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Review Article

COMPOSITE MANUFACTURING TECHNIQUES – A REVIEW ON INJECTION, COMPRESSION, PULTRUSION AND EXTRUSION PROCESS

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ABSTRACT

In this era of development of new materials with good properties, is going to be a challenge when different processing methods are available with their merits and demerits concerned with reinforcement compatibility with matrix. From the last so many years, many researchers develop different kind of techniques to manufacture good quality polymer composites. In this article, effort has been made to summarize the important techniques of developing the composites along with their effects on properties and their use in various domestic and commercial purposes.

Keywords: Polymers, Properties, Applications, Reinforcements, Processing

1. INTRODUCTION

Composites consist of two or more than two physically as well as chemically different phases in-between which a wall of interface is there. The reason of joining different phases is to achieve the optimum quality of the product that can't be produce with the single phase. These composites are attracting the researchers as well as manufacturers (aircraft, medical, electronics and construction firms) around the globe due to their low weight and less cost [1]. Matrix and reinforcements are the two main phases that form the composites. So composites are usually classified on the basis of matrix (metal matrix composites (MMCs), ceramic matrix composites (CMCs), and polymer matrix composites (PMCs) and reinforcements (fibrous, particulate and laminates) as shown in Fig. 1 [2].

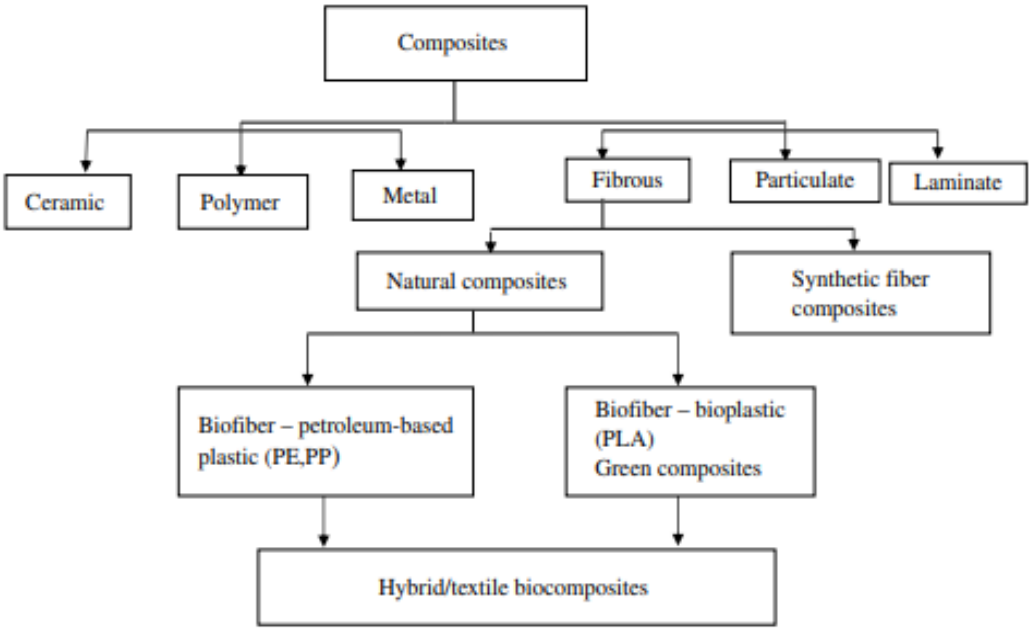

Fig. 1: Classification of the composites [2]

