Figure 5 depicts the DTG curves of the selected composites. The lowest and the highest thermal degradation occurs on sample ET 25% and sample ET 60% at temperature of 55.9 °C and 63.2 °C, respectively. For first decomposition temperature, the presence of tamarind shell fiber is predicted to increase the thermal stability of the epoxy composite.

Next, the second decomposition temperature of epoxy tamarind shell occurs between 350 °C to 430°C. This result was confirmed by using Derivative Thermogravimetric Graph (DTG). In this step, particular data such as corresponding weight loss, onset temperature of thermal degradation, and peak of weight loss temperature of the specimen can be determined using DTG curves. The highest peak of weight loss temperature is in sample ET 40% which is 341.3 °C whereas the lowest peak of weight loss temperature is in sample ET 60% which is 340.4 °C. In this stage, the degradation of some lignin part and hemicellulose part inside the samples occurred (Maheswari et al. 2008). This degradation reaction causes the biggest sample mass losses in this stage and the peak of the degradation temperature occurs between 300 °C and 400 °C.

Graph of DTG for ET 0, ET 40%, and tamarind shell particle are shown in Figure 6. In this analysis, the best samples of epoxy tamarind shell were chosen based on its thermal properties to compare with tamarind shell particle and neat epoxy sample. Based on Figure 6, the neat epoxy shows better thermal behaviour with peak of weight loss temperature at 371 °C. Furthermore, the final mass residue of neat epoxy sample is 20% after thermal degradation process which is higher compared to others.

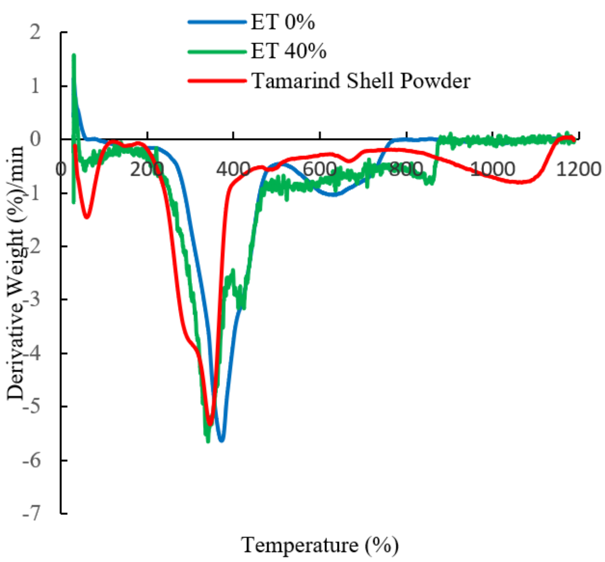

FIGURE 6. Derivative weight curve of neat epoxy (ET 0%), epoxy tamarind shell fiber (ET 40%) and tamarind shell particle

Based on the topographical images done using FESEM analysis, the fractography structure of the composite was observed. Figure 7 shows the surface of the neat epoxy which exhibits brittle properties based on the clean and smooth fracture appearance. The structure of tamarind shell particle is shown in Figure 8. The average size of the particles can be confirmed below than 100 **µ**m under the microscope observation. The average size of the particles is within the expected range since the acceptable size of particles was fixed in this study to be below 100 **µ**m. The addition of tamarind shell particle covers the brittle appearance of the neat epoxy and alters the surface appearance of the composites as shown in Figure 9 and Figure 10. The morphological structure of epoxy tamarind shell in Figure 9 with percentage of 50% tamarind shell fiber shows good interfacial bonding of epoxy matrix with tamarind shell fiber. From Figure 9, it can be observed that the tamarind shell fiber was evenly distributed in epoxy matrix compared with epoxy with 25% tamarind shell fiber in Figure 10. This property gives the result of higher mechanical properties in terms of flexural and hardness as the higher force can be exerted in epoxy composite in Figure 9 since the tamarind shell fiber improves the arrangement of particles in epoxy matrix.

