International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 02 - Issue 12 || December 2017 || PP. 07-11

Preparation, mechanical and thermal properties of composite from epoxidized linseed oil-modified resole phenolic resin

Nguyen Thanh Liem[1*], Bach Trong Phuc[1], Vu Thi Dung[2], Pham Thi Lanh[3*]
[1](*Polymer Center, Hanoi University of Science and Technology, Hanoi, Vietnam)*
[2]*(Rubber Company No 75, Son Tay, Hanoi, Vietnam)*
[3]*(Institute of Materials Science, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam)*

Abstract: In this study,resole phenolic resin (PR) was modified by epoxidized linseed oil (ELO) and the mechanical, thermal and morphological properties of the galss fiber reinforced composite materials have been investigated.ELO - PR composite material with 20 wt.% of ELO showed better physical mechanical properties without any compromise on the thermal properties when compared with unmodified PR composite. Namely, the fracture toughness (G_{IC-P} and G_{I0}) of PR-ELO composites materials (20wt.%ELO) increased by 78.3% and 84.5%, respectively; tensile strength, flexural strength and impact strength increased by 7.0%; 20.5 % and 39.7%, respectively with 20 wt.% ELO in comparison with unmodified PR composites.
Keywords: Phenolic resin, epoxidized linseed oil, composite materials fracture toughness.

I. INTRODUCTION

Phenolic resins (PR), the condensation products of phenol and formaldehyde or their derivatives, have been used widely all over the world [1,2]. PR is well known for its thermal resistance, dimensional stability… and used in such areas as adhesives, coatings, wood binders, and laminates, ... [1,3]. However, the brittleness of PR is the main reason restricts its wide applications. Natural oils can be used to toughen PR and modified products wereused as matrix in the field of composite materials [1,3,7]. In this paper, epoxidized linseed oil-modified phenolic resin is prepared and the mechanical properties such as tensile strength, izod impact strength and inter laminar fracture toughness was focused.

II. EXPERIMENT

2.1 Materials

In the present study, we use the following composition to fabricate composites:
Phenol (99%), fomalin (37%), ammonium hydroxide (25%) were obtained from Sigma-Aldrich (America). Triethylenetetramine (TETA)was purchased from BASF (Singapore). Epoxidized linseed oil (ELO) with oxirane content of 9.3%, Lankroflex E2447, delivered by Akcros Chemicals. Ethanol (99%) and cloth glass fiber were also obtained from the Tianjin Chemicals (China). All materials were used without any further purification.

2.2 Preparation of PR-ELO

The epoxidized linseed oil-modified phenolic resins (ELO-PR) were prepared with contents of epoxidized linseed oil varies from 10% to 40% by weight in comparison with the sum of phenol and formaldehyde; TETA is used as catalysts. The reactions were carried out in a glass flask with a stirrer, a condenser and heating equipment at 60^0 C and 95^0 C for50 minutes. The reaction products poured into a ceramic bowl, washed several times with water to natural and then dry at 70°C under vacuum. The finished products obtained a light yellow color and the epoxy group conversion is calculated up to 83.6%.

2.3 Composite preparation

Composite materials based on PR and PR-ELO reinforced by glass fiber were prepared by prepregs method. Resins was dissolved in ethanol to the certain concentrations then was impregnated in to the glass fiber. The prepreg sheets were placed in air at room temperature for about 15 hours to remove all the solvent. The prepreg sheets then were put into mold and pressed at 150^0C, 100 MPa for 30 minutes.

2.4 Characterization

- Mechanical properties of materials are determined according to the following standards:
- Tensile strength is determined according to ISO 527 on the INSTRON 5582 - 100kN (USA) with the crosshead speed of 2 mm/mins.

- Flexural strength is determined according to ISO 178 on the INSTRON 5582 - 100kN (USA) with the crosshead speed of 2mm/min.
- Izod impact strength was determined in accordance with ISO 180 on the Tinius Olsen Model 92T (USA).
- Fracture toughness interlaminar for the composite materials are determined according to ASTM D5528 – 01.

