Processing Techniques of Polymer Matrix Composites – A Review

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Abstract — In the present scenario development of suitable processing techniques for polymer matrix composites is one of the major challenges with respect to the energy efficient criterion of natural and synthetic fibers with the compatibilization of reinforcements in a matrix polymer. Over the last decade, intensive research and development has been carried out in order to establish suitable processing techniques for the fabrication of high performance polymer matrix composites. This article highlights the brief overview on classifications, properties, applications and various techniques adapted to manufacture polymer matrix composites.

Keywords — Processing technique, Polymer Matrix Composites (PMCs), fiber, reinforcement.

INTRODUCTION

Materials have become a symbol of the progress of human civilization, and have become milestones for dividing eras of human history [1]. The relative importance of the structural materials most commonly used, i.e. metals, polymers, composites, and ceramics, to various societies throughout history has fluctuated. Ashby M.F. [2] presents a chronological variation of the relative importance of each group from 10,000 B.C. and extrapolates their importance through the year 2020. The information contained in Ashby’s article has been partially reproduced in Figure 1. With the enlargement of modern industry, the production of light materials with high strength is required for our day-to-day applications [3, 4]. For some applications composite materials are considered to be more suitable than conventional materials as they have desirable mechanical, thermal and wear properties. [5–7]. Polymer matrix composite material is the one that uses organic polymer as matrix and fiber as reinforcement. Strength and modulus of fiber are much higher than the matrix material normally. PMCs are very popular due to their low cost and simple fabrication methods [8]. In this paper an attempt is made to through light on various techniques adopted by researches across the globe to manufacture PMCs.

Fig. 1. Relative importance of material development through history.

OVERVIEW ON PMCs

The classification of polymer materials is very large and these materials can be grouped into: thermoplastic and thermosetting materials (polyethylene, polypropylene, polyvinyl chloride, polystyrene, phenolics, polyester etc.); elastomers (natural rubber,
butadiene styrene, silicone etc.); polymeric fibers (fabric polymeric fibers, aramid fibers); coating materials (paints, lacquers, enamels etc.); adhesives (polymeric adhesives, natural-glu adhesive, casein, rosin); films (polypropylene, polyethylene, cellophane, cellulose acetate films); sponge or foam (polyurethane, rubber, polystyrene, sponge polyvinyl chloride) [9] [19] [20].

The properties of the PMC depend on the matrix, the reinforcement, and the interphase. Consequently, there are many variables to consider when designing a PMC. These include not only the types of matrix and reinforcement but also their relative proportions, the geometry of the reinforcement, and the nature of the interphase. Each of these variables must be carefully controlled to produce a structural material optimized for the conditions for which it is to be used [10]. Some of the typically properties exhibited by PMCs are high strength at low weight; ability to tailor properties to meet wide-ranging performance specifications; moulding to close dimensional tolerances, with their retention under in-service conditions; good impact, compression, fatigue and electrical properties; ability to markedly reduce part assembly; excellent environmental resistance; ability to fabricate massive one-piece mouldings; low-to-moderate tooling costs; cost-effective manufacturing processes; ability to build in, ex-mould, both colour and texture; excellent chemical and corrosion resistance.

PROCESSING TECHNIQUES FOR PMCs

The basic steps for processing of PMCs include:
1) Impregnation of the fiber with the resin,
2) Forming of the structure,
3) Curing (thermoset matrices) or thermal processing (thermoplastic matrices), and
4) Finishing.

Commonly used processing techniques of polymer-based composites are described in table 1.

<table>
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<tr>
<th>Technique</th>
<th>Type of polymer composite processed/manufactured</th>
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| Resin transfer molding | sisal fiber reinforced polyester composites [12]  
carbon fiber reinforced composites [13]  
phenoxy nanocomposite [14]  
carbon nanotubes reinforced glass fiber epoxy composites [15]  
benzoxazine– epoxy blend [16]  
carbon fabric hybrid multiscale composites [17]  
plain woven carbon fiber reinforced plastics [18] |
| Injection molding  | hybrid composites of jute and man-made cellulose fibers with polypropylene [21]  
cellulosic fiber composite foams [22]  
sisal-glass fiber hybrid biocomposites [23]  
cellulose fiber reinforced polylactide (PLA) composites [24]  
glass fiber reinforced mixed plastics composites [25]  
polypropylene single-polymer composites with sandwiched woven fabric [26]  
carbon nanotube filled polymer [27]  
polypropylene single-polymer composites [28]  
crayfish protein-PCL biocomposite material [29]  
cork-polymer composites [30]  
polypropylene-based cork–polymer composites [41] |
| Extrusion         | cellulose fiber reinforced composites [32]  
polyacrylate/multi-walled carbon nanotube composites [35]  
polystyrene/short glass fiber composites [36]  
kenaf fiber/high-density polyethylene (HDPE) composites [38]  
sugarcane bagasse cellulose/HDPE composites [39]  
polypropylene/polyamide-6 composites [40]  
polypropylene-based cork–polymer composites [41]  
functionalized cork-polymer composites [42] |
APPLICATIONS OF PMCs

Just as with most new materials, the development of high performance polymer composites has driven by military and later aerospace, marine, automotive and many more. PMCs are used for manufacturing:

i) Aerospace structures: The military aircraft industry has mainly led the use of polymer composites. In commercial airlines, the use of composites is gradually increasing. Space shuttle and satellite systems use graphite/epoxy for many structural parts.

ii) Marine: Boat bodies, canoes, kayaks, and so on.

iii) Automotive: Body panels, leaf springs, drive shaft, bumpers, doors, racing car bodies, and so on.

iv) Sports goods: Golf clubs, skis, fishing rods, tennis rackets, and so on.

v) Bulletproof vests and other armor parts.

vi) Chemical storage tanks, pressure vessels, piping, pump body, valves, and so on.

vii) Biomedical applications: Medical implants, orthopedic devices, X-ray tables.

viii) Bridges made of polymer composite materials are gaining wide acceptance due to their lower weight, corrosion resistance, longer life cycle, and limited earthquake damage.

ix) Electrical: Panels, housing, switchgear, insulators, and connectors [11] [57], and many more.

CONCLUSION

The more efficient processing methods for manufacturing PMCs are important in order to obtain more commercially viable products. Further the researchers are introducing and investigating a hybrid processes (merging manufacturing technologies into a single continuous process) as an efficient solution for shortening process chains and improving performance of processed materials [58]. The merging manufacturing technologies to process composite materials will have to face a lot of changes within the next decades and it certainly will remain as an interesting field of activity.

REFERENCES:


