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Overview on Vacuum Assisted Resin Infusion Molding Technique: A Novel approach for advanced Composites fabrication for Aircraft and Automotive applications

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ABSTRACT

Now a day's fiber reinforced polymer composites are replacing metals in various critical applications in military, aviation, automotive, and other industries due to properties shown by them are comparable or superior than the traditional metallic materials because of their less scrap waste, high productivity, low density, high strength to weight ratio, and high module-weight ratios. This review provides overview on polymer composites, their classification, different manufacturing processes and Vacuum assisted resin infusion molding (VARIM) in particular. The author's makes sincere efforts to explore the details of the process, materials and advantages of the VARIM technique with thorough literature survey up-to-date.

Keywords-*: *Glass fiber reinforced polymer, Nano-composites, Vacuum assisted resin infusion molding, Automotive and Aircraft applications

I.INTRODUCTION

1.1 Polymer Composites

Fiber reinforcement composites are a combination of fiber of high strength and modulus embedded in or bonded to a matrix with distinct boundaries or interfaces between them. The matrix and fiber both retain their chemical and physical identites; even then they produce a combination of properties which are unachievable with either of the constituents acting alone. The properties shown by various fiber reinforced polymer composites are comparable or better than the traditional metallic materials due to low density, high strength-weight ratios, and high modulus-weight ratios. Now a days, fiber reinforced polymer/Nano composites are replacing metals in many weight critical components in military, aviation and automotive industries [1]. Fiber reinforced nano composites are having high internal damping, consequently high Vibrational energy absorption within the material and reduced transmission of vibration and noise to neighbouring structures. Fibers are primarily load bearing constituents of polymer reinforced polymer composites. Different type of fibers used for fabrication of composites includes Aramid fiber, Glass fibe, carbon fiber, boron fiber, Kevlar fiber and natural fibers. Glass fibers are most common of all reinforcing fibers for polymeric matrix composites [2-11]. The salient features of Glass fibers are low cost, high tensile strength, high chemical resistance and excellent insulating properties [8, 12]. Glass fibers are manufactured by drawing molten glass into very fine threads and then immediately protecting them from contact with atmosphere or with hard surfaces in order to preserve detect free structure that is created by the drawing process [16].

Generally two types of Glass fibers are used for composites that are E-glass and S-glass. S-glass possesses better mechanical properties as compared to E-glass but its higher cost limit's it's use [16, 8, 12].

1.2 CLASSIFICATION OF POLYMER COMPOSITES

There are two main groups of plastic moulding materials:-

1) Thermoplastics:-This group of plastic can be softened every time they are heated; they can be recycled and reshaped any number of times. This makes them environmentally attractive. However, some degradation occurs if they are overheated or heated too often and recycled materials should only be used for lightly stressed components [12-14]. Thermoplastic moulding usually made by the injection moulding process which is suitable for quantity production of both large and small components and is the most widely used moulding process. For Example: - Polyethylene, PVC, Polystyrene, Polypropylene, Nylon- Star Wheels, Cams, Brush Handle.

2) Thermosetting plastic:-This group of plastics differs from thermoplastic materials in that polymerization is completed during the moulding process and the material can never be softened again. Polymerization during the moulding process is called curing.

1.3. MANUFACTURING OF COMPOSITES

The various methods of Composite manufacturing are as follows:

1. Hand and Machine Lay-up: In this technique, fiber or fabric layers are placed on a mould and resin (usually polyester or epoxy) is applied on these layers until the desired thickness is reached. To achieve a better surface quality a gel coat is applied on the mould. The thickness is controlled by using a roller to remove the entrapped layer and is then subjected to curing at room temperature.

