CHAPTER 1

INTRODUCTION

1.1 COMPOSITE MATERIALS

In an advanced society like ours, everyone depends on composite materials for some or other aspects of our lives. Composite materials have a long history of usage. For example, straw was used by Israelites to strengthen mud bricks. Plywood was used by ancient Egyptians when they realized that wood could be rearranged to achieve superior strength and resistance to thermal expansion as well as to swelling due to the presence of moisture. Medieval swords and armors were made by using layers of different materials. Composite materials are formed by combining two or more distinct materials that have quite different properties.

The 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, cold, moisture and ease of fabrication, etc. Composites are materials that comprise strong load carrying material (known as reinforcement) embedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone.
1.2 FIBER REINFORCED COMPOSITE MATERIALS

Fiber reinforced composites are certainly one of the oldest and most widely used composite materials. They consist of fibers of high strength, lightweight and high stiffness, embedded in a matrix with distinct interfaces between them. Traditional materials such as steel and aluminum are isotropic in nature but the fiber–reinforced composites exhibit anisotropy. The fiber reinforced composites have good dimensional stability and these can easily manufacture. Three major types of matrices are known: polymeric, metallic, and ceramic. Most of the composites used now in the industry are based on polymer matrices. Polymeric composites are formed by combining fibers and polymer resin which also known as fiber reinforced plastic (FRP). The term polymer refers a long chain molecule that is composed of a large number of repeating units of identical structure.

The role of matrix is to transfer load to the fibers and to provide a barrier against an adverse environment and to protect the surface of the fibers against mechanical abrasion. The binding agent or matrix in the composite is of critical importance. Polymer resins are divided broadly into two categories: thermosetting and thermoplastics. Thermoplastic refers to polymer that can be melt processed by a variety of methods, including extrusion and moulding. These include polyethylene, polypropylene, polystyrene and polyvinyl chloride. In the case of thermoset polymers individual molecular chains are chemically linked by covalent bonds during polymerization or by subsequent chemical or thermal treatment. Once formed, the cross linked networks resist heat softening, creep and solvent attack. Most commonly used thermoset polymers are polyester resins and other resins like epoxy, vinyl ester, phenolic epoxy, novolac and polyamide. Unsaturated polyesters are versatile and have been a popular thermoset used as the polymer matrix in composites. These are widely produced industrially as they possess many advantages compared to
other thermosetting resins including room temperature cure capability, good mechanical properties and transparency.

1.3 RECENT TRENDS IN COMPOSITES

The natural material like wood is getting depleted continuously while the demand for the material is ever increasing. Deforestation has created very serious environmental damage. It has become an urgent necessity to develop suitable substitute for wood. Among the various synthetic materials that have been explored and advocated, plastics claim a major share as wood substitutes. The plastics are used for almost everything from the articles of daily use to the components of complicated engineering structures and heavy industrial applications. But, the study of filled plastic composites has simulated immense interest in meeting the future shortage of plastic materials from the last decade. Also, plastic composite materials are expensive and are non-renewable. Due to high price of petroleum based products, there is a need to use suitable alternatives. One of the best alternatives for synthetic materials is agricultural and plant fiber materials. The natural plant-based fibers are abundant and have high specific mechanical properties. Many kinds of textiles, ropes, canvas and papers are produced today.

The different parts of plants such as stem, leaf, flower etc have been found to be viable sources of raw material. Polymer composites containing natural fibers have received considerable attention in the recent years.
The interest in the natural fiber reinforced polymer composites is growing rapidly due to the following specific benefits such as,

1. Specific strength
2. Easy availability
3. Light weight
4. Ease of separation
5. Enhanced energy recovery
6. Non-corrosive nature
7. Low density
8. Low cost
9. Good thermal properties
10. Reduced tool wear
11. Reduced dermal and respiratory irritation
12. Less abrasion to processing equipment
13. Renewability and biodegradability

1.4 NEED TO DEVELOP NATURAL FIBER REINFORCED POLYMER COMPOSITES

Due to the exponential growth of human population, we are facing many environmental problems. It is clear that advances in science and technology has improved the standard of living of a common man but at the same time we are facing ecological imbalances and at times, environmental disasters and it is very urgent, how to find out solutions. Therefore, from the materials science point of view, there is growing interest in green, environmentally friendly materials. If we consider composites, one of solutions can be the use of natural fibers instead of more conventional synthetic fibers.
1.5 PROBLEM STATEMENT

Composites using high strength synthetic fibers such as glass and aramid etc are used in broad range of applications such as aerospace, automotive parts, building materials and sporting goods. But, these composites are imported from overseas and need high cost to produce it. This situation has led to the development of alternative materials. In recent years, a significant amount of interest has been shown in the potential use of natural fibers to replace glass fiber in composites. Although natural fibers are not as strong as carbon or aramid, these are cost effective and biodegradable.

