

Characterization of silk and flax natural fabrics reinforced polymer composites.

¹M Phani Raj, ²K Ramasawamy, ³K Ajay Kumar

^{1,3} Department of Mechanical Engineering, VNR VJIET, Hyderabad, India.

² Composite Product Development Centre-ASL, DRDO, Hyderabad, India

Abstract. Researches attracting to develop natural fibre reinforced composites in worldwide due to their low cost, mechanical properties, bio degradability and environmental friendly. Among various natural fabrics, flax fabric from plant protein and silk fabric from animal protein are chosen in this study and developed natural fabric reinforced polymer composites with hand lay-up method upon next load carrying tests such as tensile and compressive were examined as per ASTM standards and average compressive strength in silk and flax fabric reinforcement found to be 101.26 Mpa and 67.16Mpa. Density was found to be 1.20g/cc on both.

Keywords: Silk fabric, flax fabric, polymer matrix, tensile strength, compressive strength, density, glass transition temperature.

1. INTRODUCTION

Natural fibre materials are chosen by engineers and researchers due to environmental awareness, friendly and desirable properties in comparison to synthetic fibres. Continuous research is going on to identify various natural materials such as jute, hemp, coir, banana, sisal, etc, to fabricate composites and characterize them. Among the various natural materials, Bombyx mori (b'mori) silk and flax are kind of natural material derived from animal and plant protein. For past thousands of year's b'mori silk was used in textile industries, however in recent years' silk fibroin protein was used in the applications of bio composite, Nano electronics, bio sensors, material science, tissue engineering and optical materials in were as flax fabric is been great applicant in filtration industry, packaging (bags and covers), wind energy and in sports equipment. When compared to other natural fibres, silk is used around 95% throughout the world [1] to enhance its application in different sectors.

Following reviews about researchers who have developed silk reinforced polymer composite with different polyesters.[2]Proposed that 70.vol% of silk fabric reinforced epoxy composite (SFRPs) has better adhesion properties than woven flax fibre. Summarized and compared few mechanical properties like tensile, flexural and impact strength with SFRPs (silk fabric reinforced epoxy composite) to flax fibre reinforced epoxy resin composite (FFRPs) and glass fibre reinforced epoxy resin composite (GFRPs). Tests were conducted by taking samples of SFRPs volume fraction of (30%, 40%, 50%, 60%, and 70%) without vacuum treatment and 60(N).vol% SFRP with vacuum treatment. Impact Strength is found to be maximum 71kj m⁻² under 60.vol% SFRP. Verdict of their experimental results showed that 70%.vol SFRP, the tensile young's modulus, ultimate stress and ultimate strain are all increased by 145%, 130% and 70%. Author stated that performance of the brittle epoxy matrix can be improved by incorporating high volume fraction of 70.vol% SFRP. [3]Have developed two silk –



