Machinability Study of Column Cactus Fiber Reinforced Polymer Composite Materials

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Abstract - *In the recent years with superior importance on the environmental aspects of engineering materials throughout the world has developed an interest in natural fibers and its applications in various fields. Some researchers have developed the natural fiber reinforced polymer composite materials using various natural fibers, but application of composite material require secondary operations for various applications. The present work focus on the turning operation in lathe machine, analysis the cutting force for varying the speed and depth of cut. The lathe tool dynamometer is used for measuring the cutting force of the composite materials. The Column Cactus fiber reinforced composite materials are fabricated by hand lay-up method for different volume fraction (20, 25 and 30 % Vf). Tensile, Flexural and Impact test were analysed as per ASTM standards. The highest cutting force and mechanical properties were founded in 25% volume fraction materials.*

Keywords: Column Cactus fiber, Cutting Force, Mechanical Properties, Volume fraction and Dynamometer

1. INTRODUCTION

Over a past few decades composites, ceramics and plastics have been the prevailing engineering materials. The areas of applications of composite materials have developed speedily and have even found new arcades. Modern day composite materials consist of many materials in day to day use and also being used in erudite applications while composites have already proven their worth as weight saving materials the present challenge is to make them strong in tough situations to replace other materials and also to make them cost effective. This has resulted in development of many new techniques currently being used in the industry. The composite industry has begun to recognize the various applications in industry mainly in the transportation sector. New polymer resin matrix materials and high concert fibers of carbon, glass and aramid which have been introduced recently have resulted in stable development in uses and volume of composites [1].

This increase has resulted in noticeable reduction of cost. High performance FRP (Fiber Reinforced Polymer) are also found in many various applications such as composite armoring design to struggle the impact of detonations, industrial shafts, wind mill blades, and fuel cylinders for natural gas vehicles paper making rollers and even support beams of bridges. Existing structures that have to be retrofitted to make them seismic resistant or to repair damage caused by seismic activity are also done with help of composite materials [2&3].

Investigated the mechanical properties of randomly oriented coir composites mixed with epoxy resin and finished suggestions for low-load presentations. They evaluated only the limited mechanical properties such as tensile strength, flexural strength and impact strength, and their work was restricted from the machinability point of view [4].

Discussed about the Natural fiber composite materials is one such capable material which replaces the synthetic materials for the real-world applications where we need less weight and energy conservation. The importance of the freshly identified snake grass fibers which are extracted from snake grass plants by physical process. The tensile properties of the snake grass fiber are studied and compared with the conventionally available other natural fibers. The experimental evidence also shows that the volume fraction increases the tensile and flexural strength of the snake grass fiber reinforced isophthallic polyester composite [5].

Investigated the effect of machining parameters on the surface roughness and tool wear when turning 10% SiCp/Al composites. Results indicated that higher cutting speeds result in relatively better surface finish, but resulting in increased flank wear [6].

Developed a mathematical model to predict surface roughness and tool wear in their work in order to study the main and interaction effects of machining parameters by regression analysis and ANOVA technology and suggested the best procedure for modeling and optimization of process parameter [7].

Many types of natural fibers have been investigated for their use in polymer such as Wood fiber [8], Sisal fiber [9], Kenaf fiber [10] and Pineapple fiber [11] are investigated the mechanical properties of the fiber composite materials and their uses.

Flax composites are developed and their mechanical properties are estimated. These results designate that coir can be used as a prospective reinforcing material for making less load bearing polyester composites [12].

Investigated the tensile properties of polyester matrix composites incorporated with the coir fibers. Tensile specimens composite with up to 40% in volume of long and associated coir fibers were tested and their fracture analyzed by scanning electron microscopy. A comparatively improvement was established in the tensile properties for the amount of 40% VF of coir fiber [13].

Analyzed the mechanical and machinability features of coir fiber using Taguchi method. A drill bit diameter of 6 mm, spindle speed of 600 rpm and feed rate of 0·3 mm/rev gave the minimum value of thrust force; torque and tool wear in drilling analysis. The coir fiber reinforced polymer composites showed the tensile, flexural and impact strength of 16 MPa, 29 MPa and 46 J/m, respectively [14].

Acacia Arabica and Pencil Cactus fibers reinforced polymers composites are prepared by hand lay-up method. The dielectric constant, loss factor, dissipation factor and electrical conductivity are analysed by varying the frequency for treated and untreated fiber composite specimens. The properties are high in low frequency and less in high frequency. So the above composite materials are used as the electrical insulated materials [15].

In this study, Column Cactus fibers are identified that is accessible all over the world particularly in Asian countries. The fibers are reinforced with unsaturated polyester resin and investigated the mechanical properties and machinability.

