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Composite Fabrication by Filament Winding Machine

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ABSTRACT: - *Filament winding is a process of loading high degree of fibres to take advantage of high tensile in manufacturing of hollow, generally cylindrical products. The process affords the high strength to weight ratio laminates and provides a high degree of control over uniformity and fibre orientation. Filament wound structures can be accurately machined, and labour factor for filament winding is lower than other open molding processes. The filament wound composite pipes are fabricated using high strength fiber and resin matrix by hand lay-up using 2-axis filament winding machine. The present work, the low cost filament winding machine is designed and developed for the fabrication of FRP pipes and cylindrical specimens. The concepts of an engine lathe supported by a wet winding method were being used in the development of filament winding machine. The capability of the machine to evolve specimen of 100mm diameter with 1m length is designed.*

KEY WORD: *fabrication of low cost filament winding machine*

I. INTRODUCTION

1.1 Filament Winding

Filament winding is a type of composite manufacturing process, where controlled amount of resin and oriented composite fibers are wound around a rotating mandrel and cured to produce the required composite part. It was initially used to produce pressure vessels, water and chemical tanks. The development stage of filament winding goes back to dry wire winding of rocket motor cases, which requires reinforcement. Today, the applications include aircraft fuselages, wing sections, radomes, helicopter rotor shafts, high-pressure pipelines, sports goods and structural applications of all types.

1.2 Fiber-Reinforced Polymer (Frp) Composites

Composite material is a combination of a reinforcement fiber in a thermoset polymer resin matrix, where the reinforcement has an aspect ratio that facilitates the transfer of loads among fibers, and the fibers are bonded to the resin matrix. In other words, a composite is produced by bonding of two or more materials that result in a new material that is usually stronger than the individual ingredients. Compared to metallic materials, composites have better flexibility, can handle highly corrosive environment and they are comparatively lighter in weight. North America is the largest producer of FRP composite materials and Figure 1.1 shows that. United States alone with approximately 2000 composite manufacturing units produces about 1.4 billion Kilograms of composite products each year.

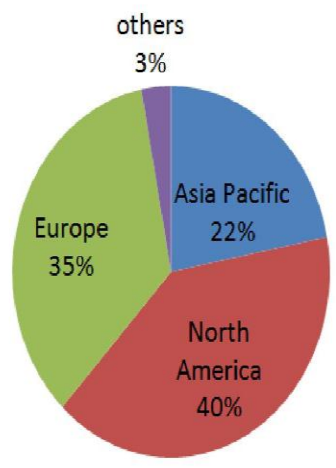

Figure 1. Distribution Of Composite Manufacturing – Continent Wise

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namely charging, compressing and ejecting. The material to be molded is preheated and placed in a mold in the charging stage. Then pressure and additional heat is applied in the compression stage. Finally the finished product is removed from the mold after sufficient curing time. Figure 1.5 shows the schematic of the entire compression molding process.

Major applications of the compression moldings are automotive components such as fenders, bumpers, and leaf springs. The major disadvantages of this process are that it cannot produce long fiber composite parts and mold costs

1.2.5 Filament Winding

Filament winding is an automated process for manufacturing advanced reinforced composite structural components. It entails the winding of resin impregnated fibers around a mandrel and then curing them so that the wound fiber can take the shape of the mandrel. The fibers are placed on the rotating mandrel by a horizontal carrier. The fiber orientation is controlled by controlling the speed of the horizontal carrier. Subsequently curing is done for an appropriate time and temperature. After curing, the wound composite is removed from the mandrel if the mandrel is not sacrificial; but, sometimes the mandrel can be a part of the design. It is used to manufacture pipes, tanks, gas cylinders, etc. the major advantages of the winding process are that it is highly automated, and capable of producing accurate repetitive fiber orientation. It does have some limitations however, which include difficulty in placing fibers parallel to the axis of the mandrel, high mandrel cost, and special treatment on the external mandrel surface needed to ensure evenness. Figure 1.6 illustrates a schematic of a 2-axis filament winding.