epoxy fabric composites, one with which is toughened by polymethylmethacrylate (PMMA) and another with polycarbonate (PC) with varying weight contents of silk fabric in each composite. On each composite they examined Tensile strength, Flexural strength, elongation, impact strength and water absorption. Their overall results found to be highest in PC-toughened silk-epoxy composite when compared with the other. Concluded that water absorption was decreased by using toughened materials like PMMA and PC in silk-epoxy composite. [4] From waste fibres produced from the silk, have developed hybrid composites with epoxy by incorporating silk, jute and glass fibres. Four Hybrid composites and their stacking sequence are GSG, SGS, JSJ and SJS (S: Silk, J: Jute; G: Glass) with varying volume contents. With all samples author has examined mechanical properties and analysed particle erosion behaviour under steam, saline and sub-zero treatments.[5] Developed two silk based composites, one with silk-epoxy with varying weight contents from 0 to 25 wt% and another one with silk-glass/epoxy as hybrid with varying weight contents from 0 to 50 wt%. Strength tests were carried on both types of composites. Their results found to be great in hybrid composite and the water absorption also found to be decreased in a hybrid composite.[6] Have studied the SFRP with epoxy against non-woven mat and woven mat and their volume fractions are 36.2% and 45.2%. Mechanical properties of SFRP composite are compared with flax (plant fibre reinforced polymer-PFRP) and glass (glass fibre reinforced polymer-GFRP) composites. They stated that SFRP woven mat has composite has higher failure strain than flax PFRP's and less than GFRP's and SFRP has superior mechanical properties than PFRP's. [7,8] Have examined impact strength, compressive strength, density, void content and weight reduction on silk fabric/epoxy composite with varying weight content from 0 to 25 wt% of silk fabric. Compression and impact strength values were gradually improved and the weight was gradually decreased by a Uniform increase of weight content in fabric. Concluded that the void content of the composite was 3.49% and 1.83% at 5, 20 wt% which has shown them great bonding in the matrix and further, examined flexural and tensile strength of the composite with varying weight content of the fabric. Their results are found to be improved by increment in weight content of the fabric. They also reported weight loss and gain of the composite by immersing specimens in various chemicals. Concluded that with suitable coupling agent of silk fabric treatment would give great bonding in composite. [9] Through Compression moulding authors have developed silk reinforced gelatin composite. The composite mechanical properties of tensile strength is 44.5 Mpa, tensile modulus is 0.65 Gpa, bending strength 63 Mpa, bending modulus is 3.7 Gpa, impact strength is 5.1 kJ/m², hardness is 96. When compared with gelatin film to the silk reinforced gelatin composite, above mentioned mechanical properties are improved by 258.9%, 400%, 317.2%, 452.2% and 264.3%. Their bio degradation test result showed loss of 52% weight in the composite at 24th hour. They have discussed about weathering test, fraction behaviour and fibre pull out of their developed composite.

Thus, an attempt has been made in this paper were to develop for silk fabric reinforced polymer composite (SFRP) and flax fabric reinforced polymer composite (FFRP) and carried mechanical tests such as tensile, compressive, density and glass transition temperature.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials

The epoxy resin employed in the present study is LY556 and the hardener is HY951 procured from Advance System Laboratories-CPDC. The silk fabric (90 GSM, t=0.18mm) was procured from chenethabhawan, Hyderabad and flax fabric (190 GSM, t=1mm) was procured from Go Green products, Chennai.

2.2 Composite Preparation

Hand lay-up method was employed for preparing composite and metallic mold (300mm x 300mm x 3mm) was considered to fabricate SFRP and FFRP composites. Primarily, resin and hardener were mixed in the ratio of 10:1 parts by weight and fabric with laid matrix were placed between polythene cover. Individual layers were trimmed accordingly. Secondly, mold was coated with wax agent and allowed to dry and next to it, individual fabric were laid uniformly over the mold and applied epoxy mixture again followed with compressing with metallic roller to avoid air gaps in between.

Territorially, mold was closely tightened and kept under room temperature. After 24th hour plates were removed and specimens were trimmed for mechanical tests which are shown in figure 1.

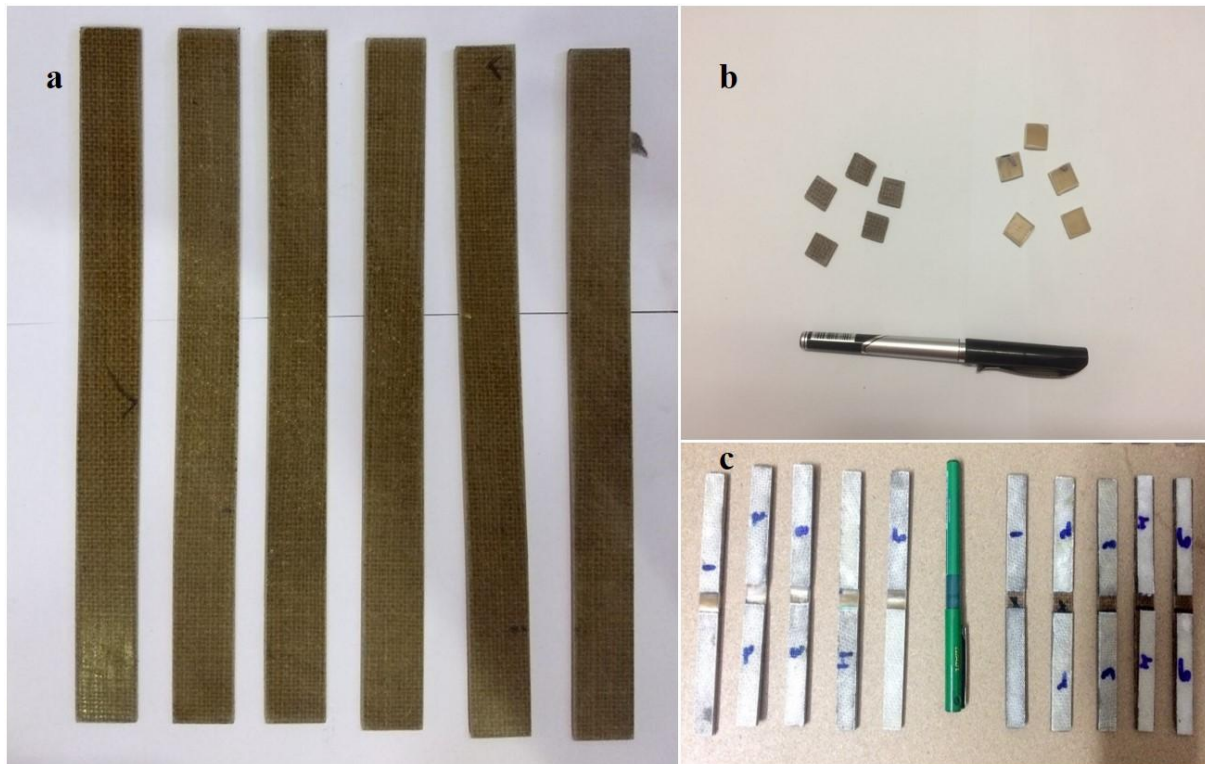


Figure.1: Test Specimens a.) Tensile b.) Density c.) Compressive

2.3 Mechanical Tests:

2.3.1 Tensile Strength Measurement

Tensile tests were carried out on INSTRON 4505 universal testing machine at ambient temperature. The standard rectangular specimen (250mmx26mmx2.20mm) were casted according to ASTM D-3039. The cross head speed was 50mm/min and minimum of 5 specimens were tested in each composite to obtain the average.

2.3.2 Compressive Strength Measurement

The Compressive strength was determined using the INSTRON 4505 universal testing machine at ambient temperature. Standard rectangular specimen (140mmx12mmx2.20mm) were casted according to ASTM D-3410. To avoid slippery during test, specimens are tabbed with glass fibre reinforced polymer at both ends of 60mm length. 5 specimens were tested on each case to obtain average and the test speed was maintained at 1.5mm/min.

2.3.3 Density

Specimens were prepared by cutting 12mmX12mmx2.20mm. 5 Specimens were tested in each composite according to the principle of Archimedes as formulated in equation.1.

$$\text{Density} = \frac{\text{Weight of object in air}}{\text{Weight of object in air} - \text{weight of object in water}}$$

} 1

2.3.4 Glass transition Temperature (t_g)

To measure glass transition temperature and to quantify the residual cure in SFRP and FFRP, 2 Specimens from each composite around 12mg by weight were considered and tested on TA, model: DSC Q200 figure 2(b) at nitrogen atmosphere, heating was carried from 30°C to 80°C at the rate of 10°C/min.

3. RESULTS & DISCUSSION

3.1 Tensile Strength

Maximum stress in SFRP and FFRP are found to be 49.8 Mpa and 40.3 MPa. For five specimens, average tensile strength, modulus in SFRP and FFRP are 46.72 MPa, 5 GPa & 36.56 MPa, 3.26 GPa. Individual specimens of both composite tensile strength results are shown table 1 and table 2. Stress vs strain plots are shown in figure 2 and figure 3 and failure specimens are shown in figure 4.