2. MATERIALS AND METHODS

2.1 Cactus Fiber

The Column Cactus cellulose fibers were extracted from stems of the Column Cactus plant. The stems are cut and retted in water for ten days. After retting, the fibers are washed in water and dried in oven to remove the moisture. The Column Cactus plants are shown in Figure 1.

Fig-1: Column Cactus plant

2.2 Fabrication of Composite Specimen

The Column Cactus fibers were cut to the required 5mm length. The Column Cactus fiber reinforced composite materials are fabricated by hand lay-up method with different volume fraction of 20, 25 and 30 % Vf. The composite specimens are cut as per ASTM standards. The unsaturated polyester resin with accelerator and catalyst was used to prepare the Column Cactus fiber composite specimens.

2.3 Mechanical Properties

The Tensile, Flexural, Impact strength test are carried out in this work for different volume fraction of 20%, 25% and 30% Vf. And then the work focus on the turning operation (machinability test) in lathe machine, analysis the cutting force for varying the speed and depth of cut for different volume fraction. The lathe tool dynamometer is used to measuring the cutting force of the Column Cactus fiber composite materials. The Figure 2. Shows the cutting force analysis in lathe machine and lathe tool dynamometer.

Fig-2: Cutting force analysis in lathe machine and lathe tool dynamometer.

3 RESULT AND DISCUSSION

3.1 Tensile test

Tensile tests were conducted for the composite specimen using the universal testing machine to obtain the tensile properties. The dog-bone specimens of the composite were prepared according to the ASTM D638 standards. Comparing the tensile test of Column Cactus fibers with the volume fraction at the range of 20%, 25%and 30% were identified.

Figure 3 shows the effect of tensile strength with different volume fraction of Column Cactus fiber composite. The tensile strength of Colum Cactus fiber with 20% Vf is lesser than the 30% Vf. Where the tensile strength of Colum Cactus fiber with 20% Vf is 9.751 N/mm^2 and 30% Vf is 12.28N/mm^2. The tensile strength is 15.16 N/mm^2 for 25% Vf which is higher than the other volume fraction.

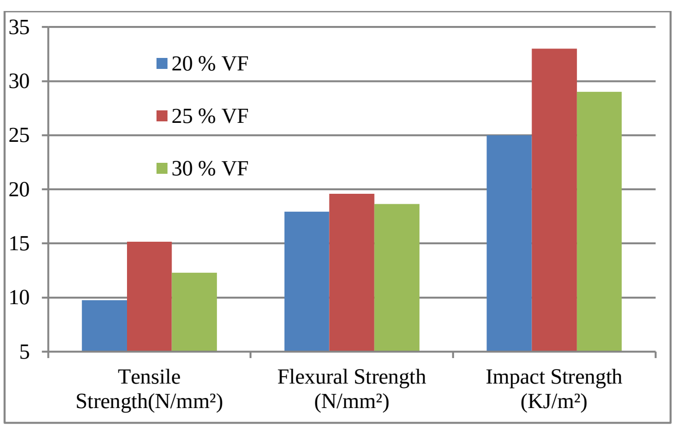

Fig-3: Effect of Tensile, Flexural and Impact strength with different volume fraction of Column Cactus fiber composites

3.2 Flexural Test

The flexural property is one of the important parameter in composite mainly useful to quantify in structural applications ASTM D 790: Standard Test Method for Flexural Properties of Polymer Composite. The samples are cut to the dimensions as per ASTM standards for flexural testing. It is also noted that the flexural strength depends upon the fiber content.

Figure 3 shows the effect of flexural strength with different volume fraction of Column Cactus fiber composite. Flexural strength of Column Cactus fiber with 20% Vf is lesser than the 30% Vf . Where the flexural strength of Column Cactus fiber with 20% Vf is 17.920 N/mm^2 and for VF 30% is 18.65 N/mm^2. The flexural strength is 19.58 N/mm^2 for 25% Vf which is higher than the other volume fraction.

3.3 Impact Test

Izod impact strength of composite samples is evaluated as per ASTM D256, using Impact Testing Machine. The samples are cut to the dimensions as per ASTM standards for Impact testing.

Figure 3 shows the effect of impact strength with different volume fraction of Column Cactus fiber composite. The impact strength of Column Cactus fiber with 20% Vf is lesser than the 30% Vf . Where the impact strength of Column Cactus fiber with 20% Vf is 25 KJ/m^2 and for 30% Vf the value is 29 KJ/m^2. The impact strength 33 KJ/m^2 for 25% Vf which is higher than the other volume fraction.

