

Conversion of Glass Reinforced and Polypropylene Matrix Hybrid Materials into Thermoplastic Laminates

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ABSTRACT: Hybridization mean combination of two fibers this concept is widely explore for textile composite. The hybridization of Glass, Carbon and Basalt material has been done with Polypropylene has been done at yarn, fabric and laminate stage. The hybrid yarns are tailor made yarn manufactured using matrix forming fiber and reinforced fiber has the potential to achieve good Laminate properties. This paper is concerned with a commingling process for hybridization of glass as reinforcement filaments with polypropylene thermoplastic filaments as matrix. The laminates have been prepared using Glass/Polypropylene hybrid yarn preform. The commingled yarn and preforms with different combination has been prepared and effect of change in glass content in Glass /PP yarn on hybrid yarn has been discussed and checked for its homogeneous glass distribution and the optimized combination has been taken for further studies.

KEYWORDS: Commingling, Thermoplastic, Preform, Laminates, Hybrid yarn, Hybridization, Glass.

I. INTRODUCTION

With the advent of high performance thermoplastic polymers, structural applications for thermoplastic composites are increasing rapidly. Thermoplastic matrix composites possess distinct advantages over thermoset matrix composites in terms of recyclability, high specific strength and specific stiffness, corrosion resistance, enhanced impact toughness, cost effectiveness and flexibility of design. The concept of hybridization in thermoplastic can be done at yarn manufacturing or fabric forming stage. The hybrid yarns are tailor made yarn manufactured using matrix forming fiber and reinforced fiber has the potential to achieve good composite properties. The different method has been developed to produce hybrid yarns. In this project commingling machine has been developed to produce hybrid yarns with different polypropylene proportion. The final properties of thermoplastic composite depend on homogenous distribution of matrix fiber and reinforced fiber in yarn structure [1], [2].

In this work, the purpose of mixing glass/polypropylene is to form structurally-hybridized materials for thermoplastic composite. Hence the commingling behavior of glass fiber filament distribution and proportion play important role in deciding laminates properties also arrangement of yarns, type of materials, structure of preforms and preform properties play significant role in structural-thermoplastic composite. This paper describe the manufacturing process of commingled yarn and preforms with different combination has been prepared and effect of change in glass content in Glass /PP yarn on hybrid yarn has been discussed and checked for its homogeneous glass distribution and the optimized combination has been taken for further studies. The hybrid preforms produced on handloom and characteristic has been check for laminate [4], [7].

II. MATERIAL AND METHODOLOGY

The Glass and Polypropylene yarn has taken for study the behaviour of hybrid yarn in laminates. The conversion process from yarn to laminate used for experiment has been given below. The processing parameter of commingling

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

process and consolidation process has been optimized using box-behnkan design. The optimize parameter has been use for further investigation. The Fig.1.(a),(b) and (c) show conversion stages from yarn to perform and Preform to laminate respectively.

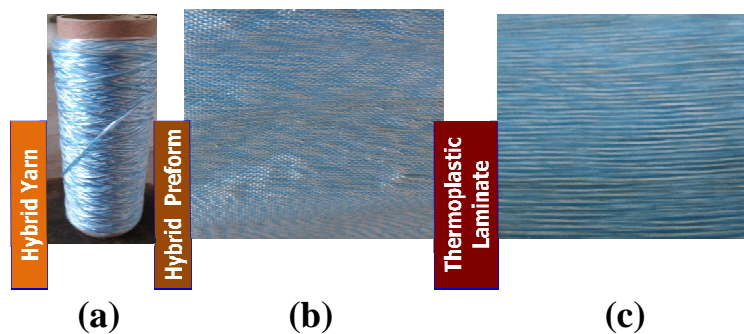


Fig.1. Stages of conversion a) Hybrid yarn b) Preform c) Laminate

The commingling machine has been fabricated for producing glass/pp combination as shown in Fig 2. The machine provided with two positive feeding zones to control overfeeds and tension of individual yarn. The passage has been kept as straight as possible to avoid bending of glass filament to avoid breakage. The ceramic jet has been fabricated for glass.



