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THERMAL AND MACHINABILITY BEHAVIORS OF UNCOATED AND NI-P COATED SISAL FIBER REINFORCED EPOXY COMPOSITES

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ABSTRACT

The natural fiber reinforced polymers have been successfully used in applications such as automobiles, constructions, infrastructure and other Industries because of its low cost, acceptable strength and stiffness, low weight and ease of degradable. The thermal, dimensional stability and machinability behaviours are generally studied in order to propose the application of composites. The thermal characteristics such as weight loss due to temperature and phase transition were studies for sisal-epoxy composites in the present investigation. The water, oil and chemical absorption characteristics were studied for coated and coated fiber reinforcements in composites. Drilling is a metal removal process and is important for the application of products during assembly. The present investigation is focused on the study of influence of drilling parameters such as spindle speed, feed rate on drilling characteristics such as thrust force, torque and delamination factor on uncoated and coated sisal fiber reinforced epoxy composites. The HSS twist drills were used and drilling test was carried out using MAXMILL CNC drilling machine. From the experimental observations, the drilling characteristics for various drill bits for the uncoated and coated sisal-epoxy composites were listed.

Keywords: *Sisal, Epoxy,TGA,DSC,Thrust force, Torque, Delamination factor, Ni-P coating.*

1. Introduction

The natural fiber composites and their applications are emerging now a days, The research on natural fibers and their possibility in polymer composites was initiated by Sathyanarayana et. Al [1]. The natural fibers for replacing synthetic fibers were suggested by Mallick PK [2]. The effects of the drilling parameters, speed, and feed rate on the cutting forces and torques in drilling of chopped composites with different fiber volume fractions investigated by Khashaba et al [3]. The effect of tool material and geometry, machining parameters and their influence on the thrust force and torque during drilling of fiber-reinforced plastics was studied by Abrao et al [4]. The mathematical model to estimate thrust force and torque during drilling of carbon fiber composites was developed by Marta Fernandes et al [5]. The drilling forces using cutting speed, feed rate and the drill point geometry as the input process parameters in drilling process of sisal fiber reinforced thermoplastic bio-composites was evaluated by Bajpai et al [6]. The drilling of coir-polyester composites evaluated by Jayabal et al [7]. sisal-vinyl ester composites performed by Velumani et al [8]. The Zea-polyester composites performed by Balaji et al [9] paved a platform for the study of machinability characteristics of natural fiber-polymer composites. Based on the literature review, the present investigation is focused on the evaluation of thermal, dimensional stability and drilling behaviors of uncoated and coated sisal fiber reinforced epoxy matrix composites.

2. Experimental Procedure

2.1 Materials

The short sisal fiber ranged from 10 mm to 70 mm was selected as reinforcement material. The five

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different fiber lengths were obtained by cutting fiber bundles using sawing machine. The epoxy resin was selected as matrix material for this study because of its availability and strength as compared to polyester and vinyl ester. The experimental set up to coat the natural fiber with Electroless Nickel Phosphorus (ENi-P) was discussed in the previous works by Hemachandran et al [10,11]. The polymerization reaction is used to transform the liquid resin to the solid by adding small amounts of a reactive curing agent namely amine based hardener (HY 951) for the preparation of composites with a mixing ratio of 10:1 recommended by the supplier.

2.2. Manufacturing and mechanical testing

As per full factorial Design of experiments, 25 sisal-epoxy composite plates were fabricated for the five levels of fiber length and five levels of fiber content. A stainless steel mould having size of 300 × 300 × 3 mm was used for composite plate fabrication using compression molding process. The composite plates were kept under the load of 2.6 MPa for 30 minutes to get uniform curing at room temperature. The tensile and flexural properties of sisal-epoxy composites were measured using the H10KL Tinius Olsen make Dual Column Table Top Universal Testing Machine. The izod impact test was performed using 104 impact tester as per ASTM standards. The uncoated and coated sisal-epoxy composites which exhibited better value of tensile, flexural and impact properties was selected for studying the thermal, dimensional stability and machinability characteristics.

2.3 Thermal studies

Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. Several methods are commonly used for analysis are

- Thermo Gravimetric Analysis (TGA)
- Differential Thermal Analysis (DTA)
- Differential Scanning Calorimetry (DSC)

TGA (Thermo Gravimetric Analysis) measures the weight loss or gain as a function of temperature. TGA can be used to measure the fibre content of composites by heating a sample to remove the resin by application of heat and then determining the mass remaining. TGA and DTA grams of fiber reinforced particles are obtained from 25^0C to 900^0C at heating rate of 10^0C/min purged in the atmospheric air of 20 ml/min.

