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PREPARATION, PROPERTIES AND MACHINABILITY STUDY OF GROUNDNUT SHELL-BROOM FIBRE-REINFORCED EPOXY COMPOSITE

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Abstract. The need for eco-friendly materials and non-polluting processing techniques has made natural fibre reinforced polymer composites potential candidates to replace GFRPs and CFRPs in semi structural applications. Ground nutshell and broom fibre (fibre strands extracted from broom grass) are easily available in market at low cost. Polymer composites consisting of 30% and 40% volume fractions of a hybrid reinforcement containing groundnut shell and broom fibre in epoxy resin were fabricated by compression moulding. The mechanical characterization of these composites was carried out by standard tensile, compressive and flexural tests in a Universal Testing Machine with appropriate set-up. The machinability study was performed by drilling experiments using a CNC drilling machine with drill tool dynamometer. Two input parameters, cutting speed and feed rate and the one output parameter, thrust force, were used for drilling process. TiAlN coated solid carbide and HSS drills were employed in the drilling experiments and a comparative study was made based on the output parameters. Solid carbide resulted in lower thrust force values and feed rate proved to be the most influential parameter on thrust force.

Keywords: Natural fibre, compression moulding, Solid carbide tool, Drilling

1 Introduction

Recently, the research attempts in natural fibre reinforced polymer composites have greatly increased. Natural fibre reinforced polymer composites involve simple processing techniques, easily procurable raw materials and relatively high biodegradability levels among all the engineering materials. Apart from researchers, manufacturers have also shown increased interest in natural fibre composites from the past decade. To substantiate this claim, the increased in use of the natural fibres in German cars from around 10000 tonnes in the year of 2000 to 19000 tonnes in 2005 could be mentioned [1]. Hemp, sisal, kenaf, and bamboo are the natural fillers which have undergone many evaluation procedures and declared fit for a good number of applications. The mechanical properties of natural fibers and the composites developed by incorporating them in different polymer matrices and various processing techniques for fabricating them have been studied by many researchers [2–4].Groundnut shell is highly rigid, non-edible portion of groundnut and is usually discarded which makes it easily procurable. Broom fibre, which is in the form of thin, long and flexible strands, is also an economic material which is commercially sold in large quantities. Consequently, a combination of these two fillers could presumably account for a suitable reinforcement phase for an epoxy matrix.

The evaluation of preparation techniques is a vital part in the research regarding composite materials. Wet hand layup is the widely used technique for manufacturing polymer composites, mainly because of its simplicity and cost effectiveness [5]. Additionally, compression moulding of the layup, aids in elimination of the air bubbles present in the resin which reduces the porosity of the composite.

Drilling is the most important machining operation performed in fibre reinforced composites for joining in assembly operations. At present, conventional drilling involves material removal by contact with a rotating metallic drill tool (mostly twist drill) is the widely used drilling process because of its simplicity and low cost involved. A lot of research on drilling of fibre reinforced composites (FRPs) has been carried out in the past. Experiments were conducted as early as 1985 to study the effect of feed rate on drilling of FRPs. In one of those early experiments, the results revealed that high feed rates resulted in crack formation around the exit edge of the hole [6]. The influence of various parameters on peel-up and push-out delaminations was analysed. The results indicated that increase of the fiber volume fraction increases the thrust force which in turn leads to increase in delamination [7]. The study of material removal mechanism established that the cutting process in epoxy composites is entirely based on fracture mechanics, unlike shearing in case of metals [8]. Mihai-Bogdan Lazar et al., performed an experimental analysis to determine the cutting load distribution along the work-piece thickness and tool radius by analyzing the thrust and torque curves in drilling of carbon-fiber) and glass-fiber reinforced composite plates. The highest loads were found at the tool tip in the vicinity of the chisel edge (in case of a twist drill) and it was recommended that a smaller chisel edge could result in lower delamination [9]. A very few research attempts were made to study the drilling characteristics of natural fibre reinforced polymer composites. The effects of drilling parameters on delamination of hemp fiber reinforced composites were studied to find out conditions for minimum delamination using Taguchi and ANOVA methods [10]. The drilling characteristics of sisal/GFRP hybrid composite was studied by employing drills made of different materials among which solid carbide proved to be the best tool material as it resulted in the lowest thrust force values [11]. In an attempt to study the delamination characteristics of bamboo-polyester composite it was observed that low diameter of drills and low feed resulted in low delamination and better hole quality [12].

