Journal of Manufacturing Engineering, December 2020, Vol. 15, Issue.4, pp 093-100

SYNTHESIS AND CHARACTERISATION OF WOVEN ROVING GLASS MAT FOR EPOXY COMPOSITES

***Mahesh Mallampati, Sreekanth Mandalapu and Govidarajulu C**

Department of Mechanical Engineering, Guntur Engineering College, Guntur, Andhra Pradesh- 522019, India
https://doi.org/10.37255/jme.v15i4pp93-100

ABSTRACT

The composite materials are replacing the traditional materials because of their superior properties such as high tensile strength, low thermal expansion, high strength to weight ratio, low cost, lightweight, high specific modulus, renewability and biodegradability which are the most basic & common attractive features of composites that make them useful for industrial applications. The developments of new materials are on the anvil and are growing day by day. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. Generally, composites consist of mainly two phases i.e., matrix and fiber. In this study, woven roving mats (E-glass fiber orientation (-45°/45°, 0°/90°, - 45°/45°),UD450GSM)were cut in measured dimensions and a mixture of Epoxy Resin (EPOFINE-556, Density-1.15gm/cm^3), Hardener (FINE HARDTM 951, Density- 0.94 gm/cm^3) and Acetone [(CH_3)2CO, M= 38.08 g/mol] was used to manufacture the glass fiber reinforced epoxy composite by hand lay-up method. Mechanical properties such as tensile strength, SEM analysis, hardness test, density tests are evaluated.

Keywords: *SEM analysis, Hardness test, Density test and Epoxy Composite*

1. Introduction

Nature has provided composite materials in living things such as seaweeds, bamboo, wood and human bone. The first reinforced polymeric based materials appear to have been used by the people of Babylonia around 4000-2000 B.C. The materials consisted of reinforced bitumen or pitch. Bundles of papyrus reed embedded in a matrix of bitumen. The art of mummification that flourished in Egypt during 2500 B.C. exemplifies one of the first filament winding processes. Suitably treated dead bodies were wrapped in tapes of linen and then impregnated with a natural resin to produce, ultimately a rigid cocoon. In India the resin was used as filling for swords hafts and in the manufacture of whetstones by mixing shellac with fine sand. The latter example may be considered as the forerunner of the modern composite grinding wheel. By 500 B.C., the Greeks were building ships with three banks of oars called triremes. They possessed keels that were much longer than could have been accomplished by using a single length of timber. Thus, it can be seen that the origin of composite technology goes back into antiquity. The relative importance of the structural materials most commonly used, i.e., metals, polymers, composites, and ceramics, to various societies throughout history has fluctuated which is shown in Fig. 1.

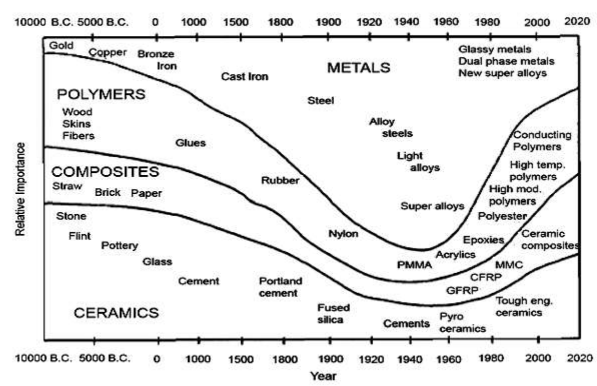

Fig.1 The importance of Metals, Polymers, Composites and Ceramics throughout History

Damrongsakkul et.al [1] worked on thermo mechanical and rheological behaviors of waste glass particulate filled polyester resins composites and found that the addition of glass particulate waste obtains from surfboard manufacturing industry was able to reduce the heat of fusion of polyester resins composite because of the decrease in the amount of polyester resins.

