Review on Manufacturing Techniques of Fibreglass Reinforced Composites

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Abstract—Combining a high strength fibre with a polymeric matrix produces a composite material with higher stiffness and strength. There are many techniques to produce composite materials, among which few techniques are discussed here based on its process, capabilities and application of composite parts. Among which hand lay-up, vacuum infusion, resin transfer molding and sheet molding compound are widely used. The prepreg is widely used for manufacturing composite parts.

Key words: Fibreglass Cloth, Fibre Reinforced Composites, Prepreg, Vacuum Infusion, Sheet Molding Compound

I. INTRODUCTION

The global nature of today’s reinforced plastics industry creates a demand from all over the world. To produce a composite item, two basic components are required, these being a synthetic resin and a strong fibre [1]. The resin, which can be in the form of a polyester, epoxy or vinyl ester, is normally supplied as a viscous liquid, which sets to a hard solid when suitably activated [1]. The fibre may be glass, carbon, or a combination of some or all of these. What makes composites unique is the fact that the material of construction and the end product are produced simultaneously. Using a suitable mould, layers of fibre are impregnated with activated resin until the required thickness is achieved [1]. After completion, the mould is removed, which further can be used to produce more no. of identical items. These products are FRP cylinders, FRP sheets, FRP components for Transformers, and switchgears products. In the manufacturing of the Fibreglass epoxy sheets are more difficult tasks as it has many intermediate processes to manufactured sheets. The sheets are the combination of the fibre cloth and resin matrix that bond with the fibre cloth to make highly strength composites. Glass fibres fall into two categories: low-cost general-purpose fibres and premium special-purpose fibres. Over 90 % of all glass fibres are general-purpose products. These fibres are known by the designation E-glass. The remaining glass fibres are premium special-purpose products [2]. Special-purpose fibres, which are of commercial significance in the market today, include glass fibres with high corrosion resistance (ECR-glass), high strength (S-, R-, and T E-glass), with low dielectric constants (D-glass), high-strength fibres, and pure silica or quartz fibres, which can be used at ultrahigh temperatures[2].

In manufacturing of epoxy sheets pre-manufacturing prepreg is needed for further processing for better quality. A prepreg consists of fibre fibreglass cloth, impregnated at a pre-determined level with a resin matrix [3].

II. VARIOUS TECHNIQUES FOR MANUFACTURING FIBREGLASS REINFORCED COMPOSITES

A. Hand Lay-Up:

It is a popular technique for manufacturing composite material with open mold. In which a pigmented gel coat is first applied to the mold by spray gun for a high-quality surface. When the gel coat has become tacky, fibreglass reinforcement (usually mat or cloth) is manually placed on the mold. The base resin is applied by pouring, brushing. Squeegees or rollers are used to consolidate the laminate, thoroughly wetting the reinforcement with the resin, and removing entrapped air. Layers of fibreglass mat or woven roving and resin are added for thickness. Catalysts and accelerators are added to the resin to cure without external heat. The amounts of catalyst and accelerator are dictated by the working time necessary and overall thickness of the finished part. The laminate may be cored or stiffened with PVC foam, balsa and honeycomb materials to reduce weight and increase panel stiffness. General-purpose, room-temperature curing polyesters which will not drain or sag on vertical surfaces [4].
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B. Spray Lay-Up:
In a spray lay-up method, the fibre is chopped in a hand held gun and fed into a spray of catalysed liquid resin directed at the mold (Fig 3). The sprayed, catalysed liquid resin will wet the reinforcement fibres, which are simultaneously chopped in the same spray gun. The deposited materials are left to cure under standard atmospheric conditions. The main application of this part is in simple enclosures, lightly loaded structural panels, e.g. caravan bodies, truck fairings, bathtubs; shower trays; some small dinghies [6]