In this research work, broom fibre-groundnut shell reinforced epoxy composites were fabricated by hand layup followed compression moulding and the mechanical characterization was carried out by standard tensile, compressive, flexural and impact tests. Machinability was evaluated by a study of drilling process parameters. Input parameters, cutting speed and feed rate and an output parameter thrust force were employed to study the drilling process. The tool and input parameter value selection were done based on the literature stated above.

2 Experimental procedure

Materials

The raw materials used for manufacturing the composites were epoxy LY 556 resin long with hardener HY 951, broom grass fiber, ground-nut shell and mansion wax. Broom grass fibers with Ground-nut shell fiber composite.

Fabrication Process

The ground nut shells were broken into small pieces and thin strands of fibre were extracted from a household broomstick. These two natural fillers were subjected to alkaline treatment by immersing in NaOH for 12 hours and then washed using distilled water. This chemical treatment was carried out to enhance the fibre-matrix adhesion which can improve the mechanical properties of the composite. Then, two hand layups, each containing 30% and 40% of these fibbers by volume were made in a compression mould made up of GI (gauge 25) sheet of dimension 300x300x3mm. The specimens were prepared in varying fibre volume fractions 30% and 40%. Later the specimens were cut from the prepared casting.

Mechanical characterization

The tensile and compressive property values of composite samples (ASTM D 3039/D 3039M) were determined using a Universal Testing Machine (Instron 3369).Test samples were prepared as per ASTM standard EN ISO 14125 (1998) to determine flexural property using three-point bending. The standard charpy impact test was used to determine the impact strength.

Machining

Rectangular plates of these materials measuring 5mm in thickness were prepared for drilling. A HSS twist drill of point angle 118 and diameter 5 mm, which is a commonly used inexpensive drill and a TiAlN coated solid carbide twist drill (CWC) of point angle 140 and diameter 5 mm were employed for the drilling operation. The laminate was sandwiched between the front and back plates of the machining fixture. The high speed drilling tests were conducted on a having spindle speed of 60-5000rpm and maximum feed rate of 4000mm/min. Machining tests were conducted under dry conditions and the cutting forces were recorded using a Kistler Quartz 3-Component dynamometer (type9257B).

Process parameters

The combinations of input process parameters cutting speed and feed rate were formed. Plan of experiments is shown in Table 1.

Table 1. Plan of experiment

R.No	Feed rate (mm/rev)	Spindle speed (rpm)
1	0.05	900
2	0.05	1500
3	0.05	2100
4	0.20	900
5	0.20	1500
6	0.20	2100
7	0.35	900
8	0.35	1500
9	0.35	2100

3 Results and discussion

Mechanical Properties

The variation of tensile strength of the composite relative to the fibre content is shown in Figure 1. Five specimens are tested for mechanical properties and average values were reported. The tensile strength is seen to vary from 15.09 MPa to 18.91 MPa.

