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Filament Winding Technique: SWOT Analysis and Applied Favorable Factors

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Abstract

Filament winding technique is an automated composite fabrication technique, which is mainly used to produce tubular structure such as storage tanks, vessels, missiles and rocket motor cases. In recent 20 years, filament winding technique has developed as a mature fabrication technology, which is depended on various applied factors. Filament wound composite product applied fields are also influenced by different favourable factors. In this paper, a proper analysis method is carried out applied factors, which can enhance filament winding technique usage rate. Primarily, SWOT (Strength, Weakness, Opportunity, and Threat) analysis of filament winding technique is fully analysed. Secondly, all the applied favourable factors were classified and discussed under six categories, which relates the Wind Energy, Building

& Construction, Mass Transportation, Chemical/Corrosion, Infrastructure, and Militray & Defense. Finally, applied favourable factors were discussed in details, and conclusion were summarized and highlighted, which can advance filament winding technique and increase filament wound composite product applied fields.

Keywords: Filament winding technique, filament wound composite product, SWOT analysis, applied favorable factors

I. Introduction

Composite material is a material made from two or more constituent materials with different chemical or physical properties, which can produce a material with characteristics different from the individual components[1, 2]. This type material can provide a stronger, lighter and less expensive compared to traditional materials. Composite materials are generally used in buildings, bridges, advanced structures such as boat bull, swimming pool panels, storage tanks etc[3, 4]. The most advanced examples perform on spacecraft and aircraft in aerospace application. However, there are several methods to fabricate composite products, which can select proper fabrication methods to meet design requirements or manufacturing challenges. In recent years, filament winding technique is a continuous fabrication method that can be highly automated and repeatable with relatively low costs compared to hand lay-up method[5]. The main advantages of filament winding technique is that it can produce extremely high stiffness-to-weight, fibre volume fraction and strength-to-weight structures compared to traditional metal designed structures such as pipes and pressure vessels and rocket motor cases[6]. Furthermore, filament wound composite products are commonly used in many fields such as transportation, construction, aerospace, which depends on filament-wound composite mechanical properties[7]. Filament wound composite product application usage can enhance filament winding technique and allow for the “state of art of filament winding machinery” to continue[8]. The main objective of this paper is to study and understand on what applied factors can enlarge filament winding technique applications and frame a SWOT analysis. A general method is used, and related factors were classified and divided into six categories.

The structure of this paper is presented in four sections: Section-I focus on the brief introduction about filament winding technique background and development, and filament wound composite product demands and applications. Section-II shows the brief description filament winding technique and its material options. Section-III deals with SWOT analysis of filament winding technique, and Section-IV, detailed discussion are performed on applied favourable factors, which can boost filament winding technique development and application fields. This paper is concluded with Section-V, which highlights the filament winding technique potential development based on applied favourable factors.

II. Filament winding technique

Filament winding process is a classical fabrication technique, which is well suited to automation manufacturing process. Filament winding technique basically has three winding patterns: circumferential, helical and polar winding[9]. Filament winding process is shown in Figure 1. For filament winding method, many continuous fibre rovings are passed through comb device, which can collect and combine the fibre bundles with tension device. Fibre tows are passed resin bath, nip roller device and the pay-out eye before being wound onto a rotating mandrel in a variety of fibre orientation, controlled by filament winding machine control system. In resin bath, fibre strands are completely impregnated with the resin. In roller device, the two stainless steel rods are used to squeeze out the extra resin, which can ensure the filament wound composite products in fibre volume fraction. In the pay-out eye, the pay-out eye is last step before fibre tows are wound around the mandrel. The pay-out eye can have linear and rotation motion, which can meet the filament winders' requirements. The filament winding process can utilize many different types of fibres and resins to achieve desired filament wound product characteristics for the finished component, which is summarized in Table 1. Glass fibre is the most commonly used in filament winding, carbon and aramid fibres are also used[10]. Two different fibres or more than two type fibres can be applied in this process, which is a potential research fields.

Filament winding gradually becomes a major composite fabrication manufacturing method, compared to other typical composite fabrication processes such as hand lay-up, pultrusion, resin transfer molding (RTM)[11]. Figure 2 shows composite market by application of different composite fabrication processes, which illustrates that filament winding technique has researched second popular composite process with 15% in Indian in 2015. During a couple of years of slower growth, the composite industry or company is moving rapidly ahead. Filament winding technique is playing an important role in advancing the use of composite material into upcoming new market areas[12].

