CHAPTER 1
INTRODUCTION

This thesis presents the results of the investigation of machinability and characterizations of some important thermoplastic polymeric composites with a special focus on engineering applications like house-hold, automobile parts, engine parts, aerospace and so on. The demand for new materials for special engineering applications is on the increase due to recent advances in automobile and aerospace industries.

This chapter presents an introduction to thermoplastic and glass fibre reinforced polymer composite materials. It discusses historical background, classification of composites. It also briefly highlights the various aspects of applications of thermoplastic polymer composites.

The demand for new material for special engineering application is on increase due to recent advances in spacecrafts, structural, automobile, IT and a host of other industries. The present day need of focuses on cheaper and flexible materials, which are fit into various applications. Other requirement includes easy availability, good physical and mechanical characteristics freedom from environmental influences like temperature and humidity. A single homogeneous material may not meet all these requirements. Hence, there is always a need for composite or filled material. With this requirement in background the present study is taken up.

Many of the applications in the world today require materials with unusual combination of properties that cannot be met by the conventional metals, alloys, ceramics or polymers. This is especially true for materials, which are needed for industries such as automobile, aerospace etc. Aircraft industries are very much in search of structural materials that have low densities yet strong, hard, impact resistant and so on. Engineers around the world have been always in search of newer materials with combination of properties.
New classes of materials, called composite materials have answered to this search to a great extent. Manufacturers, designers and engineers recognize the ability of composite materials to produce high quality, durability and cost effective products. The engineering importance of a composite material is that two or more distinctly different materials with dissimilar characteristics combine together to form a composite that is either superior or important in some other manner to the properties of the individual materials. Most of the composites have been created to improve combination of mechanical characteristics such as stiffness, toughness, wear resistance and also ambient and high temperature strength properties.

In these composites, fibres offer many superior properties such as high strength, lightweight, wear resistance etc. The fibres are embedded in a matrix that binds them together and transfers load to and between the fibres and also protect them from environments and handling.

There are a wide range of applications for polymers in wear-related situations such as bearings, gears, sprockets, sleeves, valve guides, seals, brakes, etc. the attraction of polymers for these applications lies in their high specific strength, low coefficient of friction, favorable wear characteristics, ease of processing and economic feasibility [98]. A number of material-processing strategies have been used to improve the wear performance of polymers. These include the incorporation of organic and inorganic fillers as well as the addition of glass, carbon or aramid fibres. The addition of these second-phase materials results not only in improved tribological properties but also in superior physical and mechanical properties.

Fibre reinforced polymer (FRP) composites have extensively used in wide variety of applications. The fibre industry is divided as, natural fibres-those from plant, animal or mineral sources and synthetic fibres. Many synthetic fibres have been developed specifically to replace natural fibers because synthetic fibres usually behave more predictably and are more uniform in size. Often, synthetic fibers are less costly than their natural counterparts. In the garment industry, for example, the acrylic and rayon fibers are developed to replace more costly natural wool and silk.
For engineering purposes, metal, ceramic, glass and organically derived synthetic fibers are more significant. Nylon, for example, is used for belting, nets, hose, rope, parachutes, webbing, ballistic cloths and as reinforcements in tires.

Glass fibers, the most widely used reinforcement for plastic and rubber products, are also the finest (smallest diameter) of all fibers, typically 1 to 4 microns in diameter. Because glass fibers have a large surface area in proportion to volume, surface conditions of the fiber have a strong influence on its strength and behavior.

Most glass-reinforced polymer composite products are made with E-glass (electrical glass), which has good electrical and mechanical properties and high heat resistance. E-glass is available as chopped fiber, milled fiber, continuous roving, woven fabric and reinforcing material. Tensile strength is 3400 N/mm², modulus is 10.5 million and elongation can be as high as 4.8 %.

Thermoplastic fibers are particularly effective where high-shear processing would degrade conventional glass-fiber reinforcement, thereby reducing performance of the composite.

Nylon fiber provides excellent impact resistance, surface appearance, abrasion and corrosion resistance. They are developed to provide a degree of toughness and impact strength in brittle thermoset resins. Two polyester grades provide regular and reduced shrinkage characteristics and a nylon grade is particularly resistant to alkalis. Compete fibers are often used in hybrid reinforcement systems, along with a stronger and higher modulus fiber.

