CHAPTER-9

CONTRIBUTION, CONCLUSIONS, LIMITATIONS AND SCOPE FOR FUTURE WORK

9.1 Contribution

The usage of polymers is increasing day by day owing to their high strength to weight ratio, ease of fabrication, good finish to the end products and low cost. As man is in search of newer materials, the quest for such materials is increasing day by day. Composites which are the combination of two or more dissimilar materials come under such a class of materials. As the environmental awareness is also increasing, man is showing his interest on eco-friendly materials. Both thermosets and thermoplastics are used as the matrix materials in the development of fiber reinforced plastic materials. The fibers include Glass, Carbon, Kevlar, Boron etc. Though these petroleum based fibers are indispensable materials, some times they pose environmental problem. During processing of these fibers may create health risk to the workers. In recent years the interest in the usage of natural fibers in place of synthetic fibers is increasing day by day. The advantage of natural fibers is their eco-friendly nature and abundance in the availability. As the natural fibers and the matrix materials under consideration are organic in nature, a proper bonding is expected between the components of the composite. For making a high performance composites three main factors are to be considered. They are the aspect ratio of the fibers, the bonding between the fiber and matrix and the wettability of the fibers. As natural fibers are short in length, their aspect ratio is limited. However, the natural fiber / polymer composites provide some useful properties. For instance, the processing of short fiber composites is easier than that of continuous fiber/ polymer composites. At the same time a high cost reduction is envisaged. Keeping all these factors in mind the Author has developed the short Natural finer/ polyester composites and studied their mechanical properties.
In the present study, the Author had selected polyester resin / Styrene monomer system as the matrix. As the cost of polyester resin is low, the same is preferred to use as a matrix. Naturally available sun hemp, sisal, banana and palmyra fibers are used as reinforcement. These fibers are abundantly available in India. In Vikarabad forest of Andhra Pradesh, these fibers are available. Properties of Indian hemp / sun hemp are explained in the literature, but literature is not available on sun hemp fiber reinforced composites. Similarly investigations are carried out by researchers on Oil Palm fiber based composites. Research work based on palmyra fiber obtained from its leaf stack is not available. Banana stem fiber was used by various researchers for its characterization. In the present work Author has selected Banana Fruit stack fiber to prepare composites. Sisal fiber is abundantly available in India. Based on geographical conditions, mechanical properties of fibers vary with each other and the way respective fiber bonds with matrix material also changes. This will certainly affects the mechanical properties of the composites. So the Author has decided to carry out investigation on above mentioned fiber based composites.

Preparation of specimens and experiments are carried out in PRRM Engineering College. For advanced testing facilities, the Author has used machines at NIT, Warangal. The main intention of the Author was to develop low cost materials which or esuriently and to know their mechanical properties. All the experiments were carried out in near by laboratories to avoid the additional expenditure on the exchequer. The Author has also fabricated the moulds necessary for making the test samples. The Author assembled an instrument to determine the modulus of the composites so that these facilities can also be used for training the post-graduate students.
9.2 Conclusions

In the present work, the Author has carried out some mechanical tests to evaluate the performance of the fabricated composites. These studies are presented in the thesis. The thesis consists of 8 Chapters.

In the Chapter 1, a brief introduction about the history of the development of composite materials is presented. Applications of natural fiber reinforced composites are briefly discussed. Availability and potential of the natural fibers are explained. Aim and scope for present work is also presented in the same chapter.

Development of natural fiber based composites by various researchers is discussed in the chapter 2. Experimental studies to characterize various natural fiber based composites are presented in Literature survey. Need for the present work is explained. Critical Appraisal and Objectives of present study is discussed in the same chapter. Eco-friendly nature and advantages of natural fibers are discussed. How natural fibers obtained from different geographic conditions affect the mechanical properties of natural fibers is also discussed. Need for the proposed work is also explained in this chapter.

The Chapter 3 deals with a brief description of various materials used in the present study. Method of extraction of natural fibers from plant/tree sources and processing of these fibers in the present study is also explained. Design and fabrication of moulds used and preparation of samples are narrated. Testing procedures used in the present work, to know mechanical properties are also explained.