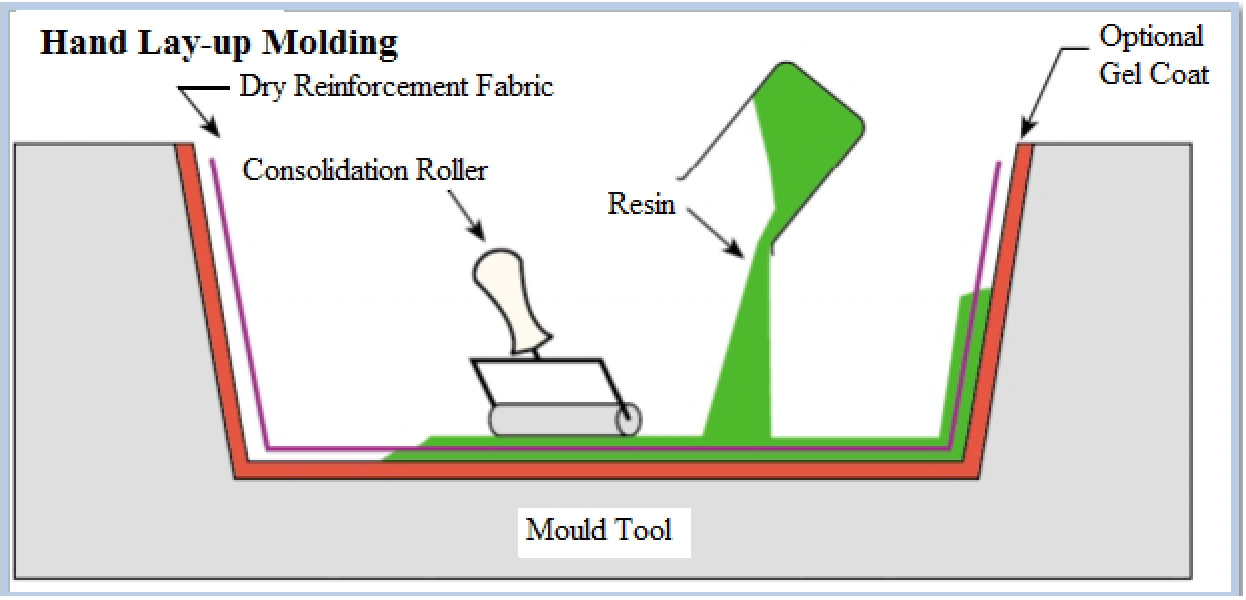

Fig.1. Hand lay-up molding [9-11]

2. Spray–up molding: In this technique, chopped fibers along with resin (usually polyester and epoxy) are deposited on a mould with the help of a suitable spraying equipment. A further curing treatment is carried out at room temperature and composite structure is made.

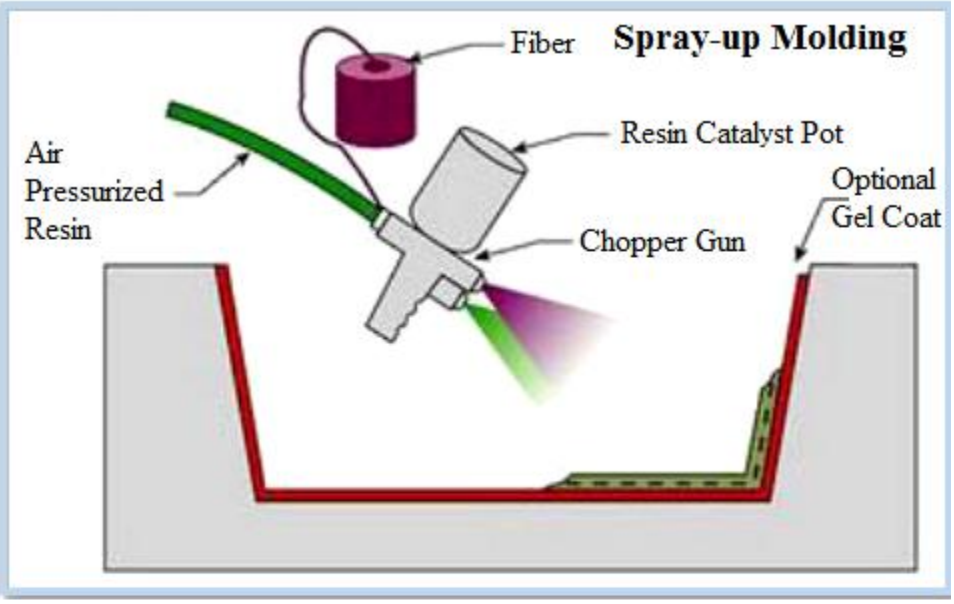

Fig.2. Spray up molding [9-11]

3. Injection molding: It is a technique, where in a high pressure is used thermoplastic and thermo set parts. The molten matrix is then forced in to the mould cavity where it freezes and is finally ejected as finished part.