**Corresponding Author - E- mail:dr.mallampati18@gmail.com*

 © SME

Furthermore, the tensile and flexural properties of the composites were increased with increasing the glass particulate contents. The results from rheological studies were able to provide the apparent flow activation energy, which could reveal that the addition of glass fibre decreased the fluidity of the molten composite materials. Vassilev et. al. [2] worked on Composites Containing Waste Materials and they found that the composite materials developed on the basis of unsaturated polyester resins showed relatively good strength characteristics and could find application in the machine-building industry for the production of housings and other parts, replacing other materials with similar parameters, but of higher cost. They also found that the materials based on epoxy resins are better electro insulators and could be successfully used for electrical insulation compounds with application in electrical constructions, radio-electronics circuitry and other types of electrical equipment and appliances. M. Sanchez-Soto et al. [3] worked on study and mechanical characterization of glass bead filled tri-functional epoxy composites and they found that both the Young's modulus and the resin strength at break were improved by the addition of untreated glass-beads. Also, the Young's modulus increased with the volume of glass filler added. Liang and et al. [4] researched on the topic of measurement of thermal conductivity of glass-bead-filled polypropylene composites. They came to a conclusion that the heat insulation property of polymeric materials might be improved by filling with inorganic glass particulate phase. They also found that the effective thermal conductivity of glass-bead-filled polypropylene (PP) composites decreased roughly linearly with increase of the volume fraction of the beads. Ibrahim and et al. [5] worked on flexural properties of glass particles filled polymer composites and he came to the conclusion that the hybrid composite reinforced with 10% glass particles presented the best overall flexural properties. It had the highest ultimate flexural strength as well as an excellent stiffness and a strain to failure comparable to that of the polymer matrix material.

2. Manufacturing of Composite

When manufacturing a composite material, the material and the structure are often made in a single process. This is related to the use of the polymer, since it cures during the process and is then no longer deformable [6].

2.1 Moulds and Plugs

To ensure that a product is made in the correct shape, production methods of composites are often based on the use of moulds. The mould is often not highlighted in the discussion of production methods, but is important for the quality of the product. Often it makes up significant proportion of the costs [7].

2.2 Categories of Production Methods

As the material and the product are made in a single step, the quality of the end product is determined to a large extent by the method of production. Manufacturing tools also determine the success of a composite product. For each product, an optimum can be found between investment in knowledge and tools and functionality. Choosing a combination of production technologies is one of the most challenging aspects of constructing with composite materials [8].

2.3. Raw materials

During the design process and when selecting a processing method, a number of choices must be made with regard to the fibre reinforcement [9].

2.4. Processing methods

The following sections provide an overview of fairly widely used techniques. They can be classified as open and closed-mould technologies [10].

2.5 Tensile Test

The addition of glass Fiber mat in epoxy composite, mechanical properties get enhanced to some extent when compared with the only epoxy. After a certain amount of addition of glass fiber mat these properties do not get enhanced and in some cases on further addition of fillers the properties get decreased. Fig. 2 shows the specimens used for the tensile test.

Fig. 2 Mechanical Testing specimens

 © SME

2.6 Chemical ingredients

The chemical ingredients used are epoxy resin (EPOFIN-556), hardener (HY-951), silicon spray, glass woven roving mats and dilute HCl for cleaning of waste glass beaker.

2.7 Apparatus Used

Weighing machine, wooden board, transparent plastic Sheet, plastic glass (Use and throw),wooden bit, cleaning brush, hammer, hack saw, file, emery papers for polishing and UTM are used for the present study.

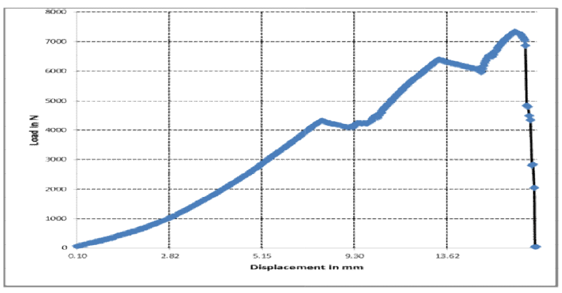

Fig. 3 Composite load vs displacement plot

Fig. 3 shows the plot which obtained for the displacement experienced by the composite during the tensile test for the applied load. And, the results of the tensile test are presented in Table 1.