3.4 Cutting force analysis

The value of resultant force is varying dependent on speed and depth of cut with varying volume fraction 20%, 25% and 30% Vf. Figure 4 shows the variation of the resultant force with the varying speed and depth of cut for 25 % volume fraction.

Cutting force increase gradually to the depth of cut. It shows that at the certain speed the cutting force decrease with increase in the depth of the cut given. Cutting force verses depth of cut for 205 rpm speed for VF 25%. For depth of the cut 1mm the resultant force is 173.279 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 231.316 N, 292.495 N and 360.308 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. Where the average resultant force 264.342 N for the speed 205 rpm.

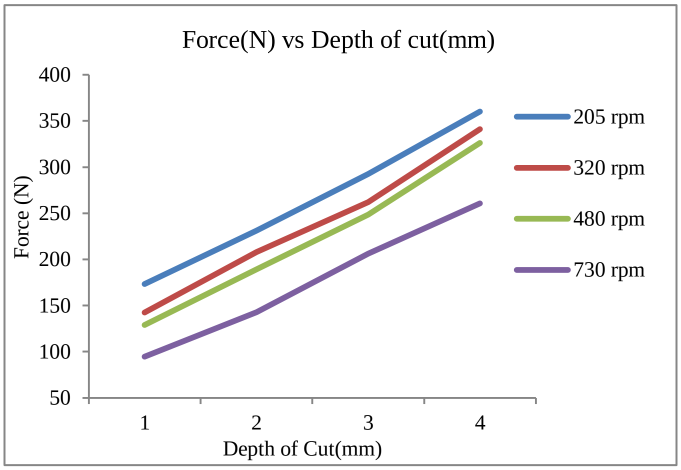

Fig- 4: Cutting force verses Depth of cut for different speed of volume fraction 25%

The cutting force verses depth of cut for 320 rpm speed for VF 25%. For depth of the cut 1mm the resultant force is 142.498 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 207.870 N, 261.947 N and 341.100 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 264.342 N for the speed 205 rpm. But for the speed 320 rpm the resultant force increase gradually.

The cutting force verses depth of cut for 480 rpm speed for VF 25%. For depth of the cut 1mm the resultant force is 129.030 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 189.208 N, 248.36 N and 326.247 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 223.209 N for the speed 480 rpm.

The cutting force verses depth of cut for 730 rpm speed for VF 25%. For depth of the cut 1mm the resultant force is 94.604 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 142.83 N, 206.24 N and 260.65 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 176.08 N for the speed 730 rpm. From it is concluded that the resultant force will increase with increase in depth of cut and decreases with increase in speed.

Figure 5 shows the variation of the resultant force with the varying speed and depth of cut for 30 % volume fraction. The cutting force increases gradually to the depth of cut. It shows that at the certain speed the cutting force decrease with increase in the depth of the cut given. The cutting force verses depth of cut for 205 rpm speed for VF 30%. For depth of the cut 1mm the resultant force is 146.82 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 204.83 N, 265.59 N and 333.106 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. Where the average resultant force 237.58 N for the speed 205 rpm.

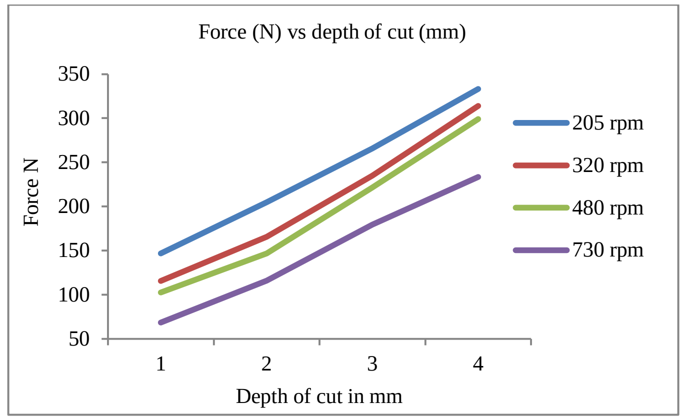

Fig-5: Cutting force verses Depth of cut for different speed of volume fraction 30%

The cutting force verses depth of cut for 320 rpm speed for VF 30%. For depth of the cut 1mm the resultant force is 115.65 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 165.61 N, 234.82 N and 314.07 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 207.53 N for the speed 205 rpm. But for the speed 320 rpm the resultant force increase gradually.

The cutting force verses depth of cut for 480 rpm speed for VF 25%. For depth of the cut 1mm the resultant force is 102.41 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 146.822 N, 221.32N and 299.16 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 192.42 N for the speed 480 rpm.

