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EXPERIMENTAL INVESTIGATION OF EFFECT OF CURING TEMPERATURE ON MECHANICAL PROPERTIES OF HYBRID COMPOSITES

Guravtar Singh Mann[1], Lakhwinder Pal Singh[2], Pramod Kumar[3]
E-Mail Id: guravtar14443@gmail.com
[1]Phd scholar, Department of Industrial and Production Engineering, Dr. B R Ambedkar NIT Jalandhar, India
[2]Associate Professor, Department of Industrial and Production Engineering, Dr. B R Ambedkar NIT Jalandhar, India
[3]Associate Professor, Department of Mechanical Engineering, Dr. B R Ambedkar NIT Jalandhar, India

Abstract-The increase in fuel prices, scarcity of petroleum products, a hazardous atmospheric divergence are the significant concerns that motivate specialists to operate in the green composite territory because of their biodegradable nature. Green composites are materials composed of particular strands and biodegradable lattice products that can supplant non-biodegradable, oil-based artifacts. In the present investigation, the aim is to construct a green composites that is completely biodegradable where the network material is selected as support for Polylactic acid (PLA) with jute and sisal fiber with manual layout pursued by pressure shaping strategy and curing temperatures ranging from 30^0 C to 90^0 C for understanding its effect on tensile and flexural behaviour of composites.

Keywords: Green composites, Sisal, Jute, Hybrid composites, Curing temperature.

1. INTRODUCTION

The idea of combining several constituents to produce the new material with a modern property that was not achievable with individual components [1]. It had been creating composite materials to make stronger and lightweight. The concept of composite combining various building and construction products had been around since ancient history for a thousand years ago. The earliest examples of building composite around 3400 B.C. when Mesopotamians glued wood strips at a different angle to plywood created, and Egyptians often rendered fibers by heat processing the glass content at very high temperatures. In an around 1200BC, Mongols develop the first modern composite bow. The contemporary composite can develop after world war-2 because the world war-2 was mostly fought with fighter planes, which requires material to be lightweight and robust. Therefore, phenolic resin was used for the first time in the fighter planes by The British royal air force in its mosquito bomber aircraft.

Further, the use of radar technology resulted in the development of glass fiber reinforced plastics which were used to make the covering of radar equipment [2]. Modern-day the strength of concrete is high. Another example is wood which is made up of cellulose and lignin. Plywood is also a form of good composite used for making furniture. Our bone is also a composite material containing collagen fiber and hydroxyl appetite matrix. The main advantages of these materials are that they can be manufactured by adding different epoxies and unsaturated polyester resins to these materials according to the requirements for different applications [3]. Liu et al. [4] studied the twin-screw extrusion and injection molding for determining thermal, mechanical properties and morphology of green composites from soy-based plastic and pineapple leaf fibers with dynamic mechanical analyzer, united testing system, and environmental microscopy. Anil et al. [5] studied the properties of the ramie fiber. The specific tensile properties of the ramie fiber calculated and compared with glass fiber. Ramie fibers exhibited good thermal stability while SEM micrographs revealed that ramie fibers have a fibrillary structure and irregular cross-section. Mishra et al. [6] experimentally investigated the mechanical properties of laminated three-ply and five-ply jute/glass hybrids composite and compared to the theoretical values. The hand layup method was used for the fabrication of composites. It was observed that the deflection resistance of the hypothetical values of the composite material, particularly for layers 3 (70 %) was much higher than that of layers 5-Taped (2%). The water absorption behavior was also enhanced with hybridization.