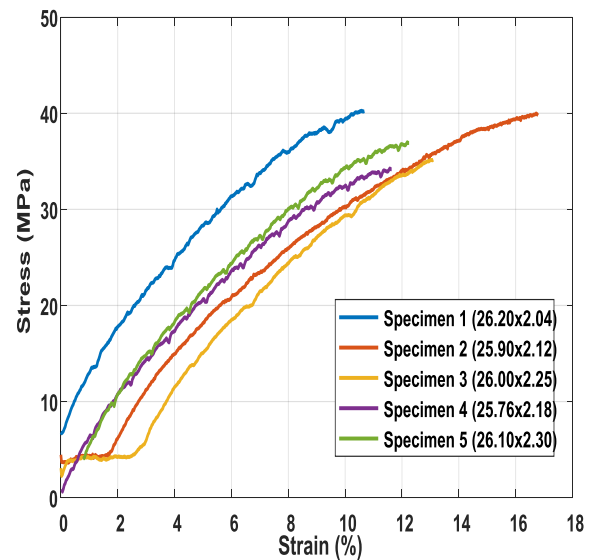
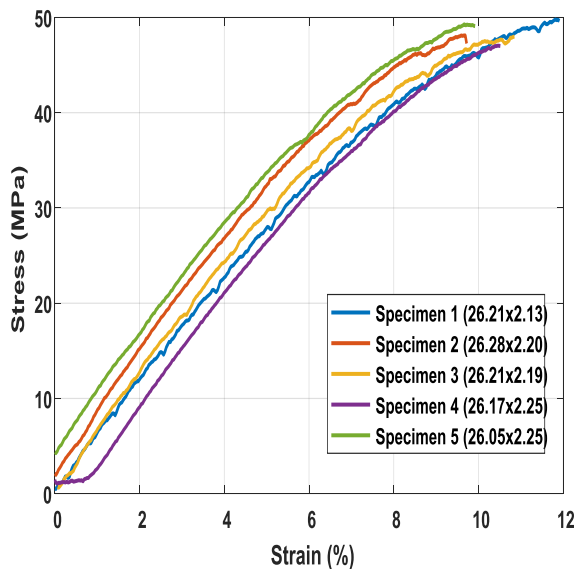


Figure 2: Tensile strength of SFRP Figure 3: Tensile strength of FFRP

Table 1: Tensile test data of SFRP

S.No	Dimension (mm)	Displacement (mm)	Load (kN)	Tensile Strength (Mpa)	Tensile Modulus (GPa)
1	26.21*2.13	3.131	2.78	49.8	5
2	26.28*2.20	1.914	2.355	40.7	5
3	26.21*2.19	2.556	2.761	48.1	5
4	26.17*2.25	2.848	2.826	48	5
5	26.05*2.25	2.748	2.757	47	5

Table 2: Tensile test data of FFRP

S.No	Dimension (mm)	Displacement (mm)	Load (kN)	Tensile Strength (Mpa)	Tensile Modulus (GPa)
1	26.10*2.20	2.423	1.922	33.9	3.7
2	26.20*2.04	2.7	2.002	37.5	3
3	26.10*2.30	2.806	2.152	35.9	3
4	25.90*2.12	4.312	2.212	40.3	3
5	26.00*2.25	3.423	2.058	35.2	3.6