Spectra, a lightweight, high strength, extended-chain, polyethylene fiber, is claimed to be 10 times stronger than steel and 75 % stronger than any other organic fibres. Two grades of spectra are available, one is a 1,200-denier fiber designed for high strength under intermittent loading conditions- sports equipment, ballistic fabrics and medical products. The other is a 650-denier fiber for high strength under continuous load-sailcloth, high-tension ropes and cables that must withstand flex-fatigue conditions. Tensile strength of spectra fibers ranges from 2550 to 2965 N/mm².
1.1 CLASSIFICATION OF COMPOSITES

Composite materials have been broadly classified into different ways based on;
(i) The type of matrix used (polymer/ceramic/metal)
(ii) The type of reinforcements used
(iii) The type of applications.

Polymeric composite materials contain polymeric material in their matrix, which again can be thermoplastics or thermosets. The major reinforcement generally used is boron, carbon/graphite, kevlar (aramid) and glass fibres.

On the basis of length of fibre, polymer composites can be classified as long and short fibre reinforced composites. On the basis of polymer matrix composites have been classified as thermoplastic, thermoset and elastomers. In this study short glass fibre (SGF) reinforced thermoplastic composites have been reported.

Recent reports on the shortage of metals have encouraged many scientists to look for new and alternative non-conventional materials [10, 89, 98]. Among these, composites and fibre reinforced polymeric materials are the most attractive. One advantage, which encouraged researchers to focus on composites, is the diverse range of mechanical and tribological properties that can be obtained using different types of reinforcement.

1.2 THERMOPLASTIC COMPOSITES

Thermoplastic composites no longer is product design constrained to the property limits and performance characteristics of unmodified grades of resins. Thermoplastics that are reinforced with high-strength, high-modulus fibres provide dramatic increases in strength and stiffness, toughness and dimensional stability.

Glass fibres used in reinforced polymer composites are high-strength, textile-type fibres, coated with a binder and coupling agent to improve compatibility with the resin and a lubricant to minimize abrasion between filaments. Glass fibre reinforced
thermoplastics are usually supplied as ready-to mold compounds (prepreg). Molded products may contain as little as 5% and as much as 60% glass by weight. Pultruded shapes (usually using a polyesters matrix) sometimes have higher glass contents. Most molding compounds, for best cost/performance ratios, contain 20% to 40% glass.

Practically all-thermoplastic resins are available in glass-reinforced compounds. Those used in largest volumes are nylon, polypropylene (PP) and acrylonitrile butadiene (ABS), probably because with reinforced thermoplastics has been based on these resins. The higher performance resins namely poly phenylene sulphide (PPS), polyether ketone (PEEK), polycarbonate (PC), polyimides (PI) and poly phenylene oxide (PPO) are also available in glass fibre reinforced composites and some carbon or aramid fibres as well.

1.3 GLASS-FIBRE REINFORCED PLASTIC COMPOSITES

Glass-fibre reinforcement improves most mechanical properties of plastics by a factor of two or more. Tensile strength of nylon, for example, can be increased from about 6895 MPa to 206 MPa and deflection temperature to almost 260°C from 76°C. Also improved in reinforced compounds are tensile modulus, dimensional stability, hydrolytic stability and fatigue endurance. Deformation under load of these stiffer materials is reduced significantly.

Fibre reinforcement of a resin always changes its impact behaviour and notch sensitivity. The changes may be in either direction, depending on the specific resin involved. This need has led to the development of impact modified compounds—specifically, nylon 6 and nylon 66 alloys, a nylon 6/6 copolymer and a polypropylene copolymer—with up to 50% improvement over reinforced unmodified compounds. While the impact properties of a glass fibre reinforced compound are not always superior to those of the unreinforced compound, the reinforced modified compounds are always superior to the reinforced unmodified grades.

Molded glass-reinforced and mineral filler reinforced plastics are used in a broad range of structural and mechanical parts. For example, glass fibre reinforced
nylon, because of its strength and stiffness, is used in gears and automotive under-the-hood components, while mineral-reinforced nylon is used in housings and body parts because it is tougher and has low warpage characteristics. Polypropylene (PP) applications include automotive air-cleaner housings, dishwasher tubs and doors. Polycarbonate (PC) is used in housings for water meters and power tools. Polyester applications include motor components-brush holders and fans-high-voltage enclosures, TV tuner gears, electrical connectors and automobile exterior panels. Camper tops, pallets and hand luggage bags are typical applications of reinforced high-density polyethylene (HDPE).

The newer glass reinforced compounds are the long-fibre materials. These compounds, available principally in nylon 66 based resins, are fabricated by pultrusion. The injection-moldable pallets thus contain fully wetted fibres equal in length to the pellet.

Continuous-fibre glass-reinforced polypropylene is available in sheet form, for stamping or hot-flow forming of large, thin wall parts such as automotive front-end retainer panels, oil pans, fender liners, upper grill panels and station-wagon load floors and for lawn mover, luggage and housings and guards for farm equipments and snowmobiles. Azdel Inc markets the glass reinforced PP and polyethylene terephthalate (PET) sheet products and plans to add sheet material based on other resin matrices.