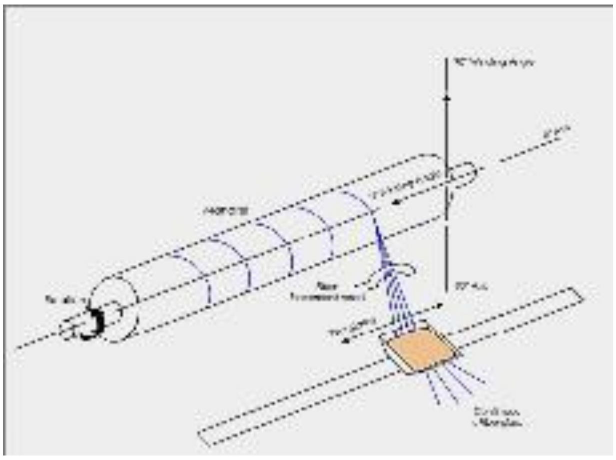

Figure 2. Schematic of filament winding

1.3 Selection Basis Of Various Processes

Considering the three major regions as in Figure 1.1 of composite manufacturing filament winding is the second largest process for manufacturing composites as illustrated by the statistics in Figure 1.7

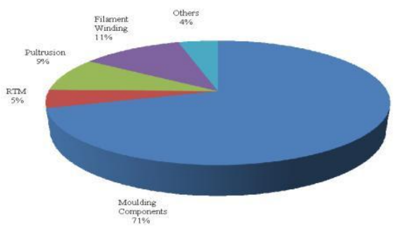

Figure 2. Distribution of composite manufacturing

Cost of composite production is also a leading factor in choosing the equipment. Figure 1.4 below gives the comparative analysis of equipment cost for different winding processes.

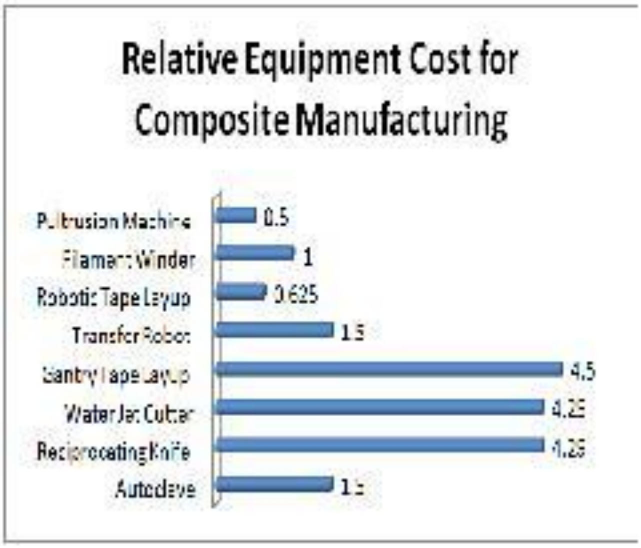

Figure 3. Cost incurred by different processes to manufacture composite

1.4 Objective of the Project

The aim of the present work is to the design and fabricates a low cost filament winding machine to produce small sized cylindrical specimens of fiber reinforced plastics.

The Conventional filament Winding machines available in the market are very large in size and are very expensive. Such machines can be used to produce medium to large sized components such as rocket motor casing pressure vessels, storage tanks, etc. To produce tube samples and other cylindrical specimens of different dimensions, for the different mechanical tests and applications, it is unworthy to procure such costly machines, particularly by the educational institutions. This motivated us to select this project. In the present work, an attempt is made to design and develop it low cost moment winding machine.

The proposed machine has simplified design and is fabricated using low cost and easily available materials. Design of such machine is not noticed anywhere in the literature till date.

II. FILAMENT WINDING

Filament winding is a type of composite manufacturing process, where controlled amount of resin and oriented fibers are wound around a rotating mandrel and cured to produce the required composite part. It was initially used to produce pressure vessels, water and chemical tanks. The development stage of filament winding goes back to dry wire winding of rocket motor cases, which requires
reinforcement. Today, the applications include aircraft fuselages, wing sections, radomes, helicopter rotor shafts, high-pressure pipelines, sports goods and structural applications of all types.

Most filament winding machines look like a lathe. The mandrel is supported horizontally between a head and tail stoke. The tail stoke is free, but head stoke is driven by required angle and speed, using a computer program. As the mandrel rotates, a carriage travels along the mandrel and delivers fiber with a given position and tension. Carriage motion is also controlled by the computer; in connection with head stoke rotation.

Winding machines are characterized by their degrees of freedom. Two of these degrees of freedoms are already defined: rotation of head stoke and horizontal movement of the carriage. Other commonly used degrees of freedoms are vertical and rotational motion of the delivery eye. Fibers pass through a resin bath after tensioning system and gets wet before winding operation. When a pre-impregnated fiber is used, wetting is not performed. Tensioning system is an important part of filament winding. This importance gets critical when winding at high angles. Since tension changes the friction force between fiber and the mandrel, it should be kept at a certain value during winding operation. Fiber tension also affects the volumetric ratio of composite at a given point. Excessive\ resin, due to a low tension, can result in decreased mechanical properties. Therefore, tensioning systems should be capable of rewinding a certain value of fiber. This condition occurs when fiber band reverses at the end of tube, while winding at low angles.