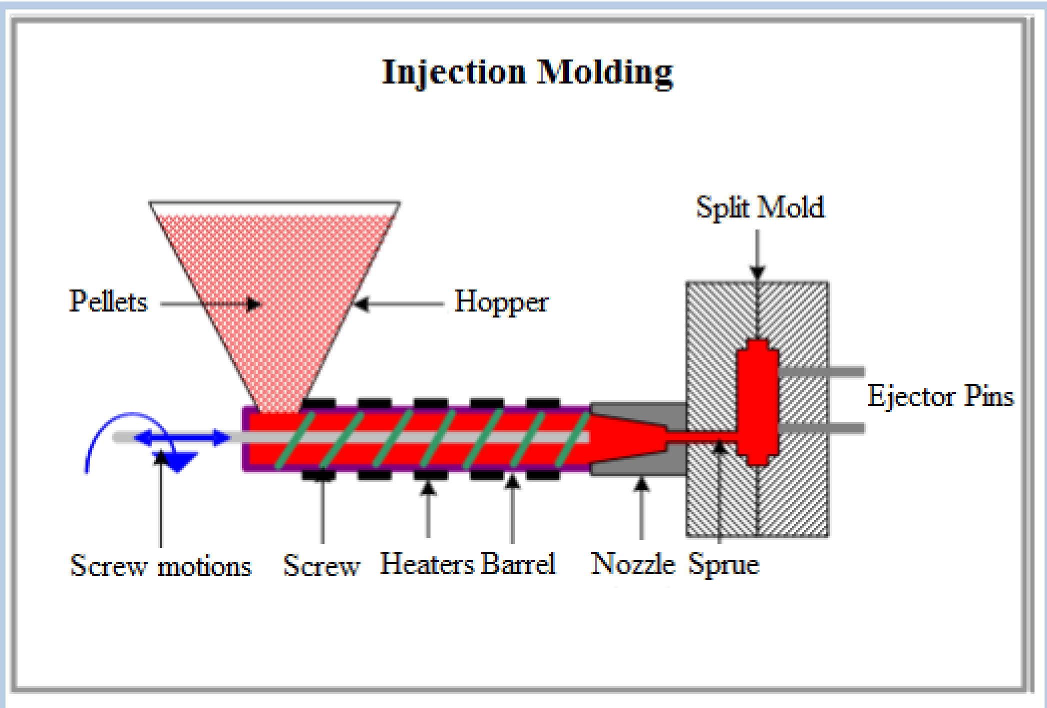

Fig.3. Injection Molding [9-11, 13]

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In case of thermoplastic injection molding, a molten thermo-plastic material is forced in to the mould cavity where it solidifies where as In case of thermo set injection molding, a reacting material is forced in to a warm mould where it is solidified by cross linking.

4. Autoclave: In this technique, heat and pressure are applied in the material. The which has a shape of the part which is to be produced. Both the thermosetting as well as thermoplastic polymers are suitable for compression moulding. This technique is preferably used for flat or slightly curved laminates lay-up is built on a mould plate

5. Pultrusion: This process is widely used for unidirectional reinforcement for simple structures such as tubes and circular rods. In this technique continuous reinforcement fibers of glass, Aramid and glass etc. are drawn through a resin bath and impregnated through a heated die in order to obtain the desired shape of the composite.

