Journal of
Marine Science and Technology

Volume 28 | Issue 1 Article 2

MANUFACTURING AND CHARACTERIZATION OF GLASS FIBER-FISHNET-WOVEN ROVING AND POLYESTER COMPOSITES

S. Sahaya Elsi
Assistant Professor, Department of EEE, University College of Engineering Nagercoil, Tamilnadu, India.

F. Michael Raj
Assistant Professor, Department of EEE, University College of Engineering Nagercoil, Tamilnadu, India.,
michaelrajf@yahoo.com

Mary S. Prince
Associate Professor, Department of CSE, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India.

A. Amala Mithin Minther Singh
Assistant Professor, Department of Mechanical Engineering, Vins College of Engineering, Nagercoil, Tamilnadu, India

R. S. Jayaram
Assistant Professor, Department of Mechanical Engineering, Amrita College of Engineering and Technology, Nagercoil, Tamil Nadu, India.

Follow this and additional works at: https://jmstt.ntou.edu.tw/journal

Part of the Other Engineering Science and Materials Commons

Recommended Citation
Elsi, S. Sahaya; Raj, F. Michael; Prince, Mary S.; Amala Mithin Minther Singh, A.; and Jayaram, R. S. (2020) "MANUFACTURING AND CHARACTERIZATION OF GLASS FIBER-FISHNET-WOVEN ROVING AND POLYESTER COMPOSITES," *Journal of Marine Science and Technology*: Vol. 28: Iss. 1, Article 2.
DOI: 10.6119/JMST.202002_28(1).0002
Available at: https://jmstt.ntou.edu.tw/journal/vol28/iss1/2

This Research Article is brought to you for free and open access by Journal of Marine Science and Technology. It has been accepted for inclusion in Journal of Marine Science and Technology by an authorized editor of Journal of Marine Science and Technology.

Journal of Marine Science and Technology, Vol. 28, No. 1, pp. 10-17 (2020)
DOI: 10.6119/JMST.202002_28(1).0002

MANUFACTURING AND CHARACTERIZATION OF GLASS FIBER-FISHNET-WOVEN ROVING AND POLYESTER COMPOSITES FOR MARINE APPLICATIONS

Sahaya Elsi.S[1], Michael Raj.F[1*], Prince Mary.S[2], Amala Mithin Minther Singh.A[3] and Jayaram.R.S[4]

Key words: hybrid composites, mechanical properties, electron microscopy, dynamic mechanical properties

ABSTRACT

Glass fibers are imparted as reinforcement material in polyester matrix and still it act as a preferred material for the marine industry. However, it is non-biodegradable material and involves high risk during processing. In this study, new monofilament fishnets were substituted as an alternative material for glass fiber in the polyester matrix. Mechanical properties of these composite specimens such as tensile strength, flexural strength and impact resistance in accordance with ASTM, were evaluated. SEM images of various composites revealed the relations between the reinforced fishnet/glass fiber and woven roving with polyester matrix. The dynamic mechanical analysis of storage modulus, loss modulus and damping factor was carried out for the different composites, compatibility of these composites and its properties was studied. The results reveal that the fishnet based composites have appreciably higher mechanical properties. Furthermore, the glass fiber, woven roving and fishnet composite has more storage modulus and significant mechanical damping. A novel hybrid composite is recommended for large marine structures and it helps to sustain green environment.

I. INTRODUCTION

Global market rapidly plays an important role in the energy conservation and emission reduction. Natural fibers are renewable and biodegradable and depends upon element and strength factors (Xi Peng et al., 2011). Most natural fibers are moisture sensitive and their strength can be changed dramatically (Netravali et al., 2003; Ma et al., 2005).

Numerous scientific works have been carried out for the development of new, stronger and lighter fibers using hybrid composites (Griffin et al., 2003; Zhang et al., 2014). The main purpose of hybrid composite is to combine the best mechanical property of brittle fibers with the excellent impact resistance of ductile fibers (Akhbari et al., 2008; Wang et al., 2008). Merging of two or more fibers into a single matrix led to achieve improved material property with many positive attributes (Selvin et al., 2004). Mechanical characterization of a glass/polyester sandwich structures for marine applications implies the use of a bonder at the interface skin/core to improve the mechanical properties and reduce the micro-cracks (Borsellino et al., 2012).

The inter-laminar shear strength, impact strength and dynamic mechanical properties of glass/ramie polymer composites revealed that higher fiber content and the reinforcement effectiveness are more and it was found that effectiveness coefficient is less when determined by the DMA analysis (Daiane Romanzini et al., 2013). However, the glass transition temperature has not changed significantly while the mechanical properties are enhanced for higher fiber content of the composite structures. While investigating the behavior of a chopped strand mat/woven roving/foam-Klegecell composite lamination structure during Charpy testing, it was obvious that the selection of reinforcement and matrix nature is a very important factor of impact properties of the composites. Furthermore, the impact strength of the hybrid structures showed different behavior significantly (Arifin et al., 2014). An improvement in the impact behavior of polymer composites with brittle reinforcements of glass fibers was attempted by mixing ductile organic fiber of nylon.