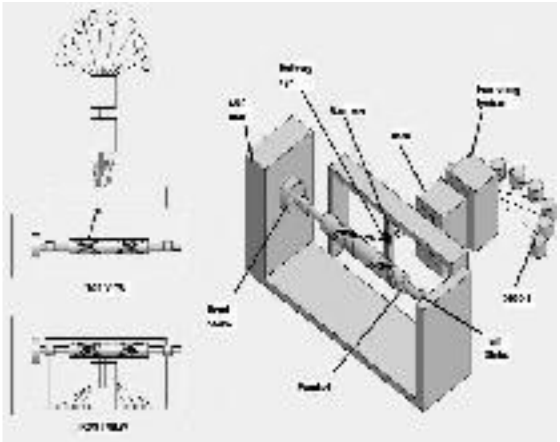

Fig.5 Filament Winding Technique

Wetting can be done by two commonly used bathing type; drum bath and dip bath.

Drum bath provide less fiber damage than dip bath. This is especially important when using carbon fibers. On the other hand, dip bath provides a better wetting action. If fibers are not wetted in a desired way, air bubbles can be trapped between them and can cause voids in the composite part. Therefore, drum baths can be heated for a better wetting action. Lowering resin viscosity, reducing fiber speed, increasing fiber path on the drum are other methods used for better wetting action.

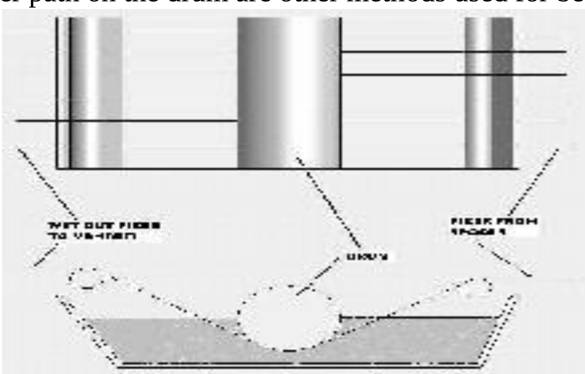

Fig 6. Drum Bath Resin System

Dip baths are used with aramid or glass fibers. If heated resin is to be used, dip baths are preferred since drum surface cools as it leaves the resin bath. During the travel of fiber through a dip bath, non-rotating surfaces are used for guidance. Non-rotating surfaces provide good wetting, and prevents fiber built out due to broken fibers at rotating surfaces. Delivery eyes can be in a variety of different shapes. The shapes are defined according to the type of application and type of fiber. Like all other fiber-connecting parts, wear should be evaluated by use of hard aluminum parts and chrome coated steel parts.

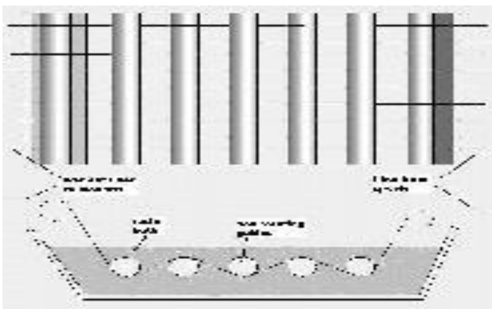

Fig7. Dip Bath Resin System

Rotating mandrel can be a part of the produced composite part (such as in production of a pressure vessel with a liner) or can be removed from composite part (such as a composite tube). If it will be removed, a press should be used for removing. All mandrels, which will be removed, should have low thermal expansions in order to reduce residual stresses after curing action. Steel is generally used when producing mandrels. If a tube is used as a mandrel, tube thickness should be uniform, in order to have a symmetric composite part. In addition, surface finish is an important point, since an interface between the composite part and mandrel is generally not permitted.

If a concave part is needed on the filament wound part, a female mold can be used. In addition, excessive wet fiber can be used in order to fill concave parts. Metal parts can be mounted on mandrel in order to guide winding action. Winding angle is the angle between fiber and the line on surface of the mandrel, which is parallel to mandrel axis. A maximum value, which is close to 90 degrees, can be approximated. Very low winding angle values need some arrangements at the ends of the mandrel, such as pins, etc.

