

Review Article

A Review on Design and Development of Filament Winding Machine for Composite Materials

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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 engine lathe supported by a wet winding method were being used in the development of filament winding machine.

Keywords: Composite Material, Filament Winding, PVC, Strength

1. Introduction

Filament winding is an automated process for manufacturing advanced reinforced composite structural components. It creates the winding of resin impregnated fibers around a mandrel and then hardening 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 position is controlled by controlling the speed of the horizontal carrier. Subsequently hardening is done for an appropriate time and temperature. After hardening, 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.

2. Winding Material

Farhan Manasiya *et. al.* (2016), present that filament winding material type, properties and process technology.

Fiber: The mechanical properties of fibers improve the overall mechanical properties of the fiber/resin

composite. Fibers are classified into groups according to their chemical composition. These are a glass C-glass, S-glass and E-glass fibers. This fiber mostly used in aerospace design. It was found to have excellent fiber forming capacity and is now used almost as the reinforcing phase in the material known as glass fiber.

Epoxy resin: It is basically the glue that keeps the composite together. A resin has good mechanical properties, good adhesive properties, good toughness properties and good environmental properties. Epoxy has a number of applications, including metal coatings, used in electronics / electrical components, high tension electrical insulators, fiber-reinforced plastic materials, and structural adhesives.

Filament winding-process technology: The process of filament winding is basically used for hollow, circular or oval sectioned products. Fibers can be use dry and be pulled through a resin bath before being wound around the mandrel.

The winding angle ' θ ' is controlled by the fiber feeding mechanism and the rotational speed of mandrel. Fig.1 shows filament after winding, the filament wound mandrel is subjected to curing and post curing operation during which the mandrel is continuously rotated to maintain homogeneity of resin content around the circumference. After curing, product is removed from mandrel either by hydraulic or mechanical ejector.

Dr. S. C. Srivastava *et. al.*(2016) explained the importance of filament winding, where weight is an issue which shows decrease of weight or increase of performance. Therefore this fabrication technique

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allows production of strong, lightweight parts, especially for components of aerospace hydrospace and military applications and structures of commercial and industrial usefulness.

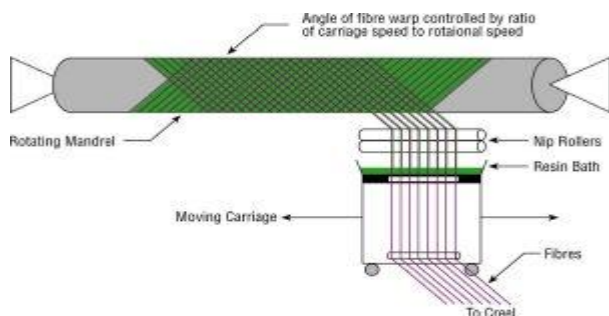


Fig. 1 Representation of filament winding process
Manasiya et. al. (2016)

Continuous fiber reinforcement provides the structural performance required of the final part. The fiber is the primary contributor to the stiffness and strength of the composite and the resin matrix that holds everything together, provides the load transfer mechanism between the fibers that are wound onto the structure, the resin matrix also to provide the corrosion resistance, protects the fibers from external damage, and contribute to the overall composite toughness from surface impacts, cuts, abrasion, and rough handling. The strength-to-weight advantages and low cost of manufacturing, the parts obtained from the process have better corrosion and electrical resistance properties. As mentioned before that winding process. Filament winding is referred to traditional filament winding process. Mechanical strength of filament wound part depends on process parameter like winding pattern and winding methods. These two parameters is use for winding process to take place from linear two till six axes process. This gives us wound part of conical or one side enclosed geometry. The properties of the finished composite can be varied with the different type of winding pattern selected. Firstly, the hoop winding pattern which is a circumferential winding that provided an angle of 90° , secondly is the helical winding in which the fibers are wended at helical angles, thirdly is the polar winding, fibres are wrapped from pole to pole, as the mandrel arm rotates about the longitudinal axis. Further parameter is first account for wet winding in which the fibers are passed through a resin bath and wound on a rotating mandrel. The second method is the prepreg winding which the pre-impregnated fiber tows are placed on the rotating mandrel. Among the two winding methods, wet winding is more commonly used for manufacturing fibre reinforced matrix composite cylinders. It having the main following advantages: low material cost, short winding time. The resin can be easily varied to meet specific requirement.