The structures of the plant fibers also provide excellent insulation against heat and noise. Most cellulosic fibers are harvested throughout the year and the supply is inexhaustible compared to the limited supply of the oil reserve from which may synthetic fibers are derived. Due to the high price of composites reinforced with synthetic fibers, the user industries demand a lower price for production of components at the same time with an improvement in quality. Natural fibers are relatively inexpensive and abundantly available, has the potential for polymer reinforcement. Roselle and sisal fibers are being examined with a view to replace synthetic fibers in many commercial products and in building materials. Among of various natural fibers, roselle and sisal fibers have good potential as reinforcement for polymer composites. Roselle and sisal fibers are rich in cellulose. It is proposed to evaluate the suitability of roselle fiber and roselle/sisal fibers as reinforcement in polymer composites to produce more economical composites.
1.6 JUSTIFICATION FOR THE SELECTION OF ROSELLE (HIBISCUS SABDARIFFA) AND SISAL (AGAVE SISALANA) FIBERS

The properties of natural fibers depend mainly on the nature of the plant, locality in which it is grown, age of the plant, and the extraction method used. Roselle (Hibiscus sabdariffa) fiber and Sisal (Agave sisalana) fiber are annual fiber plants and they are found to be important sources of fibers for a number of applications. The bast and leaf fibers have high potential as reinforcing agents in polymer composites. Roselle and sisal fibers are abundantly found in the south India region, especially in Tamilnadu. Traditionally, these fibrous materials are being used by the local people for making low cost articles such as socks, boots, mats, ropes, bags etc. These fibers have not been really examined as an ingredient for the composite materials. There is no literature available on the application of roselle fibers and roselle/sisal hybrid fibers as reinforcing material in the unsaturated polyester composites. Keeping in view the easy availability of these fibers, a comprehensive research work has been initiated on the synthesis and study of properties of roselle and roselle/sisal hybrid fiber reinforced polyester resin matrix based bio-composites.

1.7 OBJECTIVES OF THIS INVESTIGATION

In the present investigation, a study on the synthesis and mechanical properties of new series of Bio-composites involving roselle (Hibiscus sabdariffa) fiber as a reinforcing material and polyester resin based polymer matrix are reported. The mechanical properties of chopped and randomly oriented intimately mixed roselle fiber reinforced polyester composites such as tensile, flexural and impact strength properties were determined for various fiber length and fiber content (Weight percentage). Earlier roselle fiber has been used as reinforcing agent for isostatic
polypropylene (Jirawut Junkasem et al 2006) and urea–formaldehyde (Singha and Vijay Kumar Thakur 2008) where as there are no reports available to the best of our knowledge regarding the use of roselle as a reinforcing agent for unsaturated polyester matrix.

Each natural fiber (Bast or leaf) has its own special mechanical properties. The bast fibers exhibit a superior flexural and tensile strength and modulus of elasticity, but the leaf fibers show superior impact properties (Mohanty et al 2000). A combination of bast and leaf fibers reinforced composites may lead to overall improvement in mechanical properties such as tensile, flexural and impact strength. An attempt was initiated to investigate the possibility of fabricating a hybrid composite with improved mechanical properties. If such possibility is confirmed it will be possible to develop commercial applications which can replace wood and glass fiber reinforced composites. Investigations on natural fibers based hybrid polymer composite are still new and not much research has been published. So, a new attempt has been made to understand the mechanical properties (Tensile, flexural and impact strength) of chopped and randomly oriented roselle/sisal fibers based hybrid unsaturated polyester composite. For fabrication of the specimens, the method proposed by Maries Idicula et al (2006) was used.

The main objectives of this study are:

- To investigate the suitability of roselle fibers and roselle/sisal fibers as reinforcement in polyester matrix composite by determining the tensile, flexural and impact properties.

- To determine the contribution of various fiber content and length of roselle fibers and roselle/sisal fibers over the composite strength.
• To determine the effect of moisture absorption of roselle fibers and roselle/sisal fibers over the composite strength.

• To determine the contribution of alkali-treatment of Roselle fiber polyester composites over the composite strength.

• To observe the machinability of roselle fibers and roselle/sisal fibers polyester composites.

1.8 SCOPE AND PLAN OF THE STUDY

Natural fibers was used about 3000 years ago in the ancient Egypt, where straw and clay were mixed together to build walls. Over the last decade, natural fiber reinforced polymer composites received ever increasing attention due to the need of environmental friendly materials. In the past, various investigations have been carried out on natural fiber composite. Other natural fibers such as banana, jute, flax, hemp, kenaf and coir are also the most commonly used fibers to reinforce polymers, whereas the studies on roselle fiber as reinforcement for polymer composites are limited.