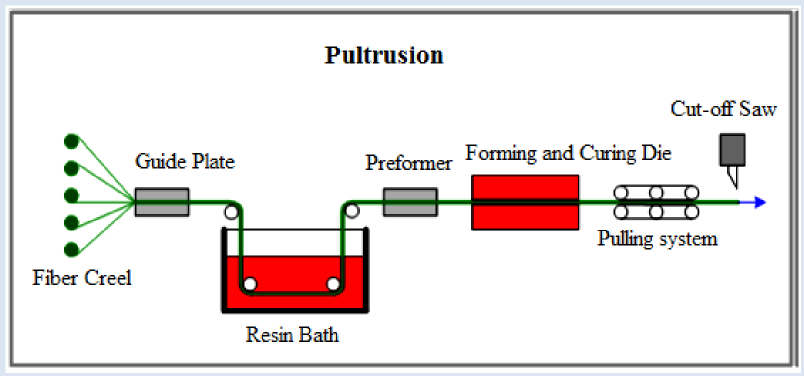

Fig.4. Pultrusion Technique [9-11, 13, 16]

II. VACUUM ASSISTED RESIN INFUSION MOLDING (VARIM)

2.1. Fabrication of Nano-composites using VARIM

Nano composites comprises of three main constituents:

Matrix (Primary Phase)-: The polymer matrix is the primary phase of the polymer nano-composites. The matrix binds the fibers together freezing in the fiber orientation. Four loads applied to the nano-composites are transferred to the principal load bearing component i.e. fibers through matrix enabling the composite to withstand flexural, compression and shear forces as well as tensile loads. The matrix must separate the fibers from each other so that they can act as separate entities. The matrix also protects the fibers from environmental degradation and mechanical damage [16]. The desirable properties of matrix include low shrinkage and moisture absorption, good strength at an elevated temperature, dimensional stability and chemical resistance. The matrix must be elastic to transfer the load to the fiber [25].

Reinforcement (Secondary Phase):

The reinforcement i.e. secondary or dispersed phase is the load bearing constituent of a composite. These are of Nano, micro, and macro levels. All loads to the applied to the matrix are transfer to the reinforcement through an interface or boundaries. The reinforcement in properties depends upon bonding between matrix and reinforcement [26-27]. The reinforcement is generally harder or stiffer than the matrix.

Interface:

Interface is the contact surface between common boundary of matrix and reinforcement fiber. It maintains the bond between them for transferring the loads. It has mechanical and physical properties that are different from those of matrix/fiber. The chemical, physical and mechanical properties vary either continuously or in step-wise manner between those of the matrix material and the bulk fiber [19]. Interface properties mainly depend upon the physical and chemical nature of the matrix and fiber. There will be some modifications of either physical or chemical characteristics or both resulting in the region which has properties quite different from those of either of two major components. The stress transfer between the matrix and reinforcement mainly depends on the interface properties [16].

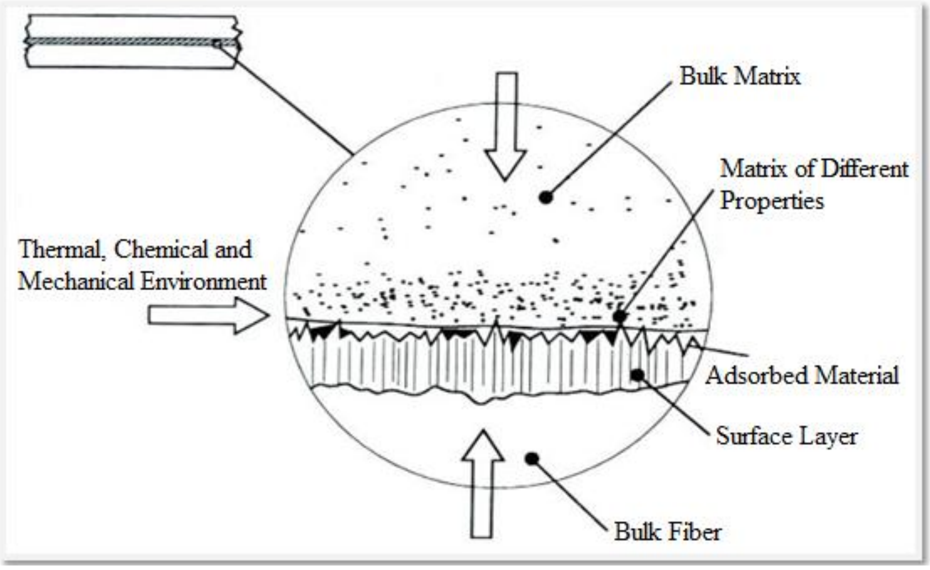

Fig.5. shows three dimensional interfaces between fiber and matrix [19]

2.2 Procedure for fabrication of Glass fiber/Nano reinforced Composites-:

The procedure for fabricating fiber-reinforcement Nano-composites is written as mentioned below:

- In each run for fabrication of Nano composite, both sheets of dimensions (30X40X0.7 and 30X10X3.2 mm^3) are fabricated as single big sheet. The weight of the processed nano-composite or big sheet is 290 grams. Out of this total weight i.e. 290 grams, the weight of fiber mat used is 200 grams.
- The amount of resin i.e. polymer and curing agent was decided on the basis of weight of the fiber being used for fabricating the nano-composite sheet.
- The weight of glass fiber used for fabricating the Nano composite sheet is 200g. the initial amount of resin infused into Vacuum Assisted resin infusion moulding (VARIM) set-up is twice the weight of glass fiber i.e. 400 grams as recommended by supplier. Polymer and curing agent were mixed in the weight ratio of 100:10. So, for infusion 400 grams of the resin into VARIM set-up, the amount of polymer (liquid) and hardener are calculated.

- Before fabricating each Nano composite sheet nanoparticle was heated in a vacuum oven at 120°C for 18h to remove the moisture contents from the clay.
- The required amount of polymer was taken in a beaker; the required amount of nanomaterial was added into the beaker and mixed with hand using a stirrer. After hand mixing homogenization is carried out at 20,000 rpm for 10 minutes. Homogenization was followed by Ultra-sonication at an amplitude of 80% for 10 minutes. The pulse is on for 40 seconds and off for 20 seconds. During Ultra-sonication, the beaker is placed in the ice bath so that temperature of mixture doesn't become very high.
- After mixing the clay, crying agent is added to the mixture at 40 and mixed with the help of mechanical stirrer for 10 minutes at 500 RPM. Finally, the mixture is degassed for 10 minutes to remove the entrapped bubbles from the mixture. The resin prepared in the last step is now ready to be infused into the VARIM set-up. For this, VARIM is cleaned with the cleaning agent. Then the releasing agent is applied on it for easily removal of nano-composite sheet. Finally, Breather is applied on all four sides of work-table for removing air bubbles entrapped in the resin.
- Fiber mats are now placed on the VARIM work table within the breather. A separator sheet is placed on the fiber mats (see figure (b) followed by placement of a perforated sheet and wire mesh on it.
- In the last, a plastic pipe was placed on the wire mesh for infusion. Vacuum was created by sealing the VARIM with the help of plastic laminated sheet. When pressure (vacuum) reached 0 Bar, the resin was infused through the pipe. Care was taken that before and after infusion pipes were made leak proof using tape so that 0 bar pressure is maintained throughout the fabrication process as shown in the figure (d).