Girisha. C et al [7] studied individual fibers (sisal and coconut) reinforced epoxy composites that undergo water-drenching tests to assess the impact of water retention on mechanical properties. The hybrid composite consists of coconut fiber (short fibers) and sisal strands (long fibers), and It was observed that due to the high content of cellulose fibers, the absorption level of dampness as the extended volume division of the fibers was increased. Moreover, the degradation of the composite samples caused by moisture was also observed at high temperatures. The results revealed that the composite water absorption model was found to follow Fickian behavior at average temperature, while the water absorption properties at temperature do not follow the Fick law. Pradhan et al. [8] evaluated the degradation of PLA with untreated wheat and soy straw by using an injection molding process. The composites are prepared with PLA pallets with wheat and soy straws at 190°C to 205°C. It has been noted that the

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composite samples were placed in a mixture of compost and soil, pH tests and moisture were tested. As a result, it has been found that CO2 released from the samples, and the samples were degraded by 70% in 45 days. Takemura et al. [9] evaluated the effect of water absorption in hemp fiber and the result in the mechanical properties and found that with higher content of the fiber the water absorption is high, and in initial days the absorption rate is high, and later after 30 days, the rate starts to be in the stagnant position. Zamri et al.[10] In this study, composites reinforced by pultruded kenaf/glass fiber hybrid (PKGRCs) were subjected to water immersion tests to study their water absorption behavior and on various mechanical properties. The specimens were immersed in distilled water at a temperature of 65 °C for six weeks. The results revealed that flexural and compression properties decreased with increasing water uptake. Joseph et al. [11] studied the thermal and crystallization properties of polypropylene composites improved by short sisal fibers. It was found that, relative to pure polypropylene resin, the thermal stability and crystallinity increased by 14^{o}C and 23%, respectively. The increased thermal and crystallinity resulted from a significant increase in interfacial adhesion between the sisal fiber and the matrix of polypropylene. Ben et al. [12] studied the heat resistant tensile properties on green composite. For that, he selected kenaf fiber and PLA resin. The tensile strength found varying according to the arrangement of the fiber in some found better strength than the matrix alone — the ethanol as a solvent used to wash the fiber. After ethanol treatment, the adhesion between the matrix and reinforcement has improved. Dhawan et al. [13] studied the effect of natural fillers in the green composite to make it more economical for the ever-growing demand. He researched three different filler materials and studied the effect of mechanical characterization. The mechanical properties have increased, and he concluded that coconut coir fillers are the better filler material than any other. Adriana R. Martin et al. [14] analyzed the thermal properties of raw and defatted sisal fibers through the TG and DSC analysis. It was observed TGA showed degradation of cellulose and hemicellulose at lower temperatures than sisal fiber because of lignin removal. Repon et al. [15] examined three types of fabrics such as jute, E-glass, and carbon Kevlar have been selected in this experiment to create composites that use polypropylene (PP) as matrix material. The goal of this analysis was to compare the properties examined, such as tensile modulus (TM), break percentage elongation (EB percent), jute E-modulus (EM), E-glass and carbon Kevlar fabric reinforced polypropylene composite. The results showed that the tensile strength, E-Modulus, and carbon Kevlar composite water absorption are higher than the composites reinforced by the jute and E-glass material. The level of elongation at break has been found in different scenarios. For jute fabric composite, fire retardant strength was found higher than E-glass and carbon Kevlar. Through the comprehensive literature review, the curing temperature has been found to play a vital role in mechanical properties. The present study "Development and analysis of Mechanical characterization of Hybrid Natural Fiber composite" is done based on the knowledge developed after going through the following research literature survey. The literature survey is done on the various parameters through which the mechanical properties of Natural Hybrid composite can be increased and is presented in such an order that it shows how the developments in the corresponding field have taken place. It also shows the recent development, advancement and future scope to enhance the knowledge and thinking of the reader.

2. MATERIALS

This section presents the materials used in the construction of Hybrid Composites. PLA is used as the organic composite matrix material with Natural fiber (jute and sisal) as production reinforcement.

2.1 Jute Fiber

It is readily available and very economical. In the market, there are different types or quality of the fiber is possible, but for convenience, the easily accessible and standard fiber is used. The natural fiber is obtained from the local market. The specimen is shown in fig. 2.1.

Fig. 2.1 Jute Mat

2.2 Sisal Fiber

It is collecting from the leaves of the Agave sisalana plant, which is found in Mexico. The tensile strength of sisal fiber is more as compare to other natural fiber. The sisal fiber is shown in fig. 2.2.

