International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:6, No:9, 2012

Ablation, Mechanical and Thermal Properties of Fiber/Phenolic Matrix Composites

N. Winya, S. Chankapoe, C. Kiriratnikom

***Abstract*—**In this study, an ablation, mechanical and thermal properties of a rocket motor insulation from phenolic/ fiber matrix composites forming a laminate with different fiber between fiberglass and locally available synthetic fibers. The phenolic/ fiber matrix composites was mechanics and thermal properties by means of tensile strength, ablation, TGA and DSC. The design of thermal insulation involves several factors.Determined the mechanical properties according to MIL-I-24768: Density >1.3 g/cm3, Tensile strength >103 MPa and Ablation <0.14 mm/s to optimization formulation of phenolic binder, fiber glass reinforcement and other ingredients were conducted after that the insulation prototype was formed and cured. It was found that the density of phenolic/fiberglass composites and phenolic/ synthetic fiber composite was 1.66 and 1.41 g/cm3 respectively. The ablative of phenolic/fiberglass composites and phenolic/ synthetic fiber composite was 0.13 and 0.06 mm/s respectively.

***Keywords*—**Phenolic Resin, Ablation, Rocket Motor, Insulation

I. Introduction

COMPOSITE materials that are resistant to ablation can be used as components in rocket and space shuttle. Hot gas generated from combustion within the combustion chamber of the rocket will have a temperature of 2000-4000 °C that is very high temperatures [1-2]. Duringthe hot gas flow through a pipe to nozzle of rocket motor to drive the rocket to the goal [3-4].As a result the corrosion has occurred. Thus the insulation must be resistant to heat and friction corrosion as well.

Phenol-Formaldehyde or phenolic resin, the oldest thermosetting polymers.Phenolic resins are oligomers synthesized by repeatedly linking phenolic monomers with aldehyde chemicals. The influence of several variables have been studied for the synthesis of phenol by many different authors using different analytical techniques. Phenolic resincan be used as heat insulation. They are resistant to heat and chemically stable. Because of the structure of Phenilic Resin has the high crosslinking density. Therefore, the phenolic resin is used in the rocket and the Space Shuttle.Because the properties of the phenolic composite has good heat resistance.Resole phenolic resin chemistry is that in the presence of an excess of formaldehyde in the mixture[5-7].

Phenolic resin and the fibers formed by the compression and drying. Process is called forming a laminate fibers used to form many types of Glass Fiber carbon fiber, and Aramid Fiber when you are forming a phenolic composite.

N. Winya, S.Chankapoe and C. Kiriratnikom with Chemical Engineering and Metallurgy Laboratory, Research and Development Department, Defence Technology Institute (Public Organization) Ministry of Defence, The Kingdom of Thailand ,47/433 ,4th Floor –Office of the Permanent Secretary of Defence Building, Changwattana Rd., PakkredNonthaburi Thailand (e-mail: nattawat.w@dti.or.th)

The phenolic and composite the ablation due to excessive heat will result in the char density of the area to be heated, which is a great feature of the insulation of the past research has studied the types of phenolic and resin and fibers [8]. The basic features are suitable for use as insulation for nozzle of the rocket motor.

The study of materials with mechanical properties of heat and corrosion, it was found that the polymer matrix composite as a result the increase in tensile, flexural, ablation, high thermal property thermal and high structure stability when compare with other material.In this study, an ablation, mechanical and thermal properties of fiber/phenolic matrix composites forming a laminate.

II. Methods

A. Materials

The commercial available resole phenolic resin was TGCI company with commercial code PL-2346, PL-9236B and PL-9236C. Table I shown the summarizes main properties of resole phenolic resin. Both fiber type was Woven Roving (Wr 600) and synthesis fiber from GRE composite company.

TABLE I
The Property of Phenolic Resin

Resole Phenolic resin	Density@ 25°C (CP)	Gel time (T=140°C)
PL-2346	200-400	2.5-4.5
PL-9236B	220-300	3-7
PL-9236C	800-1200	4-7

B. Measurements

Ablation rate was measured using oxygen and acetylene ablation testing equipment according to ASTM E285.

