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MODIFICATION AND TESTING OF FOUR AXES FILAMENT WINDING MACHINE

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Abstract. *Filament winding technology is one of the production methods in composite manufacturing technology. This paper describes the design of filament winding machine with the four axes of winding system. The current filament winding machine consists of two axes. Two axes were added to the existing design. Four axes are rotation of mandrel, the horizontal carriage, controls the pay-out eye angle and controls the radial carriage movement.*
Keywords: Filament winding, Four axes, Automated winding system.

1.0 Introduction

The development in various sectors have created demand for newer materials that are required to perform in stringent conditions such as high pressure and temperature, or highly corrosive environments, with high strength requirement. They offer several outstanding properties compared to conventional materials. To provide to customized needs, the composites industry has recognized the ability of composite materials to produce high-quality, durable and cost-effective products. In fact, composites are now one of the most important classes of engineered materials. Composites have excellent corrosion resistance and good resistance to temperature extremes and wear. Composites have been widely used in many fields including aerospace, chemical, automotive and offshore industries [1].

A composite material is a combination of two or more chemically distinct and soluble phases; its properties and structural performance are superior to those of the constituents acting independently [2]. There are varieties of processing techniques for fabricating composite such as resin transfer moulding, pultrusion and filament winding. Filament winding is the fastest process for composite cylindrical structures fabrication at low cost.

Filament winding is a process in which the resin and fibers are combined at the time of curing. Axisymmetric parts, such as pipes and storage tanks, and even asymmetric parts are produced on a rotating mandrel. The reinforcing filament, tape and roving are wrapped continuously around the form. The reinforcements are impregnated by passing them through a polymer bath. The process can be modified by wrapping the mandrel with prepreg material [3]. The products made by using filament winding are very strong, because of their highly reinforced structure. This process has also been used for strengthening cylindrical or spherical pressure vessels made of materials such as aluminium and titanium. The presence of a metal inner lining makes the part impermeable [4]. Some diagrams of filament wound products are shown in Figure 1.

Figure 1. Filament wound pressure vessel and storage tanks

In this project, filament winding with four axes of movements has been designed with four axes of winding system. The first axis is rotation of mandrel, the second axis is the horizontal carriage, the third axis controls the pay-out eye angle and the fourth axis controls the radial carriage movement. As the design consists of four movement axes, various types of product can be produced such as open-ended cylinder, close-ended cylinder, sphere, turbine blade, etc. The machine can also produce hoop and polar winding pattern.

2.0 Review on Winding Technology

2.1 Winding Methods

There are two different winding methods which are wet and prepreg windings. Wet winding, in which the fibers are passed through a resin bath and wound onto a rotating mandrel. This low-cost system is widely used in commercial applications with polyester and epoxy resins. The resin content is affected by several parameters (most of which are interrelated): resin viscosity, the squeeze roller setting, the interface pressure at the mandrel surface, winding tension, the number of layers, and the mandrel diameter. When a wet impregnation is used, there will be unlimited on the choice of fiber/resin [5].

Prepreg winding, in which the preimpregnated fiber tows are placed on the rotating mandrel. Preimpregnated rovings offer excellent quality control and reproducibility in resin content, uniformity, and band width control. These parameters can be determined well in advance of the filament winding process; not on the factory floor where many of the quality control tests must be done for wet winding [5]. The advantages of prepreg are better resin content control, minimal fiber damage due to the protection offered by the resin and more consistent composite properties. The common disadvantages of prepreg are poor fiber availability, higher cost and no room temperature cures are possible [5].

2.2 Winding Patterns

There are basically three types of winding patterns; hoop, helical, and polar winding [6]. Hoop winding is also known as girth or circumferential winding. Strictly speaking, hoop winding is a high angle helical winding that approaches an angle of 90 degrees. Each full rotation of the mandrel advances the band delivery by one full bandwidth as shown in Figure 2

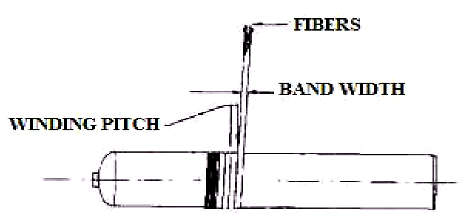

Figure 2. The diagram shows the pattern of circumferential or hoop winding

In helical winding, mandrel rotates at a constant speed while the fiber feed carriage transverses back and forth at a speed regulated to generate the desired helical angles as shown in Figure 3.

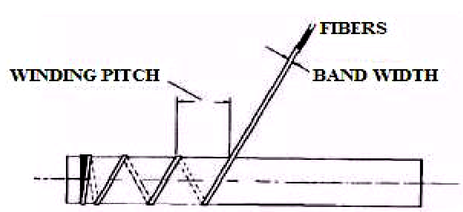

Figure 3. The diagram shows the pattern of helical winding

In polar winding, the fiber passes tangentially to the polar opening at one end of the chamber, reverses direction, and passes tangentially to the opposite side of the polar opening at the other end. In other words, fibers are wrapped from pole to pole, as the mandrel arm rotates about the longitudinal axis as shown in Figure 4. It is used to wind almost axial fibers on domed end type of pressure vessels. On vessels with parallel sides, a subsequent circumferential winding would be done.

