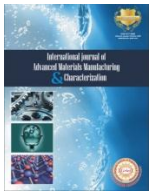

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Some Studies on Fiber Reinforced Thermoplastics Laminates Fabricated by Film Stacking Method

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ABSTRACT

Till early 1990's fiber reinforced polymer composites were based mainly on thermosetting polymers. In recent years, a rapid growth has occurred in fiber reinforced thermoplastics (FRTP) composites because of their higher toughness, impact resistance, damage tolerance and recyclability. High melt viscosity of thermoplastics presents many challenges to its processing. Newer technological developments have made thermoplastics composites viable. In the present work, glass-polypropylene, glass-polystyrene and jute-polypropylene composite laminates are fabricated by film stacking process. Film stacking is a technique for plying thermoplastics film/ sheet and fibrous reinforcement using heat and pressure. Selection of processing parameters (pressure, temperature and dwell time) for achieving optimum properties is required. Pressures applied were 4.0, 6.0, 7.5, 10.0, 15.0, 20.0 MPa and temperatures used were 200 and 210 deg C for polypropylene matrix composites; 255 and 260 deg C for polystyrene matrix composite laminates. FRTP laminates produced were characterized for various mechanical properties. Further work to arrive at optimum process parameters for different FRTP materials is in progress.

Introduction

In recent years, a rapid growth has occurred in fiber reinforced thermoplastics (FRTP) composites. The emergence of thermoplastics composites for a wide range of applications is driven by technological advantages such as higher toughness, impact resistance, damage tolerance and recyclability. They also offer faster processing cycles and high potential for automation because of absence of curing reaction.

The most difficult problem in manufacturing thermoplastics composites is to achieve complete and homogeneous impregnation of a large number of slender and sensitive fiber networks with highly viscous and gelatinous thermoplastics melt [1]. To overcome the difficulties involved in the production of composites, both pre-impregnated and in-situ impregnated concepts have been developed. The degree of impregnation is the most critical point in production and has great impact on the resulting mechanical properties of the composite material [2].

Processing of glass mat thermoplastics by hot compression molding represents a complex physical process with non-isothermal and non-Newtonian conditions [3]. Processing models were generated using regression techniques describing the effect of processing variables on void content and laminate mechanical properties. Mitschang etal [4] have investigated the processing technologies and impregnation/consolidation behavior occurring inthelaminationprocess.

In the present work, woven fabric reinforcements (glass and jute) with polypropylene and polystyrene matrices (in film/sheet form) are used. The effect of processing temperature and pressure on mechanical properties of glass/polypropylene, glass/polystyrene and jute/polypropylene composites fabricated by film stacking followed by compression molding is being studied.

Experimental Work:

The composite laminates were fabricated by the process of film stacking and hot pressing in a hydraulic compression molding press. Details of materials used for fabrication of FRTP composite laminates are given in Table 1.

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Table 1: Materials used

Material	Name
Reinforcement	Glass fiber woven fabric (550gsm) Glass fiber woven fabric (180gsm) Jute fiber woven fabric (250gsm)
Matrix (thermoplastics)	Polypropylene film (115gsm) Polystyrene sheet (415gsm)

The thermoplastics matrix-polypropylene (PP) in the form of film and the reinforcement as glass fiber(GF)/jute fiber(JF) woven fabric were taken in approximate weight ratio of 1:1. The thermoplastics matrix-polystyrene (PS) in the form of sheet and the reinforcement as glass fiber woven fabric were also taken in approximate weight ratio of 1:1. The alternate layers of GF or JF woven fabric and PP films or GF woven fabric and PS films were placed in the mould of 300 mm x 300 mm size between the platens of the press. The platens were electrically heated to the required temperature. Silicone spray was applied to the mould surfaces to prevent laminate from sticking to the mould. The thermoplastics composite laminates were fabricated using conditions given in table 2. On reaching the set temperature, the pressure was raised to the required level and heating was switched off. The laminates were allowed to cool in the mold. Laminates were then removed from the mould.

Table 2: Process parameters for JF/PP, GF/PP and GF/PS composite laminates

	Prepreg			Laminate		
Specimen Name	**Temperature (°C)**	**Pressure (MPa)**	**Dwell Time (minutes)**	**Temperature (°C)**	**Pressure (MPa)**	**Dwell Time (minutes)**
J1	200	10.0	5	200	15.0	5
PP1	210	4.0	3	210	4.0	3
PP2	210	6.0	3	210	6.0	3
PP3	200	7.5	5	200	8.0	5
PP4	200	10.0	5	200	10.0	5
PP5	200	15.0	5	200	15.0	5
PP6	200	20.0	5	200	20.0	5
PS1	255	4.0	3	255	4.0	3
PS2	255	6.0	3	255	6.0	3
PS3	260	10.0	5	260	15.0	5

