6TH INTERNATIONAL CONFERENCE ON KNOWLEDGE & INNOVATION IN ENGINEERING, SCIENCE & TECHNOLOGY

6 - 8 MARCH 2020 BUDAPEST, HUNGARY

Thermogravimetric Analysis of EPS/Glass Epoxy Composite

Şafak Yıldızhan[1,*] and Hasan Serin[2]

[1]Cukurova University, Automotive Engineering Department/Adana, Turkey

[2]Cukurova University, Automotive Engineering Department/Adana, Turkey

Abstract.

With the development of technology and insight in the many different industrial sectors the variety of the products are increasing rapidly. That diversity requires different engineering solutions and those solutions require different composite materials with variable properties. Thus, composite materials are getting great interest due to the tailorable characteristics. Expandable polystyrene (EPS)/Glass/Epoxy composite is novel material type of random discontinuous and hybrid composite. The composite material specimen has been fabricated via vacuum infusion technique in a closed mold. EPS beads and chopped glasses were mixed and filled into the mold, afterwards epoxy resin was introduced into to the vacuumed mold. Thermogravimetric analyses of composite specimen and neat resin have been conducted between 25-600 ^{o}C with a heating rate of 10^{o}C/min. The experimental results showed that main weight loss starts around 345 ^{o}C but the neat resin has a quite sharp loss after the loss started. But, composite specimen showed a decelerating model-like characteristic. The tangent lines revealed that composite specimen shows a lower thermal stability due to the EPS in the composite specimen. As a result even the slightly lower thermal stability of the composite, the peak limit of usage of EPS/Glass/Epoxy composite could be 120 ^{o}C before the major weight loss.

Keywords: discontinuous reinforcement; hybrid; material; random; thermal stability

1. Introduction

Polymer matrix composites (PMCs) have a limited range of usage temperature due to the low decomposition and melting temperatures of the polymers. There are various types of polymer resins that are used to fabricate composite materials that have high thermal durability but, most polymers have low thermal durability in comparison with metals and ceramics. The increment of the application areas of the PMCs recently, leaded to further research on composites and composite properties. There are numerous studies on the thermal properties of the PMCs (Alva, Lin, & Fang, 2018; Bertoncelj, Vojisavljevic, Vrabelj, & Malic, 2015; Chung, 2000; Kopal et al., 2019; Yu, Wu, Feng, & Yang, 2016). Many parameters such as crystallization, melting point (Cebe & Chung, 1990), glass transition temperature (Bussu & Lazzeri, 2006; Greenberg, 1987; Harmon, Nikiforov, Sahagian, Jesse, & Kalinin, 2011; Kim, Taya, & Nguyen, 2009; Siddiqui & Arif, 2018), thermal conductivity (Kim et al., 2009; Siddiqui & Arif, 2018; Takenaka & Ichigo, 2014), thermal expansion coefficient (Takenaka & Ichigo, 2014), mass loss (Bertoncelj et al., 2015) etc., and the parameters that effect the properties have been reported. In this study, the thermogravimetric analyses of a novel composite material (random discontinuous hybrid) and neat epoxy resin have been conducted.

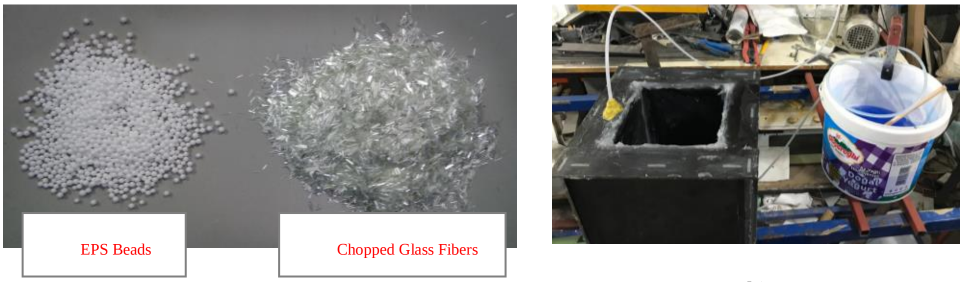
2. Material and Method

The experimental studies have been conducted in Automotive Engineering Material Laboratory of Cukurova University and Cukurova University Central Research Laboratory. A novel type of composite material which consists of chopped glass fibers, expandable polystyrene beads and epoxy resin has been fabricated and thermogravimetric analyses (TGA) of the composite sample and neat resin have been compared.

