Composite materials are engineering materials made from two or more constituent materials, that remain separate and distinct on a macroscopic level while forming a single component. There are three categories of constituent materials: matrix, reinforcement and fillers. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. The primary functions of the matrix are to transfer the stresses between the reinforcing fibers/particles, and to protect them from mechanical and/or environmental damage, whereas the presence of fibers/particles in a composite improves the mechanical properties such as strength, stiffness etc. Composite materials are being developed to replace conventional materials for competitive reasons, such as high specific strength and stiffness, high fracture toughness, good resistance to heat and cold, moisture and ease of fabrication, etc.

1.1 TYPES OF COMPOSITES

Composites can be grouped into categories, based on the nature of the matrix the type possesses. Methods of fabrication also vary, according to the physical and chemical properties of the matrices and reinforcing fibers.
1.1.1 Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of the design and enhance toughness. For example, the elastic stiffness and strength of metals can be increased, while a large co-efficient of thermal expansion, and the thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

1.1.2 Ceramic Matrix Composites (CMCs)

Ceramic matrix composites has the four classes of ceramic matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon (cement + carbon fiber) components. The advantages of the CMC include high strength, hardness, high service temperature limits, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys, but without their high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form.
1.1.3 Polymer Matrix Composites (PMCs)

The most common advanced composites are the polymer matrix composites. These composites consist of a polymer, such as thermoplastic or thermosetting resins, reinforced with fibers such as natural, carbon, boron, aramid and glass fiber etc. These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The general reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.2 FIBER REINFORCED POLYMER COMPOSITES

Fiber Reinforced Polymer Composites (FRPC) consists of fibers as the reinforcement medium with polymer resin as the matrix. These materials are used in the greatest diversity of composite applications, as well as in the largest quantities, in the light of their room-temperature properties, ease of fabrication, and cost. The matrix is required to perform several functions, most of which are vital to the satisfactory performance of the composite. The roles of the matrix in the fiber and particle reinforced composites are quite different. The binder for the particulate aggregate simply serves to retain the composite mass in a solid form, but the matrix in a fiber composite performs a variety of other functions, which characterize the behavior of the composite. It binds the fibers together, holding them aligned in the important stress direction. Loads are applied to the composite, then transferred into the fibers, which constitute the principal load bearing component, though the matrix, enables the composite to withstand compression, flexural and shear forces as well as tensile load.
1.3 DEVELOPMENT OF NATURAL FIBER COMPOSITES

Among the various synthetic materials that have been developed, plastics claim a major share as wood substitutes. Plastics are used for almost everything from articles of daily use to the components of complicated engineering structures and heavy industrial applications. But, the study of plastic composites has simulated immense interest in meeting the future shortage of plastic materials. Also, plastic composite materials are expensive and non-renewable. Due to the high price of petroleum based products, there is a need to use suitable alternatives. Some of the best alternatives for synthetic materials are agricultural and plant fiber materials. Natural plant-based fibers are abundant and have high specific mechanical properties. Many kinds of textiles, ropes, canvas and papers are produced today, using natural-plant based fibers.

Different parts of plants such as the stem, leaf, seed, fruit etc have been found to be viable sources of raw material (Figure. 1.1). Plantation of coconut are spread all over the world in tropical and sub-tropical regions and are an important item in the economy of many of these regions. Over 50% of the coir fiber produced annually throughout the world is consumed in the countries of its origin, mainly, India. The husk contains 20 % to 30 % of fiber. These fibers are one of the natural sources that have been used recently in composite applications.

1.4 POLYMER MATRIX

Polymers make ideal matrix materials, as they can be processed easily, are lightweight and offer desirable mechanical properties. The two main kinds of polymers used as matrix materials are thermosets and thermoplastics. Thermosets have a well-bonded 3D-molecular structure after curing. They do not melt, but decompose on heating. They can be retained in
partly cured condition over a prolonged period of time. Thus their use is very flexible. They find application in a chopped fiber composite form, particularly as a pre mixed or moulding compound.

Figure 1.1 Classification of natural fibers
They are most suited for fiber composites and in structural engineering applications. The Main thermosetting polymers used are epoxy, polyesters, phenolics and polyimides.

Thermoplastics have a linear or branched molecular structure, and soften at an elevated temperature and melt. The process of softening or melt can be reversed to regain its properties during cooling which facilitates the compression molding technique to mold the compound. Thermoplastics have found greater use and become an emerging group of composite matrices. They have a greater functional advantage in new avenues, including the replacement of metals in the die casting process. The Main thermoplastic polymers used are, polyethylene, polypropylene, and polystyrene and polyvinyl chloride.

1.5 FILLER ADDED FIBER REINFORCED POLYMER COMPOSITES

Additives for polymer composites have been variously classified as reinforcements, fillers or reinforcing fillers. Reinforcements, being much stiffer and stronger than polymer, usually increase their modulus and strength. Fillers were considered as additives, which, due to their unfavorable geometrical features, surface area or surface chemical composition, could only moderately increase the modulus of the polymer. Their major contribution was in lowering the cost of the materials, by replacing the more expensive polymer; other possible economic advantages were faster molding cycles as a result of increased thermal conductivity and fewer rejected parts due to warpage.

To overcome the limitations of polymers, for example, low stiffness and low strength, and to expand their applications in different sectors, inorganic particulate fillers, such as mica, CaCO₃ and alumina (Al₂O₃) can
often be added to process polymer composites, which normally combine the advantages of their constituent phases. Particulate fillers modify the physical and mechanical properties of polymers in many ways.