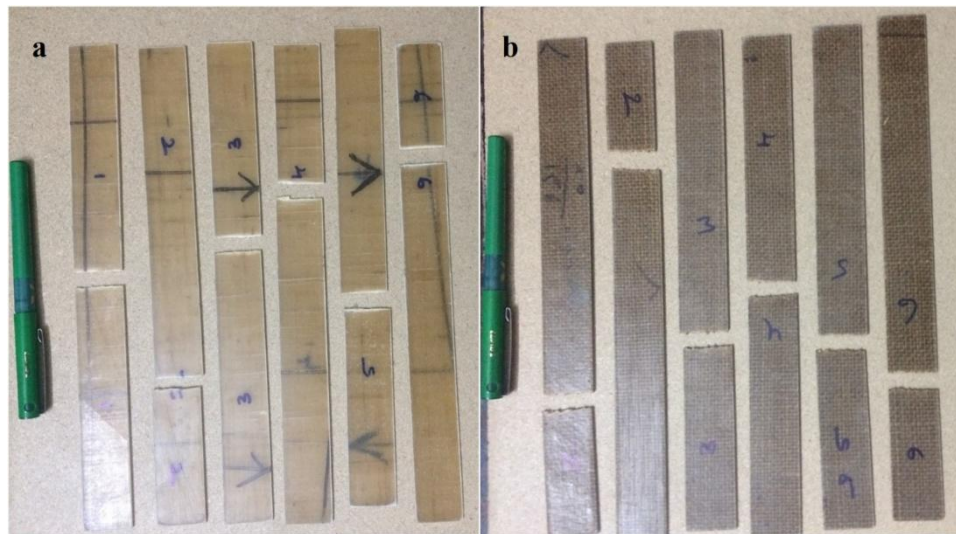


Figure.4: Tensile specimen failures a.) SFRP b.) FFRP

3.2 Compressive Strength

Maximum compressive stress, load observed in SFRP and FFRP are 105.9 Mpa, 3.052 kN and 74 Mpa, 1.954kN. For 5 specimens, average compressive strength in SFRP and FFRP are found to be 101.24 Mpa and 65.7 MPa. SFRP and FFRP individual specimens of compressive strength are reported in table. (3&4) and their stress vs strain are shown in figure 5 and figure 6.