2.1 Fabrication of Specimens

The composite sample was fabricated with vacuum infusion technique in a closed mold (Figure 1b). The EPS beads (Figure 1a) and chopped glass fibers (Figure 1a) were mixed and glued with a temporary adhesive. After the mixture was prepared, the mixture was filled into the mold and the mold was vacuumed until the absolute vacuum. Afterwards the resin was introduced into the mold and after infusion process the mold was kept at room temperature for 24 hours for pre-curing process. Next, the mold was kept in a controlled oven at 50 ^{o}C for 24 hours for the complete curing. The technical properties of the raw material were given in Table 1.

Figure 1: Composite specimen fabrication



a) *b)*

Table 1: Technical specification of the raw materials

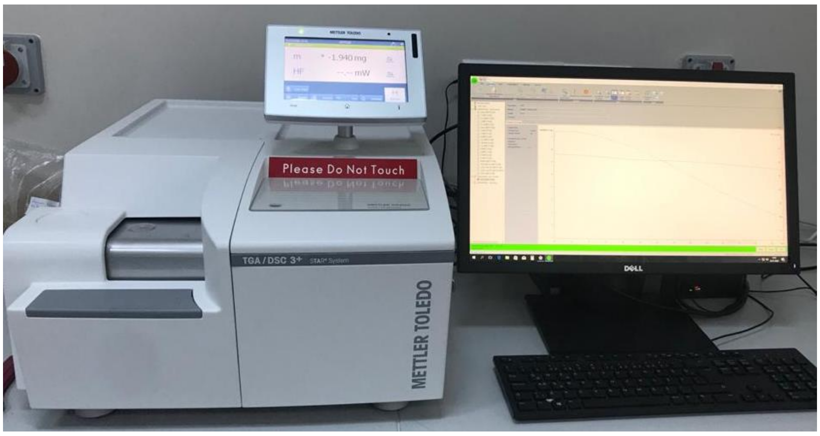
Material	Property	Value
L160 epoxy resin ("Technical Information Epoxy and Phenolic Resins Division Epoxy Resins," 2006)	Brand	HEXION
	Density (g/cm^3)	1,13-1,17
	Viscosity (mPas)	700-900
	Epoxy equivalent (g/equivalent)	166-182
	Epoxy value (equivalent/100 g)	0,55-0,60
H260 hardener ("Technical Information Epoxy and Phenolic Resins Division Epoxy Resins," 2006)	Brand	HEXION
	Density (g/cm^3)	0,93-0,97
	Viscosity (mPas)	80-100
	Amine value (mg KOH/g)	450-500
	Ratio wt% in resin	35
EPS beads	Average diameter (mm)	6
	Density (g/cm^3)	0,008
Chopped glass fibers	Length (mm)	3
	Fiber diameter (µm)	13-15
	Density (g/cm^3)	2,60
Composite Material Content	Weigth ratio of EPS beads ($W_{EPS}=w_{eps}/w_{composite}$)	0,0108
	Weigth ratio of chopped glass fibers ($W_G=w_g/w_{composite}$)	0,2166
	Weigth ratio of matrix (resin) ($W_m=w_m/w_{composite}$)	0,774

2.2 TGA Analysis

TGA is a thermal analysis method that is used to determine the qualitative and quantitative characteristics of the samples. In the study analyses of two different samples (composite sample and neat resin) were conducted in Mettler Toledo TGA 3+ model (Figure 2)

properties: 25-1600 ºC test range, 0.02-150 K/min heating ratio, 0.1 µg weight measuring resolution) from 25 ºC to 600 ºC with 10 ºC/min heating ratio.

Figure 2: Mettler Toledo TGA 3+



3. Results and Discussion

The TGA analysis results of the neat resin and composite sample are given in Figure 3 and Figure 4, respectively.

Figure 3: TGA graph of neat resin

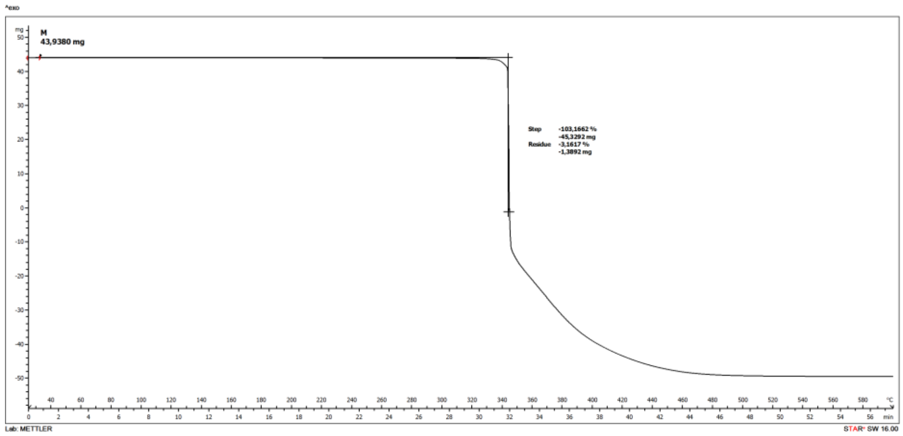
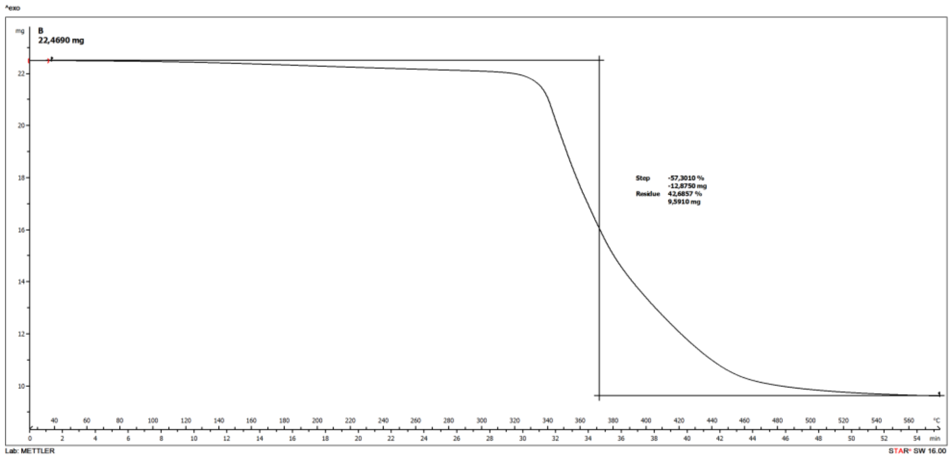


Figure 3: TGA graph of composite sample



The analyses of neat resin and composite sample revealed that composite sample had lower thermal stability. The main reason for that decrement is the EPS beads which have relatively low thermal resistance. It can be seen from the graphs mass loss started around 120 ^{o}C for the composite resin while it started around 345 ^{o}C for the neat resin. Composite specimen showed a decelerating model-like characteristic.

4. Conclusions

In this study TGA analyses of neat epoxy resin (Hexion L160-H260) and composite sample (EPS/Glass/Epoxy) have been evaluated between 25-600 ^{o}C with 10 ^{o}C/min heating rate. The experimental results revealed that;

- Neat epoxy has a high thermal stability and major weight loss starts around 345 ^{o}C.
- Major weight loss of composite sample starts around 120 ^{o}C.
- Composite sample showed a decelerating model-like characteristic.
- EPS beads decreased the thermal stability of the neat resin, but still the EPS/Glass/Epoxy composite can be used in many applications under 120 ^{o}C which is a high temperature for many engineering applications.

