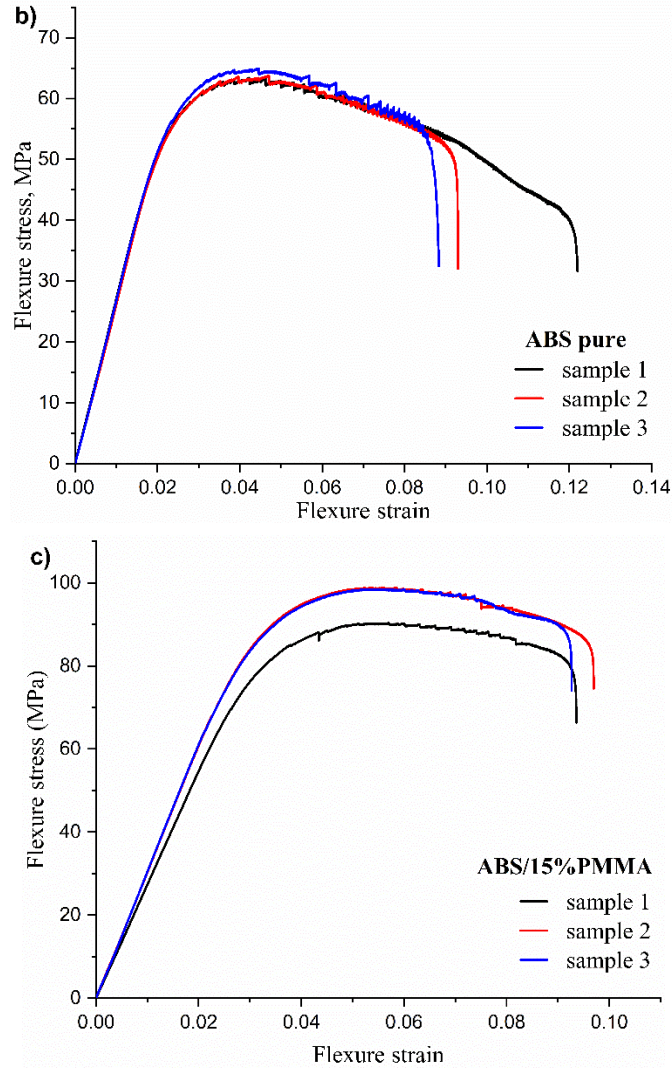


Fig.3. Flexure stress - flexure strain curves of three-point bending tests of polymers; a) PMMA, b) ABS, and c) ABS/PMMA bilayer polymer

Table 1 presents the flexural properties of PMMA, ABS, and the ABS/PMMA bilayer at a consistent crosshead speed of 3 mm/min. The flexural strength and deformation characteristics of these diverse polymers are detailed in Table 1c, with corresponding figures provided in Figure 3. Additionally, equations (1) and (2) were derived through the load-deflection method. The modulus of elasticity (E) for PMMA, ABS, and ABS/PMMA was calculated based on the load-deflection responses obtained from the three-point bending tests, utilizing the following formula [13]:

$$E_f = \frac{\sigma_{f2} - \sigma_{f1}}{\varepsilon_{f1} - \varepsilon_{f2}} \quad (3)$$

Where σ_{f1} , σ_{f2} are flexural stress, in megapascals, measured at strain (deflexion) ε_{f1} , ε_{f2} . Investigating Table 1, it appears that the ABS/PMMA bilayer has a bending stress and flexural modulus similar to those of the PMMA brittle polymer. Nevertheless, the deformation of the ABS/PMMA bilayer closely matches that of the ABS polymer, mainly due to the substantial ABS content (85%) in this bilayer polymer.

These results indicate that the three polymers become softer, more flexible, and superplastic with increasing temperature. This facilitates the thermoforming process, as showed in the literature [12], [15], [16].

Table 1. Flexure strength of PMMA, ABS, and ABS/PMMA bilayer.

<i>Material</i>	<i>Mechanical properties</i>		
	Ultimate stress (MPa)	Strain	Elastic modulus (MPa)
PMMA	95.898	0.035	3010.03
	104.096	0.039	3015.46
	125.775	0.046	3448.55
ABS	64.948	0.088	2508.52
	63.7488	0.093	2498.64
	63.203	0.122	2591.56
ABS/PMMA	90.126	0.094	2725.71
	98.338	0.093	2842.70
	98.916	0.097	2959.91

4. CONCLUSION

In this article, an examination of the three-point bending behavior of different thermoplastics at room temperature reveals the following findings:

- PMMA polymer displays notable flexural properties but tends to become brittle.
- ABS polymer demonstrates high deformation (strain) at break. The ABS/PMMA bilayer exhibits significant flexural characteristics along with high deformation at break, making it highly
- ductile due to the butadiene content in the ABS polymer. This property facilitates the thermoforming process

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