Glass fibres incorporation improves both short-term and long-term mechanical properties of a resin. The fibres also improve creep resistance, thermal conductivity and heat deflection temperature (HDT) as well as the tribological properties of the base resin. The degree of improvement depends on the efficiency of the sizing system that bonds the resin to the fibres. Glass beads and unsized milled-glass fibres, on the other hand, increase the wear factor of the mating surface and the coefficient of friction.

Glass fibres are frequently used in combination with silicone and PTFE lubricants, which offset the negative, wear effects that the glass fibres have on surface characteristics. The use of silicone only, in conjunction with glass fibers, is not recommended. However, PTEE provides far more protection to the mating surface and
should be used (with or without silicone) if the wear rate of the mating surface is important.

1.4 MACHINABILITY

The engineering industries strive to achieve either a minimum cost of production or a maximum production rate in machining. These two criteria are closely inter-related with the choice of cutting conditions like speed, feed and depth of cut. The optimization of these conditions depends on and must be related to, the machinability characteristics of the materials. It is becoming increasingly necessary to relate the available engineering raw materials and semi finished products to specific machinability ratings. It is advantageous for the industries to know in advance the machinability characteristics of a material to be processed, in addition to the normal chemical composition and mechanical data, which by themselves are not enough to cover the machining characteristics of the material.

Machinability has been a core activity of the manufacturing industry. The effectiveness of machining is controlled, among other factors by the machinability of the material that is machine. Machinability can be quantitatively assessed. The general purpose of the machinability study is to improve all faces of manufacturing by optimizing cost, productivity and quality.

Machinability is a vague concept in that it lacks a precise definition and mathematical formulae. As of now, there is no universally accepted measurement technique for machinability. For instance, some manufacturers take tool life as the basis for evaluating machinability. Other manufacturers may take machining cost for machinability assessment. On the other hand, flexible manufacturing systems, computer integrated manufacturing facilities inevitably assess the machinability, taking the total number of chips or ease of chip disposal as the basis. It is clearly seen that various researchers have taken the term machinability in various ways.

Definition of machinability are invariably based on one or more specific characteristics of the cutting process such as cutting tool life, tool wear rate, cutting
force required, surface roughness, chip breakability and the temperature at the tool work interface.

The term ‘machinability’ does not lend itself to be defined precisely. However, in the context in which those concerned with manufacture, production and research use this term, it can be defined as the property of the material which governs the ease or difficulty with which it can be machined under a given set of conditions.

Composite materials are defined as material system consisting of two or more chemically distinct constituents combined to create a newer material with properties that are different from that of either of the constituents.

In the production of composites, the matrix (the major phase) and the reinforcement or dispersion phase (the minor phase) are mixed together to obtain a homogeneous product that generally possesses superior properties than that of the individual constituents. The reinforcement is selected based on their inherent properties like stiffness and other properties, while matrix acts as a binding element [98]. Berghezan [10] defines composites as materials, which differ from alloys, as individual components retain their characteristics. Jaritz [89] defines composites as multifunctional systems that provide characteristics not obtainable from any discrete material. Kenneth [95] defines composite as homogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on microscopic scale. In general the composites can be fabricated in order that the new material has useful properties not possessed by the individual components [138]. In composite material, a high strength or high modulus materials called the reinforcement is combined with matrix material, which permits fabrication into desired engineering structure and transfers the environmental loads on to the reinforcement [138].

With this background on thermoplastic composites materials review of properties like mechanical and machinability of composites is presented in Chapter 2.
1.5 ORGANIZATION OF THE THESIS

The thesis consists of 8 chapters. The first chapter consists of introduction to thermoplastics, composites, glass fibre, machinability, the second chapter contains a comprehensive literature survey identifying the gap areas, drawing the motivation and defining the scope of the investigation. The chapter three comprises of the materials and equipment and experimental techniques and their procedures used in the investigation. The next five chapters present five interesting characterizations of thermoplastic polymer composites each resulting in recommendations for specific engineering applications. Chapter 4 reports the characterization of SGFR-nylon 6 composites, Chapter 5 reports the characterization of SGFR-polypropylene (PP) composites, Chapter 6 reports the characterization of SGFR-polybutylene terephthalate (PBT) composites, Chapter 7 reports the characterization of SGFR-polycarbonate (PC) composites and Chapter 8 reports the characterization of SGFR-polyurethane (PU) composites. Chapter 9 reports conclusions and future work. The results are depicted in the form of graphs and Tables.