Acknowledgment

The authors would like to thank the Cukurova University Scientific Research Project Coordination (FBA-2020-12502) for financial support to this project.

References

Alva, G., Lin, Y. X., & Fang, G. Y. (2018). Thermal and electrical characterization of polymer/ceramic composites with polyvinyl butyral matrix. *Materials Chemistry and Physics, 205*, 401-415. doi: 10.1016/j.matchemphys.2017.11.046

Bertoncelj, B., Vojisavljevic, K., Vrabelj, M., & Malic, B. (2015). Thermal properties of polymer-matrix composites reinforced with E-glass fibers. *Informacije Midem-Journal of Microelectronics Electronic Components and Materials, 45*(3), 216-221.

Bussu, G., & Lazzeri, A. (2006). On the use of dynamic mechanical thermal analysis (DMTA) for measuring glass transition temperature of polymer matrix fibre reinforced composites. *Journal of Materials Science, 41*(18), 6072-6076. doi: 10.1007/s10853-006-0694-3

Cebe, P., & Chung, S. S. (1990). Melting Behavior of High-Performance Composite Matrix Polymers - Poly(Phenylene Sulfide). *Polymer Composites, 11*(5), 265-273. doi: Doi 10.1002/Pc.750110503

Chung, D. D. L. (2000). Thermal analysis of carbon fiber polymer-matrix composites by electrical resistance measurement. *Thermochimica Acta, 364*(1-2), 121-132. doi: Doi 10.1016/S0040-6031(00)00631-6

Greenberg, A. R. (1987). Influence of Filler Chemistry on the Glass-Transition Behavior of a Polymer Matrix Composite-Material. *Journal of Materials Science Letters, 6*(1), 78-80. doi: Doi 10.1007/Bf01729435

Harmon, M. E., Nikiforov, M. P., Sahagian, K., Jesse, S., & Kalinin, S. B. (2011). Mapping of glass transition temperatures in carbon fiber polymer matrix composites. *Abstracts of Papers of the American Chemical Society, 242*.

Kim, W. J., Taya, M., & Nguyen, M. N. (2009). Electrical and thermal conductivities of a silver flake/thermosetting polymer matrix composite. *Mechanics of Materials*, *41*(10), 1116-1124. doi: 10.1016/j.mechmat.2009.05.009

Kopal, I., Vrskova, J., Ondrusova, D., Harnicarova, M., Valicek, J., & Kolenicova, Z. (2019). Modeling the thermal decomposition of friction composite systems based on yarn reinforced polymer matrices using artificial neural networks. *Materialwissenschaft Und Werkstofftechnik*, *50*(5), 616-628. doi: 10.1002/mawe.201800178

Siddiqui, M. U., & Arif, A. F. M. (2018). Estimation and optimisation of effective thermal conductivity for polymer matrix composites with hybrid inclusions. *Journal of Composite Materials*, *52*(16), 2139-2148. doi: 10.1177/0021998317741953

Takenaka, K., & Ichigo, M. (2014). Thermal expansion adjustable polymer matrix composites with giant negative thermal expansion filler. *Composites Science and Technology*, *104*, 47-51. doi: 10.1016/j.compscitech.2014.08.029

Technical Information Epoxy and Phenolic Resins Division Epoxy Resins. (2006): Hexion Specialty Chemicals.

Yu, G. C., Wu, L. Z., Feng, L. J., & Yang, W. (2016). Thermal and mechanical properties of carbon fiber polymer-matrix composites with a 3D thermal conductive pathway. *Composite Structures*, *149*, 213-219. doi: 10.1016/j.compstruct.2016.04.010