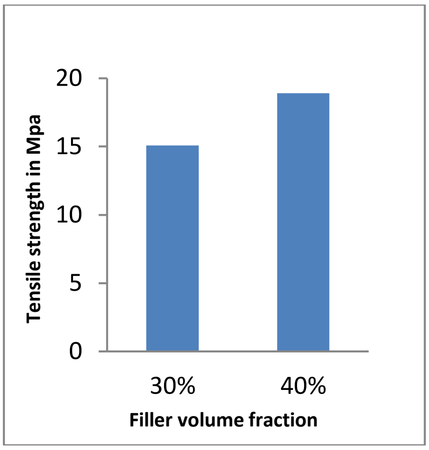


Fig.1. Tensile strength

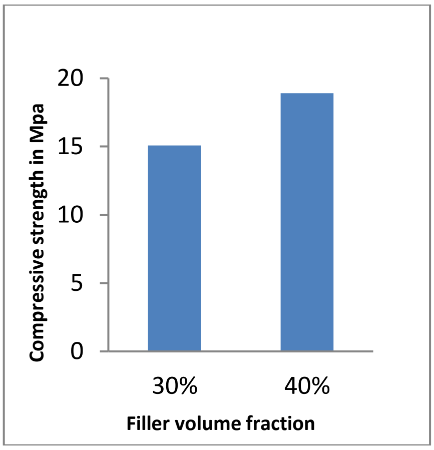


Fig.2. Compressive strength

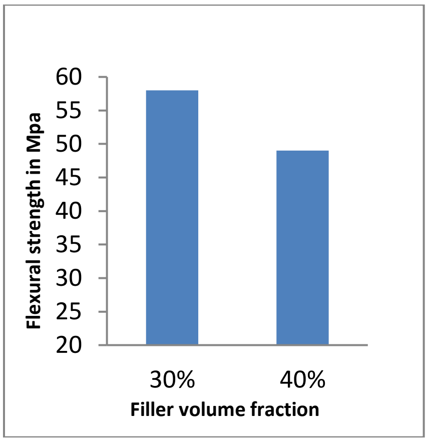


Fig.3. Flexural strength

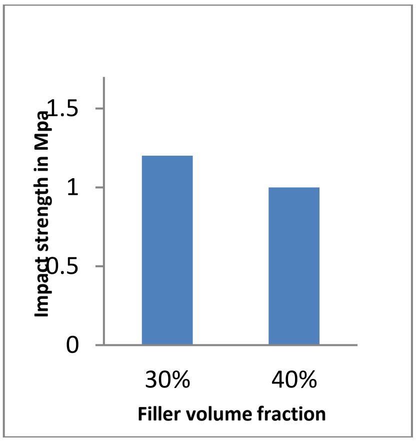


Fig.4. Impact strength

The variation of Compressive strength of the composites with 30% and 40% volume fractions are as shown in Figure 2.

The flexural strength (given in fig 3) shows a different trend compared to the tensile and compressive strengths. It is to be noted that the groundnut shell reinforcement in this composite comprises of discontinuous random pieces which paves way for non-uniform stress distribution and hence poor resistance to bending. This could be the reason for the decrease in flexural strength with increasing fibre volume percentage. The impact strength is low for both the samples.

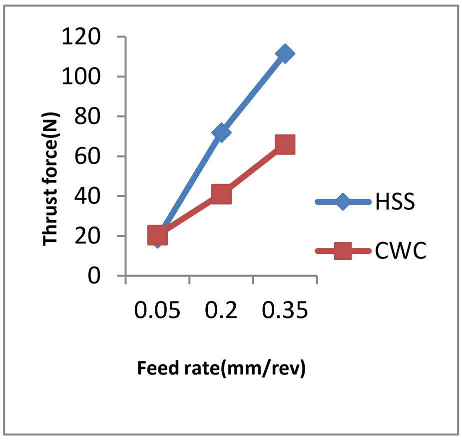
Machining performance

The thrust force was recorded using the drill tool dynamometer, as presented in Table 2.

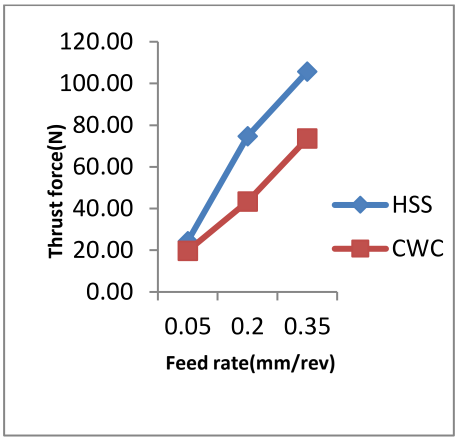
Table 2. Thrust force values of the drilled composite

R.No	Feed rate (mm/rev)	Spindle speed (rpm)	Thrust force (N)	
			HSS	CWC
1	0.05	900	18.89	20.45

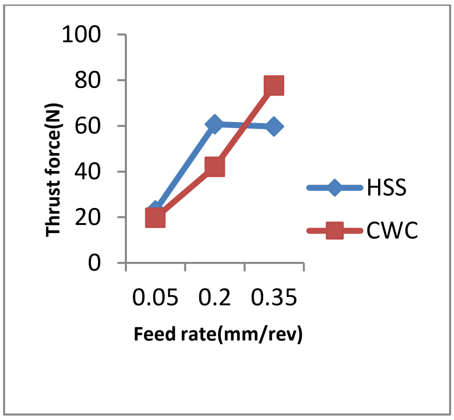
2	0.05	1500	24.37	19.73
3	0.05	2100	23.04	19.82
4	0.20	900	71.84	40.94
5	0.20	1500	74.76	43.38
6	0.20	2100	60.69	42.00
7	0.35	900	111.5	65.98
8	0.35	1500	105.7	73.57
9	0.35	2100	59.63	77.61



