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Processing and Mechanical Characterization of Self Reinforced Polymer Composite Systems

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Abstract: Self reinforced polymer composite systems mean that both the reinforcement and the matrix are of the same material but processed through different methods. Their shear and tensile strengths are comparable unlike the glass or carbon fiber reinforced polymer systems where the shear strength is only a fraction of the tensile strength. The system to be investigated are the polypropylene and polyethylene composites. Thermal and mechanical characterization of these systems were carried out which leads to interesting applications in transport, air, sea and land cargo containers, ultra light structures , packaging and electronic packaging.
Keywords: Polypropylene, Polyethylene, fibre, self reinforced composite, DSC, Mechanical Characterization.

Introduction

Polyethylene (PE) and Polypropylene (PP) are thermoplastic linear aliphatic olefins [1]. The choice of thermoplastic for a given application depends closely on two factors, the heat distortion temperature and the price. The choices of reinforcements and matrices, their disposal, their respective fractions, allow the manufacturer of the material to design practically "tailor-made" optimized parts where they would be used. Self-reinforced composites, particularly those with polypropylene and poly ethylene possess many qualities. Because of their low weight, production costs and good mechanical properties, they offer an exceptional resistance to impact with a very good recyclability (more than a dozen cycles). The density of the PP is quite low (900 kg/m^3) and that of PE is 950 kg/m^3 which allows for reduced weight of the parts compared to other composites. Many companies such as Samsonite, Lotus, and Nike use PE and PP for applications such as: luggage, storage, hood of cars, sports protection, and reinforcement of castings [2].

Thermal Analysis and Fabrication

The three major thermal events that can be observed in polymers are the glass transition, crystallization and melting. These events are not always observable in the same polymer as it is amorphous, semi-crystalline or highly crystalline [3]. DSC was carried out up to a temperature of 400 °C for the PP fabric whose melting point turned out to be 279.21 °C as it was a either a co polymer or a coated fibre, compared to a melting point of ~180 °C for the unfilled isotactic PP. For the PP sheets, the thermodynamic melting temperature T_f was determined by the method of Hoffman-Weeks. The melting temperature was determined as the maximum of the peak of fusion, at 171.32 °C. DSC scan was also conducted on the PE-Polyethylene Terephthalate (PET)co polymer fabric and the High Density Polyethylene (HDPE) sheets to determine the processing window for hot compaction.

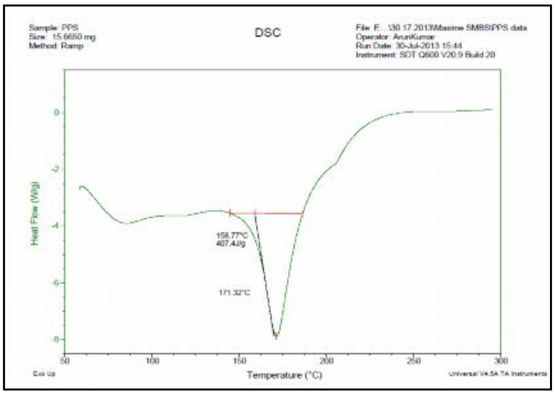

Figure 1a: DSC plot for PP sheet.

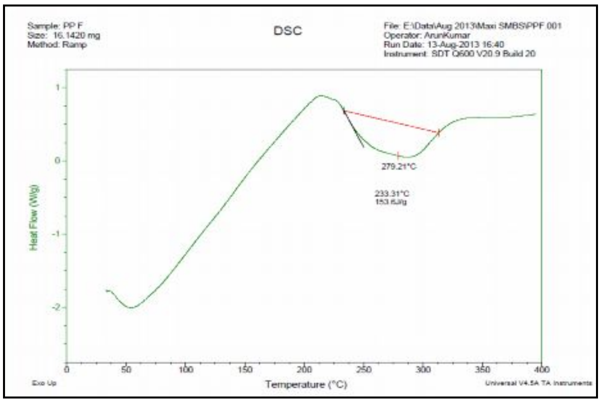

Figure 1b. DSC plot for PP fabric

The fabrication of PE and PP self reinforced composites sheets (400 x 400 mm) were done by using hot compaction method. Two sheets of either PE or PP constitute the external sides of the composite whereas a central sheet separated three layers of woven fabric of the same material on either side. Two sheets of Nylon 6,6 were used as covers for the assembly (because Nylon's melting temperature is higher than those of PE or PP) and sprayed with a silicone release agent to avoid adherence between sheets of steel and the laminate during compaction. The assembly was introduced in an oven at the ambient temperature, and then heated to a temperature of thermal softening as determined from the Differential Scanning Calorimetry(DSC) graphs, for a period of 1 hour and then cooled in the oven.

Mechanical Testing

Volume fraction of the self reinforced PP composite was 75.1% of matrix and 73.7 % matrix for the HDPE/ PE-PET co polymer self reinforced composite. The specimens were subjected to tensile, flexural and interfacial strength tests. In the case of self-reinforced composites, we apply the ASTM tensile standard D 3039 / D 3039 M - 95A, for a sample length, l = 250mm, a width w = 25mm and a thickness t = 2.5mm. The speed of the traverse is set at 2mm per minute [4]. In the case of three point flexure tests the D 790M-03 standard approved by ASTM [5] was followed at a span to depth ratio of 16:1 and the specimens were tested at a cross head velocity of 2 mm/min. To determine the adhesion between the fabric layer and the matrix, two notches were made in thetensile samples at 12.5 mm from the half-length. In this way it will be possible to observe if a delamination or a failure between the fabric and the matrix occurs. The results showed that fractureoccurs in one of the two notches and only some delaminated between the notches. So it becomes possible to know the maximum in-plane shear stresses though the failures were mixed in some specimens.

