



A Review: Thermoplastic Composites In Aerospace Applications

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Abstract. The requirements of the aerospace, automotive, maritime, defence industries, have to the research and development of various composites and of these composites produced to meet the growing demands are thermoplastic composites. The thermoplastic composites are preferred in the aviation industry as they have high strength and light weight. With weight being one of the main factors influencing fuel efficiency, the introduction of thermoplastic composites has led to the reduction in weight in the aviation sector as well as the automotive sector which leads to greater fuel efficiency, reduced cost of operations along with being eco-friendly. PEEK is one of the thermoplastics along with other high performance thermoplastics which are being used in the production of parts in the aerospace and automotive industries.

Keywords: Thermoplastic Composites, PEEK, Thermoplastics.

1 Introduction

The demands and requirements in the large-scale industries of aerospace, automotive, maritime, defence industries and wind energy are very stringent. To meet these requirements various research and developmental projects have been taken up which has led to the development of various composites to be used in the industries [1].

Composites are produced in order to gain additional properties which just one material alone can not produce. The matrix, interface and the reinforcement are the three main components of a composite. The area which provides a contact between the matrix and the reinforcement is the interface. The matrix gives the composite material the shape and wraps the reinforcing elements, it also transfers the loads from to the reinforcing elements and also preserves the structure of the fibers by preventing the reinforcements from moving independently inside the composite structure. The matrix can be made from a variety of materials like ceramic materials, plastics and metals [2].

Numerous factors such as orientations of the fibers, type of fibers hardness of the resin used, fiber fractions, bond between the fibers and the matrix and type of matrix used. Thermoplastic and thermoset matrix are used in the production of composites,

and in the recent years the thermoplastic polymer matrix are being used to produce thermoplastic composites (TPC) which have found their utility in the aerospace and automotive industries due to the upper hand that that they possess over the thermoset composites in terms of properties, the following Fig 1 gives a graphical representation of the changes which have taken place in the manufacturing of composites versus the content of composites in the airframe [9].

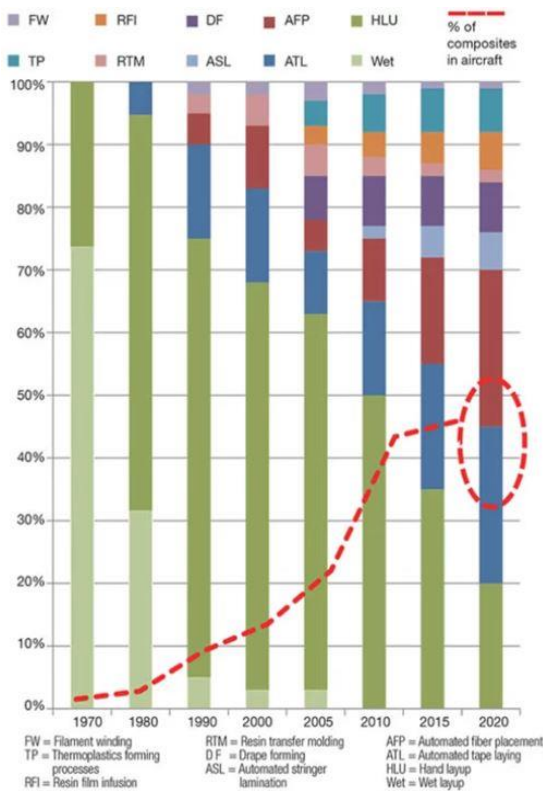


Fig. 1. Variation in manufacturing vs Content in an airframe [9].

2 Properties of Thermoplastics

Thermoplastics are materials which when heated to high temperatures begin to melt and soften up, but are solid at room temperature. The examination of the thermoplastics can be carried out in two parts namely the semi-crystalline and structurally amorphous regions. The strength and rigidity are provided by the crystalline regions and the elasticity is provided by the amorphous regions.

While examining the inner chain structure of the thermoplastics it is observed that the chains are connected to each-other via Vander Waals bonds. These bonds are weak and can be broken easily, thus when heated the thermoplastics don't have a rigid

structure leading to the lowering of the viscosity and increase in fluidity. But when the thermoplastics are cooled, the chains are reformed and solidify resulting the formation of a solid. This property by which the material can be reshaped several times is one of the greatest advantages that the thermoplastics have over the thermoset materials. Extrusion, injection molding, transfer molding, rotational molding, blow molding, thermoforming, casting, coating and compression are several of the methods that can be utilised in the formation of thermoplastic composites.

