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Research on Tensile Strength of PBT/EVA Blends

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ABSTRACT

This research study analyzes the mechanical properties of the PBT/EVA blend. Made by adding EVA to PBT in specific proportions, the samples used for the analysis will use injection molding. The percentage of EVA added to PBT was 0%, 5%, 10%, 15%, 20%, and 25%, respectively. After pressing, the samples were measured for tensile strength according to ASTM D638 standards. The results obtained are that when the content of EVA is increased, the tensile strength of the mixture decreases gradually. Because EVA has a low vitrification temperature, adding PBT reduces the vitrification temperature of the mix and affects the tensile strength. This study is a document to develop a method of mixing materials to create a polymer mixture with suitable properties for the intended use.

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1. Introduction

Poly(butylene terephthalate) (PBT) is a semi-crystalline thermoplastic engineering plastic (Fig.1). PBT has many outstanding properties, such as solvent resistance, high hardness, and short cycle time during injection molding [1,2]. PBT has exceptional thermal, mechanical and dimensional stability, so it is widely used in various applications such as engineering materials and electronics. Besides those advantages, PBT also has disadvantages of low impact strength and deformation temperature... This disadvantage more or fewer limits the applications of PBT [3,4]. To overcome those disadvantages, much research has been done to bring about the desired properties of PBT by mixing it with polymers or with other fillers such as polycarbonate (PC), polyamide (PA), acrylonitrile – butadiene – styrene (ABS), Nilon 6 [5] ...

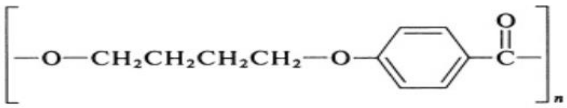

Fig. 1. *Molecular formula of PBT plastic*

Ethylene-vinyl acetate (EVA), a copolymer of ethylene and vinyl acetate, is a thermosetting polymer (Fig.2). EVA is widely used in the aerospace, electronic, and automotive industries mainly because of its good mechanical properties, electrical insulation, chemical resistance, and low cost [6-8]. Regarding the highlights, EVA is an environmentally friendly plastic because it does not contain chlorine, so when burned, it does not produce dioxin gas and is also recyclable [9]. EVA has flexibility, elasticity, and high strength, can work in an environment from -60 °C to 65 °C, and especially EVA has very high impact resistance [10,11]. In addition to the above advantages, EVA also has disadvantages, such as low tensile strength, poor resistance to thermal deformation and chemical resistance, etc. EVA has many types, depending on the vinyl acetate content in the resin. Accordingly, the mechanical properties of EVA also rely on the vinyl acetate content: when the vinyl acetate content increases, the degree of adhesion and resistance to water, salt, and some other environments decreases; flexibility, elasticity, and toughness increase solubility in solvents. In contrast, when reducing vinyl acetate content, EVA increases hardness, friction resistance, and sound insulation, ...

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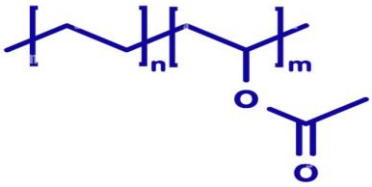

Fig. 2. *Molecular formula of EVA plastic*

Science and technology are developing faster and faster, but with significant progress, the requirements for suitable properties to meet the technical specifications of products on materials are increasing. PBT is a plastic with good mechanical properties but is quite brittle, which means low impact strength. Many studies have aimed to improve the brittleness of PBT using plasticization [12] or copolymerization [13]... A frequently used effect in research is mixing PBT with another type of polymer [14,15]. In this study, EVA resin was used to blend with PBT to improve the impact strength of PBT. Similar research by Cong Meng et al. gave results on the impact strength of the PBT/EVA composite after the research process. The results showed that the impact strength was significantly increased after adding EVA. Accordingly, compared with primary PBT, the PBT/EVA mixture (80/20) has increased by nearly 300% from the operating system, showing EVA's effectiveness in the plastic mix [16].