Results and Discussion

The tensile, flexural and in-plane shear properties of the self reinforcedPE and PP composites are given in Tables I and II. During the testing of notched in-plane shear specimens that were developed in house it was observed that the shearstrengths and the tensile strengths of the self reinforcedcomposites were veryclose unlike the carbon fibre and kevlarfibre/ thermoplastic matrix composites. Due to this near ratio, they are used in applications that demand very good shear strength at allowable tensile strengths. Their notch sensitivity is also low. Most of the polymeric self reinforced composites have low densities and so have a great demand in their use as luggage and baggage materials. This investigation brings out the efficient use of differing melting points in fabrication due to the different stereochemistry of the same material used as thefibre and the matrix.

Table I: Tensile, Flexural and In- Plane Shear Properties of a PE Composite

(Tensile Test of PE Self Reinforced Composite)						
Specimen No:	1	2	3	4	5	Mean
Maximum Load : P Max(N)	2714,30	2042,25	3009,98	2621,75	2819,20	2641,5
Disp at Max Load : δi (mm)	2,5	1,9	2,8	2,4	2,6	2,44
Max stress : σ max (MPa)	27	34,15	37,56	27,73	30,59	31,40
Strain at max load: ε max (%)	1,31	1	1,47	1,26	1,36	1,2
Flexural Test: Self Reinforced PE Composite						
Specimen No:	1	2	3	4	5	Mean
Maxi Load : *P max* (N)	147,58	137,39	140,28	144,45	130,58	140,05
Déflection at Max Load : *D* (mm)	5,84	6,57	7,61	7,80	7,01	6,97
Max Flexural Stress : *σf* (MPa)	51,93	41,95	37,55	37,2	38,85	41,496
Maxi Strain : *ε* (%)	5	5	5	5	5	5
Flexural Modulus : *EB* (MPa)	1800	1750	1700	1800	1800	1750
In-Plane Shear Test						
Specimen No:	1	2	Mean			
Maxi Load : P max (N)	2144,07	1972,53	2058,30			
In-plane shear stress : τ (MPa)	21,65	20,12	20,89			
Shear Modulus : G (MPa)	1051,97	1051,97	1051,97			
Shear strain : ? (%)	2,05	1,91	1,98			

Efficient use of the co-polymers of PP and PE havebeen madeto process the self reinforced composites and evaluate their mechanical properties after evaluating their processibility with the help of DSC. The DSC plots assist in the selection of the process window for hot compaction. Here, as the same material is used as the fibre and the matrix, the interface between them isunique andstrong and exhibits a high shear strength which is comparable to the tensile strength itself.

Conclusions

The mechanical properties of the polypropylene and polyethylene based self reinforced composites fabricated through the hot compaction method, were evaluated. Improved properties with lower density make them very suitable for various low weight applications. From the test results it can also be concluded that the adhesion between the matrix and the fibre is high and the in-plane shear test shows a close ratio of shear strength to the tensile strength.

Table II: Tensile, Flexural and In-Plane Shear Properties of aPP Composite

Flexural tests for PP composite	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Strain (mm/mm)	0,051	0,066	0,06	0,05	0,064
Midspandeflection (mm)	8,62	11,10	10,06	8,23	9,04
Maximum load (N)	135,06	125,89	167,77	127,43	282,6
Flexural stress (MPa)	5,42	5,07	5,36	4,72	8,75
Flexural stress (large support) (MPa)	5,84	5,78	5,97	5,07	9,91
Young s modulus (MPa)	1154,53	1261,57	1328,00	1205,47	1300,03
In-Plane Shear Test					
Notched samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Average section (mm²)	40,64	34,37	89,03	44,04	95,63
Maximal load (N)	1 730,32	1 527,14	1 106,43	1 496,22	1 101,09
Maximum stress (MPa)	42,58	44,44	12,43	33,97	11,51
Failure mode	(Tensile)	(Tensile)	(Tensile)	(Shear)	(Tensile)
Young modulus (MPa)	1713,412	1998,892	1677,028	1551,101	1814,092
Tensile samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Average section (mm²)	52,6	79,0	51,7	99,3	43,7
Maximal load (N)	1 597,65	2 308,42	2 294,70	1 564,35	1 255,26
Maximal stress (MPa)	30,36	29,22	44,42	15,76	28,74
Young modulus (MPa)	2173,94	1975,38	1873,89	1853,73	2589,17

Acknowledgment

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References

1. www.ineos.com/.../ineos_polypropylene_processing_guide.pdf, USA.
2. Nagarajan, P. and Yao, D, Homo-composites of Poly(Ethylene Terephthalate), ANTEC, 2005, 1559.
3. Mekyoung KIM , Predicting thermally thin burning of polymer using TGA/DSC, Masters Thesis, University of Maryland, 2006.
4. Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials, Designation D 3039/D 3039M-95a, Published by ASTM, West Conshohocken, PA.
5. Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, Designation D 790-03, Published by ASTM, West Conshohocken, PA.

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