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Mechanichal Properties of Polyester/Nanocellulose and Polyester/Microcellulose Determined By Three Point Bending Test

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Abstract -This article presents a description of mechanical properties for composites materials obtained by polyester resin and two types of reinforcements nanocellulose and microcellulose. Mechanical properties and an analysis of the results obtained by laboratory testing specimens, according to standards requirements in force, speed loading for three points bendings. Finally, conclusions and recomandations are based on the results. Mechanical test methods for reinforced polymer composites have to be appropriate to the type of composite analyzed as the structure of the product to be carried out starting from such material with their real working conditions. For any polymer composite material is appreciated the need for a minimum of trials on which it can be satisfactorily characterize material, for three bending points test 5 specimens.

Keywords**:** nanocellulose, microcellulose, polyester, three point bending

1. Introduction

Natural fibers added to synthetic polymers act as reinforcement and improve the mechanical properties of the polymer matrix (Dong & Davies 2012). Bending modulus was determined by three point bending test using AFM method for a single nanocellulose fiber with 150-180nm diameter, having 98GPa value (Cheng et al. 2009), (Cheng & Wang 2008). For nanocellulose from tunicate using AFM method, bending modulus has value145GPa (Iwamoto et al. 2009), 143 GPa (Šturcová et al. 2005).

Using MFC in composites the mechanical properties was improved. In phenol formaldehyde/MFC composites flexural stress at break increases from 320 to 425MPa and bending modulus from 19GPa to 28GPa. The higher modulus of BC composites was credited to the extremely fine, pure, and dimensionally uniform ribbon-like cellulose microfibril bun- dles, arranged in a network of relatively straight and contin- uous alignment, and also to the planar orientation of these elements obtained through the compression of the BC pelli- cles into sheets (Nakagaito et al. 2005). Results for bending tests show maximum bending modulus and elongation at break for cellulose/polyester composite show a higher modulus, probably because of strong interactions between these additives and polyester. H-bonds network are decisive for mechan- ical strength. Furthermore, relatively higher elongation at break parameter for cellulose/polyester composite confirms low percentage of additive residue that plays plasticizing role in membrane bulk (Mahdavi & Shahalizade 2015).

2. Materials and Methods

The research was carried out on two types of composite materials, made of polyester with nanocellulose and microcellulose. As matrix, orthophtalic polyester resin with styrene was used (the resin was purchased from Rompolimer. Cellulose MICROCRYSTALLINE (lot K44242630323) was bought from Merck KGaA. After successive washings with distilled water and ethanol and after separated the

clear phase, the suspension was introduced in a crystallizing apparatus in a thin film. The crystallizing apparatus was introduced in a drying closet at 105^0C so as the nanocellulose to be dried for 4 hours and thus resulting nanocellulose. The resulted nanocellulose and the microcellulose have been mixed mechanically with unsaturated polyester, thus being obtained nanocomposite and microcomposite materials which were then poured into the mould.

The contents of nanocellulose and microcellulose for the tested specimen polyester composite were 0.05 wt%, 0.1 wt%, and 0.15 wt%. The samples were tested according to ISO 178 using the tester TESTOMETRIC M350 – 5 AT, made by Testometric Company. Tests have been performed for four speeds of loading. Speed tests were chosen according to ISO 178 of 1mm/min, 2mm/min, 5mm/min, 10 mm/min. In order to consider the test variability, all tests were performed on at least five specimens, as requires the standard.

3. Results and Discussions

Bending tests and calculation of parameters were performed according to ISO178. Aiming to describe the mechanical properties of the composite, the following parameters were measured and calculated: flexural stress σ_f, flexural strain ε_f,, flexural stress at break σ_{fB}, flexural strain at break ε_{fB}, flexural modulus E and deflection s (distance over which the top or bottom surface of the test specimen at midspan deviates from its original position during flexure. For the calculation of the flexural stress σ_f, the Eq.1 was used:

$$\sigma_f = \frac{3Fl}{2bh^2} \tag{1}$$

Where F is the applied force [N], L is the span [mm], b is the specimen width [mm], and h is the thickness of the specimen [mm].

For the calculation of the flexural strain ε_f, the Eq.2 was used:

$$\varepsilon_f = \frac{6sh}{L^2} \tag{2}$$

Where s is the deflection [mm], h is the thickness of the specimen [mm], and L is the span [mm].

Flexural stress σ_f and flexural strain ε_f were calculated for all test speeds.