Table 1 [-45^0/45^0/ 0^0/90^0/-45^0/45^0] Composite Tensile Test Results

S.No	Disp. In mm	Load In N	S.No	Disp. In mm	Load In N
1	0.1	68.65	193	6.3	4001.26
2	0.13	78.46	194	6.33	4030.68
3	0.19	88.26	195	6.36	4060.1
4	0.22	98.07	196	6.39	4099.33
5	0.25	107.88	197	6.42	4128.75
6	0.31	117.68	198	6.45	4158.17
7	0.34	127.49	199	6.48	4187.59
8	0.37	137.3	200	6.51	4217.01
9	0.4	147.11	201	6.54	4246.43
10	0.46	156.91	202	6.57	4275.85
11	0.49	166.72	203	6.6	4305.27
12	0.55	176.53	204	6.63	4315.08
13	0.58	186.33	205	6.69	4324.89
14	0.64	196.14	206	6.72	4315.08
15	0.67	205.95	207	6.75	4295.47
16	0.73	215.75	208	6.78	4275.85
17	0.79	225.56	209	6.82	4266.05
18	0.85	235.37	210	6.85	4256.24
19	0.91	245.18	211	6.91	4246.43
20	0.94	254.98	212	6.94	4236.62
21	0.97	264.79	213	7	4226.82
22	1	274.6	214	7.06	4217.01
23	1.03	284.4	215	7.09	4207.2
24	1.06	294.21	216	7.18	4197.4
25	1.09	304.02	217	7.24	4187.59
26	1.15	313.82	218	7.33	4177.78
27	1.19	323.63	219	7.45	4167.98
28	1.22	333.44	220	7.54	4158.17
29	1.25	343.25	221	7.66	4148.36
30	1.28	353.05	222	7.81	4138.55
31	1.31	362.86	223	8	4128.75
32	1.34	372.67	224	8.21	4118.94
33	1.4	392.28	225	8.36	4109.13
34	1.46	411.89	226	8.69	4099.33
35	1.49	421.7	227	8.72	4109.13
36	1.52	431.51	228	8.75	4099.33
37	1.55	441.32	229	9.21	4109.13
38	1.61	460.93	230	9.24	4148.36
39	1.64	470.74	231	9.27	4099.33
40	1.67	480.54	232	9.3	4158.17
41	1.7	490.35	233	9.33	4217.01
42	1.73	500.16	234	9.36	4246.43
43	1.76	509.96	235	9.39	4256.24
44	1.79	519.77	236	9.48	4246.43
45	1.82	529.58	237	9.66	4236.62
46	1.85	549.19	238	9.84	4226.82
47	1.88	559	239	10.2	4236.62
48	1.91	568.81	240	10.23	4246.43
49	1.94	578.61	241	10.36	4236.62
50	1.97	588.42	242	10.66	4226.82
51	2	608.03	243	11.57	4246.43
52	2.03	617.84	244	11.6	4275.85
53	2.06	627.65	245	11.63	4305.27
54	2.09	647.26	246	11.69	4324.89
55	2.12	657.07	247	11.72	4393.54
56	2.15	666.88	248	11.75	4442.57
57	2.18	686.49	249	11.78	4481.8
58	2.21	696.3	250	11.81	4501.41