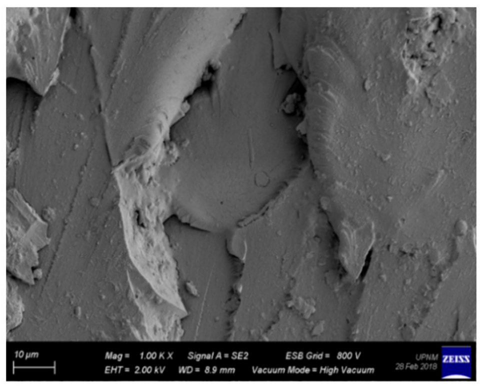

FIGURE 7. The image of neat epoxy samples under 1000x magnification

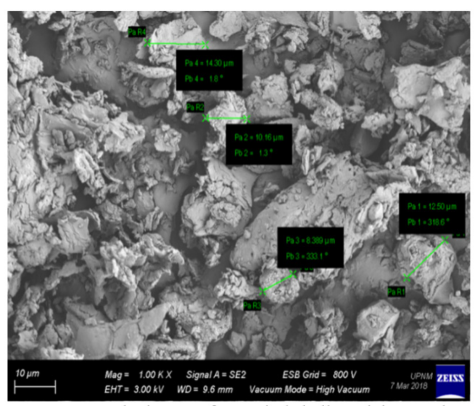

FIGURE 8. The image of tamarind shell particle samples under 1000x magnification

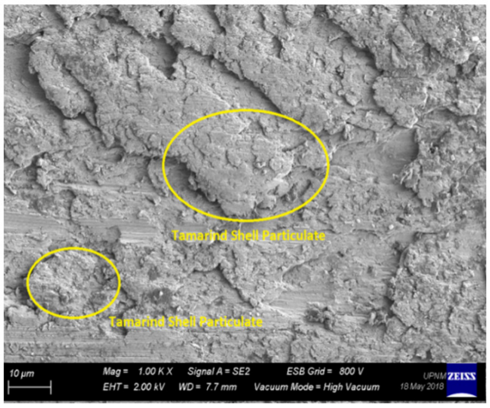

FIGURE 9. The image of 50% tamarind shell particle in epoxy composite samples under 1000x magnification

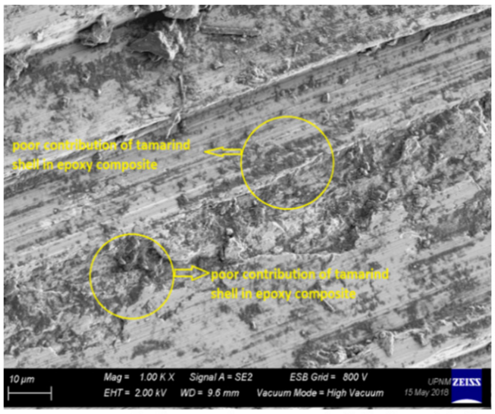

FIGURE 10. The image of 25% tamarind shell particle in epoxy composite samples under 1000x magnification

CONCLUSION

The density of the composite decreases with the increment of filler percentage. For flexural test, the best sample is sample ET 50% based on its high flexural modulus and stress. The hardness test reveals the result that the higher the percentage of filler, the higher the hardness of the samples. For thermal properties, the result shows that the incorporation of tamarind powder in epoxy matrix gives lower thermal stability.

DECLARATION OF COMPETING INTEREST

None

REFERENCES

Zafar, M.F. & Siddiqui, M.A. 2017. Manufacturing natural filler based composites: A review 505: 27–33.

Maheswari, C.U., Obi, K.R., Rajulu, A.V. & Gurudi, B.R. 2008.Tensile properties and thermal degradation parameters of tamarind fruit fibers. *Journal Reinforce Plastic Composite* 27(16–17): 1827–1832.

Binoj, J.S., Raj, R.E. & Daniel, B.S.S. 2017. Comprehensive characterization of industrially discarded fruit fiber , Tamarindus Indica L. as a potential eco-friendly bio-reinforcement for polymer composite. *Journal Clean. Prod*.142: 1321–1331.

Goudar, S.A. & Shetty, V. 2017. Comparative study on mechanical properties of tamarind shell and groundnut shell particles reinforced epoxy composite, 2017–2020.

Binoj, J.S., Raj, R.E. & Indran, S. 2018. Characterization of industrial discarded fruit wastes (Tamarindus Indica. L) as potential alternate for man-made vitreous fiber in polymer composites. *Process Safety and Environmental Protection* B(116): 527-534.

Naik, S., Halemani, B. & Raju, G.U. 2019. Investigation of the mechanical properties of tamarind seed particles reinforced epoxy composites. AIP Conference Proceedings 2057: 020023.

Srinivas K.R., Achamyeleh T., Somanath B. & Murali K.B. 2017. Experimental investigation of mechanical properties for tamarind shell particles as filler in epoxy composite. *International Journal of Engineering Research and Advanced Technology* 3(3): 40–49.

Sivarao, S., Ali, A, Amran, M., Sivakumar, L.D., Salleh, S. & Rajaizam, A. 2016. Effect of fiber loading on the mechanical properties of bagasse fiber–reinforced polypropylene composites *Advances in Mechanical Engineering* 8(8): 1–5.

Cao, Y., Shibata, S. & Fukumoto, I. 2006. Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments. *Compos Part* A (37): 423–429.

Gomes, A., Matsuo, T., Goda, K. & Ohgi, J. 2007. Development and effect of alkali treatment on tensile properties of curaua fiber green composites. 38: 1811–1820

Puneeth, S.D., Rajesh, G.C. & Sunil, K.G. 2019. Study of mechanical properties of tamarind powder with glass fiber and epoxy resin. *International Research Journal of Engineering and Technology* (IRJET) e-ISSN: 2395-0056 www.irjet.net p-ISSN: 2395-0072

Santosha, G., Ravi, K. J. & Das, D. 2020. Physico-mechanical properties of tamarind pod shell-based composite. *Polymer Composite* 41(2): 505-521.

Prakhakar, M.N., Atta, R.S. & Song, J. 2015. Thermal and mechanical properties of waste ground nut-shell reinforced polyester composites. *Composite Research Paper* 28(3): 118–123.

Ujjinappai, S. & Sreepath, L.K 2018. Production and quality testing of fuel briquettes made from pongamia and tamarind shell. *Sadhana* 43(4).