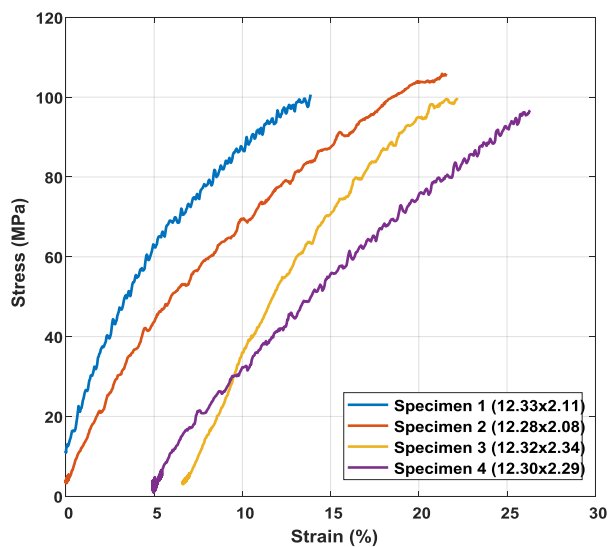


Figure 5: Compressive strength of SFRP

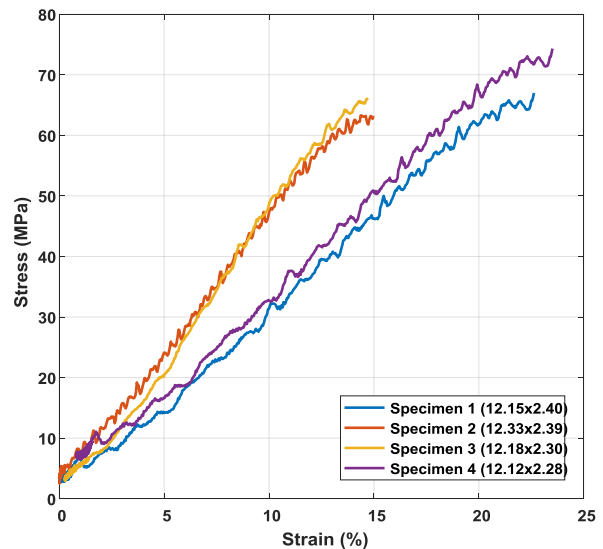


Figure 6: Compressive strength of FFRP

Table 3: Compressive test data of FFRP

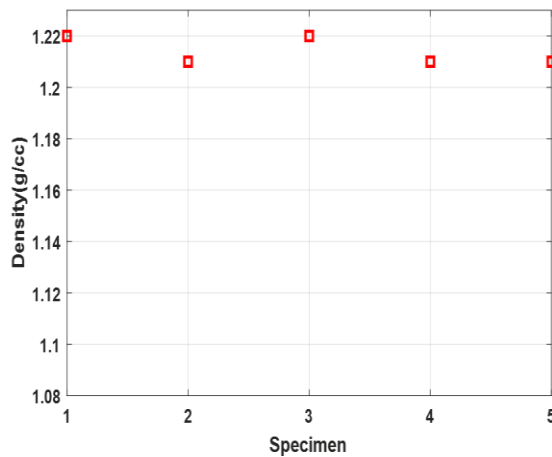
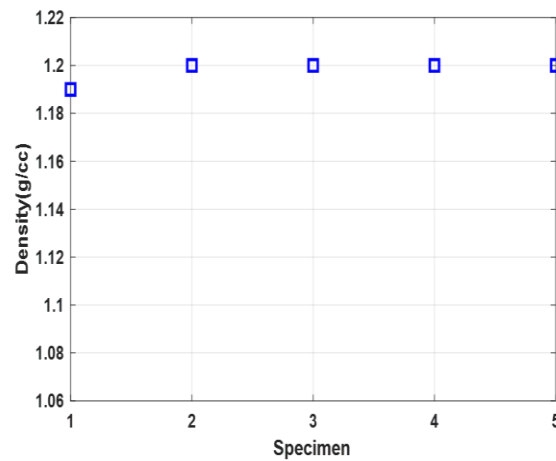
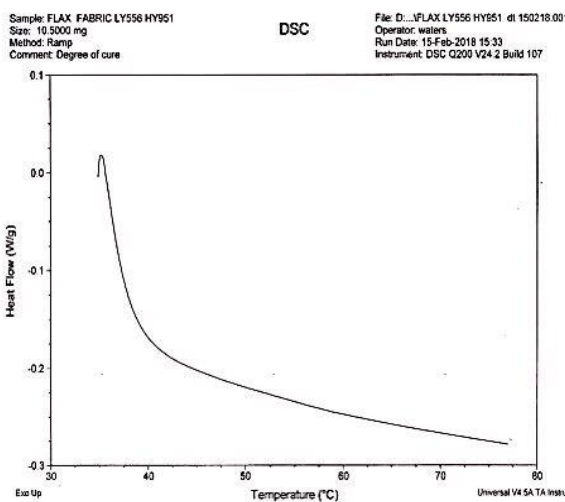
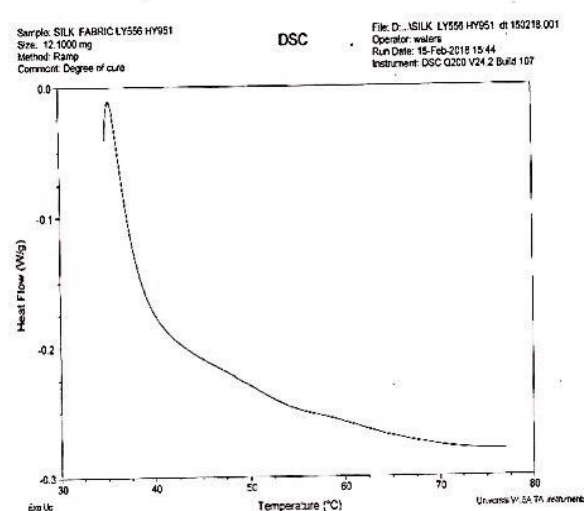
S.NO	Dimension (mm)	Displacement (mm)	Load (kN)	Strength (Mpa)
1	12.15*2.40	2.749	1.954	67
2	12.33*2.39	2.211	1.877	63.7
3	12.18*2.30	1.882	1.879	67.1
4	12.12*2.28	2.215	2.20	74
5	12.15*2.38	2.218	1.866	64