Roselle fibers have good potential as reinforcements in polymer composites. The roselle fibers are not yet frequently used as reinforcement fillers in polymer (thermoplastics and thermosets) composites. Also there is no information on the roselle fiber reinforced polyester composites to the best of our knowledge. An attempt has been made to study the use of roselle fibers as reinforcement in polymer. Sisal fibers have good potential as reinforcements in polymer composites. There is no information available regarding hybridization of sisal fibers with roselle fibers in polyester based polymer matrix composites. The present work aims at studying the mechanical properties such as tensile strength, flexural strength and impact strength of roselle and roselle/sisal hybrid fibers composites in polyester resin.
matrix. To understand the contribution of the leaf fibers (sisal) on the mechanical strength of the bast fibers (roselle) and to compare the strength properties of the roselle fiber polyester composites, roselle/sisal hybrid fiber polyester composite should be fabricated and characterized. So, this investigation is a primary or a novel study.

Roselle and sisal fibers are extracted from the stem and leaf of the plant Hibiscus sabdariffa L. and Agave sisalana obtained from Jeyamkondan region, Tamilnadu State, India. Roselle and sisal fibers find traditional, age-old applications in the form of high strength ropes in India. The roselle fibers used for low weight and high strength ropes to lift the water from Well etc. The sisal fibers used to fix together the coconut leaf and wooden rod in preparation of roof of house. These fibers have not been examined as reinforcement material for composites. Roselle (Hibiscus sabdariffa L.) fibers resemble jute and bimli fiber in general appearance and characters. In this work, the roselle and the sisal fibers are considered in chopped, short and long forms.

The mechanical properties (Tensile, flexural and impact strength) of roselle and roselle/sisal hybrid fiber polyester composite were determined under three conditions.

- Dry composite specimen
- Wet composite specimen
- Composites reinforced with fibers treated with NaOH solution

As a novel attempt, the machinability of roselle and roselle/sisal hybrid fiber polyester composites was determined. The thesis consists of 10 chapters. Chapter 1 deals with overall introductory part of this study, in which the development of natural fiber polymer composites, necessity of the
development the natural/natural fiber polymer composites and main objectives of the present investigations, are explained in detail.

Chapter 2 deals with the literature review, in which the detailed survey (water absorption, alkali treatment, machinability) of natural fiber reinforced polymer composites and the scope of this study were explained in detail. In chapter 3, studies on the separation, extraction and tensile property of roselle and sisal fibers are given. Water absorption test on roselle and sisal fibers has been conducted at 30° in water. Alkali treatment test on roselle and sisal fibers has also been carried out at 30° in 10% NaOH solution at 2, 4, 6 and 8 h durations. Chapter 4 deals with detailed study on the materials details and experimental methodology.

In chapter 5, the mechanical properties of chopped roselle fiber polyester composites and chopped roselle/sisal/polyester hybrid composites at dry condition and how the properties were influenced by fiber content are discussed. The effect of the addition of the sisal fibers with the roselle fibers on the mechanical properties of the composites are studied in detail. It also deals with the study of the optimum fiber content for chopped roselle fiber polyester composites and chopped roselle/sisal fiber hybrid polyester composites. The fractographic study on fractured surface of the composite materials has also been carried out using scanning electron microscopy (SEM). The experimental tensile and flexural properties were compared with theoretical and statistical or empirical predictions.

The mechanical properties of the randomly mixed roselle fiber composites and roselle/sisal fiber hybrid composites are discussed in Chapter 6 with special reference to fiber length and fiber content. The effects of the addition of the sisal fibers with the roselle fibers on the mechanical properties of the composites are reported in detail. The strength values of roselle fiber composites and roselle/sisal fiber hybrid composites are
compared. Fractured surface of the composite materials are studied using scanning electron microscopy (SEM). The experimental tensile and flexural properties were compared with theoretical predictions.

Chapter 7 focuses on the influence of alkali treatment (NaOH) of roselle and sisal fibers on the mechanical properties of chopped and randomly mixed roselle fiber composites and roselle/sisal fiber hybrid composites. The properties of chopped and randomly mixed fiber composites are compared. The influence of alkali treatment duration and fiber concentration on the mechanical properties of roselle/sisal fiber polyester hybrid composites was studied in detail. Scanning electron microscopy (SEM) was used for fractographic study. The experimental tensile properties of the chopped fiber reinforced composites are compared with statistical or empirical predictions.

Moisture absorption behavior of chopped and randomly mixed roselle fiber composites and roselle/sisal fiber hybrid composites and its effect on the mechanical properties is described in Chapter 8. Moisture absorption characteristics of the composites for five days are studied. Surface morphology of water immersed composites and fractured surface of the composites tested in moisture condition are studied using SEM. The experimental tensile and flexural properties of the chopped fiber reinforced composites are compared with statistical predictions.

Chapter 9 deals with the machinability study of roselle fiber composites and roselle/sisal fiber hybrid composites rod based on the thrust force, torque and delamination. MAXMILL CNC machining centre is used to machine the composite rod. Drill tool dynamometer is used to record the thrust force and torque. Machine Vision Inspection System with RAPID I software was used to measure the delamination zone and factors. Taguchi, ANOVA, Non-linear Regression model are used to predict and evaluate the
thrust force, torque and delamination factor. This is a novel attempt on the natural and natural-natural fiber hybrid composites.

Conclusions and scope for further research of the thesis are given in Chapter 10.