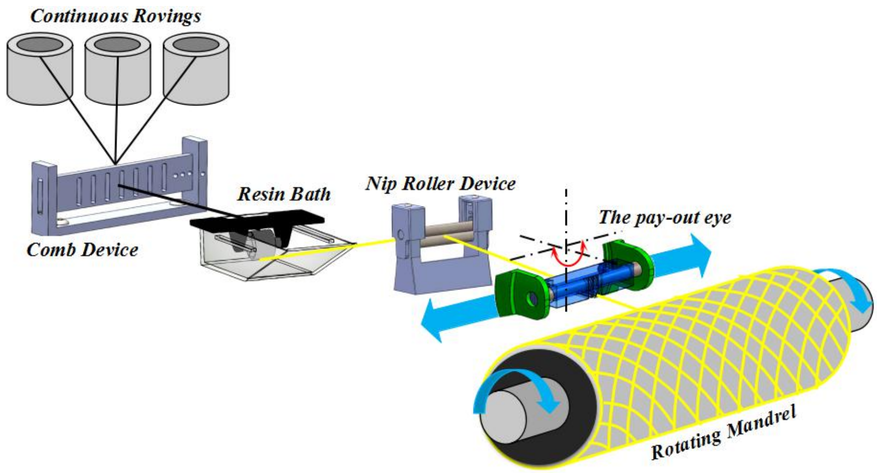

Figure 1: Schematic of filament winding process

Table 1: Raw material options used in filament winding technique

Material selection	
Resins/Matrix	Epoxy, polyester, polyurethane, polyvinylester, vinylester, phenplic, furans, polyimides,
Fibre/Reinforcement[a]	Glass fibre (E and S type), carbon fibre, boron fibre, aramid fibre

Note: [a] The fibres are used straight filament from a creel, and woven or stitched into a fabric form are not applied in filament winding technique.

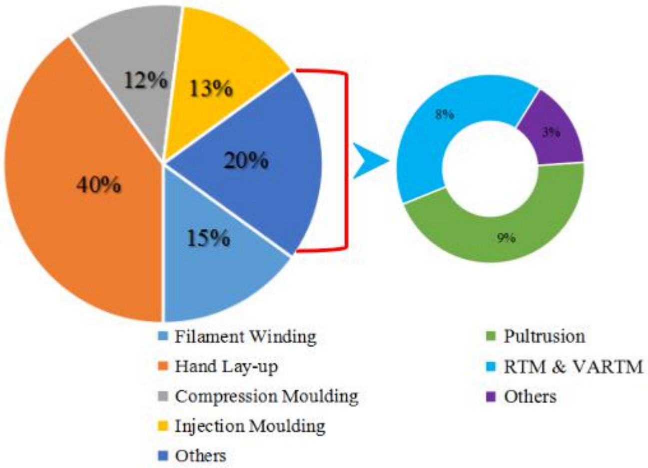

Figure 2: Composite market by application in Indian in 2015 (Source:http://icerpshow .com)

III. SWOT analysis of filament winding technique

SWOT (strength, weakness, opportunity, and threat) analysis of filament winding technique is carried out considering the general aspects are presented in Figure 2.