Fishnet meshes are made by relatively thin thread with knots or without knots. Filaments such as monofilament,

---

Paper submitted 03/12/16; revised 10/03/16; accepted 11/12/19. Author for correspondence: Michael Raj. F (michaelrajf@yahoo.com).

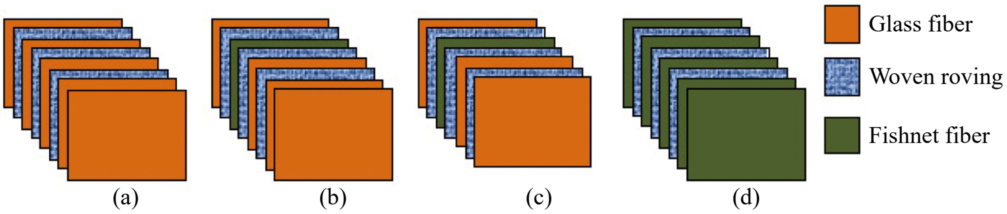
1 Assistant Professor, Department of EEE, University College of Engineering Nagercoil, Tamilnadu, India.

2. Associate Professor, Department of CSE, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India.

3. Assistant Professor, Department of Mechanical Engineering, Vins College of Engineering, Nagercoil, Tamilnadu, India

4. Assistant Professor, Department of Mechanical Engineering, Amrita College of Engineering and Technology, Nagercoil, Tamil Nadu, India.

Fig. 1. Fabricated fishnet for stretched orientation



(a) (b) (c) (d)

Fig. 2. Fabricated composites (a) 5GF/3WR (b) 4GF/3WR/1FN (c) 3GF/3WR/1FN (d) 5FN/3WR and the density has 1.487, 1.479, 1.312 and 1.114 g/cm^3 respectively. (GF-Glass fiber, WR-Woven roving and FN- Fishnet)

multifilament and multi-strand monofilament netting are commonly used. Monofilament fishnet is made from a single nylon fiber and it has better mechanical behavior, processing ability and high heat resistance (Chemsystems perp program, 2009). Gill nets made up of monofilament are the most popular commercial fish nets in the world (Holst et al., 2002) with three types of knots namely single, double and knotless net. Marine structures are prone to impact load (Sutherland et al., 2004; Sutherland et al., 2006; Baral et al., 2010). When we evaluate the mechanical behavior of multifilament waste fish net/glass fiber in the polyester matrix for the application of the mechanized boat deckhouse in marine composites improves significantly when a discarded multifilament fishnet is added into composites (Michael Raj et al., 2014; Michael Raj et al., 2015 and Michael Raj et al., 2016). When the new monofilament fishnet is added to the composites, the impact resistance is increased compared to that of the discarded fishnet composites.

The literature studies inferences that the hybrid composite structures with ductile reinforcements improves the mechanical properties. In the present work, monofilament new fishnet is used as a substitute for glass fiber in polyester to develop hybrid composites and their characteristics are evaluated. Thus, the proposed hybrid composites of new monofilament fishnet are used for manufacturing large marine structures to withstand high impact resistance.

II. MATERIALS AND METHODS

Gill net made up of monofilament fishnet with mesh 20 mm, twine diameter 8.656 μm and single knotting, was collected from Vasantham Marines, Tamilnadu, India. Glass fiber (random orientation) and woven roving has grade of 300 g/m^2 and 600 g/m^2 respectively. They were obtained from Binani India products. Unsaturated polyester (Grade: SBA2303-Isothalic) was used as matrix. Methyl Ethyl Ketone Peroxide (MEKP) was used as the catalyst and Cobalt Naphthenate as an accelerator; all those AR grade chemicals were obtained from the Ciba Gugye Limited, Chennai, India.

For 100 grams of polyester resin, 1.5 ml of catalyst and accelerator were taken at room temperature curing in accordance with the manufacturer's recommendations. The specimen was fabricated by hand lay-up method. The fishnet layer which was used in the composite specimens are stretched in orientation and obtained the given size of 400 × 400 mm as shown in Fig. 1.

The glass fiber, fishnet and woven roving were arranged layer by layer and the polyester resin coated in these reinforcement layers. Composites were prepared with different layers and they are shown in Fig. 2.

The specimen was subjected to curing for 3-4 hours and cut with a circular saw of size 300 x 300 mm. In total four composite specimens were prepared. In Tamil Nadu, Chinna Muttom Boat Yard, manufacturers uses the standard hull material of canoe with 4-7 layers of glass fiber and 2-3 layers of woven roving. The fabricated composites are same as the bottom hull structure of south Indian canoe (vallam). Composite 5GF/3WR indicates 5 glass fiber layers and 3 woven roving layers, composite 4GF/3WR/1FN specifies 4 glass fiber layers 3 woven roving layer and 1 fishnet layer. Similarly, composite specimen 3GF/3WR/1FN means 3 glass fiber layers, 3 woven roving layer and 1 fishnet layer and specimen 5FN/3WR means 5 fishnet layers and 3 woven roving layer.

