Design and Fabrication of a Low Cost Filament Winding Machine and Torsional study on the Manufactured Glass/Epoxy Composite Specimen

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Abstract— Composites are widely used in the field of aerospace, automotive structures etc. as the material possesses extensive applications and greater mechanical properties. Among the applications of composites, the shafts made of composites are giving a high strength to weight ratio, stability and efficiency. In the present scenario, filament winding has been recognized as an economical technique to manufacture composite products with high level properties. In filament winding process, resin bathed fibre winded on a mandrel having cylindrical shape. The aim of the project is to develop a low cost filament winding machine and using the machine to develop an E-glass/Epoxy composite hollow shaft to make a study on the torsional characteristics of the composite shaft and thereby concluding on the effectiveness of developed filament winding machine and the specimen developed.

Keywords: Filament Winding, Mandrel, Glass/Epoxy Composite Specimen

I. Introduction

Filament winding technology is the most effective and economical method used to manufacture composite shafts. The representation of a filament winding is shown in fig 1. The mandrel is rotating at a constant speed and fibre at a suitable bandwidth is taken out from the fibre creel and allowed to undergo a resin bath. A small container containing the resin is taken and the fibre is impregnated in it. The carriage having a linear movement is used to wind the thread on the mandrel at a specific orientation. By varying the speed of carriage movement, we can change the orientation of winding. The tension of the fibre plays an important role in the entire process since the thread is continuously moving from creel to mandrel. After completing the winding process the specimen is then cured by giving suitable heat.

Composite materials are promising competitors as basic materials and substituting metals in broad applications. Shafts are utilized in aviation and car structures and henceforth supplanting regular shafts with composite material shafts is a practical alternative. Empty shafts can be fabricated utilizing fiber winding innovation utilizing loop and helix winding layers. Fiber winding innovation offers a few focal points, for example, constant fibers through structure and capacity for ceaseless assembling. As shafts are chiefly exposed to torsional and bowing burdens, torsional attributes are requirements for supplanting traditional metallic with composite materials [1].

Schwerin exhibited the first and most seasoned clasping investigation of dainty walled chambers under torsion in 1924.

However, his analysis did not show a good agreement with experimental results. At the point when an empty shaft is exposed to torsion, at a specific measure of torsional load flimsiness happens. This is known as the torsional buckling load. Therefore, the torsional buckling load is important in the design of drive shafts. This parameter is considerably progressively basic in the plan of composite shafts, since composite drive shafts are frequently made longer. Albeit expanding the length of drive shaft does not change the static torsional stress, it can diminish the torsional clasping load limit of the poles. Along these lines, the estimation of the torsional clasping load for composite drive shafts is significant. In the accompanying area it is demonstrated that the structure must be to such an extent that the torsional buckling strength of a pole must be higher than the static torsional strength [2]. Concentrates on fatigue, conduct of cylindrical carbon fibre composites under in stage biaxial bending/torsion dynamic loading is additionally done [3]. The impact of torsional strain-rate and lay-up groupings on the reaction of cross breed shafts was considered. Torque–twisting angle changes were recorded. Test outcomes uncovered that changing precise speeds did not influence the torsional conduct of composite shafts essentially. In any case, three diverse lay-up successions brought about strikingly extraordinary torsional conduct [4].

II. Design and development

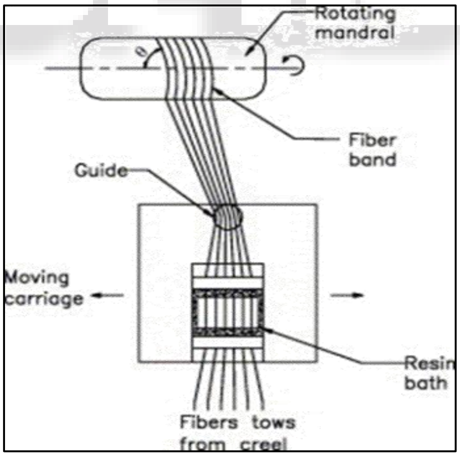


Fig. 1: Schematic of Filament winding[7]

All over the years, a recognized effective technique to produce composite products is the filament winding technique which giving superior properties[1].

This work is basically focusing on the manufacturing of a low cost filament winding machine. The prime focus should be on the mechanical parts of the machine. An automatic circuit movement of the thread which is glass fibre, has to be attained without using the control system is a must requirement. The entire system should not be complex, since all the available systems are having a complex structure and programming language requirements. The entire system should be of a small size range. This means we can carry it from one place to another and handle it with ease.