 © SME

59	2.24	715.91	251	11.84	4432.76	102	3.55	1520.09	294	13.14	6158.8
60	2.28	725.72	252	11.87	4501.41	103	3.58	1549.51	295	13.17	6188.22
61	2.31	745.33	253	11.9	4579.87	104	3.61	1569.12	296	13.2	6217.64
62	2.34	755.14	254	11.93	4599.48	105	3.64	1588.73	297	13.23	6247.06
63	2.37	774.75	255	11.96	4668.13	106	3.67	1618.16	298	13.26	6286.29
64	2.4	794.37	256	11.99	4717.17	107	3.7	1637.77	299	13.29	6315.71
65	2.43	804.17	257	12.02	4766.2	108	3.73	1667.19	300	13.32	6345.13
66	2.46	823.79	258	12.05	4815.24	109	3.76	1686.8	301	13.35	6364.74
67	2.49	833.6	259	12.08	4864.27	110	3.79	1706.42	302	13.38	6394.16
68	2.52	853.21	260	12.11	4903.5	111	3.82	1735.84	303	13.44	6374.55
69	2.55	863.02	261	12.14	4942.73	112	3.85	1755.45	304	13.47	6364.74
70	2.58	882.63	262	12.17	4991.76	113	3.88	1775.07	305	13.5	6354.94
71	2.61	902.24	263	12.2	5040.8	114	3.91	1804.49	306	13.53	6335.32
72	2.64	921.86	264	12.23	5080.03	115	3.94	1833.91	307	13.56	6325.52
73	2.67	931.67	265	12.26	5119.25	116	3.97	1853.52	308	13.59	6315.71
74	2.7	951.28	266	12.29	5158.48	117	4	1873.14	309	13.62	6305.9
75	2.73	970.89	267	12.32	5197.71	118	4.03	1902.56	310	13.68	6296.09
76	2.76	990.51	268	12.35	5246.75	119	4.06	1922.17	311	13.71	6286.29
77	2.79	1010.12	269	12.38	5276.17	120	4.09	1951.59	312	13.74	6276.48
78	2.82	1029.74	270	12.41	5315.39	121	4.12	1971.21	313	13.81	6266.67
79	2.85	1039.54	271	12.44	5354.62	122	4.15	2000.63	314	13.87	6256.87
80	2.88	1059.16	272	12.47	5393.85	123	4.18	2020.24	315	13.93	6247.06
81	2.91	1078.77	273	12.5	5433.08	124	4.21	2049.66	316	13.99	6237.25
82	2.94	1098.38	274	12.53	5472.31	125	4.24	2069.28	317	14.05	6227.45
83	2.97	1118	275	12.56	5511.53	126	4.27	2098.7	318	14.14	6217.64
84	3	1147.42	276	12.59	5540.96	127	4.3	2118.31	319	14.23	6207.83
85	3.03	1157.23	277	12.63	5580.18	128	4.33	2147.73	320	14.32	6198.02
86	3.06	1186.65	278	12.66	5619.41	129	4.36	2177.15	321	14.38	6188.22
87	3.09	1206.26	279	12.69	5648.83	130	4.39	2196.77	322	14.47	6178.41
88	3.12	1225.88	280	12.72	5688.06	131	4.42	2216.38	323	14.56	6168.6
89	3.15	1245.49	281	12.75	5717.48	132	4.45	2245.8	324	14.65	6158.8
90	3.18	1265.1	282	12.78	5756.71	133	4.48	2265.42	325	14.77	6148.99
91	3.21	1284.72	283	12.81	5786.13	134	4.52	2294.84	326	14.89	6139.18
92	3.24	1304.33	284	12.84	5815.55	135	4.55	2314.45	327	15.05	6129.38
93	3.27	1323.95	285	12.87	5854.78	136	4.58	2343.87	328	15.23	6119.57
94	3.3	1353.37	286	12.9	5884.2	137	4.61	2373.29	329	15.41	6109.76
95	3.33	1372.98	287	12.93	5913.62	138	4.64	2392.91	330	15.68	6099.95
96	3.36	1392.59	288	12.96	5952.85	139	4.67	2422.33	331	16.1	6090.15
97	3.39	1412.21	289	12.99	5982.27	140	4.7	2451.75	332	16.56	6080.34
98	3.43	1441.63	290	13.02	6021.5	141	4.73	2471.36	333	18.13	6070.53
99	3.46	1461.24	291	13.05	6050.92	142	4.76	2500.79	334	18.16	6080.34
100	3.49	1480.86	292	13.08	6090.15	143	4.79	2530.21	335	18.19	6070.53
101	3.52	1500.47	293	13.11	6119.57	144	4.82	2559.63	336	18.28	6099.95