The cutting force verses depth of cut for 730 rpm speed for VF 30%. For depth of the cut 1mm the resultant force is 68.604 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 116.07 N, 179.28 N and 233.38 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 149.34 N for the speed 730 rpm. From it is concluded that the resultant force will increase with increase in depth of cut and decreases with increase in speed. On comparing the volume fraction of 25% the values of resultant force is decreased to the values for the volume fraction 30%.

Figure 6 shows the variation of the resultant force with the varying speed and depth of cut for 20 % volume fraction. The value of resultant force is varying dependent on speed and depth of cut. The cutting force increase gradually to the depth of cut. It shows that at the certain speed the cutting force decrease with increase in the depth of the cut given. The cutting force verses depth of cut for 205 rpm speed for VF 20%. For depth of the cut 1mm the resultant force is 159.82 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 218.83 N, 279.59 N and 346.106 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. Where the average resultant force 250.93.58 N for the speed 205 rpm.

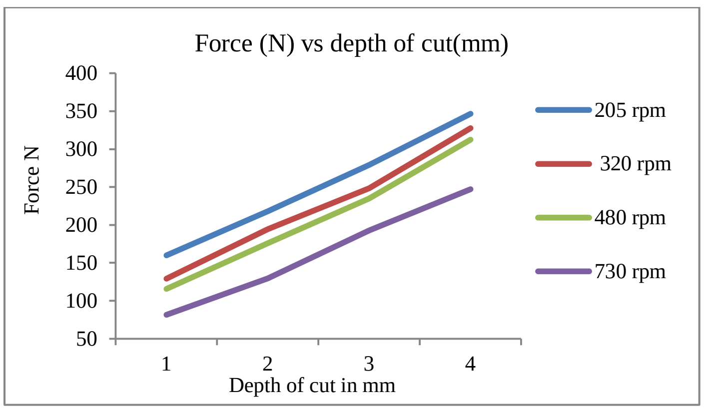

Fig-6: Cutting force verses Depth of cut for different speed of volume fraction 20%

The cutting force verses depth of cut for 320 rpm speed for VF 20%. For depth of the cut 1mm the resultant force is 129.65 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 194.61 N, 248.82 N and 327.07 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 224.87 N for the speed 205 rpm. But for the speed 320 rpm the resultant force increase gradually.

The cutting force verses depth of cut for 480 rpm speed for VF 20%. For depth of the cut 1mm the resultant force is 115.41 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 176.03 N, 234.82 N and 312.16 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 207.79 N for the speed 480 rpm.

The cutting force verses depth of cut for 730 rpm speed for VF 20%. For depth of the cut 1mm the resultant forces 81.604 N. Where the resultant for the depth of cut for 2mm, 3mm and 4mm is increase gradually in the rate of 129.07 N, 192.28 N and 247.38 N respectively. Thus it shows that the increase in the depth of cut the increase the resultant force. While comparing the speed the resultant force will decrease gradually. Where the average resultant force 162.65 N for the speed 730 rpm.

From it is concluded that the resultant force will increases with increase in depth of cut and decreases with increase in speed. Comparing to the volume fraction of 25% the values of resultant force is decreased to the values for the volume fraction 20%. But it increase when compared to the volume fraction of 30%. Clearly shows that the volume fraction of 25% has the high resultant cutting force compared to other volume fraction.

4. CONCLUSION

The present work shows the Column Cactus fiber will become a future alternative for the conventional materials due to its mechanical properties and availability. These are the some of the following conclusions based on the experimental study.

1. The tensile strength of Column Cactus fiber for VF 25% is higher compared with VF 20% and VF 30%.
2. The ultimate tensile strength of Column Cactus fiber of VF 25% is 15.16 N/mm^2, which is higher than that of other two fibers composite.
3. The percentage elongation of Column Cactus fiber of VF 25% is 1.240% which is higher than other VF 20% & 30% are 0.490% & 0.310% respectively.
4. The flexural strength for Column Cactus fiber of VF 25% is 19.58 N/mm^2 which is higher than other Volume fraction. Hence it has good flexural properties.
5. Column Cactus fiber with VF 25% has excellent ability to absorb impact force where it absorbs KJ/m^2 energy which is greater than other two Volume fraction. Hence it can be inferred that cracks cannot propagate.
6. Cutting force analysis test are concluded with following points
   - When the cutting speed increase resultant force decreased.
   - When the depth of cut increase resultant force also increases.

- When the depth of cut increases the roughness of the surface decreased.

7. It is concluded that compared to other volume fraction of 20 and 30 %, the volume fraction 25% has enhanced strength and optimum cutting force.

Overall it can be concluded that the Column Cactus fiber composite with the volume fraction of 25% have the maximum mechanical properties and resultant forces. So it can be used as the low load applications.

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