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# Investigation of Dynamic Mechanical Properties of Jute/Carbon Reinforced Composites

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***Abstract*—**In the last few decades, due to their advanced properties, there has been an increasing interest in hybrid composite materials. In this study, the effect of different stacking sequences of jute and carbon fabric plies on dynamic mechanical properties of composite laminates were investigated. Vacuum bagging system was used to fabricate the composite samples. Each composite laminate was reinforced with two plies of jute fabric and two plies of carbon fabric by varying the position of layers. Dynamic mechanical analyzer (DMA) was used to examine the dynamic mechanical properties of composite laminates with increasing temperature. Results showed that the composite sample, which has carbon fabric at the outer layers, has the highest storage and loss modulus. Besides, it was observed that glass transition temperature ($T_g$) of samples are close to each other and at about 75 °C.

***Keywords*—**Differential scanning calorimetry dynamic mechanical analysis, textile reinforced composites, thermogravimetric analysis.

## I. Introduction

NATURAL fibers have a growing usage as reinforcement material owing to their properties such as lightweight, sufficient mechanical strength and low cost [1]-[6]. However, their properties depend on many factors such as; fiber diameter, crystal structure, void structure and growing conditions [7].

Jute is a promising reinforcement material thanks to its low cost, wide commercial availability in the required form, good thermal and electrical insulation properties, among all natural fibers [8]-[11]. Instead of using natural fibers alone as reinforcement material, hybridizing these materials with higher strength fibers results in a good balance of mechanical property and cost for composite materials [12], [13].

Hybrid composites combine two or more reinforcing materials in a matrix. The mechanical performance of composites depends mostly on the properties of matrix, reinforcement materials, and their interaction. So, fabricating hybrid composites leads to better mechanical properties and reduced material costs compared to the conventional composites [14]-[19].

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Carbon is one of the most preferred reinforcement material for composite structures due to its ability to improve the tribological and mechanical properties of polymer based composites [20], [21]. Moreover, carbon fiber has excellent thermal stability [22].

Fiber-reinforced composites are mostly preferred in applications where high mechanical properties are required, such as automotive applications, aerospace industry, and so on [23]-[26].

DMA is a widely used technique to determine the temperature dependencies of the modulus and damping properties of materials [27], [28]. DMA measures the modulus and damping properties of materials by applying sinusoidal force. Modulus is divided into two parts, these are; storage modulus (E′) and loss modulus (E′′). The ratio of loss modulus to storage modulus is known as mechanical damping. Storage modulus shows the elastic behavior of material and it is proportional to the energy stored in one cycle, whereas loss modulus shows the viscous behavior of material and is proportional to energy dissipated in one cycle [1], [12], [29], [30]. The storage modulus of polymers decreases with increasing temperature whereas the loss modulus and tan δ increase up to the glass transition ($T_g$) region [31]. Moreover, the peak value of the tangent delta curve is mostly taken as the $T_g$ of the polymer [32].

In DMA measurement technique, different deformation modes are used such as three-point bending, single cantilever, dual cantilever, torsion, compression, shear and tension depending on the materials properties. For composite materials, three-point bending configuration is mostly preferred due to the fact that this configuration creates measurable strains in stiff materials and removes the combined loading induced by single/double cantilever mode [29].

In this study, the viscoelastic behavior of jute/carbon fabric reinforced polyester composite materials has been evaluated by DMA method to investigate the effect of different stacking sequences of fabric plies on mechanical performance of these fabric reinforced composites with ascending temperature.

## II. Materials and Methods

### *A. Materials*

Carbon (supplied by Spinteks, Denizli, Turkey) and jute plain woven fabrics (supplied by Ege İzmir Çuval, Izmir, Turkey) which have basis weight of 200 g/m$^2$ were used as reinforcement materials. The matrix consisted of polyester resin, accelerator (cobalt) and hardener (Methyl ethyl ketone peroxide-MEKP) which were obtained from Ada Elektrik. The ratio of polyester:cobalt:MEKP was 1:0.00175:0.002 by weight.