Glass fiber, fishnet fiber, woven roving and polyester matrix are used as the composites. The properties are tabulated in Table 1a and 1b.

The tensile and flexural tests were performed using UTMDRX30 KN, according to ASTM D-638 and ASTM D-790 respectively. Its cross-head speed 2 mm/min and gauge length 100 mm. Impact strength was measured using an Izod

Table 1a. The properties of glass/fishnet fiber and woven roving used

Fibers	Density, g/cm^3	Elongation at break, %	Tensile strength, MPa	Young's modulus, GPa
Glass fiber	2.5	4.8	2000-3400	70-73
Fishnet fiber	1.15	15-45	415.7	2 - 4
Woven roving	2.2	1.6	260	15.5

Table 1b. Properties of unsaturated polyester resin matrix (Athijayamania et al., 2009)

Appearance	Yellow viscous liquid
Specific gravity at 25 ºC	1.11
Viscostity	
(a) FC-4 (s) at 30 ºC	110
(b) Brookfield (CPS) at 25 ºC RVT model	480
Volatile content (%) at 150 ºC	42.5
Acid value (mgKOH/g)	6.97

Table 2. Mechanical characteristics of composites

Composites	Tensile strength [MPa]	Tensile modulus [GPa]	Impact energy [J]	Flexural strength [MPa]	Flexural modulus [GPa]
5GF/3WR	160.89	30.32	22.56	242.14	51.55
4GF/3WR/1FN	167.51	30.42	23.12	259.5	64.50
3GF/3WR/1FN	161.43	30.08	19.91	255.25	62.38
5FN/3WR	191.96	32.79	25.26	328.94	107.56

GF-Glass fiber, WR-Woven roving and FN- Fishnet

impact tester (Deepak Poly Plast Pvt. Ltd, India) according to ASTM D-256. Notched rectangular specimens of size 65×13 mm were cut from fabricated composite plates. The test specimen was supported by a vertical cantilever beam and it was broken by a single swing of a pendulum. When the pendulum hit the face of the specimens, the impact resistances of the composites were obtained at room temperature. Five sets of specimens were tested for each test and the mean values were reported.

Moisture absorbed in glass fiber, fishnet and woven roving incorporated composites were measured according to ASTM D-570. The five specimens with size of 76.2×25.4 mm tested and the average value was calculated. The specimens were pre-conditioned by drying in open air until constant weight was obtained. The weighed samples were submerged in seawater (pH 8.90) at room temperature for 15 days' time intervals. The specimens were removed from the seawater and the surfaces were cleaned with tissue paper before weighing.

The surface morphology of the composite was investigated using SEM (Model: SEG100). After the tensile examination of the specimens the microscopic images were obtained from COSLAB (Model: ZSM116) compound light microscope with photo a capturing software.

Dynamic mechanical analysis was carried out with a Universal V20.6 Build 24, USA instrument of model TAQ800 of temperature range 26 ºC to 200 ºC. The frequency range was 1 Hz and heating rate was 2 ºC/min.

III. RESULTS AND DISCUSSION

1. Tensile properties

The mechanical properties of the various composites are depicted in Table 2. The tensile strength of glass fiber composite 5GF/3WR is 160.89 MPa and that of the fishnet incorporated glass fiber composite 3GF/3WR/1FN is 161.43 MPa. However, the composite 3GF/3WR/1FN has tensile strength values which are comparable to those of 5GF/3WR as shown in Fig. 3. Composite 5FN/3WR has 19.31 % higher tensile strength when compared to 5GF/3WR. Therefore, it is obvious that the fishnet fiber alone has more tensile strength than the other composites. The monofilament fishnet and its composites have more tensile strength because fishnet fiber has better elastic property than glass fiber.

The interfacial adhesion of the fishnet incorporated composite was considerable. Monofilament made up of nylon plastic which helps to bond well with the polyester. The stretched orientation of the fishnet increases the tensile strength. The interfacial bonding decreases to some extent

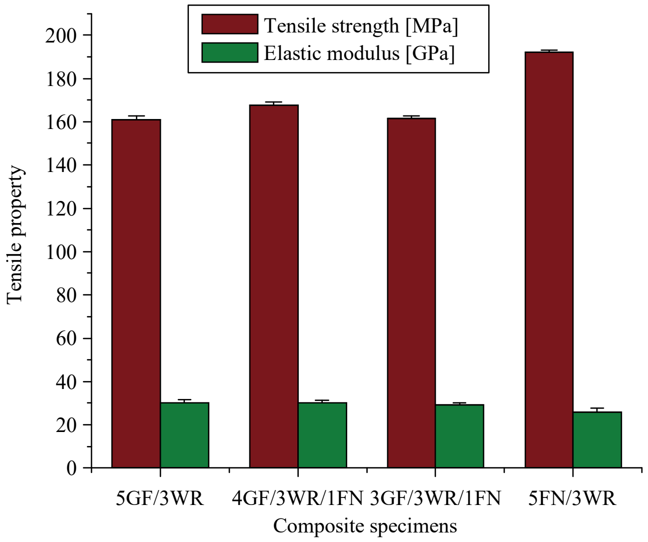


Fig. 3. Tensile strength and modulus of different polyester composites based on fishnet and glass fiber