DSC (Differential Scanning Calorimetry) is also a thermo analytical technique.In which the difference in the amount of heat required to increase the temperature of a sample and reference is measured as a function of temperature.DSC measures the amount of energy absorbed or released by a sample when it is heated or cooled, providing quantitative and qualitative data on endothermic (heat absorption) and exothermic (heat evolution) processes. Differential scanning calorimetry can be used to measure a number of characteristic properties of a sample. The photographic image of STA 6000 machine is shown in Figure 1.The thermal behaviour of composites were determined using STA 600 Perkin–Elmer Simultaneous Thermal Analyzer (A.C. Government College of Engineering and Technology, Karaikudi, India) by applying different cycles of heating and cooling.

Figure 1. Photographic image of TGA/DSC instrument.

2.4 Dimensional stability studies

The water absorption properties of uncoated and coated sisal-epoxy composites were determined according to ASTM 570-10 standard with the specimen dimensions of 75 × 25 × 3 mm. The specimens from each type of composition were taken and dried in an oven for 24 h at a temperature of 60°C and submerged in distilled water at room temperature for about 24 hrs. The weight differences between dried and submerged samples were measured at regular time intervals using a high precision weight balance. The chemical stability of composites was determined as per ASTM D 543-06 with specimen dimension of 10 × 5 × 3 mm by dipping in the Hydrochloric acid for the period of 24 hrs.

2.5 Drilling of composites

Drilling of composite plates was carried out using CNC vertical milling machine (Make: MTAB &Model: MAXMILL). The 6 mm, 8 mm and 10 mm HSS twist drills were used in the experiment to study the influence of spindle speed and feed rate on the thrust force, torque and delamination factor (Figure 2).

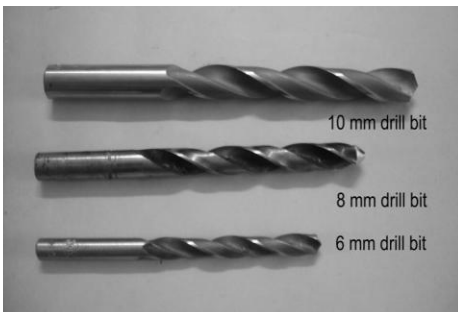


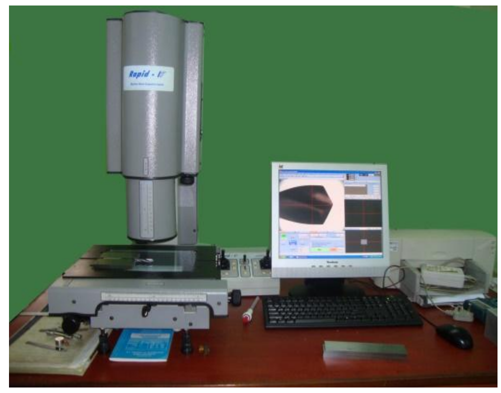
Figure 2.Photographic image of drill bits

The thrust force and torque was measured using piezo electric drill tool dynamometer (Make: Kistler). During the drilling operations, the thrust force and torque were recorded with the help of drill tool dynamometer and processed using a data acquisition system (Figure 3a).A Rapid I machine vision system was used to measure the tool wear(Figure 3b). Using the graphical suite available in Rapid-I, the drafting of drill bit profile was created by drawing using CAD package**.** Differences between the two profiles (before drill and after drill) were estimated with the on-screen digital micrometer tool to estimate tool wear. The images of drilled holes are captured using machine vision system and the delamination factor was also determined using the following formula

$$F_d = \frac{D_{max}}{D_o}$$

Where, Dmax is the maximum diameter of the damaged hole and Do is the diameter of hole.

(a)



(b)

Figure 3. Photographic image of (a) Drilling set up and (b) Machine vision system

The Photographic image of drilled sisal-epoxy composites are shown in Figure 4. 27 holes were made in each case of uncoated and coated sisal-epoxy composites. The thrust force and torque were recorded at entry of drill, middle and exit of drill in the composites and the average values were reported.