C. Vacuum Infusion:
The most popular term to describe vacuum infusion processes are Vacuum Assisted Resin Transfer Moulding (VARTM), Vacuum Assisted Resin Infusion Moulding (VARIM) etc, basically the same technology, and describe methods based on the impregnation of dry reinforcement by liquid thermoset resin driven under vacuum, and this technique made to reduce the void content inside the molded composites. With vacuum bag moulding, the bags are used to evacuate the air from laminate and to generate the atmospheric pressure required for compaction over the mold [7]. Infusion processes are plagued by limitations such as lower fibre volume fraction, lack of uniform resin distribution, higher porosity, control on thickness of part, clogging of resin and vacuum feed lines. CSIR-NAL has developed a proprietary infusion process called VERITY (Vacuum Enhanced Resin Infusion Technology), Kundan et al. (2013), to overcome the above limitations. The process is designed in such a way that it is scalable from a laminate level to a complex cored primary structure like the wing of a transport aircraft. A schematic of the VERITY process is shown in Fig.4 [8]

D. Resin Transfer Molding:
The RTM process is well suited to manufacture complex small to mid-size parts. However, a problem arises with RTM for composite parts with a high fibre content. Indeed, the permeability of the fibrous reinforcement drops drastically with an increase of the fibre content. Consequently mold filling is completed after a much longer period of time, resulting not only in a low overall throughput of the process, but sometimes in a non uniform impregnation of the reinforcement. One way to overcome this limitation is to design a mold with a thicker cavity to let the injected resin flow above the fibrous reinforcement (Fig. 5a). Once enough resin has filled up the cavity, the injection is stopped (Fig. 5b) and the upper part of the mold is pushed towards the fibrous reinforcement to compress the fibres, hence achieving a complete impregnation and reaching the desired fibre volume content (Fig. 5c) [9].

E. Sheet Molding Compound:
In the SMC-process a couple of male and female moulds are used. They are mounted in a high capacity hydraulic press and heated up to the desired curing temperature with electrical cartridge heaters. When the molds have reached this state a charge is prepared consisting of sheets of SMC
material stapled on top of each other and placed on the lower mould half as shown in Fig. 6. The size of the charge is about 20-90 percent of the mould surface and the mould temperature is between 120-180 °C for unsaturated polyester based SMC-material. Now the press is closed as fast as possible to force the charge to fill the mould. The hydraulic pressure is build up (3-20 MPa) and held until the desired cross-linking is reached which typically takes about 1 – 4 minutes. The final part is now stable and can be demolded enabling the start of a new moulding, as shown in Fig. 6 [10].

Fig. 6: Schematic Sketch of the SMC-Process [10]

1) Combination of SMC & PREPREG:
Jens Wulfsberga [11] had work on combination of carbon fibre sheet moulding compound and prepreg compression moulding in aerospace industry. The demand for fuel efficient aircraft led to the development of innovative lightweight constructions and the use of lightweight materials, such as carbon fibre reinforced plastics. In the same manner competences in new production technologies have been built up in the aerospace industry. However, current processes for producing lightweight composites with an excellent mechanical performance cause high costs and long process cycles in comparison with approved metal processes. Furthermore the used raw materials, such as carbon fibres and resin, are very expensive. In contrast to these technologies sheet moulding compound is characterized by a very high productivity, excellent part reproducibility, cost efficiency and the possibility to realize parts with complex geometries and integrated functions, e.g. inserts or coloring. The biggest disadvantage of sheet moulding compound parts is a low level of stiffness and strength because of a low fibre-volume fraction, a short fibre length and isotropic fibre distribution. In this context the combination of sheet moulding compound and Prepreg compression moulding in a one-shot compression moulding and curing process merges the advantages of both materials to create load bearing and autoclave-quality parts without an autoclave. In the following article, this new technology and its potential will be presented. This paper will also deal with the resulting material characteristics.