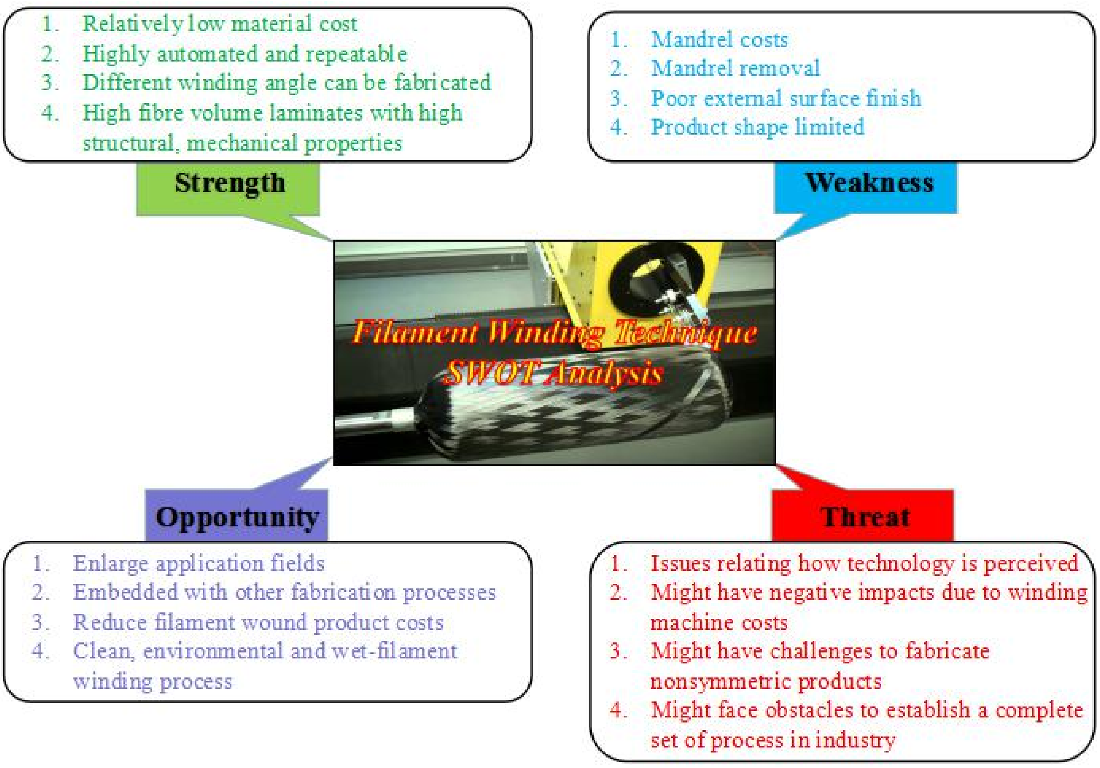

Figure 3: SWOT analysis of filament winding technique

A. Strengths

The most important strength of filament winding technique is its low cost, which is relatively less than other composite fabrication processes. The reduced costs depend on material costs, which relates to a relatively expensive fibre and inexpensive resin. Filament winding technique can have highly automated and repeatable capabilities, which can produce different products without any human intervention[13]. Typical major highlighted strength is that it can fabricate filament wound products with different winding angles, which can meet different work condition requirements. High fibre volume laminates can be used in this process with possible 60-80%, which can provide higher mechanical properties with a high strength-to-weight ratio in some cases[14].

B. Weaknesses

Like other composite fabrication processes, filament winding technique also has few weaknesses, which include mandrel cost, mandrel removal procedure, poor external surface finish and limited product shapes. Filament wound product shape completely depends on mandrel shape and types, which are commonly chosen aluminium or conical steel material. The most important feature of mandrel design is the mandrel removal procedure after curing, which can use mandrel extractor equipment[15]. Mandrel extractors can be configured to either push or pull the composite structure from mandrels. Filament wound composite products can have a much wider tolerance on dimension and roughness on outside surface finish, which can be improved using blade device. It is mainly used for manufacturing open or closed symmetrical structures, which can limit product shape ranges.

C. Opportunities

The relatively low costs on filament winding technique and filament wound products are main reasons that give an opportunity for filament winding technique development, which enlarge this technique application fields such as transportation, infrastructure, building and construction. This technique can embed other fabrication processes such as pulwinding, CNC filament winding and tap laying process(ATL), which can shapely enhance its technique innovation and development. Pulwinding is essentially a combination of pultrusion and filament winding, which can increase design flexibility and enable tubular structure products with almost any combination of fibre alignment[16]. CNC filament winding is combined with computer controlled programming technique, which can require the use of software to generate the winding patterns and machine paths with an advanced numerical control system[17]. Filament winding technique can combine with tape laying machine, which can gently curve aircraft laminates. Additive manufacturing can also embed with filament winding technique, which can have better opportunities in developed technique. Clean wet-filament winding technology can also offer a clean, environmental and efficient method of its strengths[18].

D. Threats

There still exist few threats with filament winding technique, these relates to how this technique supposes to be used and developed. Filament winding machine usually have a relatively low-cost with basic two axes of motion, which is simplest winding machine. Based on filament winding high capabilities, more than 2 axes motion can be chosen to use but with higher costs respectively, which can result in negative impacts. Nonsymmetric products may have a challenge with mandrel design and type in this process. In industry chain, it may have many issues on setup a complete set of related processes.

IV. Favorable factors for filament winding technique application

This section deals with the applied favourable factors that is used to filament winding technique application, which is shown in Figure 4. Filament winding technique application favourable factors are summarized and compared in Table 2, which can have a bright future with different applied levels. All the applied favourable factors were discussed and presented conceptually as follows:

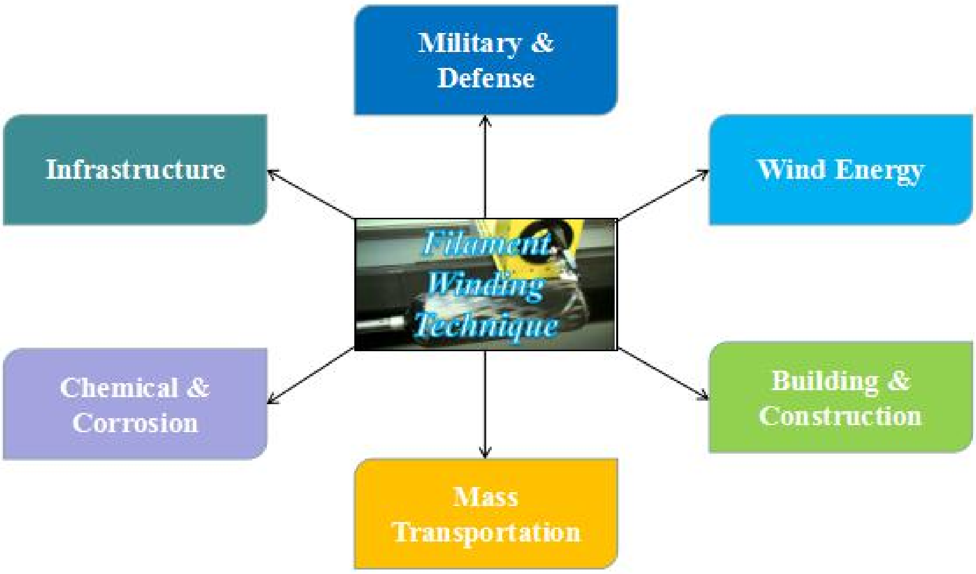

Figure 4: Classification of favorable factors on filament winding technique application

A. Wind Energy

Considering larger turbines and increasing hub heights, the wind turbine market dominated by welded steel shell towers is looking for new structural solutions for future wind energy. Inspired by the applicability of filament winding technique in wind energy production, many related products can be used in filament winding technique such as rotor blade, hub, nacelle and filament wound composite tower[19]. Furthermore, the advanced wind turbine parts are in widespread demand owing to its capability to sustain harsh weather conditions and renewable energy sources.

B. Building & Construction

Filament winding technique is also involved in commercial construction such as composite bridge decks, swimming pools and coastal structure and water storage reservoirs, in which traditional metal corrosion is an issue. Filament wound composite products with concrete columns by filament winding technique have a higher predamaged performance with different concrete column-ratio[20]. It also relates to civil structures and architectural application.

C. Mass Transportation

The filament wound composite product in mass transportation is steadily increasing based on the costs and product performance advantages. Today, it is extensively used in trucks, recreational vehicles, well-established passenger car. New transportation applications demanding higher mechanical performance levels are under development. Railroad cars, trains, automobiles, mass transit vehicles, light-weight bikes and a wide range of ground transportation systems can expand opportunities for composite materials.

D. Chemical & Corrosion

There are many examples of filament wound glass fibre reinforced polymer products being in service in chemical and corrosion applications, which including air pollution control, chemical processing, desalination, food and beverage, mineral processing and mining, oil and gas, solid waste landfill and wastewater treatment. Corrosion resistance is determined by various resin systems, which can provide long-term resistance to nearly chemical environments. Filament winding technique is used in filament underground storage tanks, fire retardant panels, pumps, tubes and valves[21].

E. Infrastructure

Filament winding technique application is increasingly being considered for use in civil infrastructure applications ranging from the retrofit and rehabilitation of buildings and bridges to the construction of new structural systems[22]. Many manufactured products are used in civil infrastructure such as water supply sewers, power grids, telecommunications, ducting and structural shapes.

F. Military & Defense

In the military and aerospace, there are many related aerospace and naval ship/submarine applications using filament winding technique. A major usage is in aircraft-type structure, space shuttle, launch tube, AUSS vehicle and missiles, which are applied with advanced composite fields. The composite material is the key to armament construction, which can make for stronger, lighter and more durable weapons as military and defense purpose application[23].

Table 2: Filament winding technique application favorable factors

Factors	Applied level	Remarks
Wind energy	Medium	Demand of wind turbine blades, wind composite tower and nacelle parts of wind turbines
Building & construction	Low	Product opportunities such as composite bridge decks, coastal structure, composite concrete structures
Mass transportation	High	Popular application such as trucks, recreational vehicles, airplanes and boats
Chemical/corrosion	Low	Storge tanks, pumps, tubes and valves
Infrastructure	High	New application such as water supply, sewers, power grids,telecommunication, tanks, scrubbers,ducting and structural shapes
Millitary & defense	Medium	Potentail application such as panels and armor for military, marine, missile and submarine tubes

V. Conclusion

This section summarizes and concludes the study on applied favourable factors for filament winding technique development. These factors were divided into six categories and discussed in details. Additionally, the SWOT analysis of filament winding technique is also presented in this specific study. The general analysis approach adopted in this study on applied favourable factors that contribute to the filament winding technique development and trends. These factors can highlight filament winding technique strengths and potential applications in the future, which can get its development direction in next decades.

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