Fig 2. Commingling Machine

Table I: Properties of Hybrid yarns with different Polypropylene content

Sample Code	PP content %	Tex	Tenacity cN/tex	Extension (%)	Nip Frequency (nips/meter)	Nip stability (cycle)	Nip Regularity (cm)
H ₁	0	288.4	24.6	1.7	17.8	4.2	2.5
H ₂	20	527.0	21.7	1.8	20.0	10.0	2.3
H ₃	25	410.7	18.3	1.7	22.2	15.2	1.8
H ₄	40	241.0	25.2	5.5	16.0	12.2	1.2
H ₅	60	481.3	22.7	2.2	16.7	12.1	2.1
H ₆	100	92.8	52.2	22.5	12.5	6.5	1.5

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

The glass filament of 300 tex and PP of 94 tex stand were taken for study and the Glass % varied by liner density and PP% by varied number of stand change during process. The lower amount of over feed has been given to Glass. The three level of air pressure (5, 6, 7 bar), Over Feed (0,2,4%) and take up speed (50,70,100 m/min) has been selected for producing yarn without glass filament breakage. The optimized parameter at 6 bar with 1% overfeed and 50 m/min take up speed has been taken to investigate the effect of change in polypropylene content. The hybrid yarns prepared were checked for commingling properties as given in Table I.

The commingled yarn with 60% PP has been considered for preparing preform. It was decided to use hand loom for producing samples and after initial trail, the selected sample will be prepared on commercial loom the handloom set up shown in Fig. 3. It was observed to maintain uniformity of weaving parameter is difficult for hand loom so tried to minimize it [8]. On handloom the different type of heald wire and reed has been selected as per yarn diameter.



Fig. 3: Manufacturing of Preform Samples

Table II: Tensile properties of hybrid preforms with different combination

Sample	Warp	Weft	GSM	Thickness in mm	End/ Inch	Pick/ Inch	Tensile strength MPa		% Strain	
							Warp	Weft	Warp	Weft
P ₁	PP	G	254	0.50	28	24	52.66	43.54	36.79	1.84
P ₂	PP	H	406	0.72	28	18	33.93	27.16	38.26	2.61
P ₃	PP	10G+10C	228	0.46	28	20	75.70	31.18	35.24	2.60
P ₄	PP/4G/ 4C	20H+10C	350	0.73	28	16	55.78	52.17	38.38	1.61
P ₅	PP/4G/ 4C	B	330	0.57	28	18	46.77	63.64	33.15	2.13
P ₆	PP/4G/ 4C	10B/10H	326	0.69	28	18	46.09	40.01	35.53	2.66

PP: Polypropylene, G: Glass, C: Carbon, H:Hybrid yarn, B:Basalt

The hybrid preforms has been prepared using hybrid yarns and combination with high performance material like Glass, Carbon, Basalt with self adhesive material PP (Table II). The six samples prepared with different combination as given

International Journal of Innovative Research in Science, Engineering and Technology

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in Table II. The sample P1, P2, P3 prepared using PP in warp with almost similar ends and picks density and in P4, P5, P6 the 4 Glass and 4 Carbon stand introduce at equal interval in PP warp. The different weft with reinforced material has been used. The sample P₂ of hybrid yarn has been taken for further investigation.

The two layer of preform Sample P2 has been taken for preparing the laminates. Hydraulic press with 20M tone capacity has been installed at laboratory for preparing laminate as shown in Fig 4. Sample has been kept at 190 °c at 14 kg/cm² pressure for consolidation after that cured at room temp.



Fig. 4: Hydraulic Press

In order to study the qualitative and quantitative effect commingling hybrid yarns, various samples of hybrid yarns have been made from glass/polypropylene filaments have been tested using standard method. The tensile testing machine used for finding tenacity and extension at break. The mingling characteristics have been evaluated in terms of nip frequency using needle insertion method, nip stability by acar's method and nip regularity using microscope studies. The preforms and laminate were tested using standard method on instron tensile tester.

III. RESULT AND DISCUSSION

Hybrid Yarn with different Polypropylene Constant

The results of tensile and extension value of hybrid yarns shows(Table I) that the Sample H1 with 100% glass and H6 with 100% PP content shows the parent yarn with commingling effect. The hybrid sample tensile value ranging between these samples. The samples H4 (40% PP) and H5 (60% PP) have higher tenacity and extension value that due to higher percentage of PP content. The H2 (20% PP) and H3 (25%) have high tenacity but low extension due to high percentage of Glass given in Table I.