Some other articles study the adhesion between PBT and EVA. The research of Pilati et al. is typically based on mixing PBT and EVA with ethylene alcohol or copolymerizing ethylene-vinyl acetate-vinyl [17]. In parallel with it, Roberto Scaffaro et al. studied the reactive compatibilization of PBT/EVA blends with an ethylene-acrylic acid copolymer and a low molar mass bis-oxazoline [18]. In the two articles above, the common point is that they both study the compatibility of the mixture, and the results show that the tertiary combination does not show any significant change in mechanical properties. In contrast, the quaternary mixture did not significantly change mechanical properties. It showed the best properties due to strain, in the presence of PBO, of EAA-g- (PBO) PBT copolymer at the impact surface as a compatible agent for the PBT/EVA blends. Cong Meng et al. demonstrated its compatibility in studying the PBT/EVA blends in another paper [16]. This ability is explained by the presence of polar esters in EVA. Because of this, the durability and impact resistance of the PBT/EVA composite have been improved [19-21].

Although some research has been done, improving the impact resistance of PBT still needs to be studied further. This paper analyzes and explores the tensile strength of the PBT/EVA composite.

After the injection molding, the PBT/EVA samples are measured for tensile strength. The mechanical properties of PBT/EVA samples are compared with the neat PBT and neat EVA samples.

2. Material and method

This study uses two types of plastic materials, PBT and EVA (Fig.3). PBT plastic is supplied by Toan Dai Hung Trading and Services Company with plastic code PBT-POCAN B4225 from India/China Lanxess plastic company (Germany). Tan Vinh Thai Trading Company supplies EVA plastic with the plastic code EVA 7350M from Taiwan of Formosa plastic company (China).

PBT is mixed with EVA according to the percentage shown in Table I and dried at 120 ^{o}C for about 2 to 4 hours, with a moisture content of less than 0.03%. The SW-120B plastic injection molding machine then presses the resin.

Fig. 3. *PBT (left) and EVA (right)*

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Table 1. *Compositions of the samples (wt.%)*

Sample	EVA (wt.%)	PBT (wt.%)
PBT	0	100
5EVA	5	95
10EVA	10	90
15EVA	15	85
20EVA	20	80
25EVA	25	75

After the injection molding process, the finished samples are obtained. At each ratio, conduct a tensile test according to ASTM D638 on a Testometric material testing machine (Fig.4).

Fig. 4. *Testometric material testing machines*

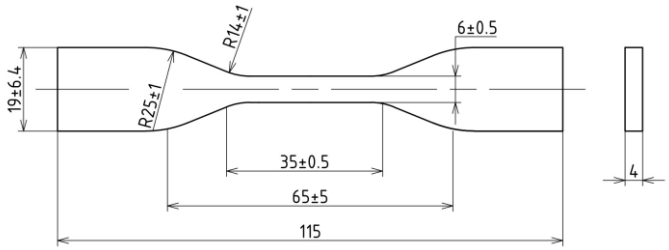

Fig.5. *Tensile test sample*

Figure 5 and figure 6 show the tensile testing process of 100% PBT samples. First, randomly select ten models from pieces with a 100% PBT, clamp each sample to the machine, pull the selection until it is completely broken (Fig.7), stop, take the sample's test data, and repeat the sequence for the following model.

Fig. 6. *Tensile strength testing process*

Fig.7. *Samples after tensile testing*

3. Results and Discussion

Samples after injection molding are obtained, as shown in Figure 8. During injection molding, samples of 100% PBT, PBT/5% EVA, PBT/10% EVA, PBT/15% EVA, and PBT/20% EVA are easily injected. The surface of the models is smooth and free of burrs. On the contrary, in the injection molding process of PBT/25% EVA, there are difficulties in the pressing process, mold jam occurs, and the product has significant shrinkage. It can be explained that because EVA resin has a low density, it has a low melting point, leading to a low crystallization temperature and a high cooling time in the mold.