3. Components of Filament Winding Machine

The main components of filament winding machine are defined as below:

- 3.1 Mandrel
- 3.2 Job holder
- 3.3 Delivering eye
- 3.4 Control system

3.1 Mandrel: Mandrel having two types- water soluble mandrels and spider/plaster mandrels. Advantage of mandrel is low cost for small production quantities and excellent dimensional reproducibility. The disadvantage is high initial tooling cost.

3.2 Job holder: The job holder is used for the operation of holding male mandrel on which the reinforced matrix is to be laid during the process running. At the same time job holder resembles one of the axis. The job holder can also be the mirror as head and tailstocks similar to a lathe machine.

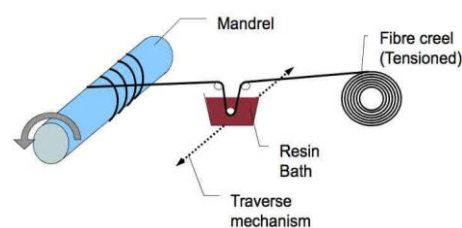


Fig. 2 filament winding process (S. C. Srivastava et. al., 2016)

4. Winding Parameters

4.1 Winding methods: In this there are two types of winding method, wet winding and prepreg winding. In wet winding the fibre is passed through a resin bath and wound onto a rotating mandrel simultaneously and in prepreg winding pre-impregnated fibre tows are placed on the rotating mandrel.

4.2 Winding patterns: Winding patterns is denoted by α . The first type of winding pattern is hoop or circumferential where α is 90° , the second type is helical winding the value of α lies in the range of 0° to less than 90° . The third type is the polar winding where the value of α is no long fixed and varies over the length of mandrel.

5. Composites materials

Samy J. Ebeid et. al.(2016) explained that composite materials offer light weight at high strength, high stiffness, good fatigue resistance and good corrosion resistance .Composite pipes can thus combine directional(anisotropic) properties to meet specific application needs. Filament winding is a process used to produce such composite pipes. Design and analysis of composites should consider many aspects not limited to material properties, examination of production parameters, investigations of geometries and loading conditions. Burst pressure is an important parameter that must be well studied in case of pipes. This, and other properties will change by altering filament type, roving size, number of layers and

winding angle (θ), to mention a few of the affecting parameters. The winding angle is measured between the rotating axis and wrapped fiber, as indicated in Fig. 3. The process, as schematically illustrates in Fig. 4, is used to wrap resin-impregnated continuous fibers around a rotating mandrel that has the internal shape of the desired product.

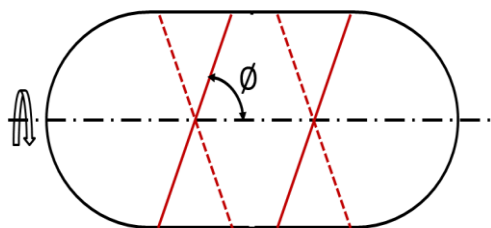


Fig. 3 Winding angle (Samy J. Ebeid *et al.*,2016)

The important objective is building a Finite Element model to find the burst pressure of different composite pipes, at high accuracy. This model can be further used as a design tool to select the best parameters for optimum design prior to production

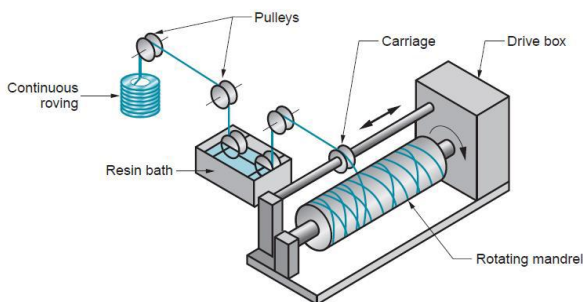


Fig. 4 Common form of Filament winding process (Samy J. Ebeid *et al.*,2016)

Analytical analysis for pipes subjected to pure internal pressure satisfy a hoop to axial stress ratio of 2:1, and the optimum burst pressure was found to occur at a winding angle of 54.7°.