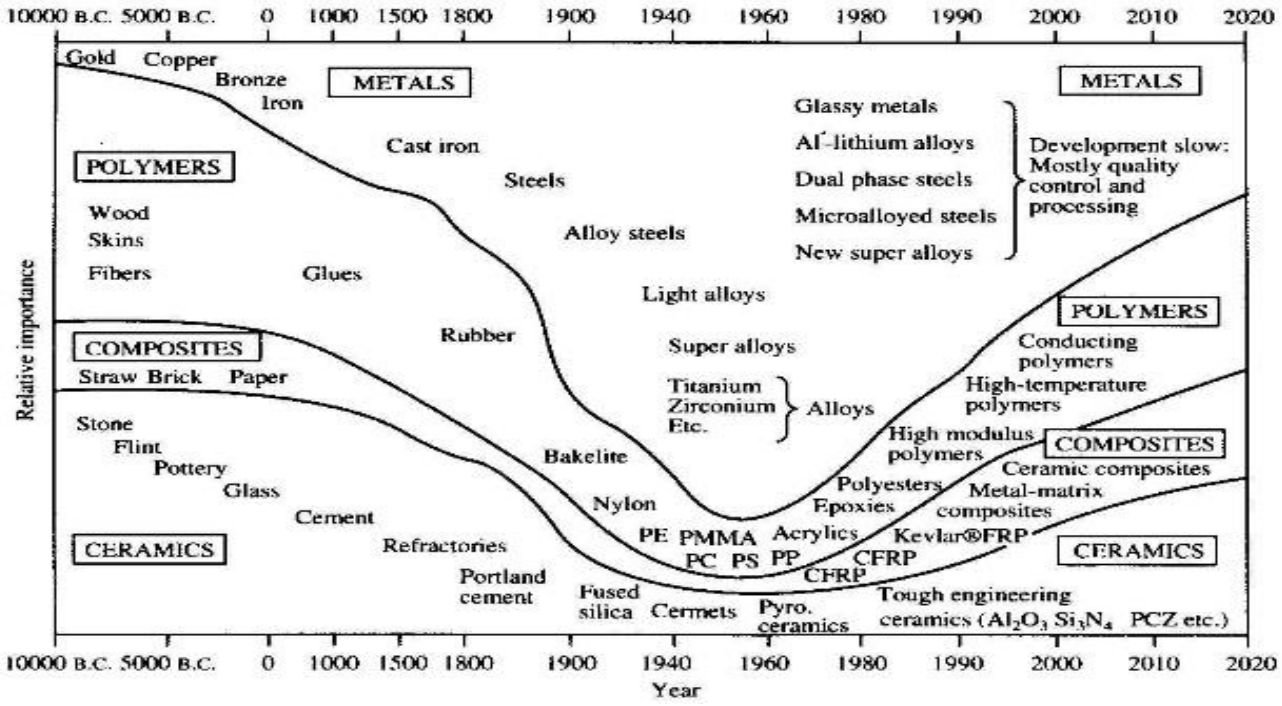

Fig. 2: Importance of materials with the passage of time [4]

Now-a-days material is one of the important aspects in the overall growth of the human civilization [3]. Moreover the use of these materials in various sectors like structural has been fluctuating. The growth in this sector can be seen by studying the role of the material starting from the 10,000 B.C. to the present and for the next 2 years also as shown in Fig. 2 [4]. To compete in today's fast growing civilization, industries are very much interested in manufacturing the components that are not only light in weight but also having good strength for their daily applications [5, 6]. Because of the better properties of composites in terms of thermal, mechanical and wear properties, they are known to be more suitable material as compared to other conventional materials [7, 8, and 9]. PMC (Polymer Matrix Composites) materials having cheap in price are very popular these days. Moreover the processes involved in manufacturing of PMC's are very simple [10]. The properties of Polymer Matrix Composites depends on various factors like the type of matrix used, reinforcements and the matrix-reinforcementinterface. The proportion of reinforcement used in the composites' manufacturing along with all other factors plays very important role to get the required product characteristics' as per the conditions prevailing or applications [11]. So in this review paper, effort has been made to enlist various methods of manufacturing these composites.

2. MANUFACTURING TECHNIQUES

There are several techniques available to process the composites. Some of the important techniques have been discussed here.

2.1. Injection molding process

It is one of the important and mostly used processing technique for manufacturing thermoplastic polymers. More than 30% of the plastics are being manufactured or processed with this technique [12]. The advantage of using this technique is its ability to manufacture critical and complex parts that required very good accuracy like in case of manufacturing critical parts of automobiles, mobile phones, housing and casings of monitors of computers. Tyre cord yarn (cellulosic man-made fiber) of high strength have been applied successfully to reinforced in polypropylene compounds made by injection moldingprocess [13, 14].The properties of Cordenka fibers were studied and proceeded with the partial replacement of this fiber with jute using injection molding process [15]. HDT (heat distortion temperatures) and stiffness of jute increased with increase in jute proportion. At about 25% of jute incorporation, provide very good level of balance showing tensile strength of 72 MPa, modulus of 3.2 GPa and impact strength of 79 kJ/m2.The injection moulding process is used to develop PLA/PEG, PLA/NBSK/PEG, and PLA/MDF/PEG composite foams and their

crystallization behaviors and microcellular structure were investigated [16]. The incorporation of NBSK and MDF fibers results in higher cell density, smaller cell size, compared to that of foamed PLA/PEG samples. The melt strength was also enhanced by (crystallization induced by N_2 gas and cellulosic fibers) foaming process. In one direction Injection molding process parameters were optimized (melt temperature, mold temperature, injection process, holding pressure and time, cooling time) by applying the Taguchi method on sisal (SF20GF10) and glass fiber (SF10GF20) reinforced hybrid composites [17].

