

EFFECT OF EPOXIDIZED PALM OIL AS PLASTICIZER ON POLYHYDROXYALKANOATES MECHANICAL BEHAVIOR

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ABSTRACT

Most of thermoplastic used nowadays are petroleum based polymer which is from a non-renewable and limited source. Previous researchers has found a thermoplastic polymer polyhydroxyalkanoates (PHA) that exhibit biodegradable properties and produced from renewable materials such as sugar and molasses. However, pure PHA are brittle materials. A modification on the mechanical properties of PHA can be done by introducing plasticizer to the materials. In this study, epoxidized palm oil (EPO) is used as plasticizer to PHA at different percentage loading. PHA with different percentage loading of (EPO) was blend using internal mixer. The mechanical properties of each sample was determine by tensile test. Results shows that stiffness of PHA was improved with 3wt% optimum plasticizer loading.

Keywords: plasticizer, EPO, mechanical properties, PHA

Introduction

In the present study of backbone binder for metal injection molding (MIM) application small numbers of them are from the renewable natural source. Most plasticizer used were petroleum based polymer such as PMMA (Chua et al. 2011) and polyethylene (Li et al. 2003). Development of biopolymer for backbone binder application will help in reducing the number of petroleum based polymer in large scale as MIM is a giant industry. The previous researcher has discovered a polymer known as polyhydroxyalkanoates (PHAs) that can be produced from renewable and biowaste resource by bacteria fermentation (Mekonnen et al. 2013; Bugnicourt et al. 2014). PHA is a biopolymer that exhibits biodegradable properties at varies environment not only in a composting plant. PHA can be processed into many forms for varies application such as packaging, molded good, films and performance additives (Bugnicourt et al. 2014). However, pure PHA is a brittle material due to re-crystallization with aging at room temperature. Thus, the mechanical properties of PHA change with time. The mechanical properties of PHA can be modified by adding a plasticizer. The addition of plasticizer enhance the molecular motion and reduce the glass transition temperature of the materials (El-Hadi et al. 2002). Development of PHA blend with natural plasticizer like EPO is very interesting as the blend will be completely biodegradable in the environment and the EPO available in this country can be fully utilized. The objective of this study is to develop suitable plasticizer for improving the mechanical properties of PHA for MIM backbone binder application.

Experimental Set Up

Materials

Polyhydroxyalkanoates (PHAs) used was in pellets form supplied by Shenzhen bright China Industrial Co. Ltd., China with density of 1.23g/ cm³. The pellets was dried for at least 2 hours at 70°C to remove the moisture before blending process. The epoxidized palm oil (EPO) used supplied by Budi Oil Holding Sdn Bhd was in semi-solid state at room temperature.

Sample preparation

The PHA was blend using the internal mixer (Hakee Internal Mixer) with 50 cm³ cell volume at 175°C with rotor speed 50 rpm for 15 minutes. The weight ratios of PHA/EPO were as follows: 100/0, 99/1, 98/2, 97/3, 96/4 and 95/5. The blends then hot pressed into dumbbell shape specimen mold at 170°C- 180°C for 5 minutes.

Characterization techniques

The mechanical properties of the blends were studied by a tensile test using Universal Testing Machine based on ASTM D638. The tensile test was run at constant speed 5mm/min with similar storage time. The average of 5 samples for each composition was calculated. The results obtained was compared to common backbone binder used for MIM.

Results And Discussion

Figure 1 Effect of EPO content on stiffness of PHA

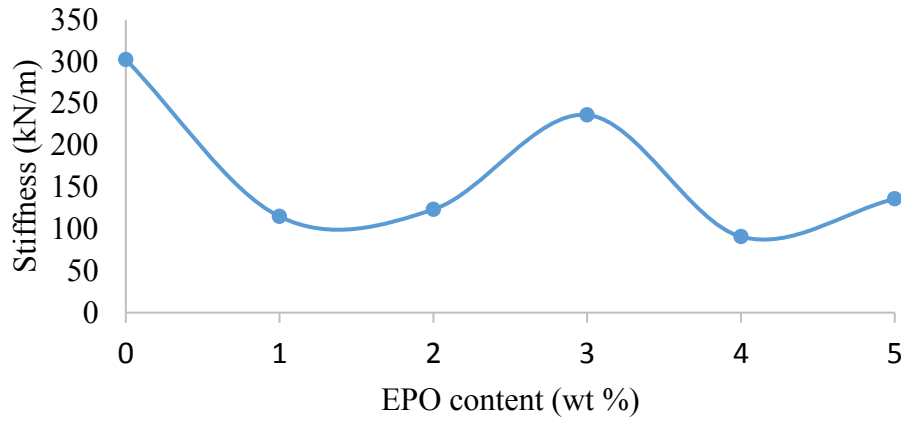


Figure 1 shows the stiffness trend of PHA as the EPO content increase. Neat PHA has the highest stiffness (302.4 kN/m) followed by 3 wt% EPO (236.2), 5 wt% EPO (135.kN/m), 4wt% EPO (90.8kN/m), 2 wt% EPO(123.2 kN/m) and the lowest of 1 wt% EPO (114.8 kN/m). The present of EPO as the plasticizer in PHA blend reduce the stiffness of PHA. This results supported by Mekonnen et al., (2013) that plasticizer reduce the stiffness of the materials. The decrease of stiffness occurs as plasticizer molecules interfered between the polymer-polymer chain which reduce the contact between polymers, prevent rupture during deformation and increase the flexibility.

Figure 2 Effect of EPO content on Young's modulus of PHA

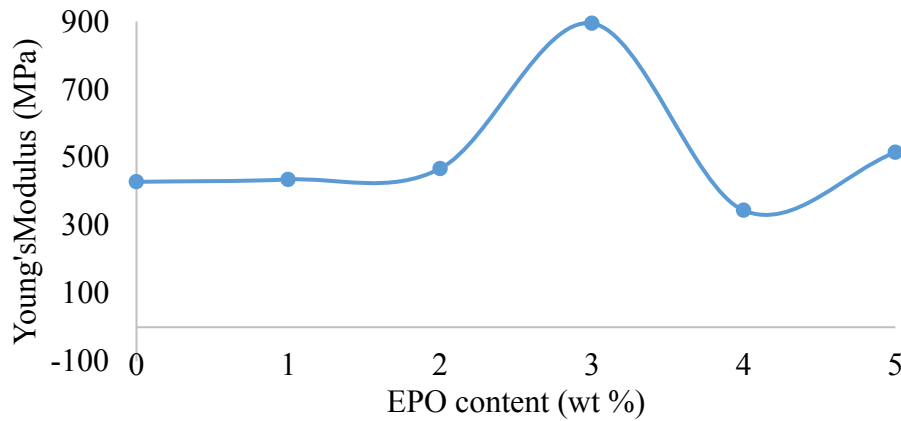


Figure 2 shows the improvement on PHAs Young’s modulus after induced with EPO at different loading.

Table 1 Young's modulus of PHA at different EPO loading

EPO content (wt%)	Young's Modulus (MPa)
0	420
1	428
2	467
3	890
4	344
5	515

Table 1 shows the Young’s modulus of PHA blend with different EPO loading. Neat PHA shows a Young’s modulus of 420 MPa while the highest Young’s modulus at 3 wt% EPO (890 MPa) followed by 5 wt% EPO (515 MPa), 2 wt% EPO (467 MPa),

1 wt% EPO (428MPa) and 4 wt% EPO (344 MPa). High Young's modulus exhibit by rigid materials which more stress required for deformation to occur. The increasing of EPO content up to 3 wt% in PHA improve the Young's modulus compared to pure PHA. However, as the EPO loading exceed 3 wt%, the Young's modulus has dropped dramatically and exhibit the lowest value. It shows the same trend between stiffness and Young's modulus as the EPO loading increase except for pure PHA. Pure PHA exhibit a high stiffness with low Young's modulus value proved that pure PHA has brittle properties.

The morphology composition with 3wt% and 4wt% of EPO loading was analyze by FESEM. The present of 3 wt% EPO shows in Figure 3, it shows good compatible morphologies and smooth fracture surface indicate that the miscible of EPO in the blend. It is also show good adhesion between the matrix and plasticizer phase morphology (Silverajah, Ibrahim, Yunus, Hassan, & Woei, 2012). The deformation of PHA phase creates not a brittle fracture and no defect cavities as observed in Figure 4.

Figure 3 FESEM image of 3wt% EPO

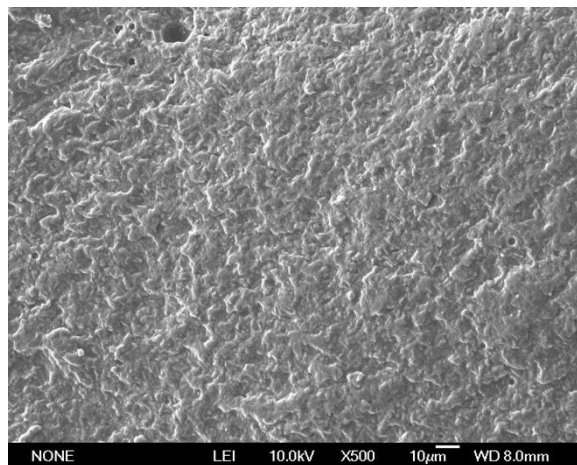
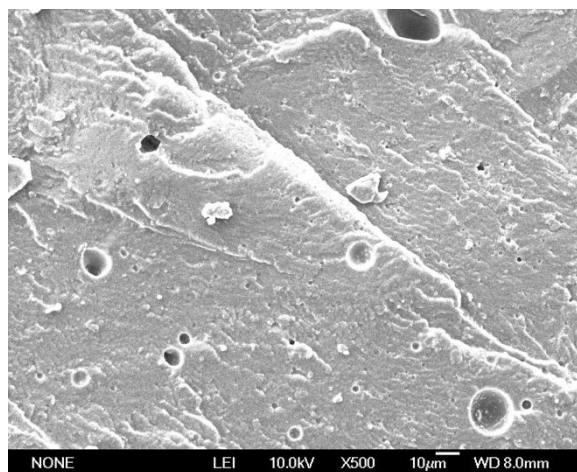