145	4.85	2589.05	337	18.31	5962.66
146	4.88	2618.47	338	18.34	6080.34
147	4.91	2647.89	339	18.37	6188.22
148	4.94	2677.31	340	18.4	6266.67
149	4.97	2696.93	341	18.43	6345.13
150	5	2726.35	342	18.46	6423.59
151	5.03	2755.77	343	18.5	6492.23
152	5.06	2785.19	344	18.53	6551.08
153	5.09	2814.61	345	18.56	6521.66
154	5.12	2844.03	346	18.59	6482.43
155	5.15	2873.45	347	18.62	6560.88
156	5.18	2902.87	348	18.65	6639.34
157	5.21	2932.29	349	18.68	6678.57
158	5.24	2961.71	350	18.71	6717.8
159	5.27	2991.14	351	18.74	6796.25
160	5.3	3020.56	352	18.77	6855.09
161	5.33	3049.98	353	18.8	6894.32
162	5.36	3079.4	354	18.83	6943.36
163	5.39	3108.82	355	18.86	6992.39
164	5.42	3128.43	356	18.89	7031.62
165	5.45	3167.66	357	18.92	7070.85
166	5.48	3187.28	358	18.95	7100.27
167	5.51	3216.7	359	18.98	7139.5
168	5.54	3246.12	360	19.01	7178.72
169	5.57	3275.54	361	19.04	7208.15
170	5.6	3304.96	362	19.07	7237.57
171	5.63	3334.38	363	19.1	7266.99
172	5.67	3363.8	364	19.13	7306.22
173	5.7	3393.22	365	19.16	7335.64
174	5.73	3422.64	366	19.22	7325.83
175	5.76	3461.87	367	19.25	7306.22
176	5.79	3481.49	368	19.28	7286.6
177	5.82	3520.71	369	19.31	7257.18
178	5.85	3540.33	370	19.34	7227.76
179	5.88	3579.56	371	19.37	7159.11
180	5.91	3608.98	372	19.4	7110.08
181	5.94	3638.4	373	19.43	7051.23
182	5.97	3667.82	374	19.46	6864.9
183	6	3697.24	375	19.49	4834.85
184	6.03	3726.66	376	19.52	4795.62
185	6.06	3756.08	377	19.55	4491.61
186	6.09	3785.5	378	19.58	4354.31
187	6.12	3814.92	379	19.61	2814.61
188	6.15	3844.34	380	19.64	2834.22
189	6.18	3873.77	381	19.68	2049.66
190	6.21	3912.99	382	19.71	39.23
191	6.24	3942.41	383	19.71	39.23
192	6.27	3971.84			

3. SEM Analysis

3.1 X-Ray Diffraction (XRD) of glass fiber

As we know the glass is an amorphous material, so the XRD analysis showed the broad peak as compared to the crystalline material having sharp peak. The reason of the coming broad peak is that the atoms of the glass powder have short range order and the atoms are randomly oriented. The XRD peak obtained for the glass fiber is shown in Figure 4. The percentage of fundamental elements present in the glass fiber identified through the XRD analysis is given in Figure 5.

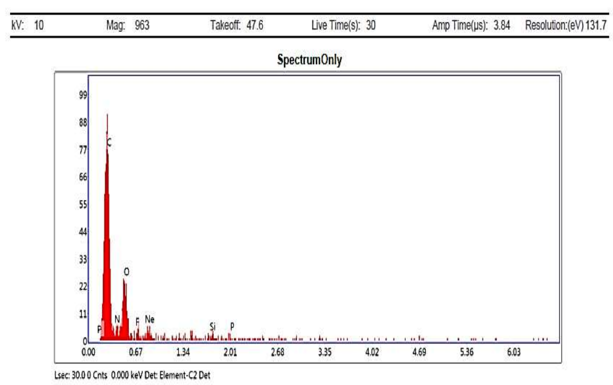

Fig. 4 XRD peak of the glass fiber

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	57.42	64.67	21.39	8.87					
N K	9.07	8.76	1.06	57.11					
O K	26.26	22.20	6.03	18.12					
F K	2.50	1.78	0.64	84.62					
NeK	1.87	1.26	0.80	79.29					
SiK	1.76	0.85	0.55	77.73					
P K	1.13	0.49	0.27	82.20					

Fig. 5 Results of XRD analysis

3.2 Scanning Electron Microscopy (SEM)

The SEM micrographs taken on the composite specimens at different magnifications are presented in Figures 6, 7 and 8.

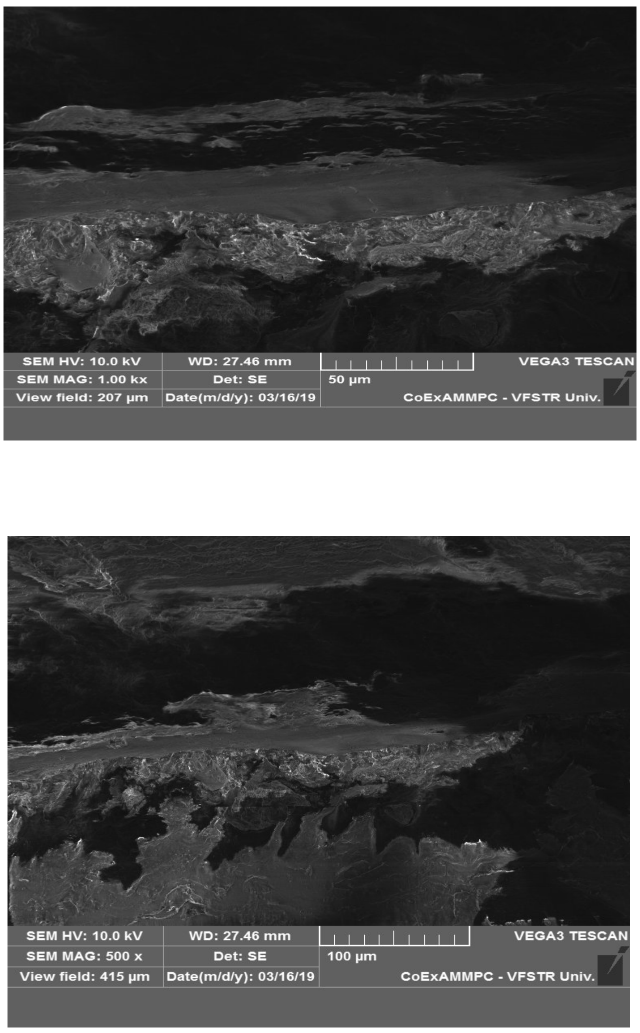

Fig. 6 SEM micrographs of composite show the glass fiber structure at 415 micro meters & 207 micro meters

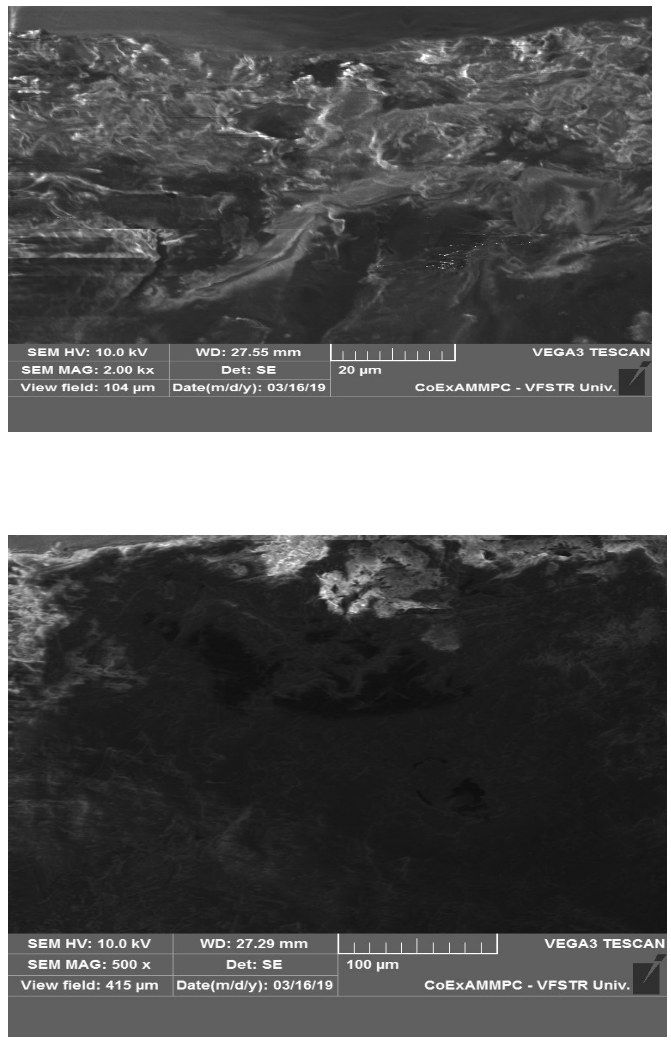

Fig. 7 SEM micrographs of composite show the glass fiber structure at 104 micro meters & 415 micro meters

 © SME

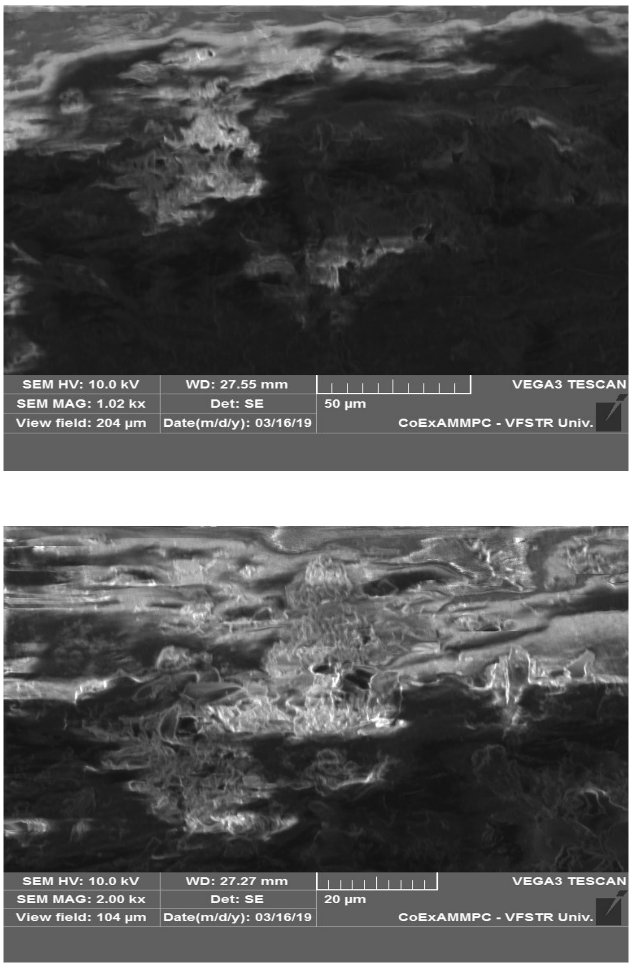

Fig. 8 SEM micrographs of composite show the glass fiber structure at 204 micro meters & 104 micro meters

3.3 Hardness Test

Micro-hardness Leitz micro-hardness tester was used to measure the micro-hardness of composite specimens. A diamond intender with an apical angle of 136° was intended over the surface of the specimen under a load of 2.94 N.

After the removal of load the two diagonals D1 and D2 of the indentation were measured. The hardness value was calculated using the below Equation.

$H v=0.1889F/L^2$

$L= (D_1 +D_2)/2$

1) 29.91HV,2) 30.33HV,3) 30.63HV,

Average: 30.29HV

To convert HV to MPa multiply by 9.807. =297.1MPa=0.2971GPa

3.4 Vickers Hardness Test

The Vicker's hardness test process is explained through the Figure 9. This test is generally used for small parts, thin sections of a body. The principle of this test is that it uses a diamond indenter to make an indent which is measured and converted to a hardness value. A square based pyramid shaped diamond is used for testing in the Vickers scale. The HV number (Vickers Hardness number) can be determined by the following equation 1.

$$HV = \frac{F}{A} \approx \frac{1.8544F}{d^2}, \quad (1)$$

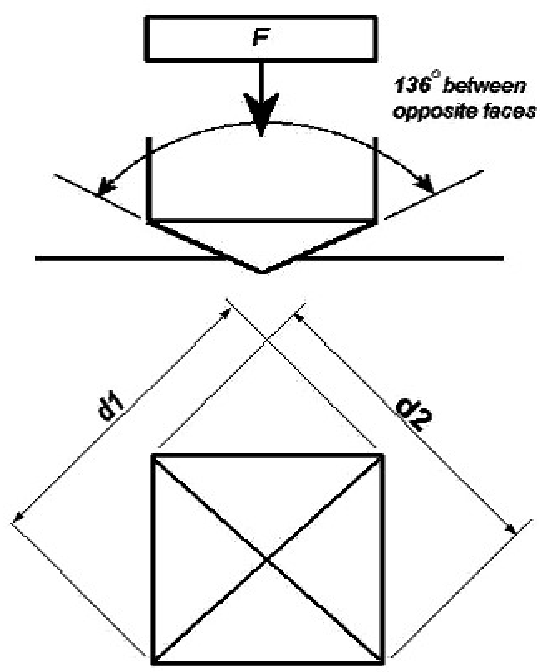

Fig. 9 Vickers Hardness Test Process

4. Conclusions

This experimental investigation on epoxy composites filled with woven roving composite mat has led to the following specific conclusions:

i. The polymer matrix composite based on the woven roving glass mat with epoxy resin and hardener [-$45^0/45^0, 0^0/90^0, -45^0/45^0$]. With three layers were successfully prepared by using hand lay-up technique and cured process under room temperature.
ii. After making laminated plate, we have cut the laminates into Standard Test specimen using ASTM (American society of Testing Materials) table. Totally twenty-eight test specimens are drawn from that Glass fiber laminate, after that test specimens are tested in the Universal Testing Machine (UTM), Each test specimen tested separately, and found out Ultimate tensile load of specimen each Specimen
iii. Binder content is also increasing with increment of fiber reinforcement, which ultimately increasing the porosity or decreasing the bulk density.
iv. Micro hardness also exhibits the similar character as that of tensile and strength. It increases with fiber loading and surface treatment. Maximum hardness obtained on 15%fiber loaded treated composite.
v. In all above cases the SEM observations agree well with the mechanical properties
vi. Impact Strength, Flexural Strength, hardness value was decreased with the increase in the content of the reinforcement (i.e., glass fiber).
vii. Glass fiber was found to be effective reinforcement in case of application involving tensile load.
viii. GF was an effective reinforcement for EPOFINE 556. The mechanical properties of EPOFINE 556 were enhanced by the addition of GF which bore the main load between the contact surfaces and protected the matrix from further serve abrasion of the counterpart. The wear performance of GF-reinforced GF/EPOFINE 556 composite was mainly governed by the process of matrix removal, fiber thinning, interfacial deboning and detachment of broken fibers from the EPOFINE556 matrix.

References

1. *R. Taurino , P. Piozzi , G. Lucchetti , L. Paterlini , T. Zanasi , C. Ponzoni , F. Schivo , L. Barbieri.(2013) New composite materials based on glass waste, Composites Part B: Engg., 45: 497-503*

2. *MetinSayer (2014) Elastic properties and buckling load evaluation of ceramic particles filled glass/epoxy composites, Composites Part B: Engg., 59: 12-20*

3. *Eric Minford, Karl M. Prewo, Robert J. Miller, Method of making hybrid composite structures of fiber reinforced glass and resin matrices, New York, US5122226 A, 1987*

4. *Sunan Tiptipakorn, Sarawut Rimdusit, Siriporn Damrongsakkul and Takeshi Kitano, (2009) Thermomechanical and rheological behaviours of waste glass fibre filled polyester resins composites, Engg. Journal., 13: 45-56*

5. *Milena Koleva, Anka Zheglova,Venceslav Vassilev and Emilija Fidancevska, (2011) Composites Containing Waste Materials, Analysis of Natural and Man-Made Materials, Bulgaria, Composites Containing Waste Materials, Dr. PavlaTesinova (Ed.), ISBN: 978-953-307-449-8*

6. *P. Valasek, M. Muller, (2013) Polymeric Composite Based On Glass Powder – usage possibilities In Agro complex, Scientia agriculturae bohemica, 44 (2): 107–112*

7. *M. Sanchez-Soto, P. Page, T.Lacorte, K. Bricen,F. Carrasco, (2007) Study and mechanical characterization of glass bead filled tri functional epoxy composites, Composites Science and Technology, 67:1974-85.*

8. *A. Ibrahim, (2011) Flexural Properties of Glass and Graphite Particles Filled Polymer Composites, Pure & Applied. Sc., 24.*

9. *Kwok Yeung Peter Wong, (2012) Measurement of Mechanical, Electrical and Thermal Properties of Glass Powder Reinforced Epoxy Composites and Modelling, Faculty of Engineering and Surveying,*

10. *M. Sánchez-Soto, A. Gordillo, M. LL. Maspoch, J.I. Velasco, O.O Santana, A.B. Martínez, (2002) Glass bead filled polystyrene composites: morphology and fracture, Polymer Bulletin, 47:587-94*

 © SME