F. Bulk Molding Compound:
R. R. Chang [12] at al. had design and manufactured a laminated composite for bicycle crank. They presented the design and manufacturing process of a carbon fibre composite bicycle crank by using the compression moulding (CM) technology. Bulk moulding compound (B.M.C.) was manufactured by mixing strands (>1”) of chopped carbon fibres in a mixer with polyester resin [13]. The crank body is treated as a composite sandwich structure, where the interior is a short fibre layer (B.M.C.) while the exterior is coated with a main long fibre layer and an inner reinforcing layer near the metallic interface ring of the crank. The composite material was hot pressed and manufactured into crank body to reduce most of its weight. In the CM process as shown in fig.8, the long and short fibre layers were joined together by a metallic interface ring. Its characteristics include base composite material, interface ring, hollow square inner wall and exterior projected rib. The inner reinforcing layer provides the maximum bending strength and to reduce stress concentration of the metallic interface ring to crank attachment.

Fig. 7: Process Cycle with the Combination of Pre-Impregnated Carbon Fibre Fabrics and Carbon Fibre Sheet Molding [11]

G. PULTRUSION:
Pultrusion is a continuous composite fabrication process where continuous reinforcing fibres are impregnated with thermostetting matrix and are pulled through a heated die to form composite profiles [13]. It has the capabilities to run continuously with constant cross section profile with the mass production volume. Thermosetting pultrusion process can be divided into three zones; heat transfer zone, pressure zone and pulling zone [14]. Firstly, the fibres are pulled from the creel through a resin bath (Fig. 9) with the proper resin viscosity. Then, polymer solution is placed in the resin bath, which contains polymer resin, filler, catalyst, release agent, pigment, Ultra Violet (UV) stabilizer and other enhancement additives. Thereafter the fibres are guided by a guide plate where the fibres and resin are impregnated. The fibres are pulled through pre-form guides to eliminate excess resin before entering a heated die where the composites are cure [15]. The heated die in most of pultrusion process is divided into two zones; a low temperature for gelation and a high temperature to cure the resin. The pultrusion die is heated by a heater and the temperature is controlled using thermocouple sensor, which interacts with heater to ensure the temperature is sufficient...
and to avoid die from overheating which can cause the defect on the pultruded profile [15].

Fig. 9: Schematic Representation of Pultrusion Process [15]

H. Filament Winding:
The filament winding process is a manufacturing technique in which a resin impregnated continuous filaments band is wound over a rotating mandrel. The synchronized movement of both the mandrel and the delivery head accomplishes the precise positioning of the fibres on the mandrel surface, leading to the desired lay-up pattern. The main process user-controlled parameters are the initial fibre’s tension, the winding speed, the winding angle, the bandwidth, the processing temperature, the initial fibre/resin fractions, the geometry and the materials systems used [16].
The filament winding process widely used to manufacturing of GRP pipes is illustrated in the figure 11.

Fig. 10: Schematic Representation of Filament Winding Process [17]

III. MANUFACTURING PROCESSES USED BY COMPOSITE MANUFACTURER

Fibre-reinforced plastics are lightweight materials with outstanding mechanical properties. On the one hand the application of those materials can have an outstanding contribution to product performance (e.g. energy efficiency). It is required to enhance production control method for the manufacturing of pre-impregnated fibre (prepreg) parts based on a survey among manufacturers of such parts. In addition to the trend of sustainability and lightweight products, the manufacturers of prepreg parts are strongly influenced by the so called turbulent environment like all other manufacturers. This means that customer’s and market behavior becomes increasingly less predictable. Furthermore, the trend of individualization accounts for high demands in terms of delivery times and delivery reliability. The survey has been carried out and goal of the survey was to assess production control challenges in prepreg manufacturing. A standardized questionnaire was used, when the survey was conducted between October 2011 and March 2012 [19]. Prepregs are used for the following reasons: high fibre-volume content (75%), customer’s requirements (88%) and requirements to positioning of fibres (50%) [19]. to manufacture prepreg, composite manufacturing company used following process by survey.

Fig. 11: Filament Wound GRP [18]

IV. CONCLUSION

It has been found that for manufacturing composite parts many different techniques are used, among those many processes are used for manufacturing prepreg parts i.e. SMC (sheet molding compound), BMC (bulk molding compound) and combination of prepreg and SMC. And by market survey prepreg are widely used for manufacturing composite parts. So for manufacturing prepreg with good quality and high productivity an automated prepreg manufacturing system is required.

REFERENCES