1.6 JUSTIFICATION FOR THE SELECTION OF MATERIALS

Due to the exponential growth of the human population, we are facing many environmental problems. It is clear that advances in science and technology have improved the standard of living of the common man, but at the same time we are facing ecological imbalances and at times, environmental disasters, and it is very urgent, to find solutions. In the field of Material science and Engineering, there is growing interest in green, environment friendly materials. Composites can be used as of natural/coir fibers instead of the more conventional synthetic fibers. In cases of urgent need, natural fibers can be replaced by synthetic fibers, fully or partially in composites. Due to the high price of composites reinforced with a synthetic, the user industries demand a lower price for the production of components and at the same time, improvements in their quality.

Natural fibers depend mainly on the nature of the plant, the locality in which it is grown, the age of the plant, and the extraction method used. Coir fibers are annual fiber plants, and they are found to be important sources of fibers for a number of applications. The natural coir fibers are abundantly found in south India region, especially in the coastal regions of Kerala and Tamilnadu. Traditionally, these fibrous materials are being used by the local people for making low cost articles such as mats, ropes, bags etc.

The total world coir fiber production is 250,000 tonnes. The coir fiber industry is particularly important in some areas of the developing world. In India, the coastal region of Kerala produces 60% of the total world supply
of white coir fiber. Sri Lanka produces 36% of the total world brown coir fiber output (Harish et al (2009)).

Some research on coir composites has been carried out on the material characterization, while research on the improvement of the mechanical properties of coir polyester composites with filler particles, such as calcium carbonate (CaCO$_3$) and alumina (Al$_2$O$_3$) has not been undertaken. Taking this into account, it is decided to evaluate the mechanical properties of filler added coir fiber composites.

The polyester resin is selected, based on its their properties, namely, room temperature curability, good mechanical properties, chemical resistance and electrical properties.

Polyester resins of the unsaturated type are formed by the reaction of dibasic organic acids and polyhydric alcohols. The resulting polymeric liquid is dissolved in reactive diluents, such as styrene, which reduces its viscosity and makes it easier to handle. Polyester resins are used in sheet moulding compounds, bulk moulding compounds and the toner of printers. Polyester resins are thermosetting and, as with other resins, they cure exothermically.

Calcium carbonate as a filler material is selected based on their following reasons.

- To give the desired mould shape
- To control the viscosity
- To produce smoother surfaces
- To increase the modulus
- To reduce the cost
A combination of fiber and alumina particles reinforced composites may lead to an overall improvement in the mechanical properties, such as tensile, flexural, impact strengths and compression [modulus and strength]. If such a possibility is confirmed, it will be possible to develop a commercial application, which can replace wood and synthetic fiber reinforced composites.

1.7 **AIM AND OBJECTIVES OF THE INVESTIGATION**

- To investigate the tensile, flexural, impact and abrasion loss behaviors of calcium carbonate-filled non-woven randomly oriented Coir-Polyester composites, with varying fiber length, fiber diameter and filler content.
- To investigate the tensile, flexural, impact and abrasion loss behaviors of alumina-filled non-woven randomly oriented Coir-Polyester composites, with varying fiber length, fiber diameter and filler content.
- To investigate the tensile, flexural, impact and abrasion loss behaviors of calcium carbonate and alumina hybrid particle-filled non-woven randomly oriented Coir-Polyester composites, with varying fiber length, fiber diameter and filler content.
- To develop prediction models for the determination of the mechanical behaviors of filler added Coir-Polyester composites, over the wide range of conditions using Regression modeling and Artificial Neural Network modeling.
- To determine the optimum fiber parameters for the maximum and minimum values of the mechanical behaviors of filler
added Coir-Polyester composites, using the Response Surface Methodology.

- To study the effect of the fabrication parameters (fiber length, fiber diameter and filler content) on the mechanical behaviors of filler added Coir-Polyester composites by the ANOVA and Response Surface Design.

- To study the particle inclusion and interfacial bond between the coir fiber and the polyester matrix by SEM images.

1.8 OVERVIEW OF THE THESIS

The Thesis consists of 5 chapters. Chapter 1 deals with the overall introduction of fiber-reinforced polymer composites, the necessity for the development of the natural coir fiber reinforced polyester composites, and the objectives of the present investigation in detail.

Chapter 2 deals with the literature review, in which the detailed survey of natural fiber reinforced polyester composites, the effect of filler materials and applications of soft computing techniques for predicting the mechanical and machinability behaviors of fiber-reinforced composites are explained in detail.

In chapter 3, a study of the properties of the composite constituents is reported. The composite preparation, specimen preparation, and mechanical testing methods are discussed in detailed. A description of the experimental methodology, statistical analysis, Artificial Neural Network (ANN), and Response Surface Methodology (RSM) are specified in detail.

In chapter 4, the mechanical properties of filler-added Coir-Polyester composites and how the properties are influenced by the fiber
length, fiber diameter and filler content are discussed. The fractured surfaces of the tested composite specimens are studied, using scanning electron microscopy (SEM). The experimental tensile, flexural, impact and abrasion loss properties were compared with the theoretical and statistical or empirical predictions. The mechanical behaviors of Coir-Polyester composites filled with calcium carbonate, alumina and a combination of both are studied. The experimental tensile, flexural, impact strengths and abrasion loss properties are compared with the statistical or empirical predictions and neural network models, to confirm the accuracy of the predictive models. The fractured surfaces of the tested composite specimens are studied, using Scanning Electron Microscopy.

The conclusions and the scope for further research on the present investigations are given in Chapter 5.