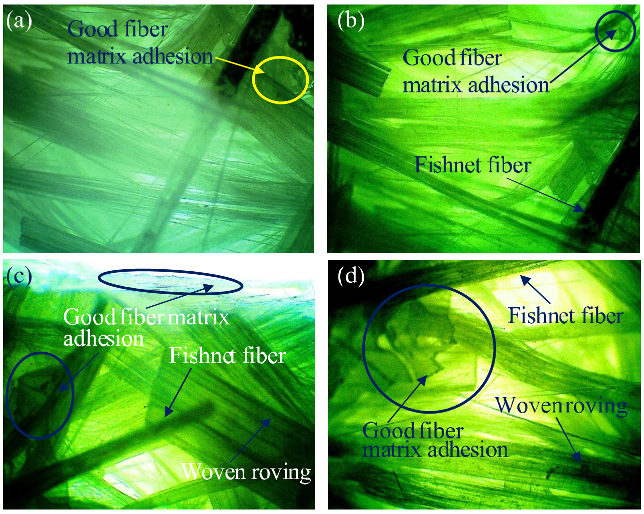


Fig. 4. Micrograph images after the tensile break (a) 5GF/3WR (b) 4GF/3WR/1FN (c) 3GF/3WR/1FN (d) 5FN/3WR. (GF-Glass fiber, WR-Woven roving and FN- Fishnet)

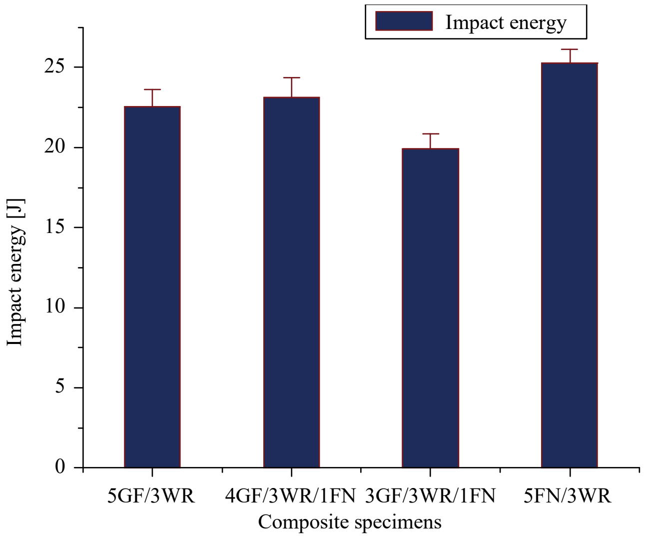


Fig. 5. The effect of fishnet/glass fiber on the impact energy

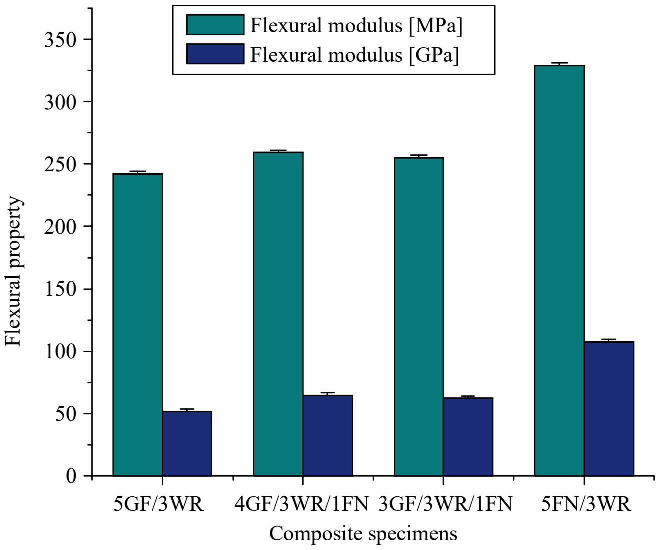


Fig. 6. Experimental results of flexural behavior of fishnet and glass fiber composites

because of the smooth surface of the new monofilament twins. The microscopic images of Fig. 4 (A), (B), (C) and (D) reveals that the interfacial adhesion of glass fiber, fishnet and woven roving with polyester matrix have good linkage. The fishnet-incorporated composites are found to have better adhesion than the glass fiber composites.

The tensile modulus result is better due to good fiber/matrix bonding and improved load transfer efficiency from the polyester matrix to the fiber of fishnet composites. The elastic modulus of a composite is main property of fibers. In the fishnet and glass fiber-reinforced polymer composites, it is expected that polymer matrix will provide required chemical protection to the fibers. The tensile modulus of 5GF/3WR was better compared to composite 3GF/3WR/1FN. The modulus of the fishnet composite 5FN/3WR increased because of the character of the reinforcement.