The mechanical properties were measured by means of a universal testing machine (Instron 8801) according to S/H H2059)

Thermal gravimetric analysis (TGA) was performed over the temperature range 30-850°C on a Mettler Toledo TGA/SDTA 851° thermal analyzer at a heating rate of 20°C/min under a nitrogen atmosphere.

Differential Scanning Calorimetry (DSC) was performed on Mettler Toledo DSC1 at a heating rate of 20°C/min under a nitrogen atmosphere.

Fourier-transform infrared spectroscopy (FTIR) was performed with a Spectrum One FT-IR spectrometer at a resolution of 4 cm^{-1}.

C. *Preparation of Phenolic/Fiber composite*

The results of the characterization of phenolic and resin by using FT-IR showed a double bond (1595.66 cm^{-1}, 1699.47 cm^{-1}), among the hydroxyl in (3350.62 cm^{-1}) and Mu. alkyl (2978.70, 2938.83, 1456.38 and 1368.03 cm^{-1}) from H-NMR analysis showed that the type of aromatic compounds (δ = 6.8-7.2 ppm), alkanes (δ = 4.5 ppm). and an aldehyde (δ = 9.2 ppm).

Preparation of phenolic composite by bringing fiber layer size at 30 × 30 cm and mixed with resole phenolic resin at 750g and is mixed in the same manner until the 10th layer as shown in Fig.1 and Fig.2

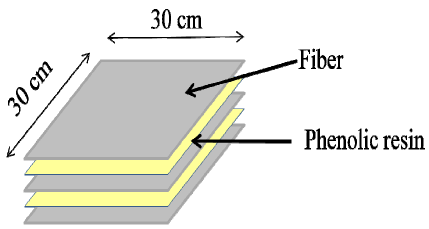

Fig. 1 Geometrical details of target configuration for composite laminates


Fig. 2 Phenolic composite forming laminates

Phenolic composite was forming laminate and put into the oven at 60 °C for 2 h and then heated to 120 °C for 2 hours and heated again to 160 °C for 2 hours as shown in Fig. 3 After that bringing to study Ablation, mechanical and thermal properties.

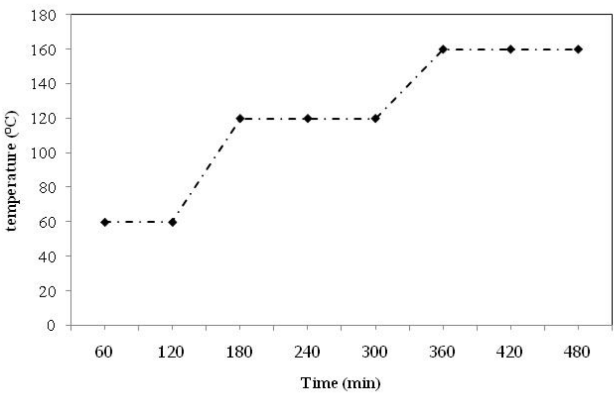

Fig. 3 Typical process procedures for fiber/phenolic composite

III. Results and Discussion

A. *Mechanical properties*

Thermal insulation for rocket motors. Determined the mechanical properties according to MIL-I-24768 by the density is more than 1.3 g/cm^3, the tensile strength is more than 103 MPa, and the ablation property is less than 0.14 mm/s.The Density of all fiber/phenolic composite are more than 1.3 g/cm^3 as shown in Fig.4 and all fiber glass/phenolic composite has density more than synthetic fiber/phenolic composite as well. The Density of all fiber/phenolic composite are more than 1.3 g/cm^3 as shown in Fig.4 and all fiber glass/phenolic composite has density more than synthetic fiber/phenolic composite as well. While tensile strength of PL-9236C/fiber glass composite and PL-9236C/synthetic fiber composite are the best condition according MIL-I-24768 standard as shown in Fig.5.

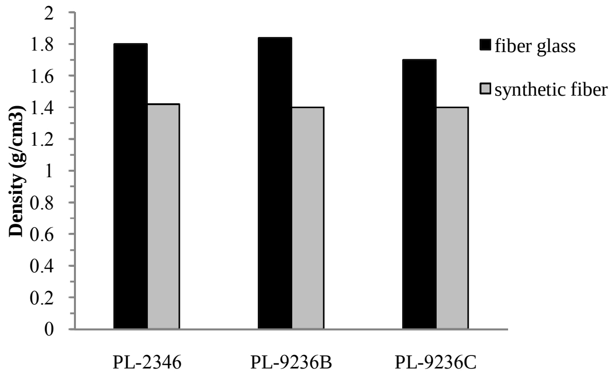

Fig. 4 Density of fiber/phenolic composite

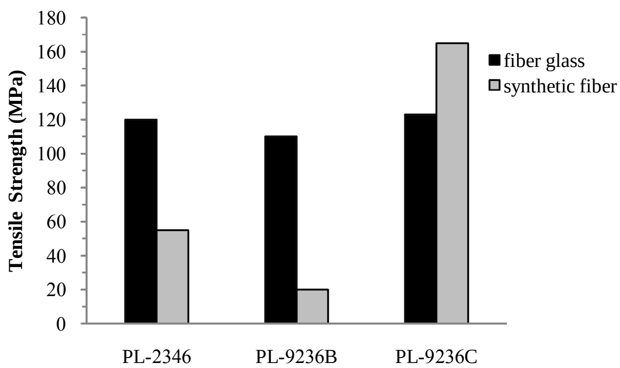

Fig. 5 Tensile strength of fiber/phenolic composite

B. *Ablation properties*

The ablation rate was measured using oxygen and acetylene ablation testing equipment according to ASTM E285. Is shown in Fig.6 and to calculate the ablation rate to the following equation (1) is.

$$ablation\ rate = \frac{thickness}{ablation\ time} \quad (1)$$

From Fig.7 shown that result of the ablation rate is less than 0.14 mm/s according MIL-I-24768 at all composites while the ablation rate of synthetic fiber composite is less than fiber glass composites about 50%. From PL-9236C/fiber composite is the best composites for thermal insulation because the tensile strength is higher than other composite.

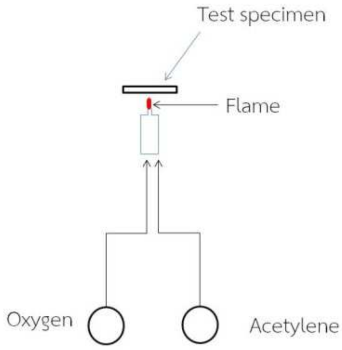

Fig. 6 Test specimen of ablation test

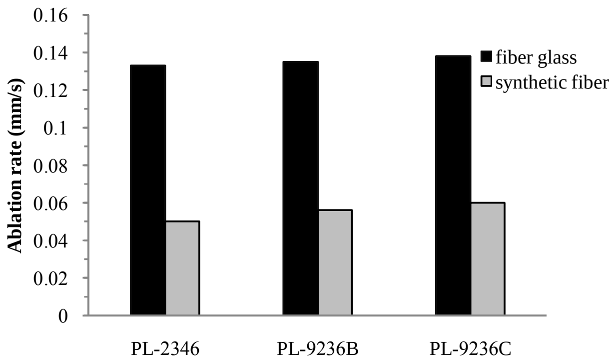

Fig. 7 Ablation of fiber/phenolic composite

C. Thermal stability

The study is a comparison between the thermal stability of PL-9236C/fiber glassand PL-9236C/synthetic fiber. Thermogravimetric Analysis: TGA is shown in Figure 8.Found that the phenolic/fiber glass composites is the second decomposition reaction at first, 300 -580 °Cof organic compounds with high molecular weight and the second , 590-670 °C. While the phenolic/synthetic fiber composite is the decomposition reaction at temperatures of 600-680 °C and at 800 ° C, the char was 46.2 percent, indicating that the phenolic /synthetic fiber composite components were not degraded. The reason for the improved char layer ablative performance was a physical barrier of the system. While the burning char also serves as insulation to protection thermal of the surface. When studies the thermal properties by using DSC (Differential Scanning Calorimetry) found that the reaction heat at the temperature about 230 °C, indicating that the crosslinking reaction. Which the phenolic is shown in Fig 9. The result suggests that use of phenolic/synthetic fiber composite as reinforcement in a composite may improve the thermal insulation in nozzle of rocket motor.

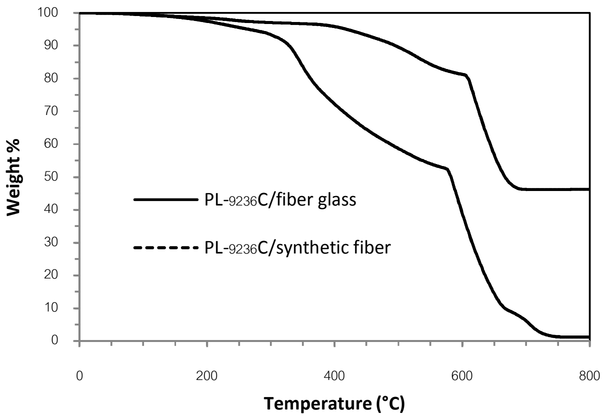

Fig. 8 TGA curves of PL9236C/fiber glass andPL9236C/synthetic fiber

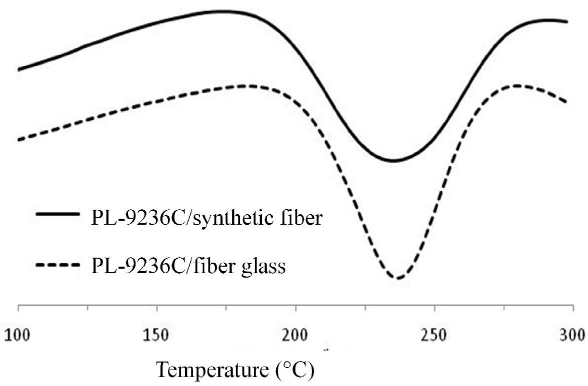

Fig. 9 DSC curves of PL9236C/fiber glass andPL9236C/synthetic fiber

IV. Conclusion

The design of thermal insulation involves several factors. The result found that the mechanical properties of phenolic/fiber glass composites and phenolic/ synthetic fiber composite according to MIL-I-24768. The tensile strength of PL-9236C/fiber glass composite and PL-9236C/synthetic fiber composite better than other composite. However the PL-9236C/synthetic fiber composite is the best composites for thermal insulation because have good the tensile strength and good the thermal stability. The result suggests that use of phenolic/synthetic fiber composite as reinforcement in a composite may improve the thermal insulation in nozzle of rocket motor.

Acknowledgement

This work was supported in part by Chemical Engineering and Metallurgy Laboratory, Research and Development Department, The Defense Technology Institute (Public Organization), Bangkok, Thailand.

References

[1] NASA space vehicle design criteria (Chemical propulsion) (1975). Solid rocket motor nozzles, National aeronautics and space administration, United state.

[2] George P. Sutton and Oscar biblarz (2001). Rocket Propulsion Element, 7th edition, John willey& sons, New York.
[3] Practice no.PD-ED-1218 (2005). Application of ablative composites to nozzles for reusable solid rocket motors, Marshall space flight center, United state.
[4] Guideline NO.GD-ED-2205 (2005). Design and manufacturing guideline for aerospace composites, Marshall space flight center. Page 8.
[5] Natali, M., Kenny, J. and Torre, L. (2010). Phenolic matrix nanocomposites based on commercial grade resols: Synthesis and characterization, Composite Science and Technology, vol.70(2010),January 2010, pp.571-577.
[6] [Jiang, Y., Zhang, X., HE, J., Yu, L., and Yang, R. (2011). Effect of polyphenenylsisesquioxane on the ablative and flame-retardation properties of ethylene propylene diene monomer (EPDM) composite, Polymer Degradation and Stability, vol.96(2011),January 2011, pp.949-954.
[7] Lu, J. (1998). Synthesis of Phenolic Resin Amines and Solid-State NMR of Phenolic Resin in NASA Rocket Motors, Mississippi State University.
[8] Firouzmanesh MR., ArefAzar A., (2003). Study of thermal stability and ablation behavior of carbon/epoxy-novolac composites, Journal of Applied Polymer Science, vol.88(2003), June 2003, pp. 2455-2461.