

# CHARACTERIZATION AND MACHINING OF FIBER-REINFORCED POLYMER COMPOSITE SHAFT

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## ABSTRACT

The ultimate purpose of the project is to manufacture a composite shaft using a lathe machine (conventional method). For this process, we have designed a special lathe attachment over which our fiber will be worn. We use an E-glass fiber and the solution is an epoxy resin mixed with hardener. Initially, the fiber is taken to the required amount and weighed. The equivalent amount of epoxy resin is weighed. Then 10% of the weight of hardener to epoxy resin is mixed. The lathe attachment consists of a resin bath in which the resin is poured. The fiber is made to dip into the resin bath so that the fiber is completely covered with resin. On the other end of the attachment, the fiber with resin is taken out and rolled over the mandrel (stainless steel rod of required dimension). The mandrel is initially wound with butter paper and coated with wax (for easy removal). As the fiber rolled over the mandrel with engaging the tool post with the lead screw. The required gear attachment for the lead screw speed is set. The lathe is rotated at the least speed. The required number of windings on the mandrel is given by moving it back and forth. Then the mandrel is removed from the chuck and made to dry. After this process, the mandrel is removed by taking out the butter paper. We get a hollow shaft that is made of compound material i.e. fiber and epoxy resin. The product is of improved strength and is used for the replacement of propeller shafts. This is a conventional way of fabricating a composite shaft with the help of a lathe machine. The design of part of it is the special lathe attachment.

**Keywords:** E-glass fiber, epoxy resin, mandrel, and hardener

## 1. Introduction

A **composite material** is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components [1-5]. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials that are stronger, lighter, or less expensive when compared to traditional materials. Since a composite material, which could be less, cost and reduced weight is capable of replacing the conventional materials. Machining of composite by an unconventional method like abrasive jet machining is gaining importance [6-10].

### 1.1 Fiber-reinforced polymer

**Fiber-reinforced polymers** or FRPs include carbon-fiber-reinforced polymer or CFRP, and glass-reinforced plastic or GRP. If classified by matrix then

there are thermoplastic composites, short fiber thermoplastics, long fiber thermoplastics, or long fiber-reinforced thermoplastics [10-15]. There are numerous thermoset composites, including paper composite panels. Many advanced systems usually incorporate aramid fiber and carbon fiber in an epoxy resin matrix [16-18].

Fiber-reinforced plastic is best suited for any design program that demands weight saving, precision engineering, finite tolerance, and the simplification of parts in both production and operation. A molded polymer artifact is cheaper, faster, and easier to manufacture than cast aluminum or steel artifact, and maintains similar and sometimes better tolerances and material strengths [19-20].

### 1.2 Why GFRP?

GFRP has a very high strength-to-weight ratio. Low weights of 2 to 4 lbs. per square foot mean faster installation, less structural framing, and lower shipping costs

Resists saltwater, chemicals, and the environment - unaffected by acid rain, salts, and most chemicals.

Domes and cupolas are resigned together to form a one-piece, watertight structure. Virtually any shape or form can be molded. Research shows no loss of laminate properties after 30 years. Stromberg GFRP stood up to category 5 hurricane Floyd with no damage, while nearby structures were destroyed

**2.Components**

**2.1Lathe**

A **lathe** is a machine tool that rotates the workpiece on its axis to perform various operations like cutting, sanding, knurling,drilling, or deformation, facing, turning, with tools that are applied to the workpiece to create an object with symmetry about an axis of rotation. Lathes are used in woodturning, metalworking, metal spinning, thermal spraying, parts reclamation, and glass working.

**2.2 Lead screw**

A lead screw (or lead screw), also known as a power screw or translation screw, is a screw used as a linkage in a machine, to translate turning motion into linear motion. Because of the large area of sliding contact between their male and female members, screw threads have larger frictional energy losses compared to other linkages. They are not typically used to carry high power, but more for intermittent use in low power actuators and positioned mechanisms.

A lead screw (Fig.1) is sometimes used with a split nut also called half nut which allows the nut to be disengaged from the threads and moved axially, independently of the screw's rotation, when needed (such as in single-point threading on a manual lathe).