2. Impact properties

The experimental results of the impact energy was displayed in Fig. 5. The specimen 5FN/3WR has 10.68 % more impact resistance when compared to 5GF/3WR. Fishnet fiber has better elastic property which aids the composite to withstand more impact load. A stress transfer as well as the quantity of fishnet fiber was more per unit area due to the stretched orientation. This will increase the impact resistance. Glass fiber is more brittle than fishnet fiber that reduces the impact resistance of composite 5GF/3WR. Woven roving is a wave

Table 3. DMA study obtained from the parameters

Composites	Tg from E" curve ºC	Tg from tan δ curve ºC	Peak height of tan δ curve
5GF/3WR	88.26	100.62	0.2871
4GF/3WR/1FN	89.86	105.42	0.4501
3GF/3WR/1FN	88.79	104.88	0.3907
5FN/3WR	51.81	90.39	0.7699

GF-Glass fiber, WR-Woven roving and FN- Fishnet

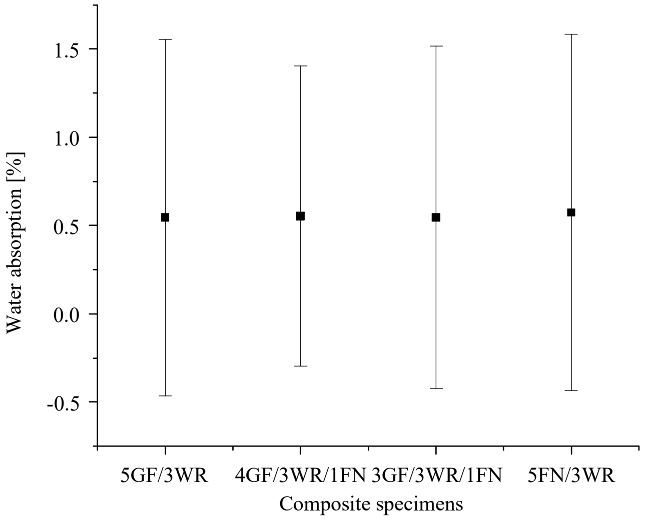


Fig. 7. Water absorption glass fiber, fishnet, woven roving and polyester composite materials at 15 day immersion of seawater in room temperature

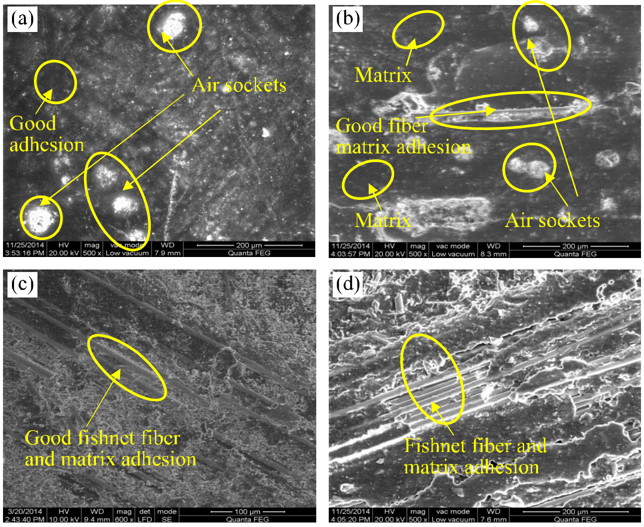


Fig. 8. SEM images of glass fiber/fishnet composites (a) 5GF/3WR (b) 4GF/3WR/1FN (c) 3GF/3WR/1FN (d) 5FN/3WR. (GF-Glass fiber, WR-Woven roving and FN- Fishnet)

pattern and highly interlaced, exhibiting a consequent increase in the resistance to shear deformation. This is the most common type of reinforcement used for large marine structures which allows rapid buildup thickness. However, continuous woven roving fibers have more impact resistant (Mohamad et al., 2003). The developed material of fishnet reinforcement can transfer stress better than the conventionally used glass fiber-based composites.

3. Flexural properties

The experimental results of the flexural property as shown in Fig. 6. The flexural strength of the glass fiber composite 5GF/3WR is 242.14 MPa and that of the fishnet-incorporated glass fiber composite 3GF/3WR/1FN is 255.25 MPa. However, the composites 4GF/3WR/1FN and 3GF/3WR/1FN have small variations of flexural strength compared to 5GF/3WR. Also, composite 5FN/3WR has 35.85 % more flexural strength when compared to 5GF/3WR. Fig. 6 clearly reveals that adding fishnet layer to the glass fiber composites 4GF/3WR/1FN and 3GF/3WR/1FN does not cause much variation in the flexural strength. The composite 3GF/3WR/1FN has seven layers but the flexural strength is more compared to composite 5GF/3WR and 4GF/3WR/1FN because of its properties of new monofilament fishnet. Furthermore, the density of the composite 3GF/3WR/1FN is lesser than that of the glass fiber composite 5GF/3WR because of lower weight of fishnet.

The flexural modulus of glass fiber composite 5GF/3WR is 51.55 GPa and fishnet composite 5FN/3WR is 107.56 GPa. However, the flexural modulus of the composites 4GF/3WR/1FN and 3GF/3WR/1FN has comparable values with composite 5GF/3WR. But the flexural modulus of the composite 5FN/3WR is more when compared to that of the glass fiber composites. Hence, the flexural properties depend on the orientation of fiber available per unit area of the composites.

4. Water absorption properties

The water absorption values of glass fiber composites 5GF/3WR were found to be less when compared to those of fishnet composite as revealed in Fig. 7. The addition of fishnet to the composites has very small variations in moisture content when compared to the glass fiber composite. However, the water absorption properties of the composites 3GF/3WR/1FN and 5GF/3WR are comparable and composite 5FN/3WR was high due to more fishnet layers composite. Hence, the water absorption properties based on of fishnet, glass fiber and woven roving incorporated composite 3GF/3WR/1FN.

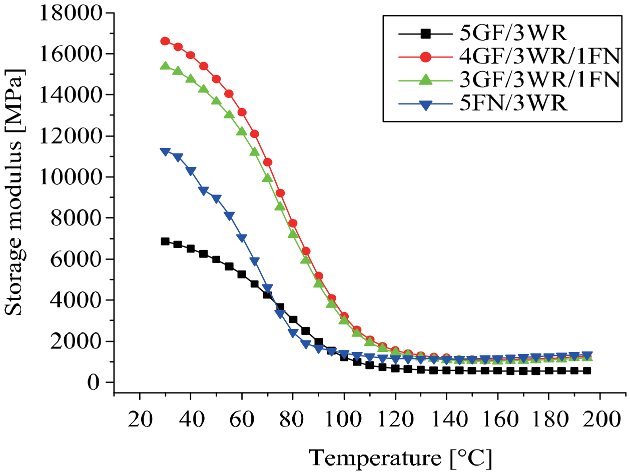


Fig. 9. The deviation of storage modulus with temperature of various composites

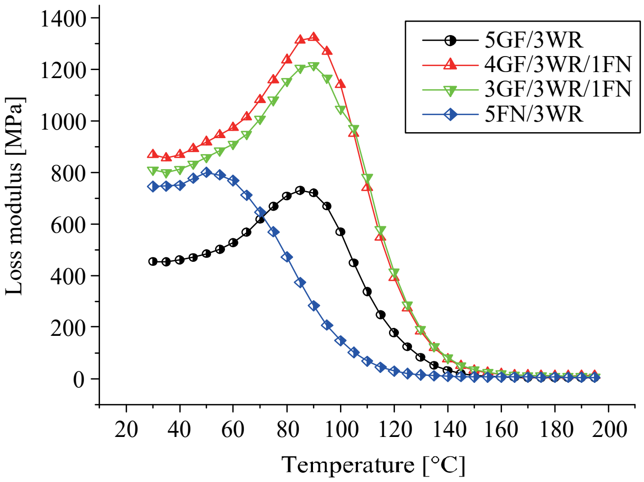


Fig. 10. Variation of the loss modulus with temperature for fishnet/glass fiber composites

5. Scanning Electron Microscope (SEM) Investigation

SEM images of fishnet/glass fiber and woven roving incorporated composites are shown in Fig. 8. From the image it is observed that the composites having good fiber matrix and there is no crack/fracture on the surface. This is due to the good interfacial bonding between the fishnet and the resin matrix. The reinforcements of fishnet, glass fiber and woven raving are polar in nature and chemically they are with partial negative and positive ends. The characteristics of polyester matrix are polar, it helps to have better interfacial adhesion and interaction with the opposite charges of the matrix. Due to the interfacial bonding dipolar relations, hydrogen bonding and Vander Walls forces are observed in the fiber matrix (Gu H, 2009). SEM observations (micro-structures) reveal some roughness on the surface, due to the prevalence of some air sockets which occurred because of hand molding. Fishnet fiber composites have low density compared to that of glass fiber composites. Hence, fishnet fiber is considered as suitable filler material for manufacturing of lightweight composite with high strength.

6. Dynamic Mechanical Analysis (DMA)

(1) Storage modulus (E')

The effect of monofilament fishnet fiber on the changes in the storage modulus (E') of the composites can be noted at a frequency of 1 Hz. The parameters obtained from DMA analysis are displayed in Table 3. The values of E' for the composites 4GF/3WR/1FN, 3GF/3WR/1FN and 5FN/3WR are found to be 16,622 MPa, 15,373 MPa and 11,270 MPa respectively. However, the composite 4GF/3WR/1FN has higher values of E' at lower temperature in the plastic region compared to those of 5GF/3WR as shown in Fig. 9. The value of E' decreases with increase in temperature. Storage modulus of composite 5GF/3WR is 6854 MPa. But when fishnet was added to the glass fiber composites, the values get proportionally increased, this increase in E' is attributed by the presence of fishnet in the composites which has more E' than the glass fiber alone.

The reinforcement efficiency of the composites was found to increase with the addition of fishnet in the place of glass fibers. It reveals that monofilament fishnet composites are found to be more efficient reinforcement than glass fiber. From the storage modulus comparison, it is found that fishnet fiber can be good substitute for glass fiber. Further, the addition of fishnet as well as glass fiber has induced good stress transfer and matrix adhesion.

(2) Loss modulus (E")

Loss modulus gives the viscous response of the composite with respect to temperature and governed by the molecular motions within the composite material. The variations of the loss modulus (E'') of glass fiber and fishnet fiber composites as a function of temperature are observed at a frequency of 1 Hz. The value of E'' depends upon the category and the quantity of reinforcement. Fig. 10 depicts the Tg value, and the values of E'' are found to vary much for different composites. The E'' curve for the composite 5FN/3WR has less broadening effect because the Tg value is 51.81 ºC. The broadening is due to the difference in the physical state of the matrix surrounding reinforcing fibers. Loss modulus has comparable values for the composites 5GF/3WR and 3GF/3WR/1FN. This corresponds to Tg value shown in Table 3. Therefore, the Tg of the composite 5FN/3WR having low values which reflects low interaction of matrix between fishnet fiber than glass fiber.

From the Table 3, 5GF/3WR, 4GF/3WR/1FN and 3GF/3WR/1FN are better composite than fishnet-based composite 5FN/3WR due to the increased rigidity of the composites which leads to stronger interface interaction with the reinforcement and matrix.

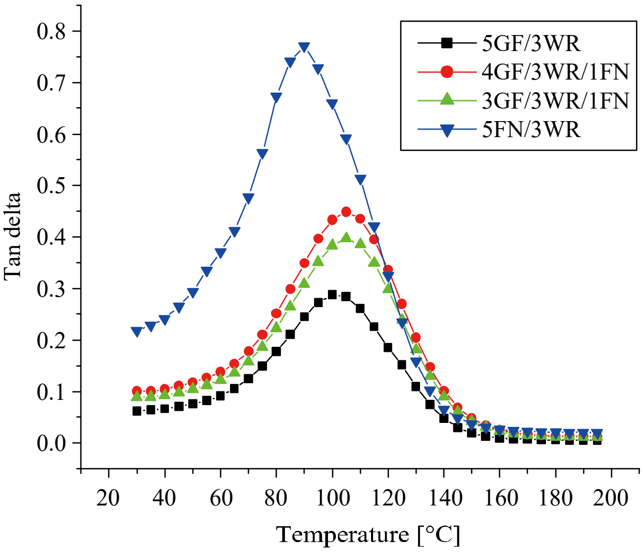


Fig. 11. The variation of tan δ with temperature of different composites

(3) Damping factor (tan δ)

The ratio of the loss modulus to storage modulus is known as a damping factor (tan δ). The damping behavior will be influenced by merging of fiber in the matrix and it depends on the quantum of fiber matrix adhesion as shown in Fig. 11. Hence, weaker fiber matrix adhesion will result in higher values of tan δ. On the above basis, 5FN/3WR composites have very poor adhesion behavior. The Tg value of the glass fiber composite 5GF/3WR is 100.62 °C and the peak height of tan δ value is 0.2871. Furthermore, the Tg value of the fishnet-incorporated glass fiber composite 3GF/3WR/1FN is 104.88 °C and the peak height of tan δ value is 0.3907 lower tan δ means that a specific composite has good load-bearing capacity. Hybrid fibers restrict the mobility of the polymer molecules; hence, the tan δ values of composites are reduced (Azhar Abu Bakar et al., 2011).

IV. CONCLUSIONS

Evaluation of the mechanical behavior of monofilament fishnet based composites shows that it has greater property than glass fiber based composites. The stretched orientation of fishnet is an important aspect of increased property of the composites. The tensile and flexural strength of the composites 3GF/3WR/1FN was better compared to that of the composite 5GF/3WR and the density of the composite 3GF/3WR/1FN is less than that of composite 5GF/3WR. The SEM image shows that the adhesion of glass and fishnet matrix are good.

The storage modulus reveals that fishnet-incorporated composite has more values than glass fiber composites. Loss modulus increases with respect to increase in fishnet layers and broadening effect also observed. However, glass fiber composite Tg value is comparable to that of the fishnet-incorporated composites with respect to the rigidity of the composite. Damping values are comparable with the composites 5GF/3WR and 3GF/3WR/1FN.

Investigation of various composites reveals the fact that partial substitution of glass fibers with fishnet improves the mechanical properties and the values are very close to the conventional material glass fiber. Therefore, partially substituted fishnet-glass fiber composites can serve as an advanced composite material for the manufacturing of large marine structures. Hence the usage of the glass fiber, which reduces the hazardous nature in this composite and helps to sustain better environment.

REFERENCES

Akhbari, M., M. Shokrieh and H. Nosraty (2008). A study on buckling behavior of composite sheet reinforced by hybrid woven fabrics. Trans CSME 32(1), 81-9.

Arifin, A.M.T., S, Abdullah., Md. Rafiquzzaman, R. Zulkifli, D.A. Wahab and A.K. Arifin (2014). Investigation of the behaviour of a chopped strand mat/woven roving/foam-Klegecell composite lamination structure during Charpy testing. Materials and Design 59, 475–485.

Athijayamania, A., M, Thiruchitrambalamb., U, Natarajana and B, Pazhanivel (2009). Effect of moisture absorption on the mechanical properties of randomly oriented natural fibers/polyester hybrid composite Materials Science and Engineering A 517, 344.

Baral, N., D. D. R. Cartié., I. K. Partridge, C. Baley and P. Davies (2010). Improved impact performance of marine sandwich panels using through-thickness reinforcement: Experimental results. Composites: Part B 41, 117–123.

Chemsystems perp program (2009). Nylon 6 and Nylon 6,6, PERP07/08S6, New York.

Di Bella., G., L. Calabrese and C. Borsellino (2012). Mechanical characterisation of a glass/polyester sandwich structure for marine applications. Materials and Design 42, 486–494.

Griffin, D. A. and T. D. Ashwill (2003). Alternative composite materials for megawatt-scale wind turbine blades: design considerations and recommended testing. Journal of Solar Energy Engineering 125(4), 515-524.

Gu, H. (2009). Dynamic mechanical analysis of the seawater treated glass/polyester composites. Materials and Design 30(7), 2774–2777.

Holst, R., D. Wileman. and N. Madsen (2002). The effect of twine thickness on the size selectivity and fishing power of Baltic cod gill nets. Fisheries Research 56(3), 303-314.

Ma, P. C. and Y. Zhang (2014). Perspectives of carbon nanotubes/polymer nanocomposites for wind blade materials. Renewable and Sustainable Energy Reviews 30, 651-660.

Ma, X., J. Yu and J. F. Kennedy (2005). Studies on the properties of natural fibers-reinforced thermoplastic starch composites. Carbohydrate Polymers 62, 19–24.

Mazuki, A. A. M., H. M. Akil, S. Safiee, Z. A. M. Ishak and A. A. Bakar (2011). Degradation of dynamic mechanical properties of pultruded kenaf fiber reinforced composites after immersion in various solutions. Composites: Part B 42, 71–76.

Michael Raj, F., Nagarajan, VA. and S, Sahaya Elsi (2016) Mechanical, physical and dynamical properties of glass fiber and waste fishnet hybrid composites. Polymer Bulletin. DOI 10.1007/s00289-016-1783-3

Michael Raj, F., V. A. Nagarajan and K. P. Vinod Kumar (2014). Evaluation of mechanical behavior of multifilament waste fishnet/glass fiber in polyester matrix for the application of mechanized boat deckhouse in marine composites. Applied Mechanics and Materials 592-594, 2639-2644.

Michael Raj, F., V. A. Nagarajan and K. P. Vinod Kumar (2015). Mechanical behavior of FRP composites with used Fish net/glass fiber and polyester matrix. International Journal of Applied Engineering Research (IJAER) 10, 6375-6378.

Mohamad Zawahid bin Shamsuddin (2003). A conceptual design of a fibre reinforced plastic fishing boat for traditional fisheries in Malaysia, Fisheries Industry, Malaysia.

Netravali, A. N., and S. Chabba (2003). Composites get greener. Materials Today 6, 22–29.

Peng, X., M. Fan, J. Hartley and M. Al-Zubaidy (2011). Properties of natural fiber composites made by pultrusion process. Journal of Composite Materials 46(2), 237–246.

Romanzini, D., A. Lavoratti, H. L. Ornaghi jr., S. C. Amico and A. J. Zattera (2013). Influence of fiber content on the mechanical and dynamic mechanical properties of glass/ramie polymer composites. Materials and Design 47, 9–15.

Selvin, T. P, J. Kuruvilla and T. Sabu (2004). Mechanical properties of titanium dioxide-filled polystyrene micro composites. Materials Letters 58(3–4), 281-289.

Sutherland, L. S. and C. Guedes Soares (2006). Impact behaviour of typical marine composite laminates. Composites: Part B 37, 89–100.

Sutherland, L. S., and C. Guedes Soares (2004). Effect of laminate thickness and of matrix resin on the impact of low fibre-volume, woven roving E-glass composites. Composites Science and Technology 64, 1691–1700

Wang, X., B, Hu, Y. Feng, F. Liang, J. Mo, J. Xiong and Y. Qiu (2008). Low velocity impact properties of 3D woven basalt/aramid hybrid composites. Composites Science and Technology 68(2), 444-450.