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Fig. 8. *Finished product samples*

Table II shows the results of the measured tensile strength of the samples. The average tensile strength of the models 100% PBT, PBT/5% EVA, PBT/10% EVA, PBT/15% EVA, PBT/20% EVA and PBT/25% EVA decreases gradually. The higher the percentage of EVA in the mixture, the lower the tensile strength. Specifically, at 100% PBT, the sample has an average tensile strength of 59.96 N/mm^2, increased to PBT/25% EVA, and the average tensile strength is 38.84 N/mm^2, a decrease of 21.11 N/mm^2 compared to neat PBT sample.

Table 2. *Stress peak test result of all samples.*

No.	Stress Peak (N/mm^2)					
	PBT	***5EVA***	***10EVA***	***15EVA***	***20EVA***	***25EVA***
1.	63.50	51.62	45.48	44.77	40.25	37.19
2.	61.42	51.77	53.55	45.88	39.77	36.83
3.	58.58	52.46	54.27	42.47	40.35	37.06
4.	58.65	54.76	52.12	42.94	40.89	36.86
5.	63.95	54.38	51.03	42.82	41.77	40.86
6.	58.99	57.67	47.99	43.61	40.20	40.22
7.	58.22	49.77	50.50	44.34	41.51	38.66
8.	58.73	54.69	51.28	42.09	44.43	40.41
9.	59.38	56.11	52.08	43.25	45.01	40.76
10.	58.13	55.15	50.29	42.84	44.28	39.58
Average	59.96	53.84	50.86	43.50	41.85	38.84

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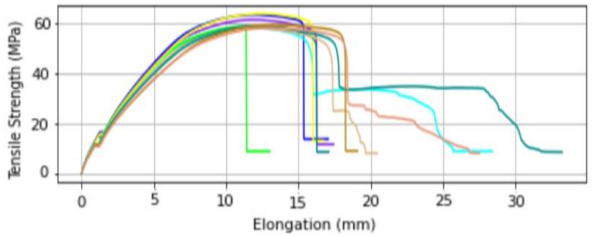
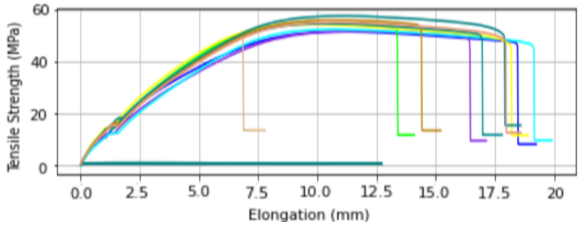
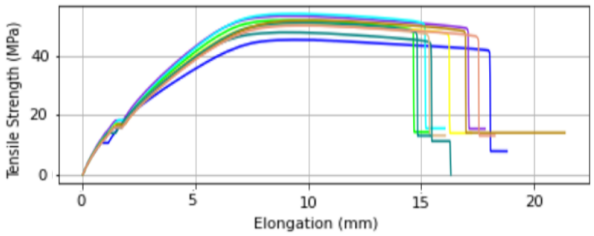


