Physical and Thermo-Mechanical Analysis of Marble Dust Filled Needle Punch Nonwoven Jute epoxy composites

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Abstract *This paper fabricate four different weight percentages of marble dust filled needle punch nonwoven jute fiber reinforced epoxy composites by hand-lay-up techniques. The water absorption, physical, fracture toughness and thermo-mechanical properties of the marble dust filled jute epoxy composites are calculated experimentally. The water absorption, flexural strength and impact strength of the particulate filled jute epoxy composites are increased with the increased in filler content of the composites. However, both the tensile strength and thermal conductivity of the particulate filled jute epoxy composites are showing decreasing in trend with the increased in filler contents. Finally, the dynamic mechanical analysis of the unfilled and particulate filled jute epoxy composites is studied using dynamic mechanical analysis (DMA) to evaluate the viscoelastic behavior of the composites and observed that the particulate filled jute epoxy composites show highest storage modulus and loss modulus as compared with unfilled jute epoxy composite.*

Keywords — *Needle punch nonwoven jute, water absorption, mechanical characterization*

I. INTRODUCTION

Fiber reinforced polymer composites have been proved as a lightest material with superior physical and mechanical properties among the engineering materials as compared with monolithic conventional metal and metal alloys [1, 2]. Now-a-days both the synthetic and natural fiber reinforced polymer composites are excessively used for structural applications, aerospace applications along with industrial components etc., but as far as synthetic fiber is concerned the use of natural fiber is more in case of structural materials due to its low density, biodegradability, low cost and environmental friendly [3]. However, water absorption in natural fiber reinforced polymer composites are more which obviously causes degradation of physical and mechanical properties. Pan and Zhong [4] also reported that with the exposure of moisture of short natural fiber reinforced polymer composites the inferior mechanical properties were observed. It is obvious phenomenon that untreated natural fiber reinforced polymer composites generally shocks more moisture as compared to that of synthetic or treated natural fiber reinforced polymer composites. Boonyapookana et al. [5] fabricated silica particulate filled polymer composites and studied fatigue crack propagation of the composites. They observed that with the inclusion of silica particulates in the composites the crack propagation rate was decreased as compared with the unfilled composites. Indra and Srinivasa [6] studied hemp fiber reinforced polymer composites as a function of temperature and observed that the storage modulus was maximum in case of 1 gm fiber loading. Pawar et al. [7] investigated mechanical and visco-elastic performance of jute fiber reinforced epoxy composites using stone waste (granite powder) as filler material.

In this paper, particulate filled needlepunch nonwoven jute fiber reinforced epoxy composites are fabricated by hand-lay-up technique and compressed under compression molding machine. After compression molding, the samples are cutting with the help of diamond cutter as per testing requirement. In this study, moisture absorption tests, physical, mechanical, thermo-mechanical and fracture toughness of particulate filled and unfilled jute epoxy composites are studied experimentally.

II. MATERIALS AND METHOD

A. *Preparation of needlepunch nonwoven jute fiber reinforced epoxy composites*

Needlepunch nonwoven jute fabric mats of areal density 200gsm is used as reinforcing material and epoxy resin is used as matrix material (Epoxy LY 556). The epoxy resin mixed with corresponding hardener (HY951) in a ratio of 10:1 by weight as recommended by the manufacturer (Huntsman International (India) Pvt. Ltd) and marble dust is used as filler material in four different weight percentages. After fabrication of composite slab and then put under compression molding machine under a load of about 50 kg for 24 hrs to get proper curing as well avoid void formation during fabrication of composites.