- Thermal stability was studied by simultaneous thermo gravimetric analyzer (TGA) by SETARAM TG (France), the measurements were performed under a heating rate of 10°C/min, within a temperature range of ambient room temperature to 800°C.
- Morphologies at the fracture surface of the samples were evaluated from scanning electron microscopy images JEOL JSM-6360 devices LV (Japan).

III. RESULTS AND DISCUSSION

3.1 Mechanical properties of PR and PR-ELO reinforced by glass fibers

Tensile strength, flexible strength and izod impact strength of composite materials based on PR and PR-ELO with different contents of ELO were investigated. The results are shown on fig. 1 and fig. 2.

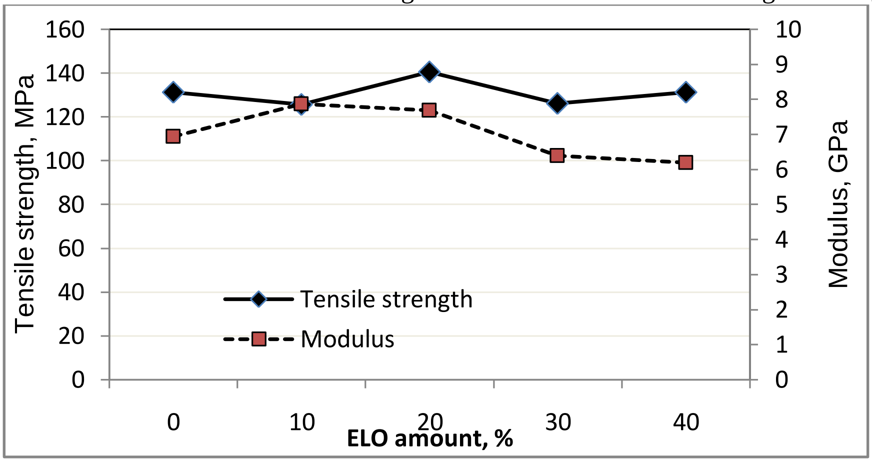

Fig. 1: Effect of ELO to tensile strength and modulus of composites

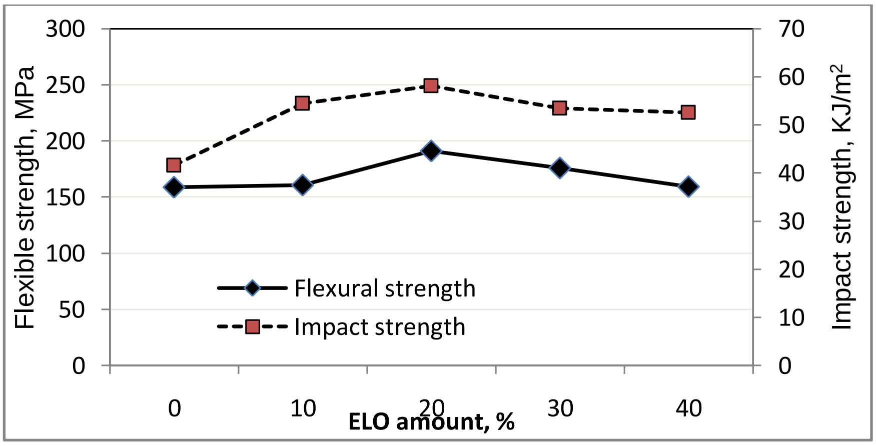

Fig. 2: Effect of ELO to flexural strength and izod impact strength of composites

Figure1 and figure 2 show that the tensile strength, flexural strength and impact strength of the modified phenolic resins increases with ELO contents up to about 20%. These results mean that the modification reaction with ELO increases the mechanical strength of phenolic resins, resulting in increased flexural and tensile strengths. The flexural and tensile strengths of composite using PR-ELO as matrix are much higher than that of unmodified phenolic resins, and the maximum value appearing at the 20% ELO content. Namely, the tensile, flexural and impact strengths of PR-ELO composites materials (using 20wt.%ELO) increased by 7.0%; 20.5% and 39.7% respectively in comparison with unmodified PR composites.