Properties of TPC depend on type of fibres, orientation of the fibers, length of the fibers, placement of the fibers, fiber fraction percentage, hardness of the resins used and the type of reinforcement material used. Thermoplastics composites can be classified as shown in Table 1:

Table 1. Classification of thermoplastics [1]

	High Performance Thermoplastics	Engineering Thermoplastics	Standard Thermoplastics
Amorphous	PEI	PPC PC PPO	ABS PS PVC
Semi-crystalline	PEEK PEKK LM PAEK PPS	PET PA (Nylon) POM (Delrin)	PP HDPE LDPE

3 Advantages

Due to the advantages possessed by the TPCs, its usage has significantly increased in the aerospace industry. Various studies have been carried out to reduce the fuel costs in the aviation industry since this is one of the major factors in operating an aircraft. The desirable characteristics possessed by TPCs have led to its increased utilisation in the aviation and automotive industries which require high strength but light weight materials which are to be produced at a very high rate. Thermoplastic resins when used in the production of composites don't require a curing cycle when compared with thermoset resins [3]. The higher cost of production of composites made from thermoset is due the loss of time required for curing, but thermoplastic resins when used can be cured faster without any time loss and solidify when under heat and pressure [1]. This leads to the introduction of automation of production thus lowering the required to produce the composites. This in turn has a huge impact in the production of composites for the aerospace industry which require high production rates due to the ever-growing demand for aircrafts, this is one of the key factors which play a pivotal role in the utilisation of thermoplastic resins in the manufacture of composites in the industry. Another major advantage in that the thermoplastics have is that they have a higher product life when compared with thermosets in addition to this, thermoplastics don't need to be stored under any special conditions. Thermoplastics can be produced in conditions other than clean room conditions, which gives it an ad-

vantage over thermosets since maintaining a clean room condition for the production of composites leads to higher costs of production as well as leading to production delays. Another important advantage of thermoplastics is that they are reusable in nature due to their ability to be reformed under appropriate applications of heat. This is an important property to have in the recent years which gives TPCs a critical edge over thermosets in the area of renewability and eco-friendliness [4]. Aircraft parts which are exposed to humid conditions tend to undergo corrosion, but when thermoplastics are used in such applications, they tend to resist corrosion since they have low water absorbency. In addition to this, thermoplastics show an improvement in their mechanical properties when exposed to moisture and humid conditions. Virgin thermoplastic have a greater impact resistance when compared with thermosets [5]. Thermoplastics possess a crystalline structure due to which they are highly resistant to chemicals [6]. Fig 2 given below gives a comparison between the tensile strength of thermoset and thermoplastic polymers versus the raw material costs [9].

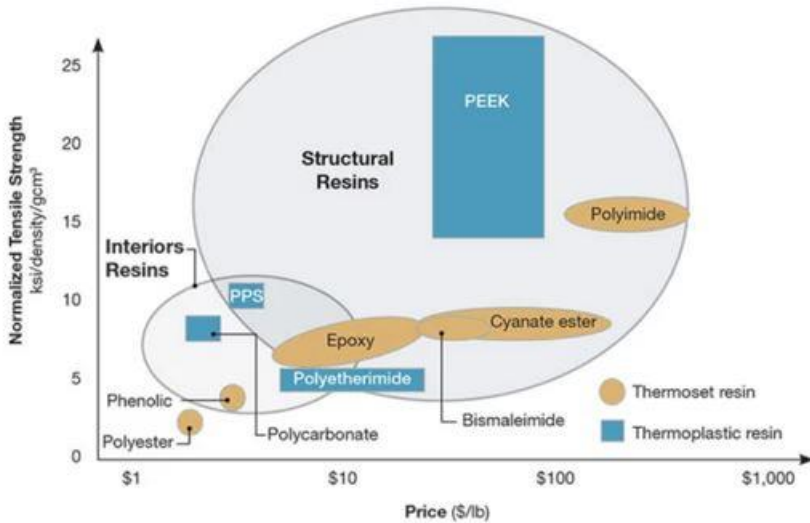


Fig. 2. Normalised tensile strength vs price for raw materials of thermoset and thermoplastic polymers used in aerospace industries [9]

Although TPCs have such advantages they also have some undesirable characteristics such as high cost of raw materials and also high pressure and temperature requirements in the production of thermoplastic composites [1].

4 Applications

The frequently used thermoplastics and their classifications are given in Table 1, the high-performance thermoplastics have a greater high temperature resistance, chemical resistance and abrasion resistance when compared with engineering thermoplastics and standard thermoplastics [1].

Glass fibers (GF) or Carbon fibers (CF) are used as reinforcement materials for composites made from PEEK, PEKK, LM PAEK, ABS and PPS in the aviation industry. TPCs are used in the aviation sector in the civilian sector, military applications and space related studies in the recent years. A study carried out in 2019 has shown the projected rate of growth in the usage of thermoplastics in the civilian sector of the aviation industry and the defence industry [7] as shown in Fig3.



Fig. 3. Forecasted growth of thermoplastics

The aerospace industry from 1980s has been concentrating on the usage of thermoplastic composites in aircrafts and the usage of composites has been increasing steadily in the production of various components [8] as shown below in Fig 4.