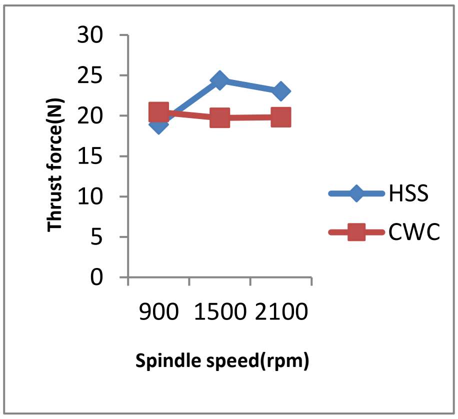
(a) At 900rpm



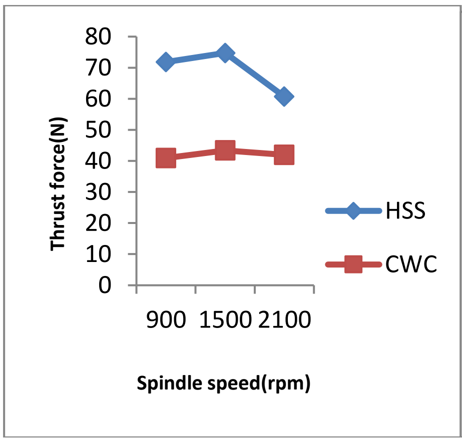
(b)At 1500rpm



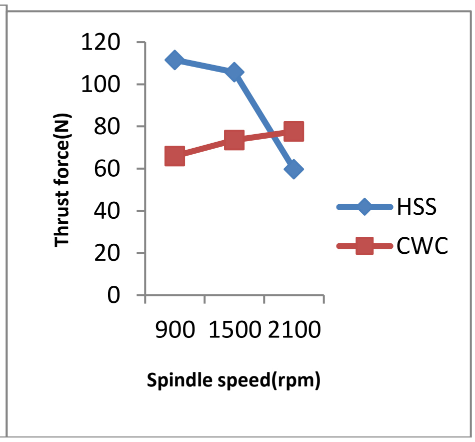
(c) At 2100rpm



(d) At 0.05 mm/rev



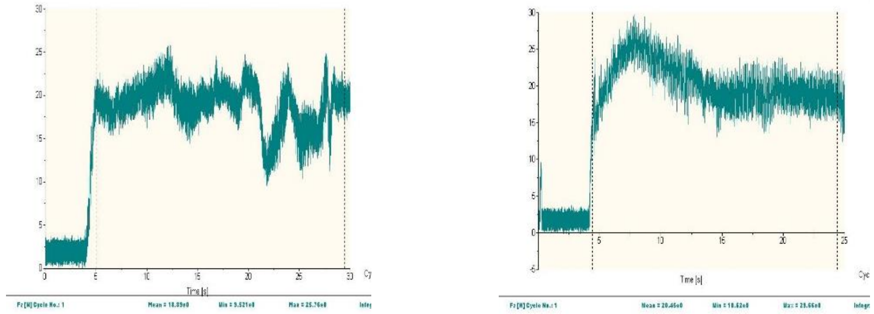
(e) At 0.20 mm/rev



(f) At 0.35 mm/rev

Fig.5. (a),(b),(c)-Thrust force vs feed rate (d),(e),(f)-Thrust force vs spindle speed

From the graphs presented in fig.5, it is very clear that feed rate is the most influential parameter than spindle speed. In most of the cases, the CWC drill has resulted in lower thrust force values. Exceptionally, the HSS drill has recorded thrust force values lower than the solid carbide drill for the highest feed and spindle speeds (graphs c and f). The TiAlN coated solid carbide drill tool seems to be the best for drilling at normal speeds and feeds. In the thrust force vs time signals shown below, a sudden increase in the thrust force is observed in a time close to 5 seconds. This trend is similar for all the input parameter combinations. The reason for this sudden increase could be the transition of the chisel edge from a layer of resin matrix to the reinforcement layer.



(a) (b)

Fig.6. Thrust force(N) vs time(s)(a-HSS drill, b-Solid carbide drill)

Fig.7. Drilled composite

5 Conclusion

The hybrid natural fibre composites were fabricated and characterized successfully. The feasibility of drilling the composite by conventionally used twist drills has been established. There are good chances of optimal drilling(with low thrust force values) at feed rates upto 0.35mm/rev. Feed rate has proved to be the most influential parameter on the thrust force, than spindle speed.

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