3.2 Effect of ELO to the toughness of composite materials

The toughness of composite materials is determined through interlaminar fracture toughness (G_{IC}) when conducting separate tests of two material layers. The results show in figure 3 and table 1.

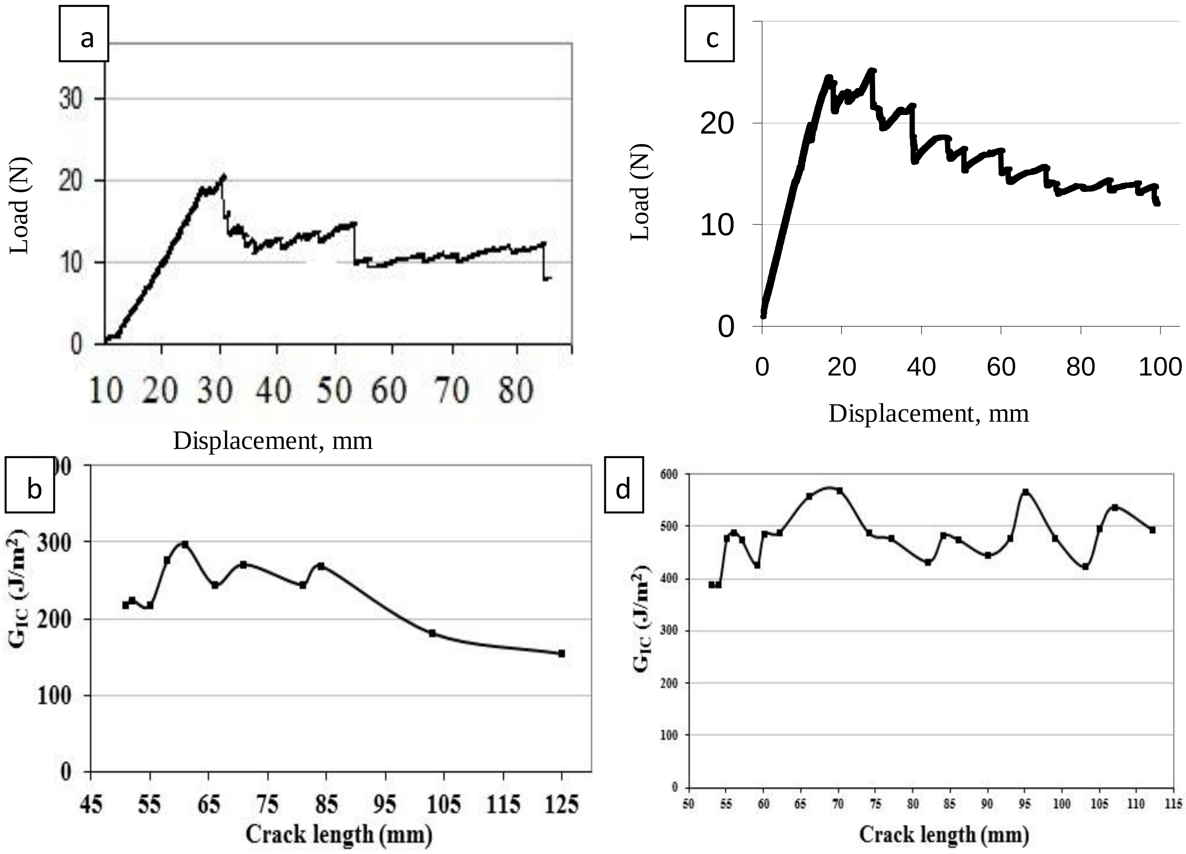

Figure 3: The interlaminar fracture toughness of PR (a,b) and PR-ELO (c,d) composite materials

Table 1: G_{IC-P} and G_{I0} of PR and PR-ELO composite materials

Sample	G_{I0} (MBT) J/m^2	G_{IC-P} (MBT) J/m^2
Unmodified PR composite	217.5	259.6
PR-ELO (20wt.% ELO)	387.8	478.9

The reults in figure 3 show that in the composite materials based on PR, the development of crack steps occurred irregularly while composite materials based on PR-ELO, the developments cracks occur more regularly, the cracks are shorter and the reduction of force is greatly reduced.