B. *Water absorption and Mechanical Properties*

The water absorption test is conducted as per ASTM standard test method D570 (ASTM 1998). The tensile property of the particulate filled jute epoxy composites is evaluated using universal testing machine as per ASTM standard D-3039 method. Similarly, the three point bending test is also carried on the same universal testing machine with test standard (ASTM D-2344). The impact strength of similar sets of the unfilled and particulate filled jute epoxy composites is calculated according to ASTM D256. Finally, Fracture toughness (KIC) is evaluated in crack opening mode (mode-I) using same UTM (Instron) in single end notch bend (SENB) configuration confirming to ASTM D5045. Thermo-mechanical properties of the particulate filed jute epoxy composites are obtained by performing dynamic mechanical analysis (DMA) (ASTM D4065). DMA is conducted in atmospheric environment at fixed frequency of 1 Hz, heating rate of 2°C/min and within temperature range of 25–120°C.

III.RESULTS AND DISCUSSIONS

A. Effect of filler contents on moisture absorption of nonwoven needle punch jute fiber epoxy composites

Fig. 1 shows the water absorption curve of the marble dust filled nonwoven needle punch jute epoxy composites and observed that with the increased in filler content the water absorption percentages also increases which shows good agreement with past studies [8, 9]. The increase in water absorption directly related to the void content of the composites.

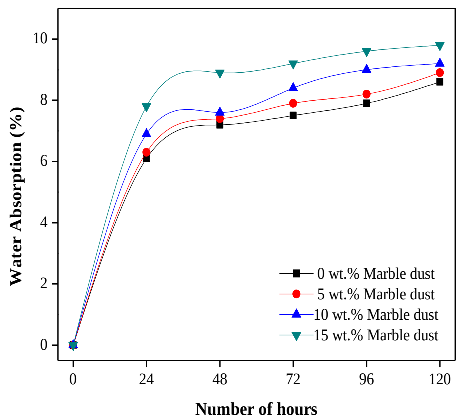

Fig. 1. Water absorption characteristics curve of unfilled and particulate filled jute fiber epoxy composites

B. Effect of filler contents on tensile strength of nonwoven needle punch jute fiber epoxy composites

Fig. 2 shows the tensile strength graphs of marble dust filled nonwoven needle punch jute fiber epoxy composites. The tensile strength of the filled composites is decreasing in trend with the increased in filler content. The reason for decrease in tensile strength is due to increased in void content of the filled composites. Untreated jute fiber reinforced composite the tensile strength decreased with the increased in filler content which is in accordance with published literature [10, 11]. The decreased in tensile strength is due to weak interfacial area between matrix and filler content with the increased in filler content in the composites. The sharp edges of filler particles results in areas of high stress concentration and crack initiation. The tensile strength of the jute fiber reinforced polymer composites were severely decreased by the increased in moisture absorption rates at different aging process.

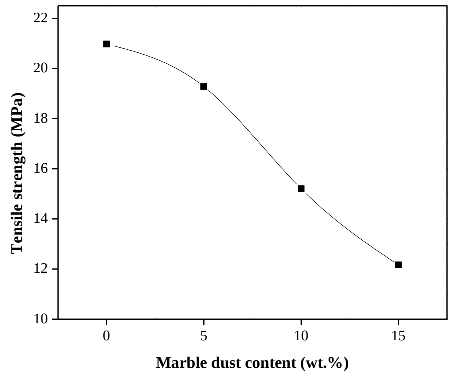

Fig.2. Effect of tensile strength for unfilled and particulate filled jute epoxy composites

C. Effect of filler contents on flexural strength of nonwoven needle punch jute fiber epoxy composites

The flexural strength of the marble dust filled nonwoven needle punch jute epoxy composites with the increased in filler content are shown in Fig. 3. The flexural strength of the particulate filled jute epoxy composites is increased gradually with the increased in marble dust content. The maximum flexural strength is observed in case of 15wt.% marble dust filled jute epoxy composites (46 MPa) and minimum strength is observed for unfilled jute epoxy composites (35 MPa) as presented in Fig. 5. Similarly, Shinji [20] studied kenaf fiber reinforced polyester composites the flexural strength was increased to 62% for 45wt.% of kenaf fiber reinforcement. The increased in flexural strength is attributed to extrinsic toughening mechanism due to presence of long fibers and intrinsic toughening mechanism due to presence of granite particles along the path of damage.