In the chapter 4, the effect of fiber length on tensile strength is found out. By changing the length of the fiber and impregnating the same in polyester resin specimen sheets are prepared and tensile test is conducted to know the tensile strength. It is found that, as the length of the fiber is increased up to a certain
extent, the tensile strength is also increased. Further increase in the fiber length has resulted with decrease of the tensile strength. The fiber length at which, the composite has resulted with highest tensile strength is called as optimum fiber length. Optimum length for sun hemp, sisal, palmyra and banana fiber are found. Curtis and Bader (Curtis, 1978) have given explanation for low tensile strength of the composite made out of low fiber length. When the fiber lengths are low, the ends of the fiber act as notches and generate considerable stress concentration capable of initiating micro-cracks leading to the failure of composite. Similarly, in case of more length [> critical length (or) > Optimum length] of fibers may fail because of the statistically distributed defects on those long fibers are more. Also it is observed the difference between the theoretical and practical values of tensile strengths. Various reasons for the difference between the theoretical and practical tensile strengths are explained.

Tensile tests are conducted on specimens and various tensile properties of sun hemp, sisal, palmyra and banana fiber reinforced composites are calculated. Load Vs Elongation curves are drawn for these composites and ultimate tensile strength is calculated for these composites. Also stiffness is calculated. Stress and corresponding strain for the specimen are tabulated and the relationship between the same is represented in the form of Graph. The value of Young’s Modulus is also, calculated. % of Elongation is calculated using formula. Bar Charts are drawn to compare stiffness, Ultimate Tensile Strength, percentage of Elongation and Young’s Modulus for all four types of composites is also represented at the end of the Chapter 5. From the table 4.1, 4.2 through 4.4 and graphs 4, sun hemp fiber reinforced composites have resulted with highest Ultimate tensile strength of 60.04 MPa, whereas the same for palmyra composite is 42.65 Mpa.

In the chapter 6, the effect of Fiber Volume Fraction / Fiber Weight Ratio on tensile strength is experimentally found out. By keeping the fiber length equal to optimum
fiber length of each respective fiber, composite specimens are prepared. Experimentally found out tensile strength values are compared with practical values. Piggott's equation, which is used to calculate theoretical tensile strength of short fiber composite, is used. Graphs 6.1 through 6.4 are drawn between tensile strength and fiber weight ratio. These graphs include theoretical and experimental tensile strengths. In all types of natural fiber reinforced composites, it was observed that, as the fiber volume fraction is increased up to certain extent, the tensile strength has increased. Further increase in volume fraction has resulted with decrease of tensile strength. The above statements are well supported by the graphs 6.1, 6.2, 6.3 and 6.4.

It was observed that Stiffness of sun hemp fiber reinforced polyester composite is 2700 MPa, which more than other three types of composites. Stiffness value for sisal composite was observed to be less than other composites.

In chapter 7, flexural properties of the natural fiber reinforced composites are explained. By impregnating fibers of optimum length in polyester resin composite specimens are prepared for finding flexural modulus of the composite experimentally. The author has developed a set up for determining the flexural strength of the composites prepared. The set up is used to load the specimen in a uniform fashion with weights in equal steps in an ascending order. As the load increases, deflection is observed to be increased. Graphs are drawn between Load and corresponding deflections. W/y value is obtained from the graph. By substituting this value in equation 7, flexural modulus of each type of composite is calculated. Similar type of results is observed by Pothan and Thomas (Pothan, 2004), who have developed banana fiber reinforced polyester composites and studied their mechanical properties. It is observed that flexural modulus of the composite is more than a plain polyester sheet. Flexural modulus of sun hemp polyester composites is better compared to other types of natural fiber polyester composites. It is proved that introducing fibers in
polymers will certainly increase the flexural modulus. **Sun hemp reinforced polyester composite’s flexural strength** 3265 MPa, which is more than other three types of composites.

In Chapter 8, the importance of impact strength of composites, which are used for automobile applications are explained. Specimens are prepared by impregnating natural fibers in styrenated polyester resin. Izod impact test is carried to know the impact strength of the composites. At different fiber weight ratios, impact strength is experimentally found out. Bar charts are drawn to compare impact strengths of sun hemp, sisal, palmyra and banana fiber reinforced composites. *It is observed that Banana fiber reinforced composites have better impact strength.* Various results obtained in the work are presented in the table 9.