Table 4: Compressive test data of SFRP

S.NO	Dimension (mm)	Displacement (mm)	Load (kN)	Strength (Mpa)
1	12.33*2.11	1.471	2.613	100.4
2	12.28*2.08	1.703	2.571	100.6
3	12.32*2.34	1.626	3.052	105.9
4	12.30*2.29	2.728	2.811	99.8
5	12.36*2.10	3.642	2.582	99.5

3.3 Density

Average density in SFRP and FFRP was found to be 1.21 g/cm^3 & 1.20 g/cm^3 and their individual specimen density is plotted in figure.7 and figure 8. It is observed that both composite has light weight density.

**Figure 7: Density of SFRP****Figure 8: Density of FFRP****Figure 9: T_g of FFRP****Figure 10: T_g of SFRP**

3.4 Glass transition Temperature (t_g)

Composites which were cured at room temperature were tested for glass transition temperature and their differential scanning calorimetry curves plotted in figure 9 and figure 10. Step wise endothermic was observed with increase in the heat flow and during the process, resin transformation from solid to a viscous liquid was carried successfully till 80°C .

4. Conclusion

Hand lay-up method successfully employed in fabricating natural fabric reinforced polymer composites. Silk and flax fabric reinforced polymer composite laminates were examined to check flaws such as cracks, voids, porosity, fabric wrinkling and erosion with non-destructive examination-ultrasonic testing (UT) by dry scan method, laminates were found to be free from the flaws. Average tensile strength, modulus in SFRP and FFRP are found to be 46.72 MPa, 5 GPa & 36.56 MPa, 3.26 GPa. Maximum tensile load, volume fraction in SFRP & FFRP are found to be 2.826 kN, 41% & 2.212 kN, 66%. Upon applying Archimedes principle, density of the both composites was shown 1.20g/cc. Tensile specimens which were failed at approximately at the centre position has showed highest strength when compared to other. Average compressive strength, compressive load in SFRP and FFRP are found to be 101.24 MPa, 3.052kN and 67.16 MPa, 2.20kN. Glass transition temperature at 80°C was successfully carried both the composites and their degree of cure at 80°C was found to be cured. By comparing, SFRP has shown greater load carrying results to the FFRP.

Acknowledgments

I would thankful to Rama rao, Composite product development centre-DRDO, Hyderabad for allowing to carry experimental tests and Principal of VNR VJIET, Hyderabad for project funding.

References

- [1] Khan GM, Yilmaz ND, Yilmaz K. 2017 *Handbook of Composites from Renewable Materials*. 377-409.
- [2] Yang K., Ritchie R. O, Gu Y, Wu S J and Guan J 2016 *Materials & Design* **108** 470-478.
- [3] Shah D U, Porter D and Vollrath F 2014. *Composites Science and Technology* **101** 173-183.
- [4] Priya S P and Rai S K 2006 *Journal of reinforced plastics and composites* **25(1)** 33-41.
- [5] Priya S P and Rai S K 2005 *Journal of reinforced plastics and composites* **24(15)** 1605-1610.
- [6] Priya S P, Ramakrishna H V, Rai S K. and Rajulu A V 2005 *Journal of reinforced plastics and composites* **24(6)** 643-648.
- [7] Gupta S 2011. *Preparation and Characterization of Waste Silk Fiber Reinforced Polymer Composites* (Doctoral dissertation).
- [8] Priya S P and Rai S K 2006 *Journal of industrial textiles* **35(3)** 217-226.
- [9] Shubhra Q T, Alam A K M M and Beg M D H 2011 *Materials letters* **65(2)** 333-336.