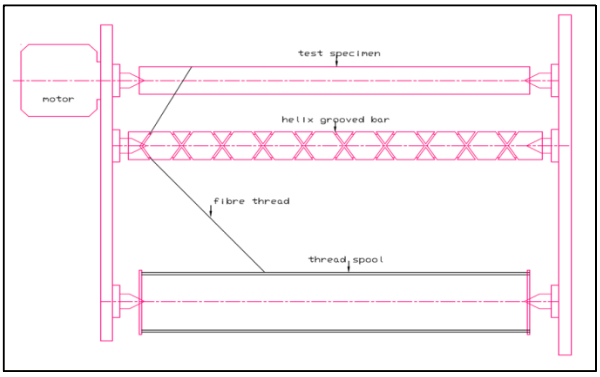


Fig. 2: Proposed design of filament winding machine.

The main parts are

- Mandrel- For winding the fibre.
- Nylon rod (helix grooved) - Thread movement.
- Motor- For rotating the mandrel
- Regulator- For controlling the speed of rotation.
- Bearings- To reduce friction.
- Iron rod- For making the supporting frame.
- Gears- To control the orientation angle.
- Fibre Reel/Thread spool- Material storage.
- Brush- For applying epoxy resin.

A. *Mandrel*

Mandrel is the rotating part which rotates at an rpm suitable for winding. Apart from other machines, here the mandrel speed is varied accordingly to get the needed orientation of the fibre without losing the tension on the fibre. The tension of fibre is the main factor which helps in the continuous or regular winding. A wooden circular rod is taken as the mandrel in this set up since after winding in order to get hollow shaft specimen we can drill out the wooden rod easily without harming the specimen.

B. *Nylon Rod*

This is the main part of the machine which is responsible for the continuous movement of fibre from one end to another.

Since we need 45° orientation of fibre, from the equation tan

$$\theta = \frac{\pi d}{L} \quad (1.1)$$

Where, θ is the helix angle

πd is circumference and

L is the lead

θ is 45° which is required and the diameter of rod 15mm. 12.75mm lead is chosen which is for attaining a ratio on the tan θ relationship. This is the major calculation leading to the selection of gear number. The ending of the helix is grooved such that as the rod is rotating, the fibre changes its track to move forward and backward continuously.

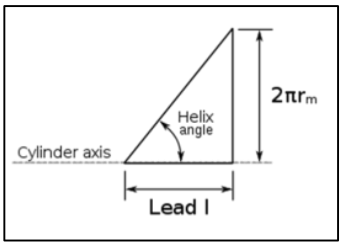


Fig. 3: Helix angle and Lead relation [10].

C. *Gears*

Gears are used to control the speed and thereby the angle of orientation. From the lead screw relation equation a ratio which needs to produce an angle 45° is found. This ratio is taken as the gear ratio for the driving and driven gears. Spur gear for module 1 is chosen. The driven gear is having a teeth number of 23 which is standard number. The previously obtained ratio is multiplied with this 23 to get driving gear teeth number. Tan θ= π×15/ (12.75), which means if θ to be 45° a number 3.69 to be multiplied with the denominator. This 3.69 is used as gear ratio. Hence driven gear has 85 teeths.

III. EXPERIMENT ON SPECIMEN

Fig. 4: Manufactured specimen.

Torsional testing on the specimen is done by using Torsional testing machine. One side of the specimen is fixed and torque is applied from other side.

The specimen fixed at the centre of the torsion meter using screws. The torsion meter is then clamped in the grip of the torsional testing machine. Straining shaft was pulled out and one end of the torsion meter was pulled out and then inserted into the chuck at the straining end. Then straining shaft paused so that other end would enter the chuck with the point at zero. The wheel was adjusted to be horizontal using tare target.

Angle of twist (in °degrees)	Torque (in kgcm)
1	75
4	175
6	260
8	320
10	370
14	500
16	580
18	620
20	710
22	800