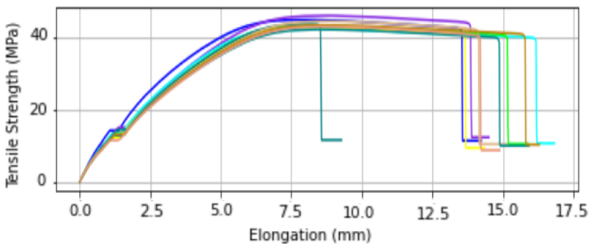
a) 100% PBT sample



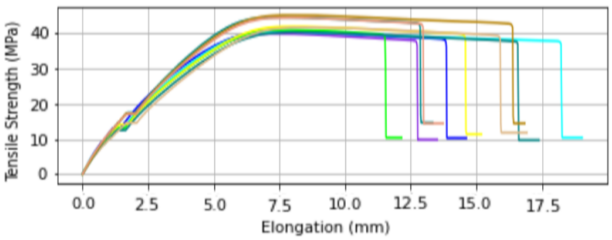
b) Sample 95% PBT-5%EVA



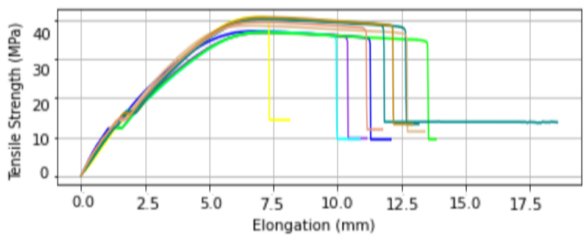
c) Sample 90% PBT-10%EVA



d) Sample 85% PBT-15%EVA



e) Sample 80% PBT-20%EVA



f) Sample 75% PBT-25%EVA

Fig. 9. *Stress-displacement curve of the samples*

Figure 9 depicts the variation of tensile force (MPa) with tensile length (mm) from the figure showing that the difference between samples in a ratio of not too significant variation ranging from 10-15%; some samples may have a more considerable difference than the rest of the samples. However, it generally only affects the measurement results in a little.

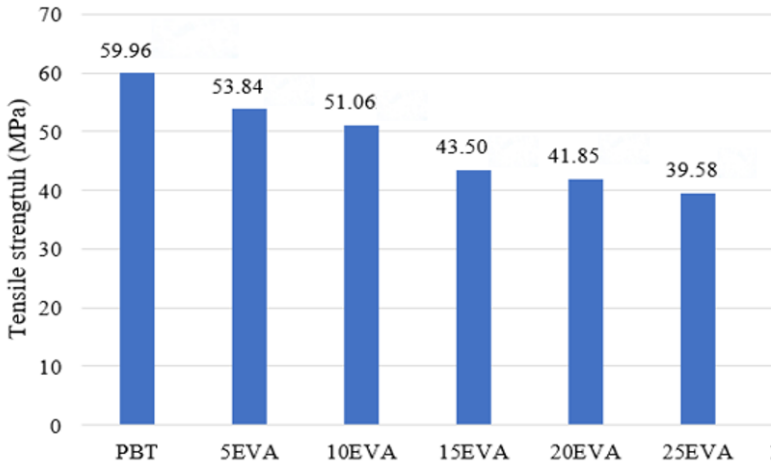


***Fig. 10**. Average tensile strength of the samples*

Figure 10 shows that the tensile strength of the mixture gradually decreased from 59.96 MPa to 39.58 MPa with increasing EVA content, a decrease of 33.98% compared to the 100% PBT blend. The reduction in tensile strength can be attributed to the difference in the vitrification temperature of PBT and EVA resins. The glass transition temperature of PBT is 65 °C [22], so the laboratory temperature (25 °C) shows that PBT has not reached the glass transition temperature threshold, which is why the PBT sample has properties of hard and crispy. Meanwhile, the glass transition temperature of EVA is -33.1 °C [10] because the laboratory temperature (25 °C) has far exceeded the glass transition temperature threshold, so EVA has soft and flexible properties. Therefore, when the PBT/EVA mixture increases the EVA content, the glass transition temperature of PBT tends to decrease gradually, leading to a decrease in the tensile strength of the PBT/EVA blend compared to neat PBT.

4. Conclusions

After the research process, the obtained results proved that when increasing the EVA content, the tensile strength of the mixture tends to decrease steadily, and the strains tend to increase, showing that PBT has reduced brittleness. After the research process, the obtained results proved that when increasing the EVA content, the tensile strength of the mixture tends to decrease steadily, and the strains tend to increase, showing that PBT has reduced brittleness. However, there are also other results due to external conditions.

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