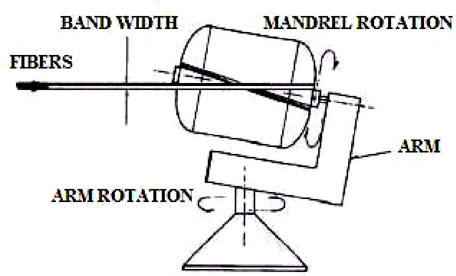

Figure 4. The diagram shows the pattern of polar winding

3.0 Design and Analysis

3.1 Preliminary Stage on the Design

Before the design concept is carried out, the machine has to analyzed and find out the problem of the existing machine. Some solutions were suggested to overcome the problems. After gathering all the information and identified the problems, the next step was designing and analyzing the machine structure. In term of design, it involves preliminary design and detail design, where several ideas or design concepts were generated first and then, the best idea was chosen as the final design. While the analysis involves the stress analysis and kinematics analysis of winding movement such as speed and feed rates. The machine modifications include lead screw and motor. While the component redesign and analysis involve carriage, slide way, and overall machine structure.

3.2 Modification of the Design

Based on the concept design, the existing machine only need a little modification design on clamping system which involves tail stock and chuck. Basically, the design consists of four axes of movements. First axis is rotation of mandrel, second axis is the carriage traverse axis, third axis controls the pay-out eye angle and fourth axis controls the horizontal stroke movement. Three motor will be used to drive the machine. One is to rotate the mandrel, second is to drive the carriage and the other one is to drive the delivery system or pay-out eye. The other axis is control manually. It is fourth axis that controls the carriage arm.

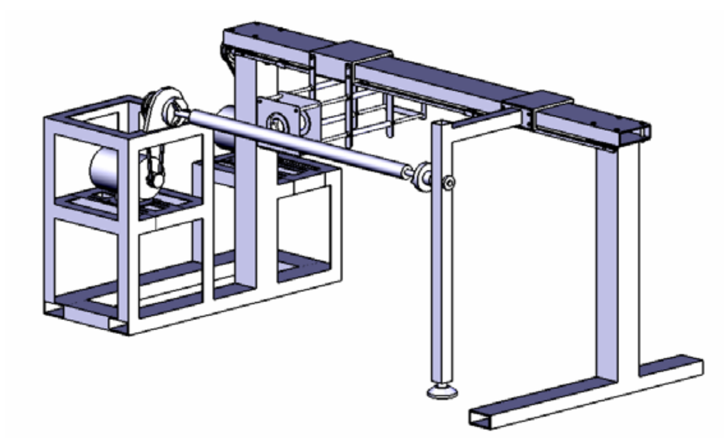

Figure 5. The isometric view of the machine

All the motors are controlled separately, one controller will control the spindle motor to make rotation of mandrel, and a second controller will control the lead screw motor to make movement of carriage traverse axis, while the last controller is used to control the rotation of pay-out eye. By implementing this solution, the spindle speed, and the lead screw speed, and the pay-out eye rotation speed were controlled independently. Figure 5 shows the final design after modification of existing machine has been made, while in Figure 6 shows the details drawing of the machine, where all of the improvements have been taken into account.

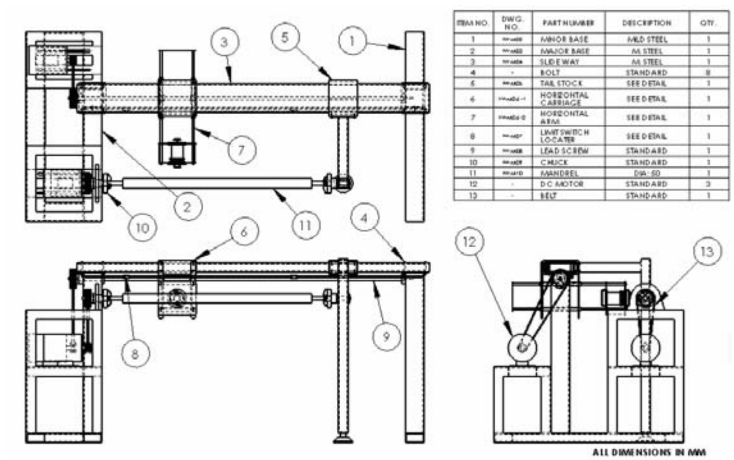

Figure 6. The orthographic view of the machine

After completing the design stage, the stress analysis of the machine structure was conducted to investigate whether the structure is able to withstand the static and dynamic loading or not. Commercial finite element package, ALGOR was used to carry out the analysis. The results showed that the machine structures with selected material are able to endure loading either in static or dynamic condition. Fabrication process took about 3 months. The finish product is shown in Figure 7.


Figure 7. The Filament Winding Machine with four axes of winding system

4.0 Conclusion

This project was successfully performed and a new design of filament winding machine was fabricated. The existing filament winding machine consists of two motion axes, one is the spindle rotation and the other one is carriage horizontal traverse axis. By incorporating the additional two axes into existing machine design, a new filament winding machine with four axes has been successfully fabricated which is the third axis controls the pay-out eye angle and the fourth axis controls the radial carriage movement.

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