### *B. Methods*

To produce four-plied fabric reinforced composite laminates, vacuum bagging system was used. Fabrication was realized at the room temperature (20 ± 2 ºC). First of all, resin was prepared by mixing specified amount of accelerator and hardener to the polyester resin. After cleaning the tempered glass with acetone, two layers of releasing agent was applied to the tempered glass by waiting 10 minutes between them to dry. Then one layer of polyester resin was applied to tempered glass and one layer of fabric was laid on it. This process was continued until the required number of fabric layers were achieved. After laying fabric layers and applying resin, peel ply and perforated film were laid on the fabric layers. Finally, vacuum sealant tape pasted around the sample and vacuum bag attached on it. A small hole is opened on the vacuum bag to enable the manifold tube to pass through it. Then, vacuum pump is opened to suck the excess resin from the sample.

Vacuum pump works for 2 hours (about 1 bar) and then it is switched off. Also, vacuum tube is cut and closed with sealant tape to prevent air entrance. Sample waits for 24 hours at that position for curing. After 24 hours, vacuum bag is opened and composite plate separated from both tempered glass, peel ply and perforated film. And excess resin which is stored at resin container is cleaned out after process.

Three composite samples that have fabric alignment of jute-carbon-carbon-jute (JCCJ), carbon-jute-jute-carbon (CJJC) and carbon-jute-carbon-jute (CJCJ) were fabricated. Fig. 1 shows the vacuum bagging system set-up.

Fig. 1 Vacuum bagging system set-up

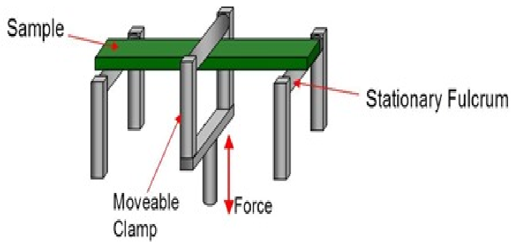


Fig. 2 Three-point bending configuration [33]

RMI DX04T DMA with three-point bending configuration was used for DMA of composite samples (Fig. 2). Samples which have dimension of 10 mm x 50 mm were cut from composite plates. Three test specimens were cut from each composite plate. Tests were performed at a frequency of 1 Hz and the temperature programs were run from 30 to 150 ºC under a controlled sinusoidal strain, at a heating rate of 3 ºC/min.

## III. Results and Discussion

Dynamic mechanical analysis results are examined in three parts: Storage modulus, loss modulus and damping factor (tangent delta).

### *A. Storage Modulus*

Storage modulus shows how stiff a material is. It is approximately similar to the Young modulus [31]. Fig. 3 shows the variation of storage modulus of composite samples as a function of temperature. As it is seen from Fig. 3, the storage modulus values of samples had come approximately to same level (1 GPa) after 85 °C. However, at the beginning temperature of testing while CJJC sample had a storage modulus of 14 GPa, CJCJ and JCCJ samples had storage modulus of 8 GPa and 4 GPa, respectively.

It was observed that sample that has carbon fabrics at the outer layers has the highest storage modulus. Taking into consideration that the measurements were done at three-point bending configuration and the force was applied to the outer layers of the composite (Fig. 2), this result becomes more meaningful. Most likely, carbon fabrics at the outer layers withstand the force that was applied.

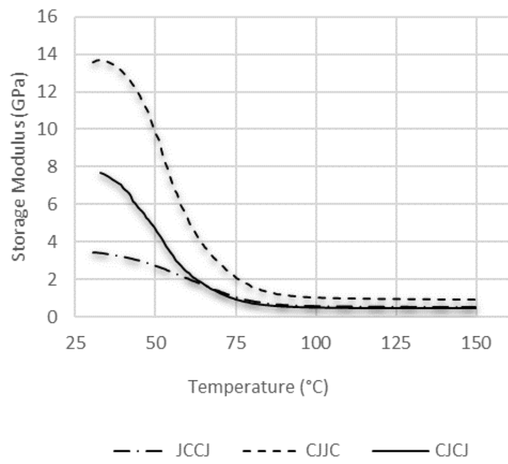


Fig. 3 Storage modulus curves of samples

### *B. Loss Modulus*

Loss modulus is viscous response of the materials. The variation of the loss modulus as a function of temperature is shown in Fig. 4. It was observed from Fig. 4 that loss modulus curves of CJJC and CJCJ samples have had peak at about same temperature (50 °C), whereas JCCJ sample have had a peak at about 70 °C. Moreover, when the peak values were examined, it was seen that while highest loss modulus value of CJJC is 2 GPa, it is 1 GPa and 0.4 GPa for CJCJ and JCCJ samples, respectively.

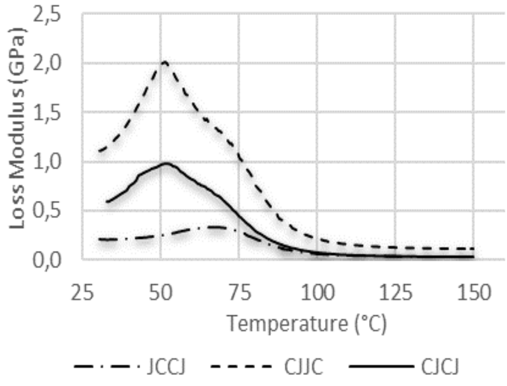


Fig. 4 Loss modulus curves of samples

When loss modulus results are examined, it is observed that composite laminate sample which had carbon fabrics at the outer layers and jute fabrics at the inner layers (CJJC) reached the highest loss modulus value among other samples. This can be due to the fact that, carbon fabrics at the outer layers resist the applied force and owing to this fact, loss modulus of this composite sample became higher.

### *C. Tangent Delta*

The damping factor (tan δ) gives information about correlation of the viscous and elastic components of a viscoelastic material [31]. The variation of the tan delta of the composites as a function of temperature is shown in Fig. 5.

As it is mentioned above, $T_g$ value can be obtained from the peak point of Tan delta curves. It was observed that, $T_g$ values of JCCJ, CJCJ and CJJC samples were 78.6, 72.7 and 79 °C, respectively. They were so close to each other. When it was considered that all three samples composed of same amount of polymer matrix, carbon fabric and jute fabric, this result was meaningful.

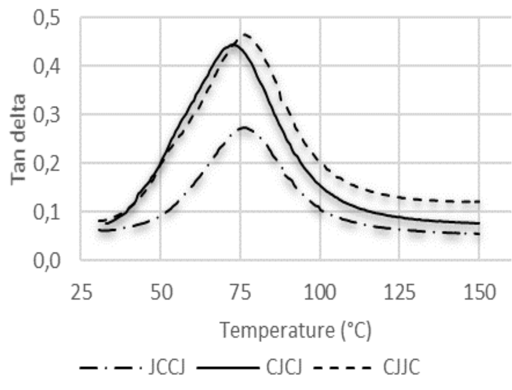


Fig. 5 Tangent delta curves of samples

It was reported that when the matrix and reinforcement material has high bonding strength, the mobility of molecular chains decreases and this causes reduction in damping factor [34]. It was seen that, JCCJ sample has had the lowest tangent delta value. It is known that adhesion of natural fibers to matrices is insufficient compared to conventional fibers [7], [35]. It can be concluded that, by positioning two carbon fabric layers one after the other, higher adhesion was achieved.

## IV. Conclusion

In this study, DMA of three different jute/carbon fabric reinforced composites were investigated and results showed that changing the position of fabric layers has a great effect on both storage and loss modulus of composite samples. By positioning high strength fabrics (carbon) to the outer layers resulted in high storage and loss modulus. Furthermore, it was observed that $T_g$ value of samples were not affected from the positions of the fabric layers.

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