**Fig.1 Lead screw**

**2.3Gear Ratio**

**Gear ratio** is nothing but by changing the gearing between the spindle and the lead screw you can change the amount the saddle moves for every revolution in the spindle. In this way, it is possible to cut threads with various pitches. i.e-the distance between the threads is typically expressed as a distance or as threads per inch (Fig.2).



**Fig.2 Gear ratio**

When you want to cut the thread with a certain pitch you look at the handy table that is printed on the table and it will tell you the configuration and size of the gears that should be used to achieve the desired pitch (Fig.3).



**Fig. 3 Gear ratio table**

**2.4 Special lathe attachment**

We required a special lathe attachment to manufacture a composite shaft, so we designed a lathe attachment (Fig.4).



**Fig. 4 Top view of special lathe attachment**

**3.Materials Required**

**3.1 E-glass fiber**

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers

and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". This structural material product contains little or no air or gas is denser and is a much poorer thermal insulator than is glass wool (Fig.5).



**Fig. 5 E-glass fiber**

### 3.2 Resin - epoxy (ARALDITE LY556)

Aspect (visual) : clear, pale yellow liquid  
Epoxy content : 5.30 – 5.45 eq/kg  
Viscosity at 25 C : 10,000 – 12,000 MPa s  
Specific Density ( $\rho$ ) at 25 C : 1.15 – 1.2 gms/cm<sup>3</sup>  
FlashPoint:  $\geq 200^\circ\text{C}$   
Storage temperature : 2 – 40 °C

### 3.3 HARDENER (ARADUR HY951)

Viscosity at 25 °C: 10 – 20 MPa s  
Specific gravity at 20 °C : 0.95 – 1.05 g/cc  
Flashpoint: 110 °C  
Vapour pressure at 20 °C: 0.3 Pa

## 4 Experimental setup

### 4.1 Attachment and mandrel setup

Initially, the tool post is removed from the compound rest. The attachment is placed over the compound rest in the lathe using fasteners. The mandrel is mounted on the chuck. The mandrel is drilled on one face internally. The tailstock is supported to lock the mandrel. The setup is as follows (Fig.6).



**Fig. 6 Overview of an experimental setup**

### 4.2 Other tools and safety gears

- Gloves
- Aprons
- Weighing machine
- Vernier caliper
- Cutter
- Butter paper
- Lubricant

### 4.3 Wax coating

Wax polish (Fig.7) is used to enhance and protect the wooden furniture and floor giving them a natural soft sheen and a matt finish. This wax polish is used as a releasing agent in this manual reinforcement process. A thin layer of the wax polish is coated over the Polythene sheet that has been wrapped over the pipe for the easy removal of the specimen after curing. A thin layer of wax is also coated over the glass plate to avoid sticking the FRP during the reinforcement process.



**Fig. 7 Wax coating**

### 4.4 Resin and hardener preparation

A small bowl made of ceramic is taken. It is cleaned with the acetone solution to remove the impurities if any present in it. The resin (Araldite ly556) equal to the weight of the fiber is taken in the bowl. The hardener equal to 10 percent weight of the resin is mixed with the resin in the ceramic bowl. The resin

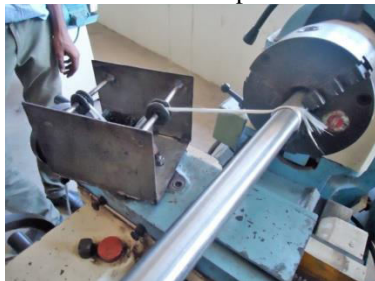
and hardener (Fig.8) have to be finely mixed in the bowl.



**Fig.8 Resin and hardener preparation**

#### 4.5 Initial winding

The fiber is knotted on the mandrel at the same time the gear ratio is fixed for the optimum movement of compound rest (Fig.9). The mixed proportion of resin is poured into the resin bath. The lead screw is engaged for linear movement. The lathe is started with the minimum speed.



**Fig 9 Initial winding**

#### 4.5 Final winding and change over lead screw direction

After completion of one winding, the lead screw is reversed with the help of a lever. The following figures(10-11) show the forward and backward movement of the lead screw.