Figure 4 shows the morphology of fracture surface for 4 wt% EPO. The presence of voids can be observed clearly indicating region of accumulate EPO in PHA matrix. The inhomogeneous dispersion between PHA and EPO contribute to low Young's modulus. Therefore better dispersion of EPO in PHA at lower EPO loading compare to high EPO loading where empty void formed.

Figure 4 FESEM image of 4 wt% of EPO



As this study of PHAs mechanical properties improvement focuses on MIM backbone binder properties comparisons has been made accordingly to the research done by Kong et al.(2012), Raza et al.(2013) Huang&Hsu.(2009), and Liu et al. (2001) on various backbone binder. Researchers claimed that the range of successful backbone binder is in the range of 200 to 300 MPa of Young's modulus. As the value falls in the range of common binder used. It is positively shows that plasticized PHA is qualified to be used as backbone binder for MIM.

Conclusion

The PHA/EPO blends were prepared and the mechanical properties was analyzed by tensile test. The effect of EPO on mechanical properties of PHA was studied in this paper. The optimum value of EPO loading in PHA blends that improved the mechanical properties in terms of Young's modulus of PHA is 3 wt%. At 3wt% EPO loading, the blend shows high value in both Young's modulus and stiffness. The efficiency of EPO loading as plasticizer was higher in order 3 wt% > 5 wt% > 2 wt% > 1 wt% > 4 wt%. All of the plasticized PHA qualified to be used as backbone binder for MIM application as the Young's modulus fall in the Young's modulus range of common binder used for the application.

References

- Bugnicourt, E., Cinelli, P., Lazzeri, A., & Alvarez, V. (2014). Polyhydroxyalkanoate (PHA): Review of synthesis, characteristics, processing and potential applications in packaging. *Expresspolymlett*, 8(11), 791-808.
- Chua Abdullah, M., Sulong, A., Muhamad, N., Abdullah, M., & Che Haron, C. (2011). Optimization of Injection Parameters Using 16µm Stainless Steel Powder (SS316L) at 63 Vol. %, 63.5 Vol. % and 64 Vol. % Powder Loading by Taguchi Method for Metal Injection Molding. *KEM*, 471-472, 558-562.
- Huang, M. & Hsu, H. (2009). Effect of backbone polymer on properties of 316L stainless steel MIM compact. *Journal Of Materials Processing Technology*, (209), 5527-5535.
- Kong, X., Barriere, T., & Gelin, J. (2012). Determination of critical and optimal powder loadings for 316L fine stainless steel feedstocks for micro-powder injection molding. *Journal Of Materials Processing Technology*, 212(11), 2173-2182.
- Li, S., Huang, B., Li, Y., Qu, X., Liu, S., & Fan, J. (2003). A new type of binder for metal injection molding. *Journal Of Materials Processing Technology*, 137(1-3), 70-73.
- Liu, Z., Loh, N., Tor, S., Khor, K., Murakoshi, Y., & Maeda, R. (2001). Binder system for micropowder injection molding. *Materials Letters*, 48(1), 31-38.
- Mekonnen, T., Mussone, P., Khalil, H., & Bressler, D. (2013). Progress in bio-based plastics and plasticizing modifications. *J. Mater. Chem. A*, 1(43), 13379.
<http://dx.doi.org/10.1039/c3ta12555f>
- Raza, M., Ahmad, F., Omar, M., German, R., & Muhsan, A. (2013). Role of Debinding to Control Mechanical Properties of Powder Injection Molded 316L Stainless Steel. *AMR*, 699, 875-882.
<http://dx.doi.org/10.4028/www.scientific.net/amr.699.875>
- Silverajah, V., Ibrahim, N., Yunus, W., Hassan, H., & Woei, C. (2012). A Comparative Study on the Mechanical, Thermal and Morphological Characterization of Poly(lactic acid)/Epoxidized Palm Oil Blend. *International Journal Of Molecular Sciences*, 13(12), 5878-5898. [http://dx.doi.org/10.1016/s0167-577x\(00\)00276-7](http://dx.doi.org/10.1016/s0167-577x(00)00276-7)
<http://dx.doi.org/10.1016/j.jmatprotec.2012.05.023>