2.2. Compression molding process

This process is commonly used to make PMC's (Polymer Matrix Composites) where reinforcement has been done to embed them into matrix face to increase the strength of the composite. This Compression molding process is not only advantageous in mechanical strength but also thermal properties are enhanced. This process is very simple to use as there is no need of special instruments or equipments. This process has high reproducibility and cycle time is also very low. Moreover the process is very simple to use. This technique is used under specific range of temperature and pressure [18]. Combination of extrusion and sheet moulding along with compression is used to reduce the cost by decreasing the cycle time [19]. This technique has attracted the automobile companies to manufacture the thin and light products like panels of automobiles and their structures as shown in Fig. 3.

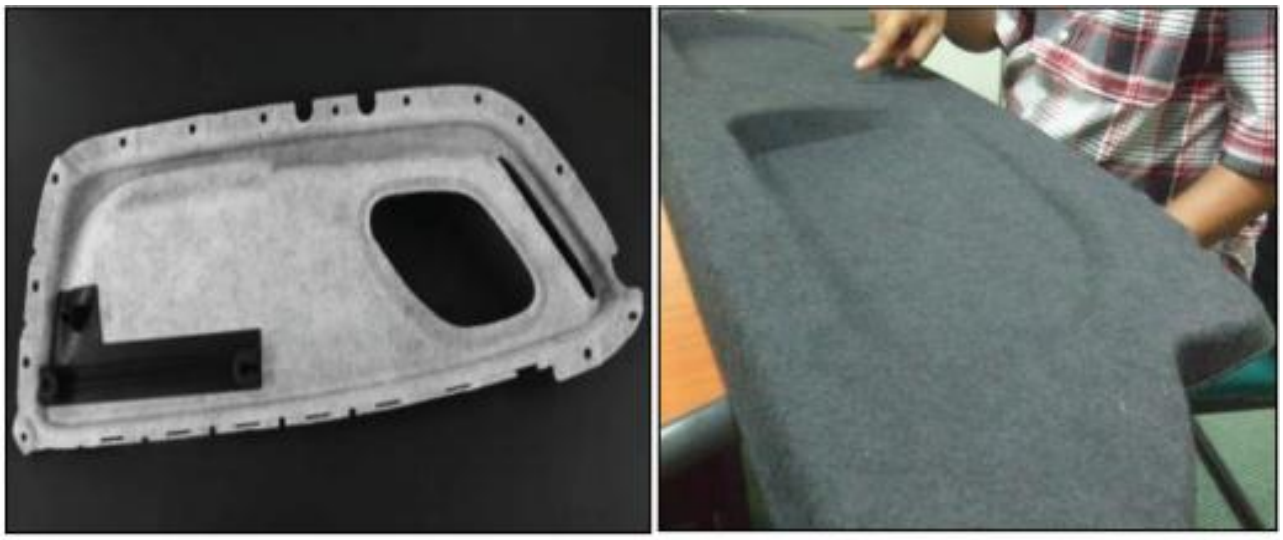

Fig. 3: Penal of Kanif Fibers Fabricated By Compression Molding Process

Fig. 4: Pultruded glass fiber composites

Compression moulding helps in retaining the isotropic properties of the composites as it does not change the orientation of the fibers due to which the physical properties of the composites remains unchanged. Higher strength in terms of tensile and impact can be easily achieved by this technique [20]. It has been practiced on making several types of composites by adding woven jute and jute glass and hybridization of kenaf and glass [21] and polyurethane with kenaf as reinforcement [22] to evaluate their strengths in terms of tensile, flexural and impact that shows good results.

2.3. Pultrusion process

It is continuous process of fabricating the composites by reinforcing impregnated fibers with matrix (thermosetting) and are then pulled through the heated die to make composites as per the profile of the die [23]. It is usually used where large production is required with same cross sectional profile as shown in the Fig. 4.

This technique is attracting the various sectors of industries like construction, automobile and aerospace. By this process 70% fiber ratio can be achieved that is very high when compared with other processes and also very cost effective to make profiles [24, 25]. Continuous fiber in form of yarn are required and are not limited to only glass and carbon fibers [26]and with very good and comparable properties [27-29]. The limitation is restriction to the rectangular, hollow bar beam and round profiles only. This fabrication technique is better than injection, filament winding and extrusion as the properties are improved due to the fibers under tension during the pulling of the fibers from the die [30] and also it increases the thermal properties along with mechanical [31]. The easy production, high productivity and less cost has proved this process better than other fabrication methods [32, 33]. This method of production has replaced the other materials like wood, PVC and the aluminum in various applications of engineering field [34]. The one very big example of this pultrusion application is developing vertical elements that had replaced the stanchion of steel in the railing of shipboard [35].