J1: Jute fabric/PP, PP1-PP6: Glass fabric/PP, PS1-PS3: Glass fabric/PS

Prepregs are single layer of reinforcement fabric impregnated with thermoplastics matrix. They are prepared by placing one layer of thermoplastics film on either side of reinforcement fabric and layup is hot pressed in compression moulding press. Thermolplastics film melts and impregnates the reinforcement fabric to make a prepreg. To fabricate a FRTP laminate, several prepreg layers stacked together are hot pressed in a compression moulding press. The electrically heated platens heat the mold and pressure is applied. The temperature and pressure can be precisely controlled to ensure the desired processing conditions in the mold. Details of hydraulically operated compression molding press are given in Table 3.

Table 3: Details of compression molding press

Parameters	Specification
Make	Flowmech, India
Pressure range	0-20 MPa
Capacity	30 tonne
Temperature range	RT to 300 deg C
Mode of operation	Hydraulic

Testing and Characterization:

The laminate is taken out from the mold and its edges are trimmed to size. Laminate is cut into specimens of appropriate dimensions for evaluating various mechanical properties as per ASTM standards (table 5).

Table 4: Mechanical properties and test methods

Property	Test method
Tensile	ASTM D 3039
Flexural	ASTM D 790
Impact strength	ASTM D 256
Moisture Absorption	ASTM D 570

Results and Discussion:

Differential scanning calorimetry (DSC) test was conducted to evaluate the thermal properties of thermoplastics matrix (PP). Melting point (MP) of PP obtained by DSC was 169.5 deg C. Based on MP of PP, two molding temperatures 200 and 210deg C were used for hot press molding of GF/PP and JF/PP laminates. Melting point (MP) of PS obtained by DSC was 234.5 deg C. Based on MP of PS, two molding temperatures 255 and 260deg C were used for hot press molding of GF/PS laminates. The results of mechanical properties characterization of GF/PP laminates are given in table 5.

Table 5: Mechanical Properties of FRTP Laminates

S No	Property	Specimen							
		PS1	PS2	PP1	PP2	PP3	PP4	PP5	PP6
1	Tensile Strength, MPa (ASTM D3039)	28.03	48.67	75.66	76.00	80.01	100.26	93.46	94.14
2	Tensile Modulus, GPa (ASTM D3039)	1.33	1.64	1.10	1.27	4.012	3.60	4.10	3.98
3	Elongation at Break, % (ASTM D3039)	2.67	4.02	7.45	7.71	8.64	7.42	7.69	7.163
4	Flexural Strength, MPa (ASTM D790)	57.32	67.2	25.43	29.1	24.28	37.24	32.81	32.15
5	Flexural Modulus, GPa (ASTM D790)	5.62	6.34	1.86	2.67	1.31	1.86	2.06	1.72
6	Izod Impact Strength, J/m (ASTM D256)	–	–	–	–	816.43	764.84	1101.42	918.01

Following observations are made from results given in *table 5*:

1. For GF/PP laminates, tensile and flexural strengths are maximum for PP4 (Pressure-10MPa, Temperature-200 deg C) while tensile and flexural modulus, % elongation and Izod impact strength are maximum for PP5 (Pressure-15MPa, Tempearature-200 deg C).
2. For GF/PS laminates, all mechanical properties are higher for PS2 (Pressure-10 MPa, Temperature- 260 deg C).

Weight fraction, volume fraction , density of prepreg plies and laminates are given in table 6. Moisture absorption of 3 laminates (J/PP, GF/PP and GF/PS) is also given.

Table 6 : Weight Fraction, Volume fraction, Density and Moisture Absorption of FRTP Laminates

	Prepreg			Laminate					
Specimen Name	Weight Fraction	Volume Fraction	Density (g/cc)	Weight Fraction	Volume Fraction	Density (g/cc)	Thickness (mm)	Moisture Absorption (%)	
								24 Hours	7 Days
J1	0.60	0.47	1.02	0.60	0.47	1.02	3.2	5.73	17.1
PP5	0.50	0.22	1.19	0.51	0.23	1.18	3.27	3.01	4.63
PS3	0.57	0.33	1.49	0.58	0.34	1.49	4.02	1.87	3.56

Moisture absorption for J/PP is found to be maximum. It is due to high moisture absorption by jute fibres. Natural fibres like jute absorb more moisture when compared to glass fibres.

Conclusions:

The effect of pressure and temperature used during hot press moulding of Glass/Polypropylene and Glass/Polystyrene composite laminates by film stacking method on mechanical properties is studied. The effect of moisture on three types of FRTP composites (Jute/ Polypropylene, Glass/Polypropylene and Glass/Polystyrene) is also studied. More experiments are in progress to arrive at optimum process parameters for the above materials.

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