Table 1: Torsional Testing Tabulation

IV. RESULTS AND DISCUSSIONS

At an angle of twist 22° the specimen found to be broken. The corresponding torque read from the scale found to be 800 kgcm. At this stage there exist a maximum stress experienced by the specimen. It can found by using the equation[1]

$$Torque = \frac{\pi}{16}\sigma_{\max}\frac{(D^4-d^4)}{D} \quad (1.2)$$

Where D= 25.4 mm

d= 24.6 mm

Torque= 78456.0 Nmm (800kgcm), maximum stress found to be 203.20 N/mm^2

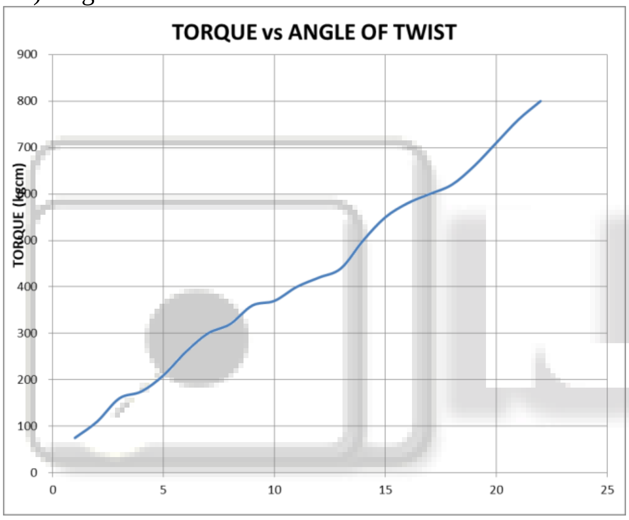
The strength of the specimen can be obtained from finding out the torsional stiffness using the equation,[1]

Torsional stiffness=Torque/(Angle of twist) (1.3)

The torsional stiffness at this maximum stress is 204.245Nm/Rad.

This means that a very good torsional stiffness is attained for the specimen even with such a small thickness. For each torque and corresponding angle of twist the torsional stiffness value can be generated and plotted. Torsional strength can be said that the maximum torque the specimen can withstand and at the same time the maximum deflection also can be noted. From the graph plotted it made clear that the efficiency of the developed filament winding machine is excellent such that it can be used to manufacture composite products. Therefore it can be said that many high cost machine can be removed by this simple low cost filament winding machine.

Fig 5 shows the torque(y axis) v/s angle of twist(x axis) diagram



ANGLE OF TWIST (in degrees)

Fig. 5: torque(y axis) v/s angle of twist(x axis) diagram

It is clear from the graph that a good strength is shown by the specimen for the corresponding torque application. A maximum torque of 800kgcm was needed to induce a breakage in the specimen.

It is clear from the graph that a good strength is shown by the specimen for the corresponding torque application. A maximum torque of 800kgcm was needed to induce a breakage in the specimen. Which is good strength for the specimen since the thickness taken for the specimen is 8mm only. Since we have taken this much thickness only, the angular deformation shown by the specimen is 22° at maximum torque. If we increase the thickness, there will be an increase in strength and a decrease in angle of twist. Therefore it is clear that thickness of the specimen plays a role in the torque capacity and angular deformation. Which means thickness is directly proportional to torque applied and inversely proportional to the angle of twist.

Fig 6 shows Torsional Stiffness v/s Angle of twist diagram

Fig. 6: Torsional Stiffness v/s Angle of twist

From fig 6 it is clear that as the applied torque increases then the specimen stiffness is decreasing. Since we have taken only 8mm thickness to the specimen, the variations shown in the graph is quite good in mentioning that the specimen is stiff enough. For a maximum torque applied and for corresponding angle of twist, the torsional stiffness shown by the specimen is very high. Therefore if we increase the thickness, it may result in the increase in torsional stiffness. That means thickness and torsional stiffness are directly proportional to each other. Hence for the specimen, the quality shown by it is excellent for strength and stiffness. And similarly if an increased strength and stiffness requirement only parameter needed to vary is thickness of the specimen. So the machine has good efficiency.

V. CONCLUSIONS

The filament winding machine developed is having a good efficiency in producing composite products. The machine holds an exceptionally ease of assembling it. No complex structures are involved in the design and no requirement arising on programming systems and control systems. The machine works purely in mechanical manner on which the electronic part required is a motor which is of normal torque capacity and a regulator which can be used for adjusting the speed of motor continuously.

The gear arrangement for attaining the orientation angle is very simple to manufacture and is too easy to fix on the mandrel and the nylon rod. The nylon rod arrangement and gear arrangements are the major part on the automatic winding and speed variation requirement for orientation angle. The specimen manufactured using the filament winding machine, composed of E-glass fibre and Epoxy resin. This specimen is tested under the torsional testing machine and arrived at a good result. From the result it is find out that when thickness of the layers are increased there will be an increase in torsional strength and torsional stiffness of the composite product. It can be concluded that the proposed design for the filament winding machine has very good efficiency and the product developed is having high strength.

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