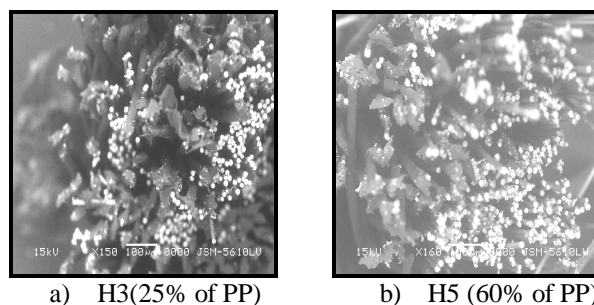


Fig.5: Homogeneity of hybrid yarns at different Glass: Polypropylene content

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

The commingling characteristics of hybrid yarns it is observed that 100% polypropylene interlaced yarn give poor interlacing properties and 100% glass give unstable yarn. The hybrid yarns gives better commingling characteristics compared to 100% polypropylene or glass mingled yarn. The specimen H3 with 25% PP content give high nip frequency with good nip stability compared to other hybrid yarns that may be due to PP filaments commingled properly with glass give better commingled behavior and also give homogenous mix. The specimen H4 and H5 give almost similar characteristics.

The SEM analysis of hybrid yarn at different Polypropylene content has been investigated. It has been found that H3 and H5 give better mixing compared other yarn as shown in Fig 5 (a),(b) that may be due to may result due to proper opening of glass and PP in processing stage and give good commingling behavior. Hence, to study the effect of processing parameter glass: polypropylene content 75:25 is investigated further.

Hybrid yarn Preforms and Laminate

The hybrid preforms has been prepared using hybrid yarns and combination with high performance material like Glass, Carbon, Basalt with self adhesive material PP (which melt under heat). The properties of perform investigated as shown in Table II. The P1 and P3 show higher strength both in warp and weft direction compare to P2 due to PP content in hybrid yarns. The PP content resulting high extension of preforms but this PP filament will melt during final process and give self adhesion between layers and glass, carbon and basalt gives reinforcement. Hence in preform number of epi and ppi need to take as per final property requirements of laminate. Even P5 with basalt give better strength then P1 with glass. Hence new basalt material gives better reinforcement then glass. The glass and carbon also increase the strength of preforms significantly. The possible combination has been prepared. The P2 has been taken for preparing Laminate.

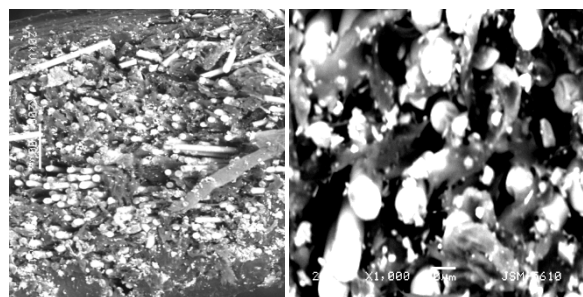


Fig. 6: SEM of cross section of Laminate with hybrid yarn distribution

Laminate has been prepared from sample P2 and SEM analysis of sample has been done as shown in Fig 6. The laminate shows homogeneous mixing of PP and Glass after consolidation. But the void are generated hence the optimization of consolidation process is required before further investigation.

IV.CONCLUSION

The behavior of Glass/PP hybrid yarn studied with different processing parameter and process optimized. The influence of air pressure, overfeed, Take up speed and % polypropylene content in hybrid yarn on commingling characteristics has been investigated. The studies show that the commingling characteristics of hybrid yarn have been greatly influenced by air pressure and % of matrix forming fiber. The hybrid yarn with different Glass/Polypropylene content viz. 75:25 give better commingling properties. The hybrid yarns with Glass/Polypropylene content of 75:25 and 40:60 give homogenous mixing of matrix and reinforced filament within hybrid yarn. The Preform structured with self adhesive matrix fiber greatly influence mechanical properties of laminate. The hybridization done of preforms using different combination of reinforced fiber with polypropylene matrix. The preform with Glass and Carbon give higher strength. It has been found that commingling method of mixing reinforced and matrix filament reduce the mass transfer distance of the matrix into the textile preforms manufactured using this commingled hybrid yarn. Hybrid yarn

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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fabric give homogenous mix of reinforced and matrix material in final laminate. Optimizations of processing parameter to prepare Laminates are further required to investigate.

ACKNOWLEDGMENT

The author greatly acknowledges the Member Secretary of Gujarat Council of Science and Technology for providing financial support for this project. Also thanks to weaving and testing lab staff of Textile Engineering Department for helping during sample making and testing.

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