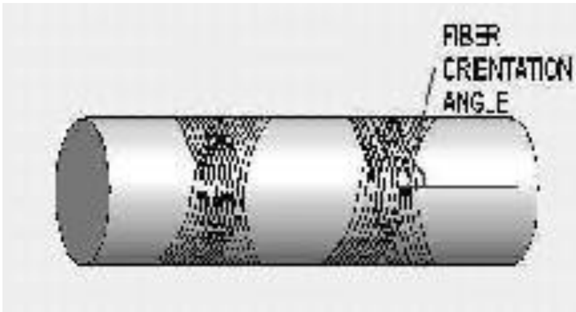

Fig8. Fibre Orientation Angle

There are many reasons to use filament winding as a composite manufacturing method.

First, many part such as rocket motor cases or pressure vessels require reduced radius at the end openings. For these applications, generally a metal, plastic or rubber liner is used. Rubber liners require a dissolvable material in order to support the rubber liner.

Secondly, filament winding is an effective way to produce high strength tubes. This situation holds especially when there exists an internal pressure. In addition, it is even possible to wound endless tubes for pipelines, etc. Having no connection points, endless tubes are more economical and reliable.

III. FABRICATION DETAILS

3.1 Fabrication Of Main Frame

Anglers of (38 x 34 x 4.5)mm are cut to the required lengths of 1270 mm (02 Nos. for horizontal base) 600 mm (03 No.s for horizontal base) 950 mm (03 No.s for vertical frame) and 1000 mm (03 No.s for vertical frame). M.S flats of size (30 x 4) mm are cut to be required lengths for horizontal support at the top. The cut angular bars are then welded to obtain the required frame structures) as shown in Figure 5.1. All the other components of the machine are mounted on this main frame.

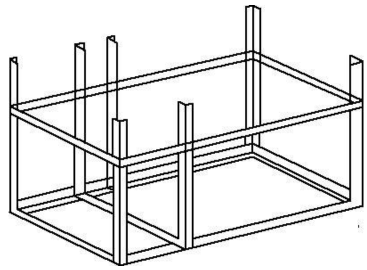

Fig 5.1 Main frame

3.2 Wooden Mandrel

Mandrel is the cylindrical rotating member supported in the bearings. During the filament winding process, resin-impregnated filaments are wound around a mandrel to create a composite material cylindrical part or structure. The structure is cured and the mandrel is removed.

Mandrels of different diameters are made from wood. The ends of the mandrel are turned to 25mm to mount on bearings. Provision is made to remove the bearing blocks to change the mandrel. The mandrel is driven using 368watts AC motor with 1440rpm, through a pulley by using a sleeve that connects the pulley shaft and the mandrel end for positive drive. The dimensions of the Mandrel is shown in figure 5.2.

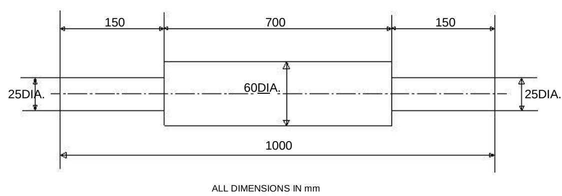

Fig 9. Wooden Mandrel

3.3 Carriage Assembly

A round nut (75mm outer diameter) is used as carriage. A sliding block is bolted to the bottom of the nut and is made to slide between the guide ways. This prevents the rotation of the nut. An aluminium lever for adjusting the center distance between the mandrel axis and the point of deviation of the fiber is mounted on the top surface of the nut.

The details of the carriage assembly are shown in figure 5.3

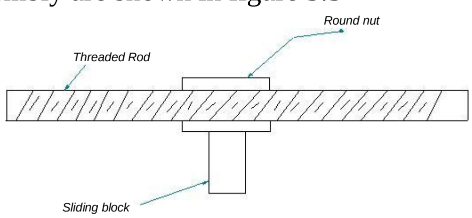

Fig 10. Carriage assembly

3.4 Motor

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Fig 11 AC single Phase Motor

Two motors are used in this machine for transmission of power. A single phase AC Induction motor having 0.5HP(0.37KW) capacity with 1440rpm is used for driving the mandrel and a Single Phase AC Induction Motor having 1HP(0.736KW) capacity with 1440rpm is used for driving the Carriage.

3.5 Bushed Bearings

Figure 5.5 shows a simplest type of bushed bearing. It consists of a cast iron Block, a brass or gun metal solid bush, a shaft. The block consists of a horizontal cylindrical part with an integral rectangular plate. The base plate is provided with bolt holes for bolting down the bearing in position. The bolt holes are rectangular with semicircular ends. This type of large bolt holes facilitate the proper alignment while bolting. The outer surface of of the bush is finished so as to ensure light press fit, when fitted in the bearing block. The inner surface of the bush is finished to H7tolerance. The shaft may be finished to give the required kind of clearance fit depending on the application.

