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Overview of Manufacturing PMC's Using Traditional and 3D printing Technology (FDM)

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Abstract: **Composite materials are those materials which are made by combining two or more materials with unique properties. Polymer matrix composites are one of the most important composites which are used in various industries due to their light weight, high stiffness and high strength. Because of its advantages it is important to know the manufacturing techniques of PMCs. PMCs are used by automotive, pharmaceutical, sports and aerospace industries. This paper gives detailed review of different traditional and 3d printing methods of manufacturing Polymer Matrix Composites. These methods are more effective in making special shapes west bullet proofs, boat bodies and heavy cylinders. In recent research on effecting manufacturing of composite materials, it is found that the 3d printing technology makes some difference in making PMC with much better properties. In this review we also discuss about one of the 3d printing methods, that is Fusion Deposition Modeling for making PMCs with improved strength and properties.**

Keywords: **Stiffness, Strength, Polymer Matrix Composite, Manufacturing, FDM, 3d printing.**

I. INTRODUCTION

Composite materials are made by combining two different materials having unique properties to achieve the best properties suitable for various applications. Polymer matrix composite is one of the various types of composite materials possessing its own properties for various applications. As composite material is made by adding two phases that are matrix and reinforcement fibers, in polymer matrix composites, polymers are taken in matrix phase and the other suitable materials are taken in the form small fiber particles. Thermosetting resins are the most widely used polymers in PMCs. Matrix material serve several functions in the composites. They provide bulk form of product, hold the fiber particles in place and distributes load uniformly throughout the matrix phase. Commonly used reinforcement fibers are glass, carbon and Kevlar. Advanced polymer matrix composites use boron, carbon, Kevlar as reinforcing fibers in with epoxy as the matrix. Polymer matrix composites are used in automotive industries which benefits reduction in weight and also some time reduces the production cost of the vehicle parts. Most common parts made by PMCs are exterior body panels, components under the hood, battery trays and protective shields. In marine application, the composites are for making power boats and sailing yachts. The reason for the use of composites in marine application is relatively less cost as compared to wood and metal work, less skill of operator and increased life time with less damage to the manufactured parts. Because of various advantages the composites are also used in aerospace applications which need needs high strength and less weight.

The 3d printing technology is the recent developing manufacturing method for making effective products. These Additive manufacturing is used for making tools and rapid prototypes at the design and construction stage in aviation, automobile and military industries, architecture, medicine, goldsmithing, food and footwear industries, where in a relatively short time a real model can be made to be presented to a customer or sponsor. The 3D printing technology made it more effective of making prototypes, spare parts or complete devices with improved properties, usually of small size. 3D

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printers are also used in medicine for printing prosthetics, implants, and bioprints using cells (wound healing). Extended applicability and wider dissemination of 3D printing, as well as higher performance requirements necessitate seeking multi-material solutions and use of state-of-the-art composites. Composite properties depend on many factors, i.e. particle size, shape, orientation and distribution of the reinforcement phase in the matrix as well as the methods that we follow for manufacturing.

II. MANUFACTURING METHODS OF POLYMER MATRIX COMPOSITS (PMC'S)

There are several manufacturing methods for processing polymer matrix composites. The method selected based on type materials we select and application required. The various methods are hand layup method, Autoclave method, filament winding method and reaction molding.

A. Hand layup method

It a method in which the mold is prepared as one side open with the required shape. The fibers of reinforcement are layed on the surface and matrix material in the form of gel is painted over the fibers. This painting is continued until the required thickness is obtained. It is the most economical process which involves less equipment. Because of this process is done by hand, we can have a better control on the fiber orientation in the matrix material. The molds can be made up of wood, sheet metal, plaster and FRP composites. The molds are coated with gel to get the better surface quality. This is the oldest commonly used manufacturing process. Most of the aerospace composites are made by hand layup method. This method is used to make polyester and epoxy resin parts such as boat hulls, tanks and vessels.