The data in figure 3 and table 1 has once again demonstrated the effectiveness of the modify PR by ELO: G_{IC} of PR-ELO/glass fiber composites with 20 wt.% ELO is much higher than that of PR/glass fiber composite. Namely, the G_{IC-P} and $G_{I0}$of PR-ELO composites are 478.9 J/m^2 and 387.8 J/m^2; G_{IC-P} and $G_{I0}$of PR composites are 259.6 J/m^2 and 217.5 J/m^2. The G_{IC-P} and G_{I0} increased by 78.3% and 84.5%, respectively (MBT method).

3.3 Thermal properties of PR and PR-ELO

Conducted thermal analysis TGA with heating rate of 10 degree per minute to measure the thermal resistance of PR and PR-ELO. The results are shown in figure 4.

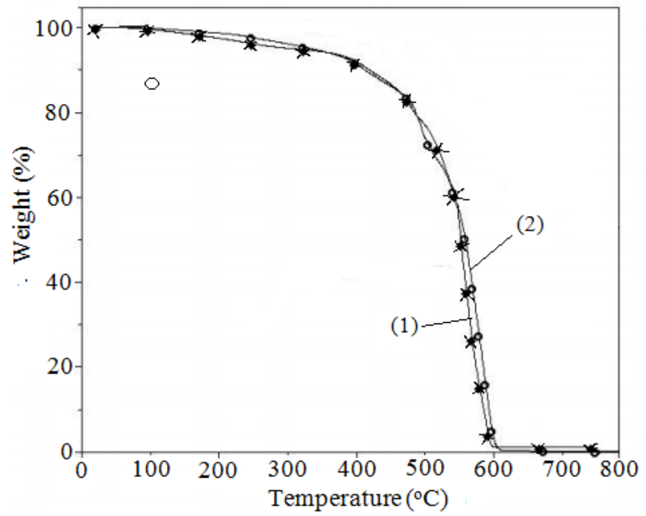

Figure 4: TGA diagrams of PR (1) and PR-ELO (2)

According to TGA of PR (curve 1 - figure 4) and PR-ELO with 20 wt.% ELO (curve 2 - figure 4): both PR and PR-ELO starts to decompose at about 400^{o}C. The decomposition process is almost entirely at temperatures of about 600^{o}C. Therefore, the thermal properties of ELO-PR resin are not affected by the presence of ELO.

3.4 Morphology

The scan electron microscope (SEM) of composite materials based on PR and PR-ELO are shown in figure 5. For the PR sample, the SEM image is smooth, brittle fracture surface, almost no resin on the destroyed surface of the fiber. The PR-ELO sample (20 wt.% ELO) exhibits many small cracks on the surface, many irregular ridges and deformation lines in PF-ELO continuous phase. It means that the destroyed process takes place in two materials is completely different and the main cause is the presence of ELO in the matrix.