This study was done to simulate the structural behavior of composite pipes subjected to internal pressure. FEA prediction of the burst pressure for a four layered filament wound composite pipes made of E-glass/epoxy, carbon/epoxy and aramid/epoxy composites using LPF concept. Then it is concluded that the optimum winding angle is 55°. The lowest burst pressure was recorded to be at 0° winding angle. The burst pressure at the optimum winding angle [$\pm 55^\circ$] for the three materials E-glass/epoxy, aramid/epoxy and carbon/epoxy is predicted to be 10.9, 25.5 and 29.4 MPa respectively.

6. Production of PVC/GF composite pipes

J. F. Silva *et al.* (2010) presented that two processing techniques commonly used with thermosetting matrices were studied: filament winding and hand lay-

up. Polymeric matrix composite materials are being increasingly used in different industrial and commercial applications, especially in the automotive, aerospace and military markets. The important advantages which included increases toughness, damage tolerance, increases durability, possibility of reprocessing and recycling. Production of PVC/GF composite pipes: The homopolymer of PVC was used to impregnate the glass fibers in the production of composite pipes by filament winding.

The piping production process starts by the impregnating of the glass fibres by the PVC plastisol, followed by its winding around a circular mandrel using filament winding equipment with numerical control. The polymer reticulation and consolidation were done with a hot-air heater. Reticulation of the plastisol during piping production was controlled by measuring its surface hardness, according to the manufacturer information, must be above 80 Shore A. This process has the advantage of being automatic and capable to be easily implemented in an industrial scale. Mousa Tabatabai Gargari, (2006), explains the types of pipe as following.

6.1 Fiberglass pipes

Fiberglass pipe is made from glass-fiber reinforcements embedded in, or surrounded by cured thermosetting resins. Other ingredients are frequently included to increase various properties or characteristics. These pipes do not corrode, they are resistant to chemical attacks and are light-weight. These pipes also have smooth walls that reduce the head loss, and thus require less pumping power.

6.2 Polyvinylchloride pipes

Polyvinylchloride (PVC) gets its properties from combinations of additives and modifiers which plasticizers, providing varying degrees of flexibility and resistance to Ultra Violet (UV) light degradation; and pigments, used selectively to provide color. Once the additives and modifiers have been combined with the resin, the resulting material is called PVC compound and is in granular form. In the next stage of manufacturing, these granules are melted down, blended thoroughly and extruded into pipe. PVC pipes are corrosion resistant, light-weight, they have smooth surface, and nontoxic qualities. Some grades are used in food and chemical processes due to the inert nature of PVC. Because of limitations in extrusion technology that is used for production of these pipes, manufacturing large diameter pipe such as the one in this project was not feasible. In most of the manufactures' catalogs the maximum size was 36 in. (914 mm).

6.3 Welded steel pipes

One type of steel pipe is spirally welded pipe is manufactured by continuous welding. The procedure is briefly explained as:

Coils are loaded on the decoiler of the Spiral Pipe machine. The strip is straightened and edges are milled to desired joint geometry. The strip is guided into a forming station, where it is formed to produce a cylindrical hollow body at a predetermined forming angle, ensuring proper welding gap between the abutting edges. Inside, and later, outside welding is performed by an automatic submerged arc process. Pipes are cut to a predetermined length by an automatic plasma arc cutting device. After accomplishment of inside and outside welding, while on the production machine the full length of pipe is examined by automatic ultrasonic unit for checking welding defects. Flux and slag from inside the pipes is cleaned. Pipes are inspected for any visual defects. Each pipe is hydrostatically tested to a given pressure as desired standard. The spirally welded steel pipe is coated for corrosion and erosion resistance on the inside and on the outside. Another type of steel pipe; longitudinally welded steel pipe is manufactured by electric resistance welding and electric fusion welding to convert flat rolled steel bars, plates, sheets and strips to tubular products. The welding seem in this pipe is a straight line.

Conclusions

A low cost machine was modified for filament winding and it is design and fabricated, to improve the tensile strength of the composite material.

It is expected that experimental results will show the optimization of filament winding angle for the different diameters of the work piece. The development machine will be capable of changing the different winding angle to improve the tensile strength of the fibre.

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