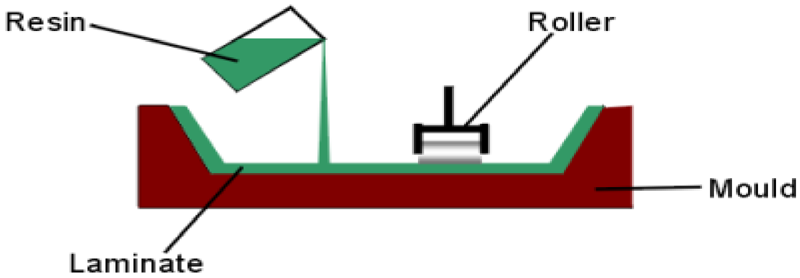

Fig. 1 Hand Lay Up Method

B. Autoclave method

Autoclave method is process of part molding by one of the open molding methods in which the part is cured by a subsequent application of vacuum, heat and inert gas pressure. The molded part is first placed into a plastic bag, from which air is exhausted by a vacuum pump. This operation removes air inclusions and volatile products from the molded parts. Then heat and inert gas pressure are applied in the autoclave causing curing and densification of the materials. Autoclave curing enables fabrication of consistent homogeneous materials. The method is relatively expensive and is used for manufacturing high quality aerospace products.

An autoclave is a closed vessel in which processes occur under simultaneous application of high temperature and pressure. This process needs high pressure. Composites cure under heat and pressure provides a superior part because the voids are reduced due to the pressure. The part is placed in the pressure vessel, and heated, pressure is applied simultaneously.

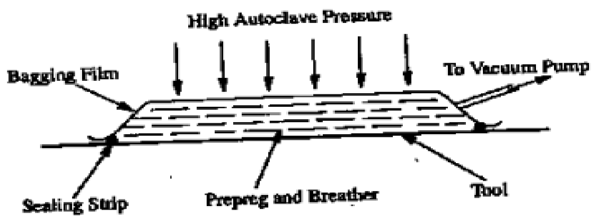

Fig. 2 Autoclave Method

Vacuum bagging can be used in an autoclave. Thermoset composites are cross linked and thermoplastics are melted. The pressure helps bond composite layers, and removes more voids in matrix. Very large parts can be made. But it is highly expensive.

C. Filament winding method

It is a method which involves continuous filament of reinforcement material wound around the mandrel in layers. It is used for making round cylindrical parts. A tape of resin impregnated fibers is wrapped over a rotating mandrel to form a part. These windings can be helical or hooped. Parts vary in size from 1'' to 20'. Winding speeds are typically taken as 100m/min. The winding tensions are 0.1 to 0.5kg. High strengths are possible due to winding designs in various directions. This process can be automated and provides high production rate. High strength and different sizes of products can be made. It has a control of strength in different directions. But complex shapes cannot be obtained. The surface is poor. This method is used for making pressure vessels, storage tanks pipes. Also used to produce rocket motors, launch tubes, drive shafts etc.

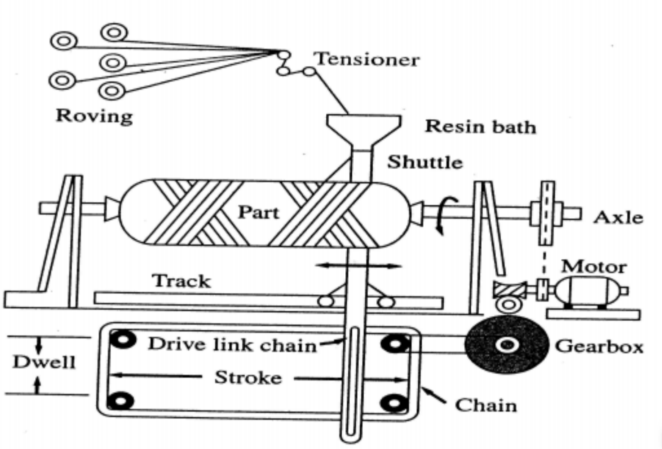

Fig. 3 Filament winding method

D. Reaction moulding method

Two reactive ingredients are pumped at high speeds and pressures into a mixing head and injected into a mold cavity where curing and solidification occur due to chemical reaction. Stack of laminate consists of fibers impregnated with sufficient thermoplastic matrix and polymer films of complementary weight to give the desired fiber volume fraction in the end product. These are then consolidated by simultaneous application of heat and pressure. Generally, a pressure of 6 to 12 MPa, a temperature in between 275^0C to 350^0C and dwell time of up to 30 minutes are appropriate for thermoplastics such as polysulfones and polyetheretherketone.