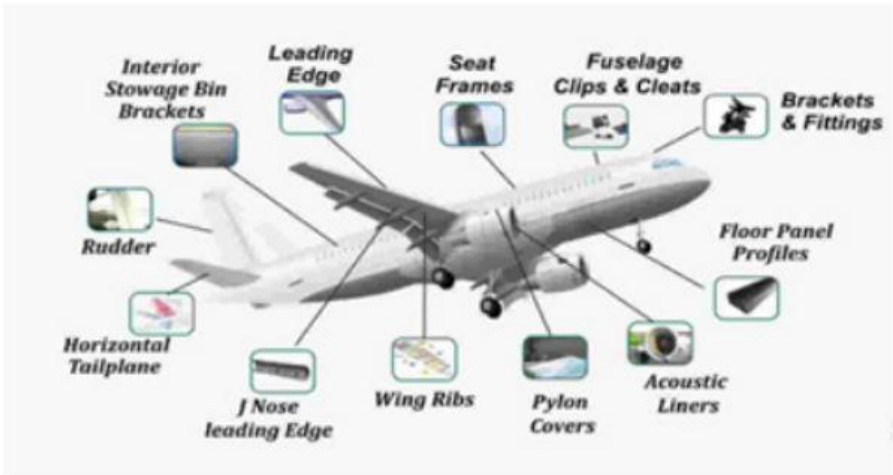


Fig. 4. Various components produced using thermoplastics [1]

The growth and usage of thermoplastic composites has been exponential over the past couple of years and this trend is set to follow even in the coming years as shown in the Fig5 below which shows the compound annual growth rate (CAGR) in the usage of composite flyaway weight condition by volume for various types of aircraft types:

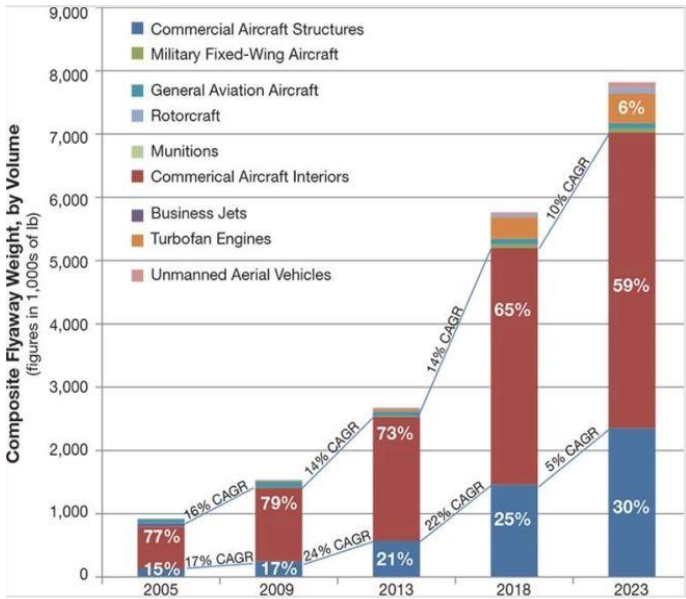


Fig. 5. Forecasted growth of composites in flyaway condition [9]

The following Fig6 gives an example of the most commonly produced parts like ribs, clips, brackets and stiffeners of an aircraft which are produced using thermoplastic composites.

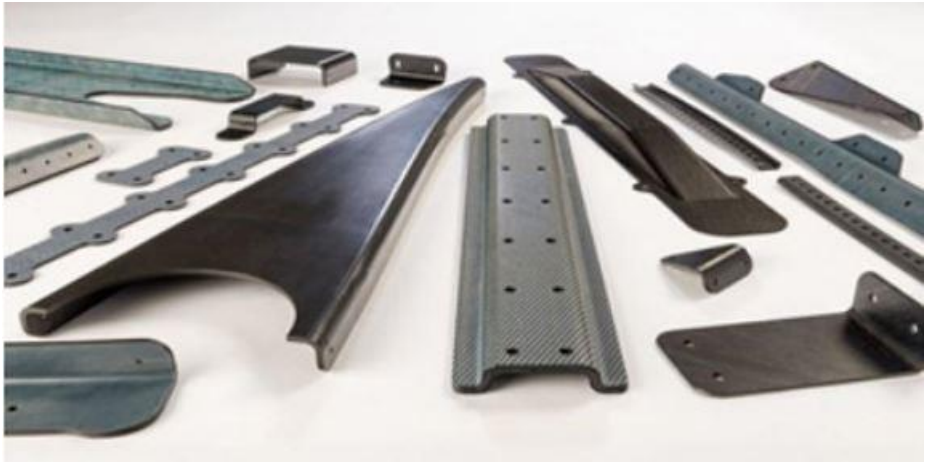


Fig. 6. Commonly produced parts of an aircraft using thermoplastics [10]

5 Conclusion

Thermoplastic composites have an upper hand in the production of composites since they use thermoplastic resins which do not incur higher cost of curing. The thermoplastic composites also have a significant advantage in being light weight and possessing high strength, both of which are contributing factors in their utilisation in the automotive and aerospace sectors as both strength and weight are important factors to be considered. In the case of aviation sector, the utilization of thermoplastic composites has shown an increasing trend since the 1980s and is still growing. Thermoplastic composites are used in the production of components of the airframe, interior and other parts of the aircraft. The percentage of thermoplastic composites being used in the airframe of the aircrafts is also showing an increasing trend. The utilization of glass fibers and carbon fibers as reinforcing materials has greatly increased the strength of the thermoplastic composites. The utilization of these composites will only continue to grow in the future due to the inherent advantages that they possess.

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