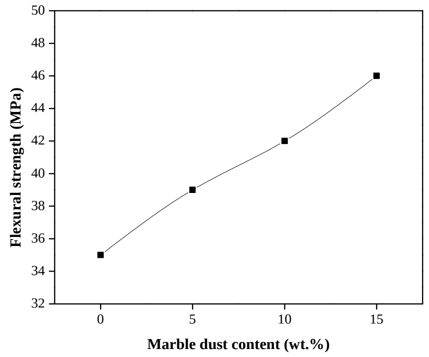

Fig. 3. Effect of flexural strength for unfilled and particulate filled jute epoxy composites

D. Effect of filler contents on impact strength of nonwoven needle punch jute fiber epoxy composites

The impact strength of the laminates was tested by Izod impact test rig. The energy absorbed while a specimen is impacted by a heavy blow is shown in the Fig. 4. The impact energy of needle punch jute epoxy composite rapidly increased from 31J to 38J (22.6%) for inclusion of 5 wt.% marble dust. However, for inclusion of 10 and 15 wt.% marble dust the impact energy improved marginally to 41J (7.9%) and 43J (4.87%) respectively. It shows that the hybrid combination of marble dust as filler in needle punch jute epoxy composite have better impact energy than unfilled one. This improvement in the impact energy may be attributed to energy absorbed by marble dust particles present on the plane of fracture before resulting in resisting the fracture [7]. Breakage of the specimen starts with the crack propagation due to loss of adhesion between fibers and matrix and then initiates fiber breakage and fiber pullout.

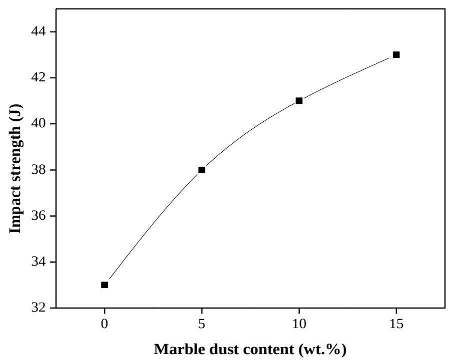

Fig.4. Effect of impact strength for unfilled and particulate filled jute epoxy composites

E. Effect of filler contents on fracture toughness of nonwoven needle punch jute fiber epoxy composites

Fig. 5 shows the stress intensity factor of marble dust filled nonwoven needle punch jute epoxy composites under three different crack lengths evaluated using initial notch depth method. It can be observed that with the increased in crack length the fracture toughness also increased up to 0.3 a/W ratio. However, on increased of a/W ratio further from 0.3 to 0.5 the fracture toughness is marginally decreased. Addition of marble dust has positive effect on stress intensity factor of needle punch jute epoxy composite. The value of K_{IC} at a/W ratio of 0.5 for unfilled needle punch jute epoxy composite is 2.51MPa.m$^{1/2}$ which further improved to 2.93, 3.49 and 4.44MPa.m$^{1/2}$ for incorporation of 5, 10 and 15 wt.% marble dust. This improvement accounts to 16.73%, 39.04% and 76.89% as compared to unfilled needle punch jute epoxy composite. The crack propagates through the thickness of the specimen from one fabric layer to the next. Such crack arresting, bridging mechanisms and crack deflection were responsible for the significant enhancement in fracture toughness.

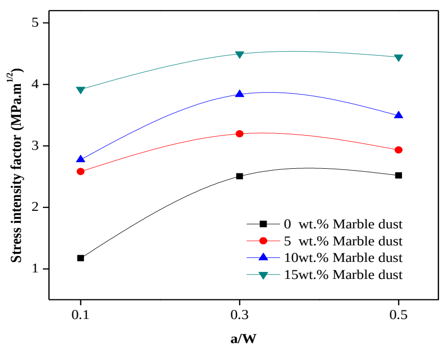

Fig. 5. Effect of stress intensity factor for unfilled and particulate filled jute epoxy composites