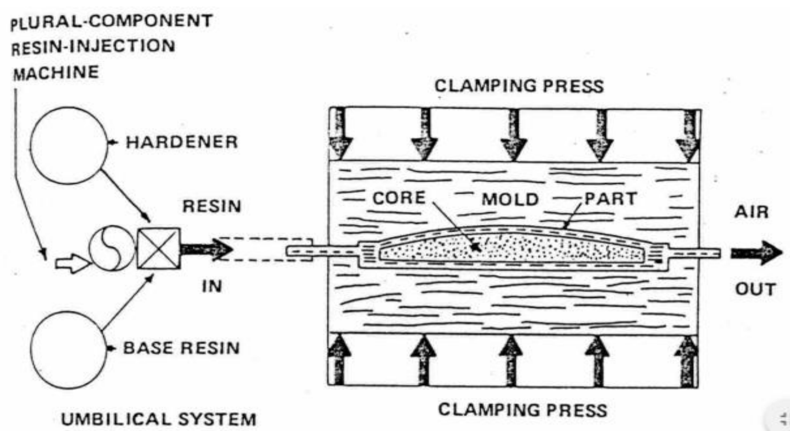

Fig. 4 Reinforced thermoset injection with fiber combination

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D. Fusion Deposition modeling by 3d printing technology (by single nozzle printing on the reinforcement material)

FDM technology also known as fused filament fabrication (FFF) is currently the most widespread way to rapid production of items utilizing additive manufacturing. This method is a well-known technology patented in 1989 by Scott Crump, a co-founder of the Stratasys Company. 3D printing by FDM consists in depositing a filament of thermoplastic material. The required model can be manufactured by depositing a layer contour, then filling the inside with plasticized material by zigzag movement of the head. After printing one layer the head moves along the Z axis initiating the build-up of the next layer. By using this method we can also manufacture complex shapes with less effort. The production process begins with creating a model in the CAD program, then the model is inserted into the program enabling control of process parameters such as head movement, feed rate, layer thickness, head and table temperatures, slicing, support application, etc. Such a program generates a G-code, which uploaded in a 3D printer enables making a real model. The most common drawbacks associated with FDM technology include: - stepped layers - visible paths of the deposited material due to a certain distance between edges of subsequent layers. This effect can be minimized by printing lower layers as well as reducing the diameter of the extruder (which will extend the process and raise the cost). - Overhang and bridging - printing of each model begins from the first layer applied onto a build plate. A subsequent layer is printed onto the surface of the previous one. If an item has elements set at an angle relative to the vertical axis (e.g. at 45^{o}) the filament may not have a support and collapse. In such cases, supports should be generated at the model preparation stage to prevent damage. A bridge, that is parts of the model supported on its two ends, is a particular, troublesome case of overhang. Therefore, in the case of long overhangs, auxiliary supports have to be designed, then removed during the final machining of the print.

Manufacturing a composite structure using a single head by printing on the reinforcement material (Fig 5a), is a method similar to creating multilateral structures. Composite materials are obtained in a multi-stage process, where depending on the number of layers number of stages of manufacturing decided. Each printing stage is designed by specifying a division plate, which helps in stopping the printing and depositing the reinforcement phase on the print. The composites made by this method are reinforced with continuous fibre, cloth, or mat. Manufacturing of composite structure consists of following things:

a) Single head printing on a reinforcement material

b) Dual materials printing

c) In-nozzle impregnation

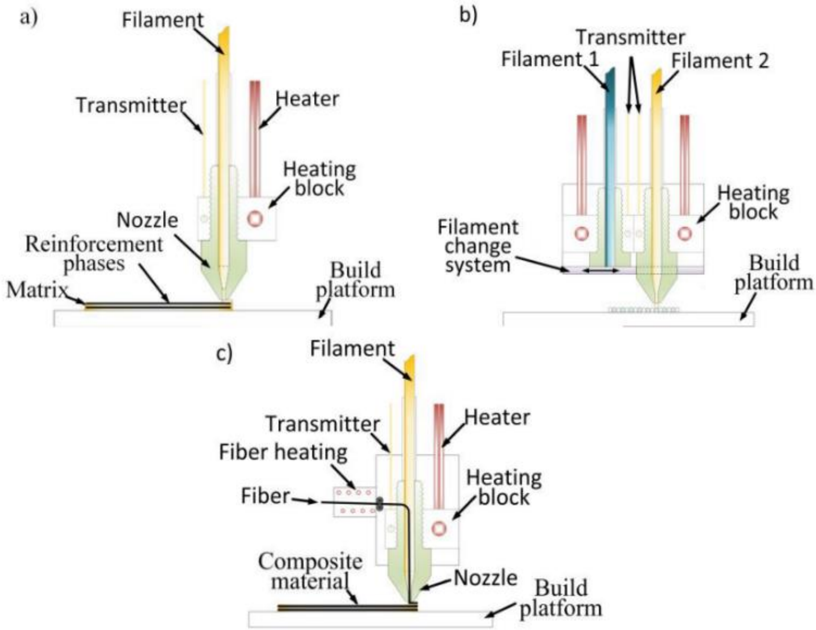

Fig. 4 Manufacturing steps involved in FDM method

The limitations of this type of printing include restrictions associated with the process and with the thickness of individual layers of the reinforcement material in the composite. If a bunch of reinforcing fibres is too thick, the reinforcement phase may get deformed because fibers stuck to a jet of plasticized material may get shifted. The layer of reinforcement commonly found in the literature is approximately 0.5 mm thick.

III. CONCLUSION

Polymer Matrix Composites are used in various industries for which making, design and development of PMCs more important. Apart from introduction to the polymer matrix composite, this paper explains about various techniques of making Polymer Matrix Composite. It reviews the processing techniques of PMCs like Autoclave method, Filament Winding method and Reaction injection molding method. It also provides the applications of the processes used to make various parts related to different industries. In addition to traditional methods we have, a 3d printing technology is also included to get more effective composite materials. FDM is the common 3d printing technology which is used to make various products with effective properties according to our requirements. As PMCs are used in aviation industries, the PMCs must possess the required properties to withstand the complex situation in their application. So for making PMCs, we must select the effective methods to manufacturing them without losing their properties.

REFERENCES

[1] ASM International ( ) Engineered Materials Handbook, pp. Ohio: ASM International. [Comprehensive set of handbooks.]

[2] Peters S. T., Humphrey W. D., and Foral R. F. (1991). Filament Winding, Composite Structure Fabrication, pp. US: SAMPE (Society for the Advancement of Material and Process Engineering). [Filament Winding.]

[3] VCH Publishers ( ). International Encyclopedia of Composites, (ed. S. M. Lee), pp. New York: VCH Publishers. [Comprehensive six-volume encyclopedia.]

[4] M.K. Kang, W.I. Lee, H.T. Hahn, Analysis of Vacuum Bag Resin Transfer Molding process, Composites A 32 (2001) 1553-1560.

[5] A. Khattab, Exploratory Development of VARIM Process for Manufacturing High Temperature Polymer Matrix Composites, Ph.D thesis, University of Missouri, 2005.

[6] M.S. Koefoed, Modeling and Simulation of the VARTM Process for Wind Turbine Blades, Industrial Ph.D. Dissertation, Aalborg University, 2003.

[7] A. Ragondet, Experimental Characterization of the Vacuum Infusion Process, PhD thesis, University of Nottingham, 2005

[8] J.W. Boh, L.A. Louca, Y.S. Choo, S.E. Mouring, Damage modeling of SCRIMP woven roving laminated beams subjected to transverse shear, Composites B 36 (2005) 427-438.

[9] N.C. Correia, F. Robitaille, A.C. Long, C.D. Rudd, P. Simacek, S.G. Advani, Use of Resin Transfer Moulding

[10] Patent US 5121329 A: Apparatus and method for creating three-dimensional objects; 9 Cze 1992

[11] Dudek P.: FDM 3D printing technology in manufacturing composite elements. Archives of Metallurgy and Materials, 58(2013),nr.4,1415-1418