It is found that, better tensile and other mechanical properties for natural fiber reinforced composites can be obtained by impregnating fibers with optimum length and fiber weight ratios of respective fibers. *These natural fibers will not pose any health problems or risks during their processing.* The cost of these fibers is also less compared to artificial fibers. As these fibers possess good damping properties they can be used for making automobile parts. Good crash behavior of natural fiber composites has created interest to the designers of automobiles.

### 9.3 Limitations

1. Specimens were prepared with a maximum fiber weight ratio of 60 % and the Author has gone for only random orientation of fibers, in order to have isotropic properties to specimens.

2. Since the mould dimensions were limited, maximum fiber length for the experimentation was 70 mm. It is observed that random orientation of the fiber is difficult fiber length more than 70 mm.
3. Polyester resin was selected as matrix material as it is available at low cost.
4. Four types of fibers (Sun hemp, sisal, banana and palmyra) were considered for research work.
5. Composites were prepared using one type of fiber. Two different fibers were not mixed (or) other filler materials were not used for preparing composites.
6. Lignin / wax that were present on natural fibers was removed using 1% NaOH solution, before fibers are impregnated in the resin. No other chemical treatment method was adopted to clean lignin / wax.
7. To characterize a composite, it requires to conduct various tests like water absorption studies, microscopic studies, creep test, fatigue test, tensile test, compression test, void content test, impact test, density and chemical resistance test etc. In the study Experiments were conducted to find out tensile strength, flexural modulus and impact strength of the composites.
### Table 9 Results obtained in the research work

<table>
<thead>
<tr>
<th>S.No</th>
<th>Property</th>
<th>Sun hemp Fiber reinforced Polyester Composite</th>
<th>Sisal Fiber reinforced Polyester Composite</th>
<th>Banana Fiber reinforced Polyester Composite</th>
<th>Palmyra Fiber reinforced Polyester Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Optimum Fiber Length (mm)</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Optimum Fiber Weight Ratio (%)</td>
<td>54</td>
<td>54</td>
<td>51</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>U.T.S (MPa)</td>
<td>60.04</td>
<td>50.50</td>
<td>59.00</td>
<td>42.65</td>
</tr>
<tr>
<td>4</td>
<td>Young’s Modulus (MPa)</td>
<td>1819.39</td>
<td>1269.13</td>
<td>1822.58</td>
<td>1316.36</td>
</tr>
<tr>
<td>5</td>
<td>Percentage % of Elongation</td>
<td>3.3</td>
<td>3.92</td>
<td>3.24</td>
<td>3.24</td>
</tr>
<tr>
<td>6</td>
<td>Flexural Modulus (MPa)</td>
<td>3265</td>
<td>1830</td>
<td>1743</td>
<td>3022</td>
</tr>
<tr>
<td>7</td>
<td>Impact Strength (J/cm²)</td>
<td>5.45</td>
<td>6.50</td>
<td>5.30</td>
<td>1.70</td>
</tr>
</tbody>
</table>

### 9.4 Scope for Future Work

Maximum tensile strength obtained for natural fiber reinforced composite in present study is 60.04 MPa (for Sun hemp fiber reinforced composite). By making hybrid fiber reinforced composite, it is expected that the tensile strength will be more than the maximum tensile strength, which is obtained in the present study. Hybrid composites can be made by impregnating natural and artificial fibers in resins.

One way to obtain better mechanical properties of natural fiber based composites is impregnating natural fibers in resins, which are richer in mechanical properties. Similar type of work can be carried out using other natural fibers like Hibiscus,
Cycus leaf stack, human hair and Coconut fiber mat obtained from the trunk of the tree, which are available abundantly in India.

Blending of resins is one way of obtaining better mechanical properties for composites. Natural fibers can be treated with chemicals and can be used for conducting similar type of work.

By increasing the size of the mould, it is possible to prepare cast sheets of composites of weight ratio more than 60 %, for additional research work.

Water absorption studies, creep analysis, Void content tests, Density and weight reduction studies can be carried out on similar type of composites. Chemical modification of natural fibers also can be carried out. The Author would like to carry such studies as the Post-doctoral work.