F. Effect of filler contents on dynamic mechanical analysis of nonwoven needle punch jute fiber epoxy composites

The storage modulus of the marble dust filled nonwoven needle punch jute epoxy composites as a function of temperature are shown in Fig. 6. It is observed that below glass transition temperature all the particulate filled jute epoxy composites show higher storage modulus as compared with the unfilled jute epoxy composites. However, for particulate filled jute epoxy composites the storage modulus dropped drastically between the temperature range of 35°C to 50°C whereas for unfilled jute epoxy composite the storage modulus drops around 75°C to 80°C. Therefore, the glass transition temperature of unfilled composite is higher than the particulate filled composites as shown in Fig. 6. The storage modulus of 5 wt.% marble dust filled jute epoxy composite shows highest storage modulus as compared with the unfilled and other particulate filled jute epoxy composites. For 10 and 15 wt.% marble dust addition the value of storage modulus is lower as compared to addition of 5 wt.% marble dust but higher than unfilled needle punch jute epoxy composite.

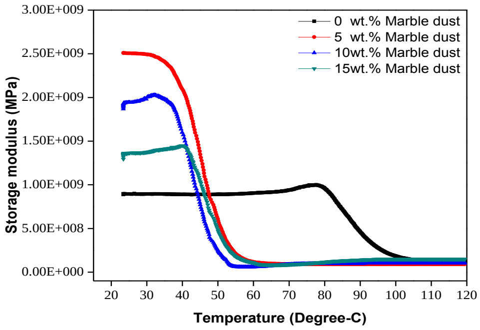

Fig. 6. Variation of the storage modulus with the temperature for unfilled and particulate filled jute epoxy composites

G. Effect of filler contents on thermo-gravimetric analysis of nonwoven needle punch jute fiber epoxy composites

Fig. 7 shows the TGA curves of the marble dust filled jute epoxy composites with four different percentages of filler content. The heating range of the particulate filled and unfilled jute epoxy composites from 30°C to 500°C. Initial heating below thermal degradation temperature removes moisture content present in the composites. However, maximum thermal degradation of composite takes place in this region as shown in Fig. 7. A sudden drop in mass of the unfilled composite is around 290°C but up to 290°C all most all the unfilled and particulate filled composites show similar trend and are closely intact with each other. Whereas, the particulate filled jute epoxy composites the mass loss starts after 350°C. The increased in weight loss is due to incorporation of marble dust in the jute epoxy composites [12, 13].

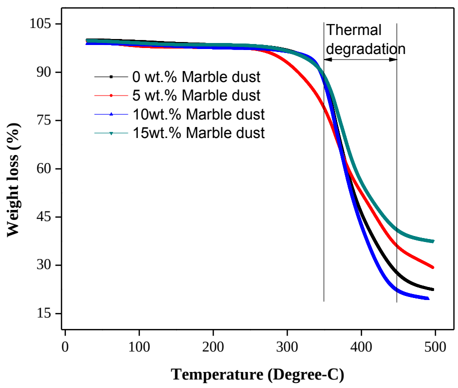

Fig. 7. Thermo gravimetric analysis of unfilled and particulate filled jute epoxy composites

IV. CONCLUSIONS

The following conclusions are drawn from this study for the unfilled and marble dust filled jute epoxy composites as

1. A new set of marble dust filled four different needle punch nonwoven jute epoxy composites are fabricated by hand-lay-up techniques.
2. The water absorption of the unfilled and particulate filled composites is increased with the increasing in number of days. The void fraction and hardness of the composites are increased with the increased in filler content.
3. The tensile strength of the unfilled and particulate filled jute epoxy composites are showing decreasing trend with the increased in filler content. However, with the increased in filler content the bending strength, impact strength and stress intensity factors of the proposed composites are increased.
4. The storage modulus of the unfilled and particulate filled jute epoxy composites the particulate filled jute epoxy composites show highest storage modulus and loss modulus.

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