The 7th International Conference on Composites: Characterization, Fabrication and Application (CCFA-7)

Dec. 23-24, 2020,
Sahand University of Technology, Tabriz, Iran

Super toughening of PLA through blending with SEBS and Nano-clay

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***Abstract*- Polylactic acid (PLA) is known as a biocompatible and biodegradable polymer that shows brittle behavior during the tensile strength test. Mixing has always been one of the most cost-effective ways to improve the properties of polymers. For this reason, in this particular work alloying with rubber particles has been selected to improve the fracture behavior of PLA. In this study, SEBS rubber was used to enhance the toughness and mechanical properties of this polymer. Besides, the effect of different amounts of clay on Nano-composite's properties was studied. After blending, the rheological, physical, and mechanical properties have been measured. For this aim, measuring tools such as tensile, DMTA, and SEM were used to illustrate the material blends' properties and degree of exfoliation of nanoplates. Finally, it was found that the system, which consisted of 20% by weight of SEBS rubber and 2% by weight of nano-clay, has shown the most improvement and the highest toughness.**

Keywords - Super toughening, PLA, SEBS, Nano-clay

I. INTRODUCTION

PLA is a biodegradable and biocompatible polymer that has always been in the center of attention due to its application and its properties such as, natural main source, high yield stress, being easy to process and so on. PLA brittleness and its mechanical weaknesses have reverse effect on its utilization. Lots of researchers have worked on enhancing the toughness of this material in a variety of approaches, including blending with another plastic phase with higher toughness especially rubbers, adding thermoplastic elastomers and thermoplastic volcanized into the PLA matrix. Addition of an elastic phase to the PLA matrix improves the ability to damp and dissipation energy through various mechanisms such as micro crazing [1]. Many researchers have worked on the usage of elastomeric phases within the PLA matrix in different percentages of rubber phases. Even though the best results generally occurring around 20% of introduced rubber phase, there is a trend which illustrates smaller rubber particles culminate in more damping ability and dissipate energy and improve toughness at a same time. In addition there is an optimum amount of nanoparticles or Nano sheets which has the best performance. This optimum amount which is called percolation threshold, refers to chemical, physical and mechanical properties of components and depends on processing parameters and circumstances [2]. For reaching to percolation threshold and achieving the best results we need to choose the best formulation of components.

(One space)

II. EXPERIMENTAL

Materials

The PLA (2003D) was bought from Nature Works LLC (Minnetonka, USA). Its density according to ASTM D792 was 1.24 g / cc and the glass transition temperature (Tg) and its melting temperature range (Tm) were 55-60 ° c and 145-160 ° c, respectively, and its MFI was 6g / 10 min based on ASTM D1238.

SEBS (Styrene-Ethylene / Butylene-Styrene) with code H6170 from DYnasol Calprene Company in powder form and with 33% by weight of styrene. Also, Nano-clay with code (Closite 20A) from Southern Clay Company was used and its specific weight was equal to 1.77 g / cc.

Sample preparation

All neat materials for making compounds (PLA, SEBS, and Nano-Clay) and production samples were dried in a vacuum oven at 60°C for at least 12 hours before each test. Internal Mixer (Brabender Plasticator W50) were used to make compounds with a volume of 60CC equipped with a precise software system was used to measure and display torque and temperature continuously. To achieve better mixing, the filling factor of the device was considered to be 0.75 for making all samples. The rotors rotate rpm was considered.

The samples produced are shown in Table 1. It should be noted that the use of 20% by weight of the dispersed phase in the PLA matrix has always been considered in previous studies by other researchers [1] and for this purpose PLA / SEBS alloy 20.20 w / w was selected as the base alloy The effect of adding 2% and 4% by weight of Nano Clay to this system and its effects were investigated.