Fig 12 Bushed Bearing

3.6 Bi-Directional Switch

In the filament winding machine, fibres are wound in different angles for strength point of view. To achieve different fibre orientation angle, it need reversing of rotation of motor which drive the carriage rod. For this purpose the bi-directional switch is used.

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Fig 13. Bi-Directional Switch

There are Stop, Forward and Reverse buttons, two low current double pole double throw relays for the control circuit (thin wire lines) and the power circuit (thick wire lines) which uses a double pole single throw relay (RMAIN) and a double pole double throw relay (RDIR). The circuit is drawn with the control circuit isolated from the power section; that enables the use of relays with coils that operate at a different voltage from the mains. Where that is done, the relay coils must all operate at the same voltage and power for them is applied to A and B.

Note that there is no protection for motor overload other than any fuse or circuit breaker in the mains supply.

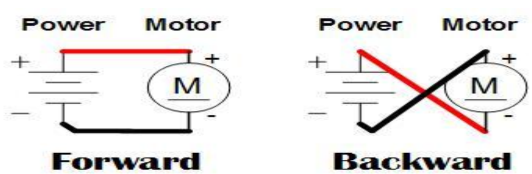

Fig 14. Basic Circuit for Reversing Of Motor

3.7 Sleeve

A sleeve is used to obtain positive drive between pulley shaft(mandrel) and the mandrel. A cylindrical block of 35mm diameter and length 70mm is selected. A hole of 25mm diameter is drilled through the length of 70mm. The details of the sleeve is shown in figure 3.9.

Fig 15. Sleeve

IV. Performance Test And Cost Estimation

The performance test setup of fabricated low cost filament winding machine is shown ill fig 6.1

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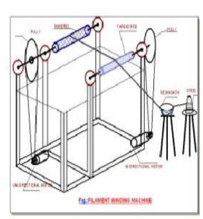

Fig 16. Performance Test Set up

The machine has been tested for its performance by synthesizing a jute/vinyl Ester composite cylindrical pipe.

V. Filament Wound Sample Produced By The Machine

Fig 17. Pipe Sample

VI. Cost Estimation

The cost of the machine is estimated based on the materials used to fabricate the machine. The details are given in Table 6.2.

Table 1. Cost Estimation

Item	Material	Rate RS	Quantity	Cost Rs
Threaded rod and nut assembly	Mild Steel	1000/-	01No.s	1000=00
Motor	-	1000/-	02 No.s	2000=00
Angular	Mild Steel	35 per kg	20kgs	800=00
Flat bar	Mild steel	35 per kg	05kgs	175=00
v-belt	Poloyester cord	300/-	02 No.s	600=00
Bush Bearing	-	150/-	06 No.s	900=00
Pulley a)Smaller b)bigger	Cast iron Mild steel	200/- 500/-	01 No. 01 No.	200=00 500=00
Mandrel	Wood	400/-	02 No.s	800=00
Switch & wires	-	-	-	500=00
miscellaneous (nuts,bolts, paint,fabrication)	-	-	-	1250=00
		Total		Rs 8725=00

6.1 Advantages

1. Increased Strength (fiber processed under tension)
2. High Fiber Content
3. Highly Automated
4. Consistent Quality
5. Low Labor Required
6. High Strength

6.2 Applications

1. High Pressure Air Tank used paint ball, emergency care, fire fighting
2. Fuel tank used hydrogen, CNG & LPG
3. High Pressure GRP Pipe
4. Pressure and storage Vessel
5. Coupling and joint fitting
6. Air craft and space
7. Industrial part
8. Military parts

VII. Conclusions

A low cost filament Winding machine has been designed and fabricated. Following are the conclusion drawn from the performance test on the fabricated machine.

1. The machine can be successfully used to fabricate small sized specimens with any fiber and resin combination.
2. The machine is capable of producing cylindrical parts of different diameters using mandrels of different sizes.
3. Different combination of fibers and resins can be used to produce cylindrical tubes.
4. However, the machine developed has a limitation that the length of the specimen that can be produced is limited to 500 mm.
5. Weight of the mandrel could be reduced to decrease the load on the motor, rotating the mandrel.
6. Machine has the provision to control the parameters like pitch length, helix angle and pipe length.
7. The machine has the ability to adjust the stroke length (max. carriage movement).
8. Sufficient tension in the fiber is achieved by using more than one fiber guide blocks.
9. Unskilled labor can also handle the machine with little care.
10. The machine has good aesthetics ergonomical features.

We thank all the staff members of the department and friends who helped us directly and indirectly to complete the project successfully.

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