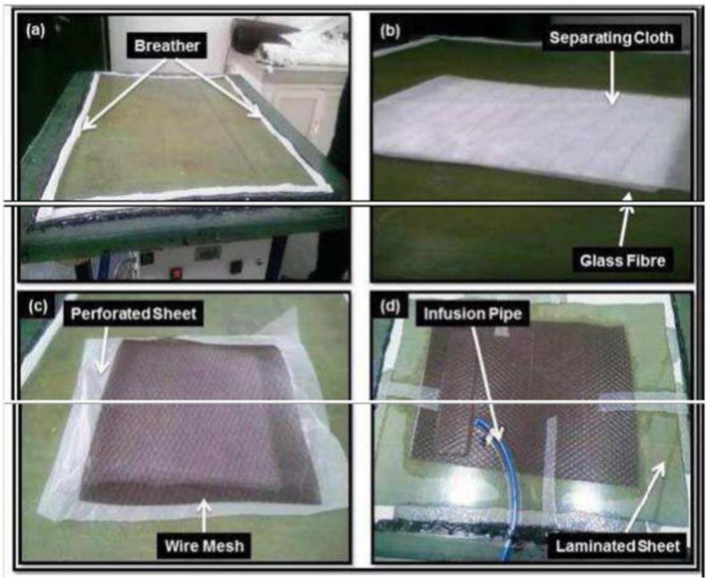

Fig.6. shows various steps involved in fabricating fiber reinforcement polymer layered Nano-composites using VARIM (a). Breather for removing entrapped air, (b). Fiber mat covered with separating cloth, (c). Perforated sheet and wire mesh placed on the separator and (d). Infusion pipe below the laminating sheet [10, 19]

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2.3. Recent Applications of VARIM Process:

VARIM possesses several applications such as:

1. Marine applications: VARIM technique is used in fabricating marine parts such as deck, trays, hulls etc where strength to weight ratio is the key aspect. These large structure marine parts are manufactured from 6 m to 40 m which is basically very difficult to manufacture by using any other techniques with less scrap and high productivity.

Fig.7. Large structures marine decks, hulls and trays using VARIM technique [21]

2. Grid/Grating and construction applications:

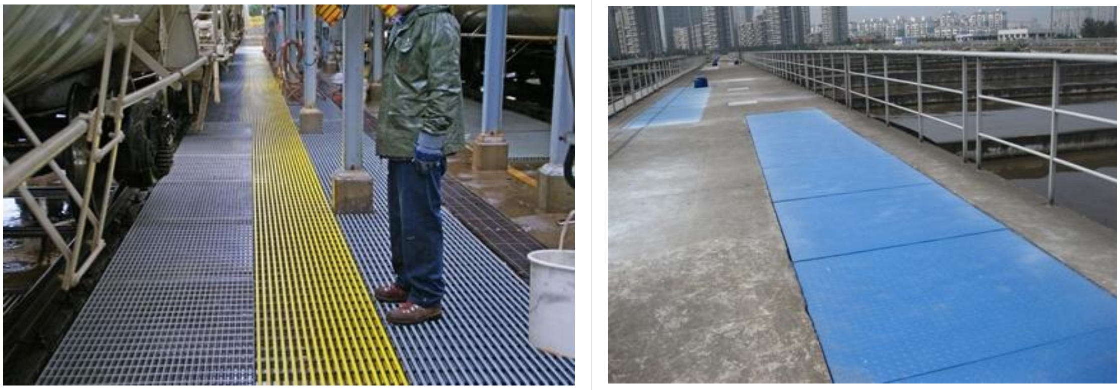

Fig.8. Steel gratings and structures using VARIM technique [13, 21]

VARIM Technique is used to fabricate steel grit/grating and other construction applications because of various advantages such as high durability of buildings, resists corrosive attack, high cycle time and low environmental impact with high stiffness.

3. Aircraft and Automotive part applications:

(a) (b)

Fig.9. Complex aircraft parts (a) and automotive parts (b) fabricated using VARIM technique. [10, 13, 21]

VARIM technique is especially used to fabricate complex irregular shape aircraft and automotive parts where strength and weight consideration is high which is rather very difficult to manufacture by using other techniques. The complex parts fabricate by using VARIM process possesses high dimensional tolerance, wide range of accuracy and less scrap wastage making high performance vehicle with overall low manufacturing cost.

IV. CONCLUSIONS

Vacuum assisted resin infusion molding was used to fabricate the glass fiber reinforcement polymer Nano-composites which possesses low density, high strength-weight ratios, and high modulus-weight ratios properties in aircraft and automotive applications. This paper overview the recent trends and technologies for fabricating fiber reinforced nano-composites. The parts fabricated from VARIM process exhibits good dimensional acuuracy, good surface finish with large scale productivity, uniform resin distribution at high viscosity, less scrap, low volatile organic content composition, toughened resins. The main key feature of part fabricate by using this molding technique is production of void free nano-composites.

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