**Fig 10 Change over the lead screw direction**



**Fig.11 Movement of the lead screw**

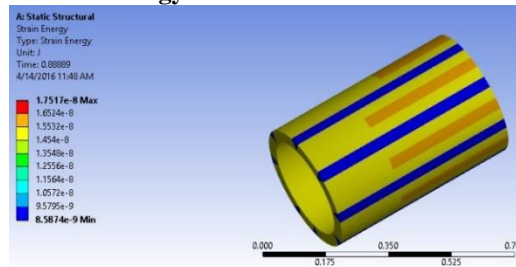
During the forward movement, the fiber is first made to roll on side of the bobbin and passed to the resin bath, and taken out of the other side of the attachment through another bobbin and wound on the mandrel. Initially, the lever is in the position as shown in figure 6.7. After one winding the lathe is stopped and the lever is changed as shown in figure 6.8. Now the lead screw moves backward. As a result of this, the fiber winds again and forms the second windings over the mandrel. The process is repeated to the required number of windings.

## 5. RESULT AND CONCLUSION

### 5.1 Software analysis

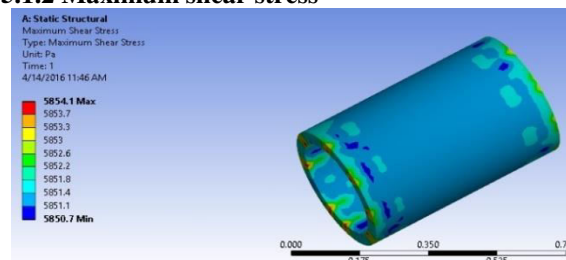
We have analyzed (ANSYS Software) our composite shaft and the following are the analysis module (Figs.12-15).

#### 5.1.1 Strain energy



**Fig. 12 Strain energy analysis**

#### 5.1.2 Maximum shear stress



**Fig. 13 Shear stress analysis**

### 5.1.3 Shear elastic strain

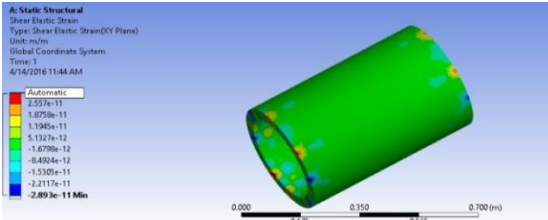


Fig. 14 Shear elastic strain analysis

### 5.1.4 Total deformation

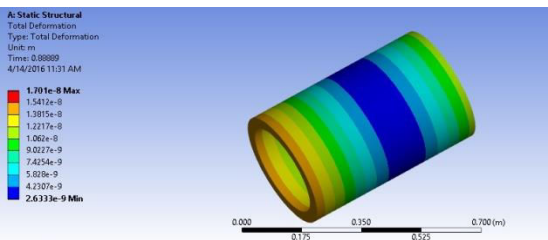


Fig. 15 Total deformation analysis

## 5.2 Conclusion

- Strain energy is the energy stored by the element when undergoing deformation. The external work done on an elastic member in causing it to distort from its unstressed state is transformed into strain energy which is a form of potential energy. The strain energy in the form of elastic deformation is mostly recoverable in the form of mechanical work. Figure 12 shows the strain energy is moderate in the composite shaft.
- **Shear stress** is defined as the component of stress coplanar with a material cross-section. Shear stress arises from the force vector component parallel to the cross-section. Normal stress, on the other hand, arises from the force vector component perpendicular to the material cross-section on which it acts. From figure 13 the shear stress is minimum and it is preferable.
- Internal strain within metal is either elastic or plastic. In the case of elastic strain, this is observed as a distortion of the crystal lattice, in the case of plastic strain, this is observed by the presence of dislocations –the displacement of part of the crystal lattice. Such strain effects can result in unwanted cracking of the material, as is the case with residual plastic strain. From figure 14 the shear elastic strain is moderate. The dislocation of the atoms in

the crystal structure of the composite shaft is uniformly distributed

- Deformation in continuum mechanics is the transformation of a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body. In a continuous body, a deformation field results from a stress field induced by applied forces or is due to changes in the temperature field inside the body. The total deformation is minimum in the middle and keeps increasing along either side of the composite shaft. From the theoretical and software analysis we conclude that it is preferable to be replaced as propeller shaft in the automobile.

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