Fig. 2.2 Sisal Fiber

2.3 PLA

Polylactic acid (PLA) as one of the most significant biodegradable polymers that holding potential to replace petroleum-based polymers is used as matrix material. This material comes from renewable resources such as wheat, starch, and sugar cane. To maintain the status of green, the grade of PLA matrix used is 3052D.

Fig. 2.3 PLA

3. METHOD OF FABRICATION

After initial trials, the curing temperature of 30^{0}C, 60^{0}C and 90^{0}C were set at different temperatures up to 110^{0}C, and it was found that there was variation in few mechanical properties such as tensile strength and flexural strength. Hence, it was decided to maintain the maximum curing temperature at 90^{0}C from the observation of trails. Inside the closed die, the curing was performed to examine the influence of curing on different mechanical properties. Depending on the healing time for 10, 15, 20 minutes, the number of trails was set as healing time. This time is the amount of time required to achieve an optimum viscosity or module at a specific temperature for an adhesive to be fully cured for the manufacture of composites to protect against breakage in fiber-matrix bonding.
Preheating of the PLA granules was and fiber materials were carried at 90^{0}C temperature for the term of 3 hours in the hot air oven. After cleaning of the die was carried and the heating temperature was set inside the die. Once the die temperature exceeded the PLA granules were distributed across the die's two halves for composite manufacturing. The granules were spread evenly into the cavity and then caught jute mat put in the cavity over the PLA granules and then weighted sisal fiber over the jute mat layer. Then another layer of jute placed over the sisal fiber, the remaining PLA granules were scattered over the jute fabrics put in the cavity. The temperature is controlled in compliance with the healing and load specifications.

4. MECHANICAL CHARACTERIZATION

4.1 Tensile Strength Test

The tensile test was carried out using ASTM D3039 standard. Computerized Twin Screw UTM unit with a load limit of 1000 kg is used for this purpose. Fig. 4.1 shows the composite sample for tensile testing.

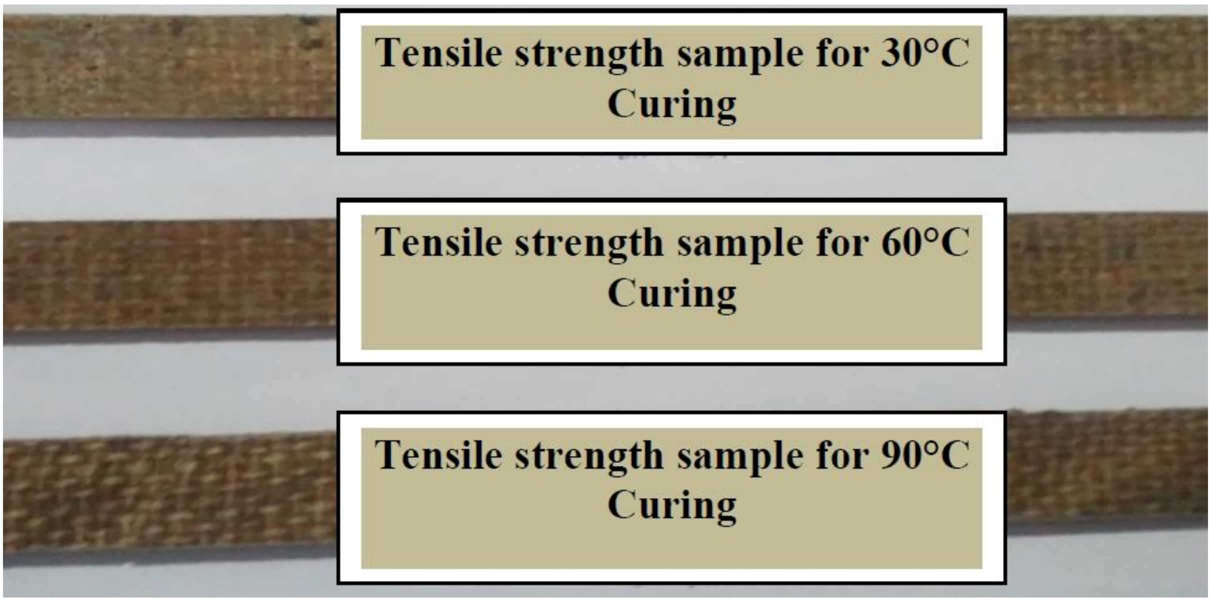

Fig. 4.1 Composite Sample for Tensile Testing

4.2 The Flexural Test

As demonstrated by the ASTM standard D790-02, flexural testing is also performed on the corresponding UTM unit. It's a bowing test of three dimensions. The bending test size is 120x15x4 mm according to the ASTM standard. Fig. 4.2 shows the composite sample after flexural testing.

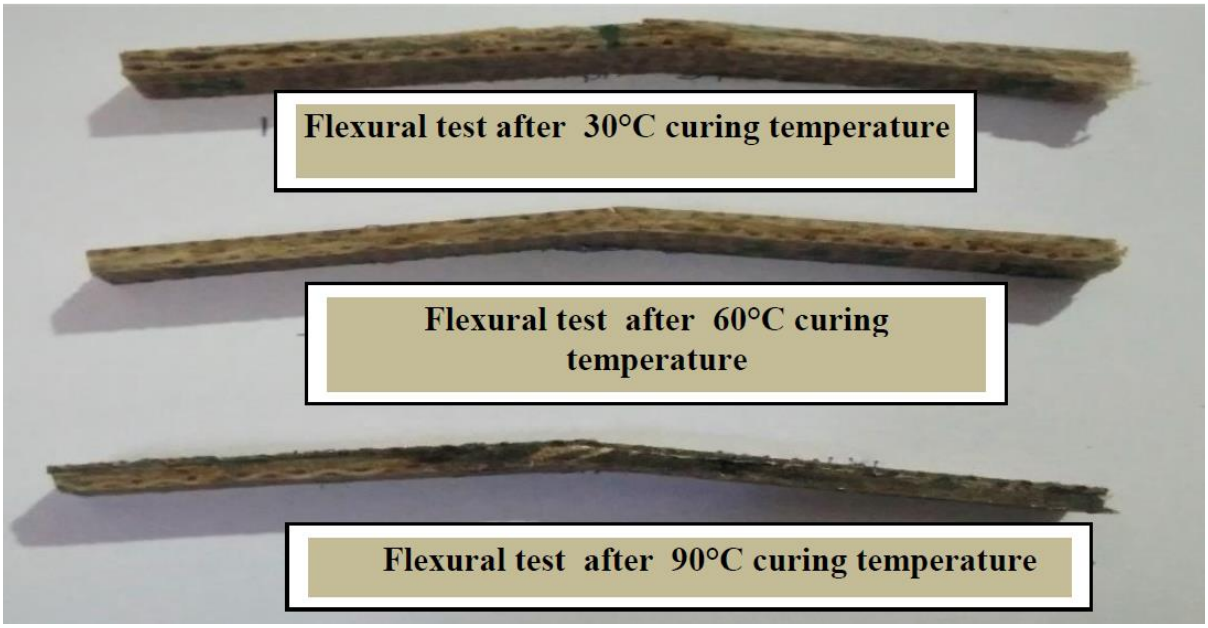

Fig. 4.2 Composite Sample after Flexural Testing

RESULT AND DISCUSSION

Hybrid composite of Sisal and jute were fabricated using PLA as resin as per ASTM standards the fabrication temperature was 160°C, 170°C, 180°C and 190°C while the curing of samples was carried at 30°C, 60°C and 90°C. From the experimental results, it is found that accumulation of sisal in jute. Tensile properties of sisal observed to be improved the tensile strength of composite. The maximum tensile strength of 88.56 MPa at a curing temperature of 30^0C with duration of 15 minutes is observed. Results show the significant effect of various curing temperatures on the tensile strength of hybrid composite made up of jute and sisal at 30^0C, 60^0C, 90^0C respectively.