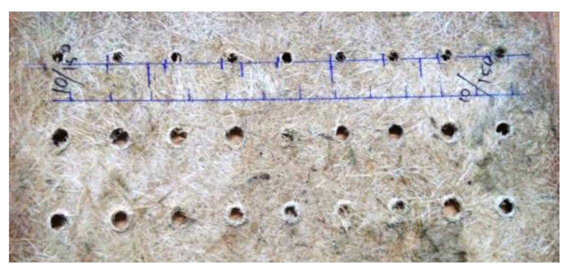


Figure 4. Photographic image of drilled sisal-epoxy composites

3. Results and discussion

3.1.Thermal Studies of composites

A collection of methods that measure the property of a material as a function of temperature is called thermal analysis. Thermogravimetry curve is indicated in blue colour for decomposition, volatilization and oxidation. After the peak temperature, the material tends to decompose. Finally, only the carbon is presented in the pan of the instrument.The STA curve for uncoated sisal fiber reinforced epoxy composites shown in Figure.5 indicated that at temperature above 420^{o}C, the major weight loss occurs correspondingly phase transition was obtained. In Figure.6 the thermal degradation occurs at 500^{o}C and the peak value thus obtained is at 560^{o}C. Thus Ni-P coated sisal fiber reinforced epoxy composites provided better result in thermal testing. The thermal studies are used for the selection of composites when it is exposed to the medium temperature applications.

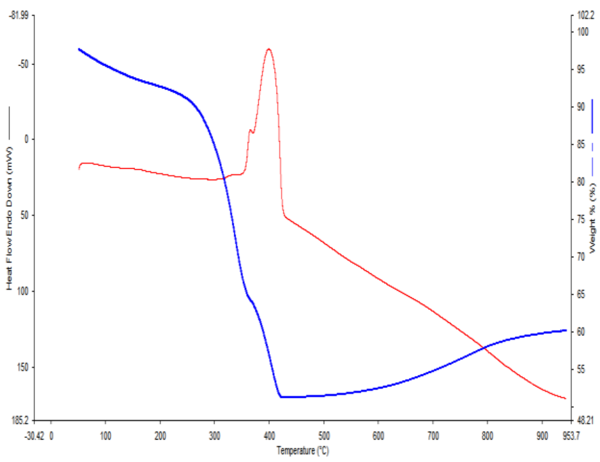


Figure 5. STA curves of uncoated sisal fiber reinforced epoxy composites.

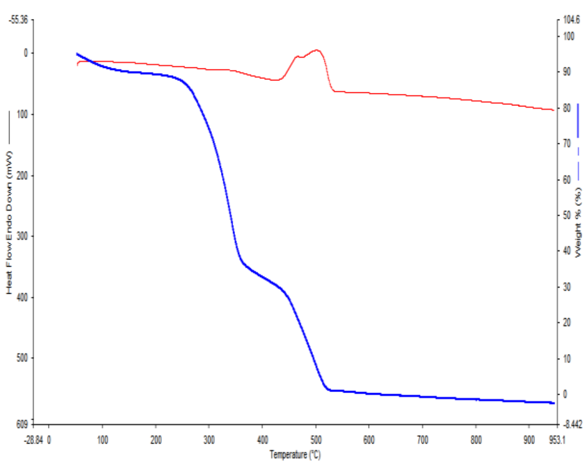


Figure 6. STA curves of Ni-P coated sisal fiber reinforced epoxy composites.

3.2.Dimensional stabilty of composites

The water absortption rate of 4.2 %, oil absorption rate of 3.7 % and chemical absorption rate of 0.8 % were obtained in uncoated sisal-epoxy composites.The Ni-P coated sisal fiber reinforced epoxy composites exhibited lower water,oil and chemical absorption rate of 2.8%, 1.9 % and 0.4 % respectively.

3.3 Machinability studies of composites

The Thrust force values for 6 mm , 8 mm and 10 mm drill tests in uncoated and coated sisal-epoxy composites are shown in Figure 7.The thrust force values ranged from 22 N to 65 N were obtaind in coated sisal –epoxy composites when drilled using 6 mm HSS twit drills. Subsequently, 39 N to 110 N and 42 N to 142 N were obtained in 8 mm and 10 mm drill tets respectively.