2.4. Extrusion process

This process first started at the end of the 18th century when hot-melt extrusion was first invented for the manufacturing of lead pipes [36]. Thereafter it has been used in food, plastic and rubber industry to manufacture various other items like bags and sheets. The extrusion process comprised of steps as shown in Fig. 5.

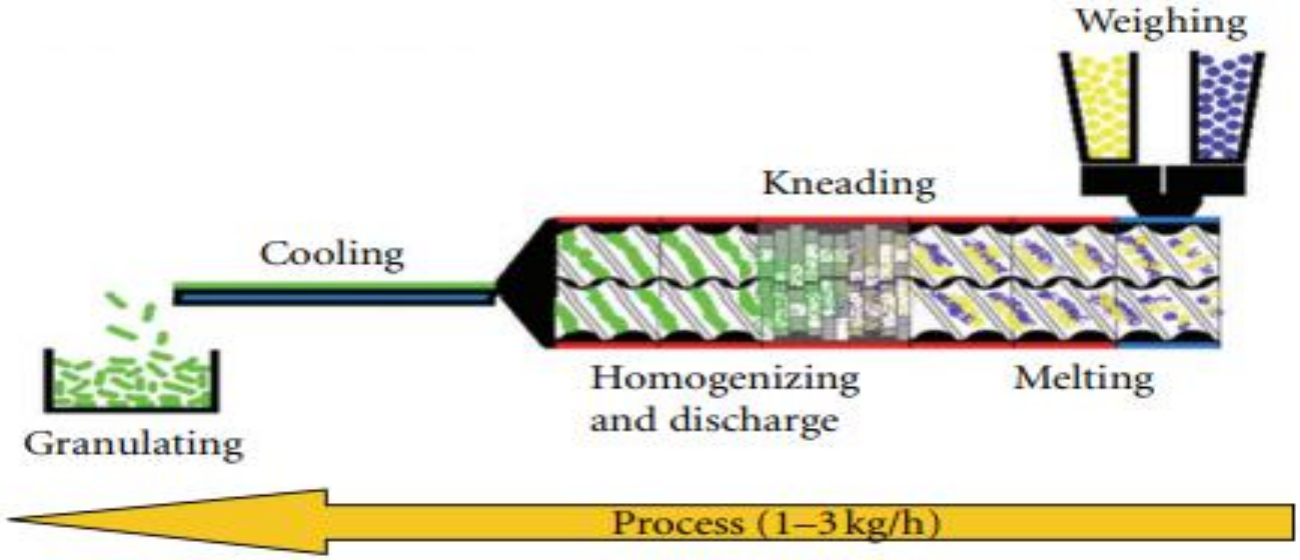

Fig. 5: Hot Melt Extrusion Process (Schematic Diagram) [37]

It consists of one cylindrical barrel (stationary) in which one (single screw extruder) or two screws (twin-screw extruder) rotates. Parts are clamped and bolted together and at the end of the extruder, there is a die called end plate die that is connected at the far side of the barrel as per the extruded material. The process parameter like screw speed, temperature of the barrel and pressure are controlled by the electronic unit [38] where L/D ratio (length to diameter ratio) plays very important role. This process is being widely used in plastics and rubber industries. The products are like pipes, hoses, wires, cables, polystyrene tiles and rubber sheets etc. and the

commonly used plastics are polystyrene, vinyl, polypropylene, polyethylene [39, 40]. Self-styles extrusion cooker is one very good example of extrusion utilization in the food processing industry [41]. In the field of veterinary and animal sciences, the production of pelletized feeds and implants [42] attracted a lot and in crop protection, production the poorly soluble agents as solid molecular dispersions [43] are of great use. Extrusion alone has been practiced a little in making composites out of that. Most of the times extrusion is just used to mix the reinforcement and matrix and thereafter used in the injection moulding machine to make sheet out of that. But some recent research has been done to make biodegradable composite rod from the PLA and Banana Waste (leaves) [44, 45], Nylon [46] to make rod completely by a single screw extrusion process that showed some good results in terms of mechanical and thermal analysis.

3. CONCLUSION

From the above discussion it has been concluded that compression moulding is a simple and easy process to manufacture the composites along with its economic use. But injection moulding produce better results and process is very fast. So if good production is required without change of profile, injection moulding is the better option. In case of pultrusion, one needs fibers in yarn form so that they can be pulled from the extrusion die which inturn results into good tensile strength due to their stretching. In extrusion manufacturing, chopped and powder form fibber can be used to make composites but use is limited to particular profiles of the product. Research is going on to increase the use of extrusion process for making more composites as with this process, one can utilize the waste of the fibers also.

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