The melting temperature of PLA is 160^0C at this temperature the PLA starts flowing between the reinforcements and when to die is cooled for there may be some chances that some voids are left due to which the adhesion is not maintained and fiber pull out can take placed which can decrease the tensile strength of the fabricated composite. So when curing was carried for at various temperatures 30°C, 60°C, 90^0C. At 90°C die is still hot and when material is taken out from the die still there is no uniform distribution of the PLA due to which tensile strength comes out to be 65.77 MPa and for 60^0C it comes out to be 70.65 MPa. While for flexural strength, it was observed that maximum flexural strength was recorded at 99.538 MPa at 30^0C curing temperature for hybrid composites. For the improved flexural strength, the between the fiber and PLA should be strong. The melting temperature of PLA is 160^0C at this temperature the PLA starts flowing between the reinforcements and when to die is cooled for there may be some chances that some voids as shown in Fig. 5A are left due to which the adhesion is not maintained and fiber pull out can take place which can decrease the tensile strength of the fabricated composite. So when curing was carried for at different temperatures 30°C, 60°C, 90°C at 90^0C die is still hot and when material is taken out from the die, even there is no uniform distribution of the PLA due to which tensile strength comes out to be 75.774 MPa and for 60°C it comes out to be 86.697 MPa.

CONCLUSION

The present work can be concluded with a note influence of curing temperature on the mechanical properties of green composites with polylactic acid as matrix material and natural fibers as reinforcement using compression molding process. It can be concluded that the addition of jute and sisal fibers would enhance tensile and flexural strengths. It can also concluded that a tensile strength of 88.43 MPa can be achieved with Heating temperature of 165°C and curing temperature of 30°C which is due to the excellent adhesion of PLA with fibers as shown in Fig. 5B.

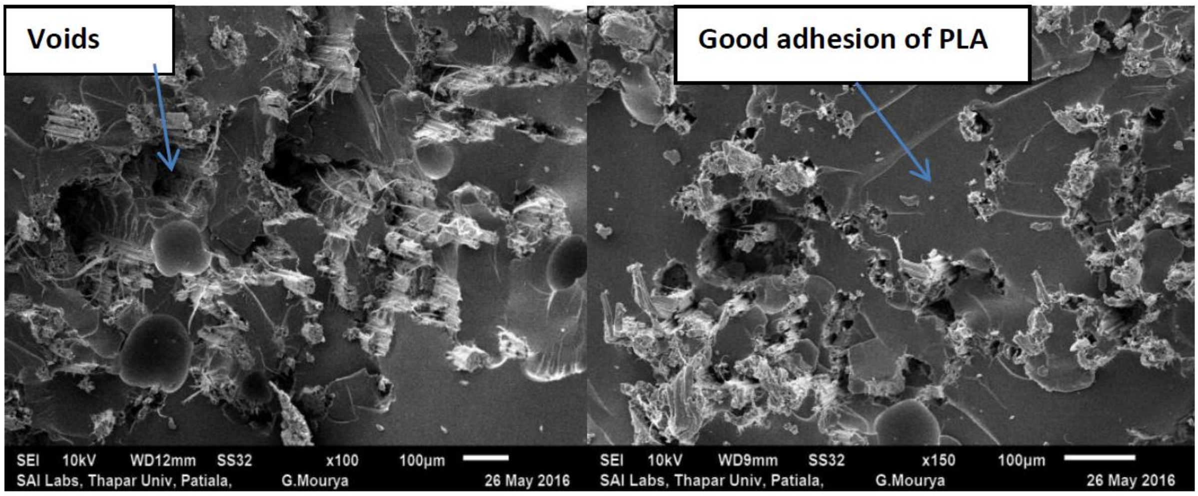

Fig.6 (A) SEM Image Before Curing **(B)** SEM Image After Curing

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