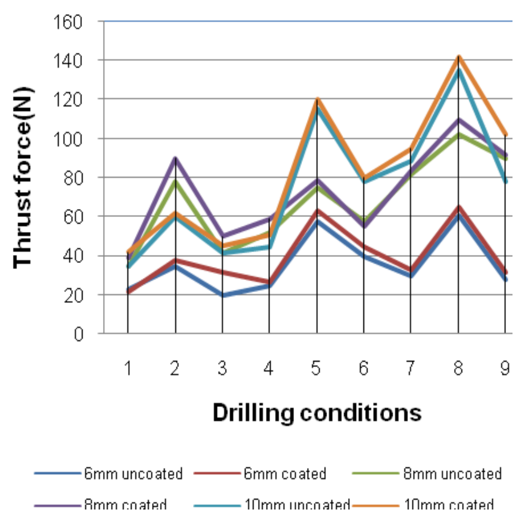


Figure 7. Thrust force values in drilling of sisal-epoxy composites.

The torque values for 6 mm , 8 mm and 10 mm drill tests in uncoated and coated sisal-epoxy composites are shown in Figure 8.The maximum torque values of 3.74 Nm and 3.9 Nm were obtained during drilling of uncoated and coated sisal fiber reinforced epoxy composites using 6 mm drill bits. The maximumtorque values of 4.36 Nm and 4.67 Nm were obtained during drilling of uncoated and coated sisal fiber reinforced epoxy composites using 8 mm drill bits. The maximum torque values of 5.78 Nm and 5.92 Nm were obtained during drilling of uncoated and coated sisal fiber reinforced epoxy composites using 10 mm drill bits.

The delamination factor values for 6 mm , 8 mm and 10 mm drill tests in uncoated and coated sisal-epoxy composites are shown in Figure 9.The delamination factor ranged from 1.022 to 1.102 was obtained during drilling of uncoated sisal fiber reinforced epoxy composites using 6 mm drill bits.The 10 mm drill bits produced low delamination factor ranged from 1.021 to 1.054 in coated sisal fiber reinforced epoxy composites.

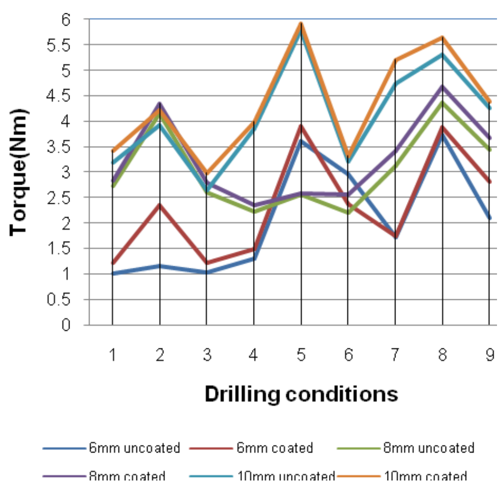


Figure 8. Torque values in drilling of sisal-epoxy composites.

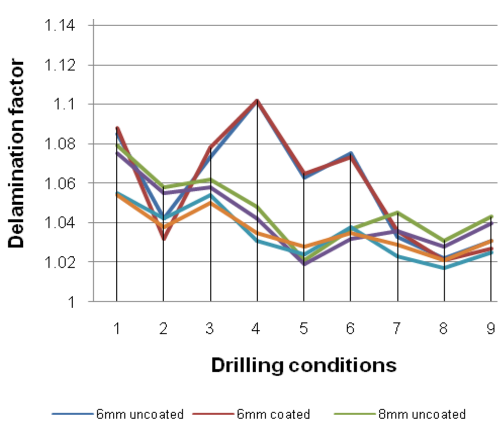


Figure.9 Delamination factor values in drilling of sisal-epoxy composites.

4. Conclusions

The peak temperature in uncoated and coated sisal fiber reinforced epoxy composites were observed using TGA/DSC plots. The lower values of water ,oil and chemical absorption rate were obtained in coated sisal-epoxy composites as compared with uncoated sisal fiber reinforced epoxy composites. The drill tests were conducted using 6mm, 8 mm and 10 mm HSS twist drills in uncoated and coated sisal epoxy composites. The thrust force ranged from 22 N to 142 N was obtained in sisal-epoxy composites. The torque values ranged from 1 Nm to 5.92 Nm was obtained in sisal-epoxy composites. The delamination factor ranged from 1.017 to 1.102 was obtained in sisal-epoxy composites. The surface roughness (R_a) obtained from this investigation ranged from 1.104 to 1.635 µm.

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