TABLE I: SAMPLES DATA

Sample	PLA Wt%	SEBS Wt%	Nano Clay Wt%
PLA	100	0	0
SEBS	0	100	0
PLA/ SEBS	80	20	0
(PLA/ SEBS) / Nano Clay	80	20	2
(PLA/ SEBS) / Nano Clay	80	20	4
(PLA/ Nano Clay) / SEBS	80	20	2
(SEBS/Nano Clay) / PLA	80	20	2

III. RESULTS AND DISCUSSION

1. *Rheological properties*

Figure 1 shows the frequency-storage modulus diagram for fabricated alloys and is also compared with pure PLA. As can be seen, with the addition of SEBS to PLA, the elastic modulus increases at low frequencies and becomes closer to Non terminal behavior.

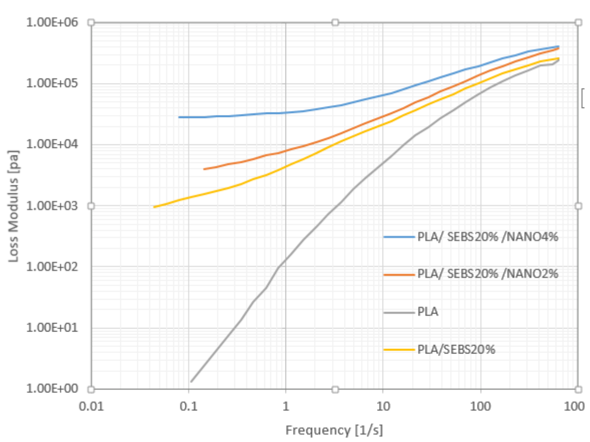

Fig. 1: Loss Modulus against frequency (frequency sweep mood)

2. *Mechanical tests*

Tensile test results are shown in Figure (2). As can be seen, pure PLA shows an almost brittle behavior with high modulus and strength and low elongation at break (3.92%). The addition of SEBS elastomer thermoplastic to pure PLA changes the fracture behavior of the material from brittle to ductile, in which case the yield stress decreases and the elongation increases to a higher breakpoint (11.6%), as well as the energy required for a break also increased. Based on these results, the toughness mechanism is accurately determined, and the results show that the SEBS phase within the matrix is dispersed as particles.

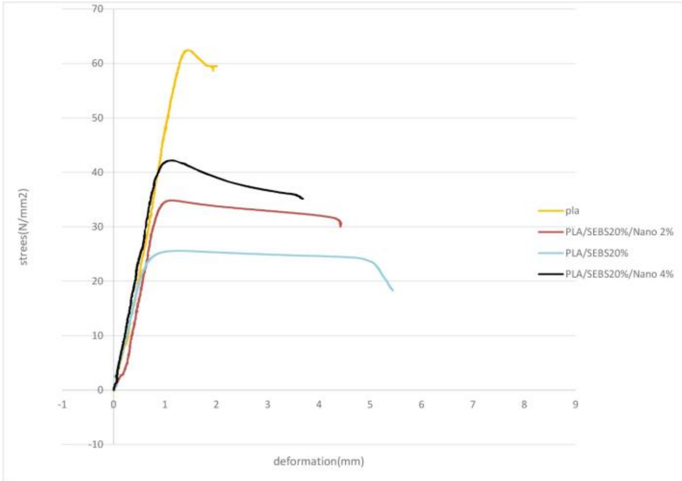

Fig. 2: Tensile test results stress against elongation

The impact resistance test results repeat the tensile test results. It should be noted that the impact resistance of PLA / SEBS / Nano Clay 80/20/4 sample is much lower than all samples, which can be related to the phenomenon of blocking stress fields within the matrix structure [3]; which the high percentage of nano prevents the stress from spreading in the structure of the material and the network created by nano not only did not help to improve the toughness but also reduced it.

IV. CONCLUSION

As observed, the use of rubber can increase the toughness of PLA. In this study, SEBS was used, and the particles dispersed inside the PLA matrix were dripped. The presence of nano-plates causes the rubber droplets to disperse from each other and the particles to become smaller, but it should be noted that the high percentage of nano itself due to the formation of a three-dimensional network within the matrix can prevent stress transfer between stress fields around rubber particles and reduces toughness. Therefore, the optimal percentage should always be considered while using nano-plates.

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