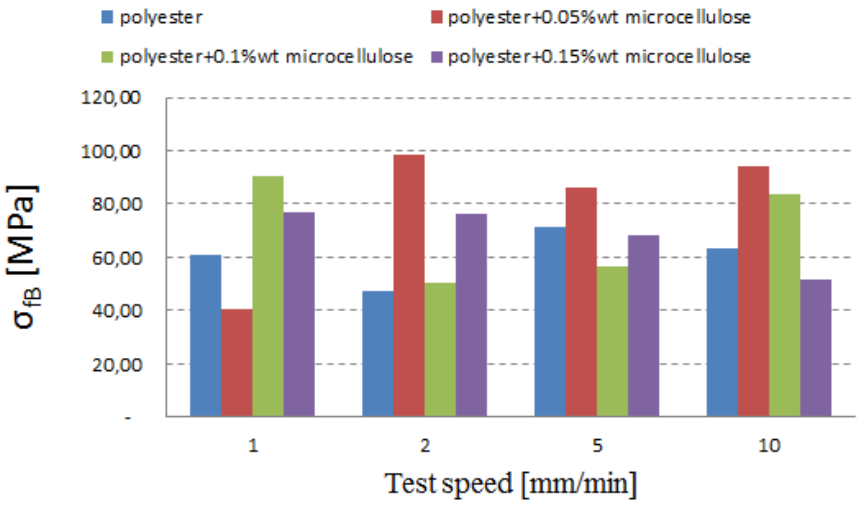

Fig. 1. Flexural stress at break vs. test speed for polyester/microcellulose composites

Flexural stress at break for polyester increases at high test speed, maximum value having 71 MPa for 5mm/min test speed, Fig.1. For high speed values for flexural stress at break of polyester +0.05%wt microcellulose is higher than all polyester/microcellulose composites and polyester, having 98 MPa for 2mm/min test speed.

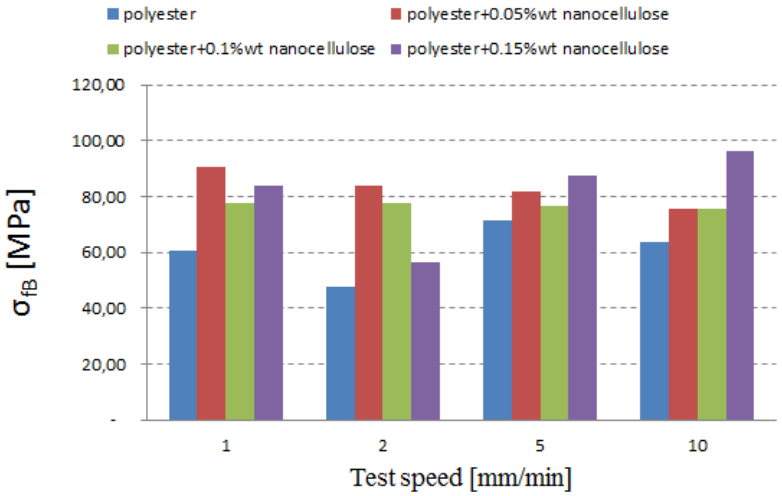

Fig. 2. Flexural stress at break vs. test speed for polyester/nanocellulose composites

For high speed values for flexural stress at break of polyester +0.15%wt nanocellulose is higher than all polyester/nanocellulose composites and polyester, maximum value is 96 MPa for 10mm/min test speed, Fig. 2.

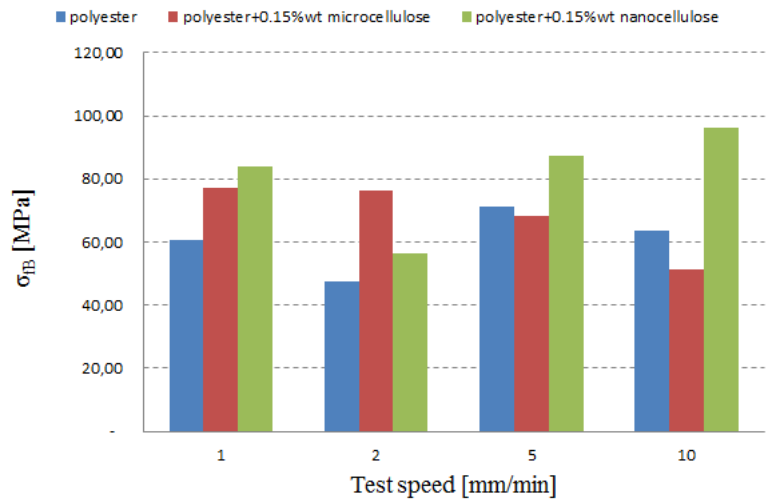

Fig. 3. Flexural stress at break vs. test speed for polyester/microcellulose and polyester/nanocellulose composites at 0.15% wt filler

For high speed values for flexural stress at break of polyester +0.15%wt microcellulose is higher than all polyester+0,15%wt nanocellulose composites and polyester, Fig. 3.

In order to determine flexural modulus, we calculated the deflection s_1 and s_2, corresponding to the given values ε_{f1}=0.0005 and ε_{f2}=0.0025 with Eq.3.

$$s_i=\frac{\varepsilon_{fi}L^2}{6h}(i=1,2) \quad (3)$$

Where s_i is one of the deflection [mm], ε_i is the corresponding flexural strain with values given above, L is the span [mm], and h is the thickness of the specimen [mm].

For the calculation of the flexural modulus E, Eq.4 was used:

$$E=\frac{\sigma_{f2}-\sigma_{f1}}{\varepsilon_{f2}-\varepsilon_{f1}}. \quad (4)$$

Where E is the flexural modulus [MPa], σ_{f1} and σ_{f2} are the flexural stress at deflection s_1 and s_2.

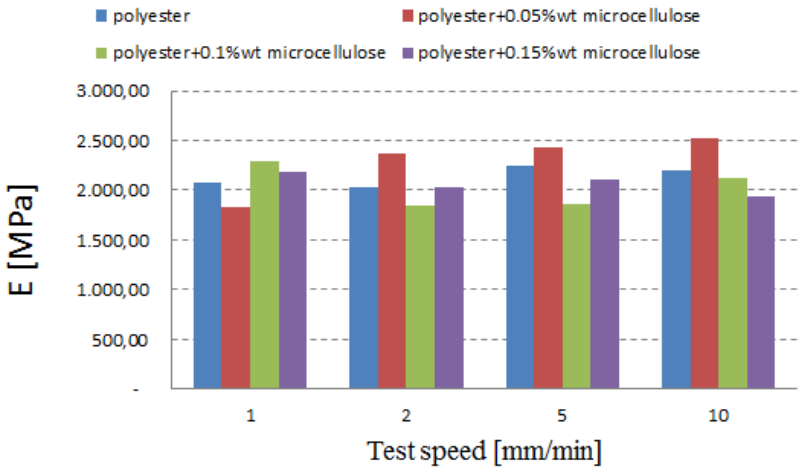

Fig. 4. Bending modulus vs. test speed for polyester/microcellulose composites

Bending modulus for polyester increases at high test speed, Fig.4. For high speed values for bending modulus of polyester +0.05% microcellulose is higher than all polyester/microcellulose composites and polyester, having value 2530 MPa for 10mm/min test speed.

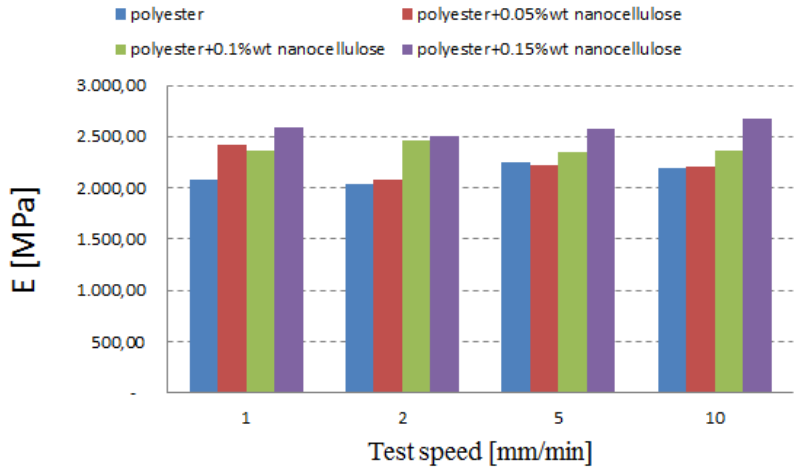

Fig. 5. Bending modulus vs. test speed for polyester/nanocellulose composites

Values for bending modulus of polyester +0.15% nanocellulose is higher than all polyester/nanocellulose composites and polyester, having value 2677MPa for 10mm/min test speed, Fig. 5.

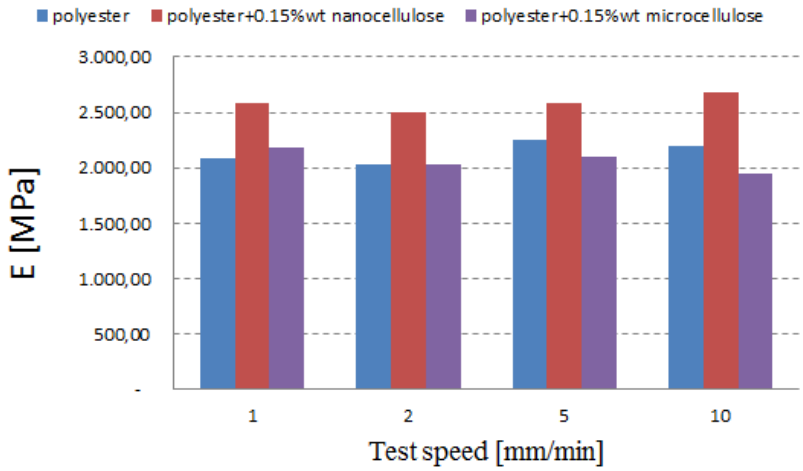

Fig. 6. Bending modulus vs. test speed for polyester/microcellulose and polyester/nanocellulose composites at 0.15% wt filler

Values for bending modulus of polyester +0.15% nanocellulose is higher than polyester +0.15% microcellulose composites and polyester, Fig.6.

4. Conclusions

The addition of micro and nanocellulose in polyester composites improves the quality of the fiber/matrix interface having a significant effect on the mechanical properties of this composites. Flexural stress at break was improved with 50% for polyester+0.15% nanocellulose composites than polyester at test speed 10 mm/min. Bending modulus was improved with 22% for polyester+0.15% nanocellulose composites than polyester at test speed 10 mm/min. The results of this study suggest that micro and nanocellulose are comparable to other natural fibers used as reinforcement in polymer matrices. They are completely suitable for use as reinforcement in composites.

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