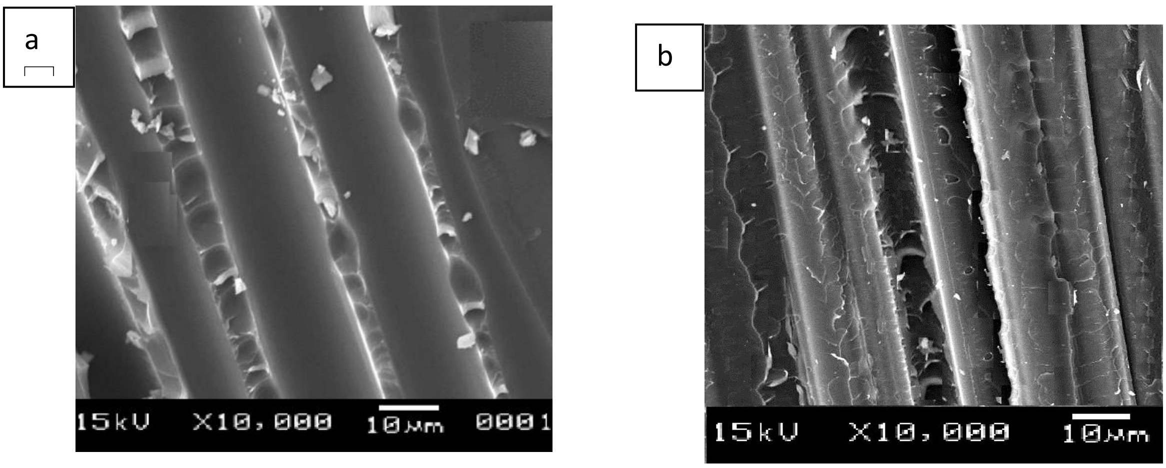

Figure 5: SEM images of fracture surfaces of composite materials based on PR(a) and PR-ELO (b)

IV. CONCLUSION

In this work, a PR-ELO composite have better mechanical properties and interlaminar fracture toughness in comparision with unmodified PR. The best ELO content for toughening effect is 20 wt.% (based on the mass of phenol). At the certain ELO content, the tensile, flexual and impact strength of composites based on PR-ELO increased by 7.0%; 20.5% and 39.7%, respectively; and the frature toughness (G_{IC-P} and G_{I0}) increased by 78.3% and 84.5%, respectively in comparision with unmodified PR composites.

V. ACKNOWLEDGEMENTS

The authors are thankful to Project KC.02/16-20 and National Key Laboratory of Polymer and Composite Materials, Hanoi University of Science and Technology for financial and equipment support of this research.

REFERENCES

[1]. Yu Hu, Wenlong Geng, Hong You, You Wang and A. Douglas Loy. Modification of a Phenolic Resin with Epoxy - and Methacrylate-Functionalized Silica Sols to Improve the Ablation Resistance of Their Glass Fiber-Reinforced Composites. *Polymers, Vol 6, 2014, 105-113.*

[2]. W. Li, F. Liu, L. Wei, T. Zhao. Synthesis, morphology and properties of polydimethylsiloxane modified allylated novolac/4,4′-bismaleimidodiphenyl methane. *Eur. Polym. J., 42, 2006, 580 – 592*

[3]. Yue SITU, Jianfeng HU, Hong HUANG, Heqing FU, Hanwei ZENG, Huanqin CHEN. Synthesis, Properties and Application of a Novel Epoxidized Soybean Oil-toughened Phenolic Resin. *Chinese Journal of Chemical Engineering, Vol. 15 (3), 2007, 418 – 423* .

[4]. Yue Situ, Jianfeng Hu, Hong Huang, Heqing Fu, Hanwei Zeng, Huanqin Chen. Synthesis and application of phenolic resin internally toughened by chain extension polymer of epoxidized soybean oil.*Frontiers of Chemistry in China, Vol. 3 (2), 2008, 235 - 241.*

[5]. H. C. Min, Y. B. Ho, J. C. In. The effect of chain length of flexible diacid on morphology and mechanical property of modified phenolic resin.*Polymer, 43(16), 2002, 4437 – 4444* .

[6]. S. Q. Ma, W. K. Lu, Q. Lin, et al. Studies on the reaction process of epoxidized linseed oil and phenol and their structure characterization. *Journal of Harbin Institute of Electrotechnics, 19 (1), 1996, 8 – 13.*

[7]. H. D. Wu, C. C. M. Ma, J.M. Lin. Processability and properties of phenoxy resin toughened phenolic resin composites. Journal of Applied Polymer Science, 63(7), 1997, 911 – 917.

[8]. C. Kaynak, O. Cagatay. Rubber toughening of phenolic resin by using nitrile rubber and amino silane. *Polymer Testing, 25(3), 2006, 296 – 305.*

[9]. Tran Vinh Dieu, Nguyen Thanh Liem, Bui Chuong. Anh huong cua cau tao phenol den tinh chat co ly cua nhua phenol-fomandehyt dung lam chat ket dinh cho vat lieu ma sat. *Journal of Science and Technology, Vol. 13 (1), 1995, 28 - 32.*

Corresponding authors:
Nguyen Thanh Liem
Polymer Center, Hanoi University of Science and Technology, Hanoi, Vietnam

Pham Thi Lanh
Institute of Materials Science, Vietnam Academy of Science and Technology,
18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam