Mechanical and Thermal Properties of Glass/Polyester Composite with Glycerol as Additive

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***Abstract*-There has been an increasing interest to improve the mechanical properties of the polymer based laminated composites. In this paper, glycerol is used as a solvent to improve the mechanical properties of glass/polyester laminated composites. Polyester resin is modified with 0, 5 and 10 wt% of glycerol. Glycerol and polyester resin are synthesized by hand stirrer. Hand layup method is used to manufacture the laminate made of bi-directional glass woven roving mat and modified polyester. The effect of glycerol is validated by subjecting all samples to the laminate mechanical testing. Results revealed improvement in the mechanical properties of the composites subjected to direct tension and compression test at ambient temperature (27^{o}C). Impact toughness is evaluated under both ambient and low temperature (-10^{o}C) conditions, as polyester resin is more brittle at low temperatures. Thermo gravimetric analysis results showed minor weight loss due to decrease in the cross-linking density of polyester with the addition of glycerol. It leads to the result that we can use this composite with glycerol as advanced material for wind turbine blade.**

***Keywords*- Polyester resin, Filler, Mechanical testing, Thermal stability**

I. INTRODUCTION

Polymer-based composite materials have been used in many applications due to their high strength, stiffness and low density. Laminated composite structures have many superior advantages, but the susceptibility of matrix material at low temperature is a conventional character of these materials. Hence, many investigations on the mechanical behaviour of laminated composites at ambient or low temperature conditions have been performed [1-6]. Tian Li et al studied the effect of hyperbranched polyester as additives for epoxy, which results in 10% increase of tensile strength and toughness [7]. Epoxy modified with silica powder with hyperbranched polyester showed fluctuation in tensile strength but showed poor toughness compared to neat polyester. Jin et al modified epoxy resin with nano-Al_2O_3 and nano-SiC particles to improve the thermal stability of upto 360^{0}C [8].

The aim of this study is to modify polyester resin with glycerol to improve the mechanical properties of the glass/polyester laminated composites evaluated at ambient and low temperature conditions.

II. EXPERIMENTAL

A. Preparation of samples

Bi-directional woven glass fabric and polyester resin added with glycerol is used to manufacture glass/polyester composites. Bi-directional glass woven fabric of 600 GSM is used as reinforcement for the composites. Polyester resin of 1.2 g/cm³ density is used as matrix material. A laboratory grade of glycerol ($C_3H_8O_3$) used as filler or plasticizer having density of 1.26 g/cm³. Polyester resin is modified with glycerol of 0,5, 10 wt% and mixed thoroughly by hand stirrer for 10 min. Hand layup method is used to manufacture the composites with [0^{0}/90^{0}] stacking sequence and 7 plies of bi-directional glass woven fabric. The weight fraction of the polyester in the composite is 40%. As per polyester grade, it is allowed to cure at room temperature for 12 hrs and post curing in hot air oven at 80 ^{o}C for 2 hrs. The glass/polyester composites with nominal thickness of 5mm are obtained. Addition of glycerol above 10% resulted in curing delay and shrinkage.

B. Characterization and measurements

The tensile and compression strength are measured with universal testing machine according to ASTM D 638 and ASTM D 695 respectively. The notched impact testing is carried out on a charpy impact testing machine at ambient and low temperature conditions using a 2 J hammer. The test is conducted according to ASTM A 370; the blow of the hammer is edgewise.

Thermo gravimetric analysis conducted on a NETZSCH STA 409PC/PG thermal system at a heating rate of 10^{o}C/min under nitrogen atmosphere is used to evaluate the weight loss of the composite.

III. RESULTS AND DISCUSSION

A. Tensile strength

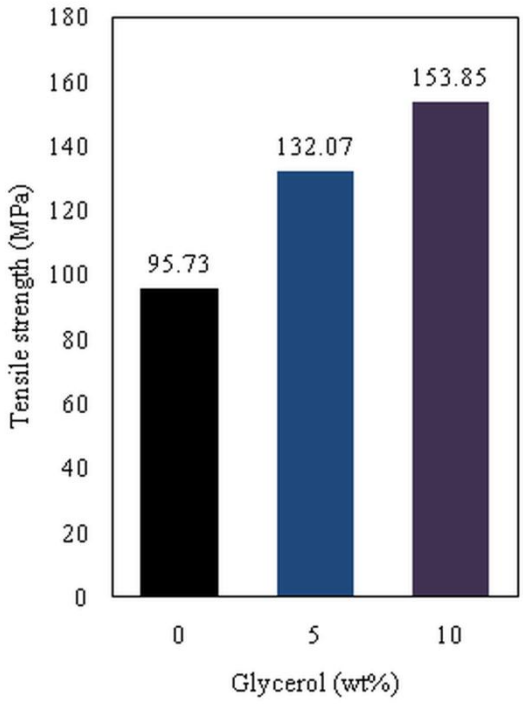

Fig.1 Effect of glycerol on the tensile strength of the composites

Composites of straight sided rectangular cross section are subjected to direct tension test. It is observed that the polyester modified glycerol have good fibre-matrix adhesion. Results revealed that the composites with the addition of 5 and 10 wt% of glycerol increases the tensile strength by 31.9% and 46.5% respectively, compared to the composite with neat polyester Fig.1.

B. Compression strength

The compression strength of the composites with different weight percentages of the glycerol is evaluated. Composite bars are placed between the hard faces of compression tool and it is loaded. The applied load and cross-head displacement are continuously monitored to determine the compression strength of the composites. Fig.2 showed improvement in the compression strength of composites with the addition of 5 and 10 wt% of glycerol by 60.03% and 76.96% respectively, compared to the composite with neat polyester.

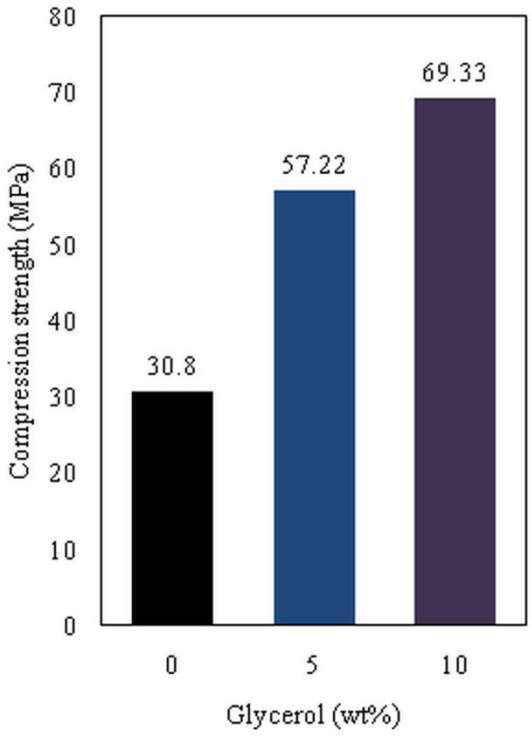

Fig.2 Effect of glycerol on the compression strength of the composites

C. Impact toughness

Impact toughness of the laminated composites is affected by temperature. The effect of glycerol on the impact toughness of the composites is shown in Fig.3 at ambient and low temperatures. Centrally notched composites are held at both ends and it is subjected to 2 J hammer at the back face. It is observed that the composites with 5 and 10 wt% of glycerol increases

the impact toughness by 66.6% and 80% at ambient temperature, compared to the composite with neat polyester. Matrix becomes brittle with decrease in temperature results in low impact toughness compared to the impact toughness at ambient temperature. At low temperature, composites with 5 and 10 wt% of glycerol increases the impact toughness by 78.8% and 88.6% compared to the composites with neat polyester. This indicates the interaction between glass woven roving mat and modified polyester resin is strong that the fibre is not extracted from the matrix easily when the composites are impacted with 2 J hammer. On the other side, composites are destroyed easily due to the poor interaction between glass woven roving mat and neat polyester.

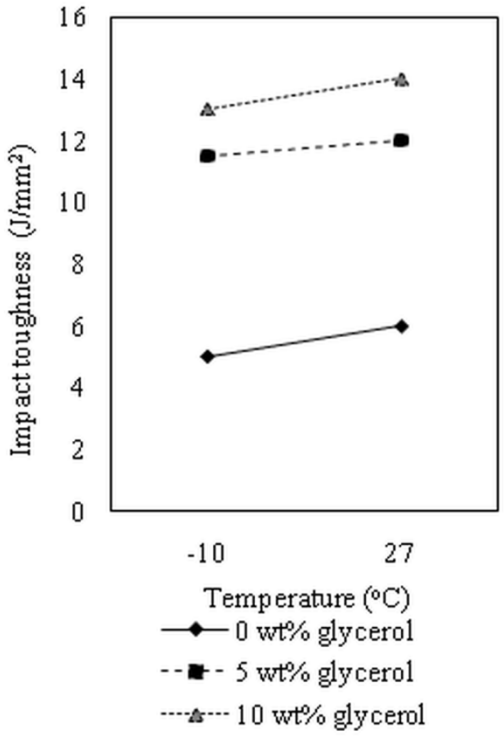

Fig.3 Change in impact toughness of composites due to temperature

D. Thermal stability

Thermo gravimetric analysis (TGA) is a method of thermal analysis used to measure the thermal stability of the composites, which observes the changes in physical and chemical properties of materials as a function of increasing temperature and time. TGA determines the weight loss or gain by decomposing the composites. The thermal properties of the glass/glycerol filled polyester composites are measured by thermo gravimetric analysis at a heating rate of 10^{o}C/min under nitrogen atmosphere. Fig.4 shows that the degradation of composites occurs in two-stages. The weight loss of unreacted polyester resin or other impurities occurred at the first stage between 34^{o}C and 360^{o}C. The weight loss of cured polyester resin occurred at the second stage between 360^{o}C to 440^{o}C. It is found that the weight loss of the composite with 5 wt% and 10 wt% of glycerol is higher than the weight loss of the composite with neat polyester. It may be due to the decrease in cross-linking density of polyester, due to the addition of glycerol. TGA thermograms of composites with glycerol exhibit similar thermal stability of upto 360^{0}C compared to composites with nano-Al_2O_3 and nano-SiC particles [8].

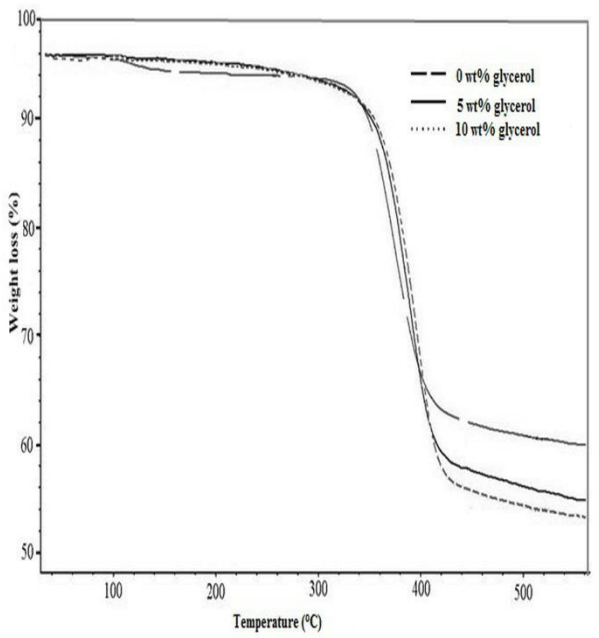

Fig.4 TGA thermograms of the composites with various percentages of glycerol

IV. CONCLUSION

This experimental study investigates the mechanical and thermal properties of glass/polyester laminated composites with various weight percentages of glycerol. Glycerol as a filler or plasticizer in the polyester increases the interfacial adhesion between the fibre and the matrix, which

results in improved mechanical properties at ambient and low temperature conditions. The modified polyester matrix could be further developed with different reinforcement to improve the properties depending on the application.

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