Effect Of Moulding Temperature On The Properties Of Polypropylene/High Density Polyethylene/Clay/Glass Fibre Composites

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Abstract

Polymer nanocomposites have emerged as a high-tech engineering material for a variety of applications. The present paper emphasis on the comparison of polymer nanocomposites synthesized under different moulding temperature and the effects of moulding temperature on the preparation of polymer nanocomposites by different characterization techniques. Also aims to investigate the enhanced physical and mechanical properties of polymer nanocomposites with different nanofillers. Polymer hybrid nanocomposites based on poly propylene(PP) (80% of blend)and high density poly ethylene(HDPE)(20% of blend) blend is selected for the present study. Nanofillers such as nano kaolin clay (2%) and/or glass fibre(GF)(20%) is incorporated in the polymer matrix.

The properties of processed goods, particularly based on polymer blends, are highly depend on the processing variables and the effect of moulding temperature. The study shows that there is an optimum moulding temperature at which maximum mechanical properties are obtained [1,2].

Similarly, the actual surface temperature of the mould cores and cavities are related to, but not necessarily the same as, the temperature of the fluid passing through the channels in the mould. It is generally understood that melt temperature has an effect on viscosity. But melt temperature also has an influence on the final molecular weight of the polymer in the moulded part[3,4].

Keywords: Polymer nanocomposites, nano kaolin clay, injection moulding, moulding temperature.

1. Introduction

A nanocomposite is as a multiphase solid material where one of the phases is a nanomaterial which has one, two or three dimensions of less than 100 nanometers (nm), or structures having nano-scale repeat distances between the different phases that make up the material. In the broadest sense this definition can include porous media, colloids, gels and copolymers, but is more usually taken to mean the solid combination of a bulk matrix and nano-dimensional phase(s) differing in properties due to dissimilarities in structure and chemistry [5]. Polymer nanocomposite(PNC) is a polymer or copolymer having dispersed in its nanoparticles. These may be of different shape (e.g., platelets, fibres, spheroids), but at least one dimension must be in the range of 1 to 80 nm. These PNC's belong to the category of multi-phase systems (blends, composites, and foams) that consume nearly 95% of plastics production. These systems require controlled mixing/compounding, stabilization of the achieved dispersion, orientation of the dispersed phase, and the compounding strategies for all multiphase systems, including PNC, are similar [6-8].

Synthesis of polymer nanocomposites include mixing /addition of nanofillers into the polymer and moulding the graft obtained into desired shapes [9]. Polymer–clay nanocomposites can be synthesized via four mixing approaches depending on the starting materials and the processing techniques; they are in–Situ Polymerization, emulsion polymerization, solution exfoliation and melt intercalation [10]. Moulding or moulding is the process of manufacturing by shaping pliable raw material using a rigid frame or model called a pattern. Injection moulding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials [11,12]. Material is fed into a heated barrel, mixed, and forced into a mould cavity where it cools and hardens to the configuration of the cavity[13].

In injection moulding, moulding conditions have a significant influence on the final properties of the material regardless of the part design. Two of the process conditions that have a substantial influence on the behaviour of the polymer are the melt temperature and mould temperature. Melt temperature is the actual temperature of the polymer as it exits the nozzle and enters the mould. Similarly, the actual surface temperature of the mould cores and cavities are related to, but not necessarily the same as, the temperature of the fluid passing through the channels in the mould. It is generally understood that melt temperature has an effect on viscosity. But melt temperature also has an influence on the final molecular weight of the polymer in the moulded part. Mould temperature has perhaps a less obvious but often more profound effect on final properties. In semi-crystalline materials the mould temperature is an important factor in determining the degree of crystallinity in the polymer [14, 15].

2. Experimental

2.1 Materials

Polypropylene homo polymer (PP): (REPOLH110MA) and **high density polyethylene** (HDPE) (REPOL H110MA) were supplied by M/s Reliance Industries Ltd., Hazira, Gujarat

Nanoclay: Nanocaliber-100 both modified and unmodified clay with ion exchange ,supplied by English Indian Clays Limited ,Veli, Thiruvananthapuram, Kerala,India. The clay is one dimensionally nano sized, ion exchanged with cationic amino salts and spray dried. **Glass Fibre** supplied by SHARON ENTERPRISES INDIA LIMITED, Kochi, Kerala, was used in the study.

2.2 Methods

Preparation of hybrid composites: All composites were prepared in an internal mixer Torque Rheometer (Thermo Haake Rheocord 600). The rotor speed was set at 50 rpm. The components of 40 g were loaded to the mixing chamber through the hopper and compounded at 160^{0}C temperature for 8 minutes , with rotor speed of 50 rpm. Nano clay used was preheated to about 75^{0}C for 45 minutes to remove moisture content and polymers taken in the 80% PP and 20%HDPE by weight are melt compounded in the Haake melt mixer. The composites so prepared were hot pressed in a hydraulic press, cut into pieces and moulded using a semi-automatic plunger type injection moulding machine.

Testing of hybrid composites: The specimens obtained after moulding were tested for tensile and flexural properties in a Shimadzu Autograph Universal Testing Machine (UTM)), impact strength in Resil Impact Testing Machine according to ASTM standards. Thermal characterization is done by differential scanning calorimetry(DSC) and TAΘ600 model is used for thermogravimetric analysis (TGA). SEM images were taken with JSM 6390 with an accelerator voltage20 kV on a vacuum atmosphere. X-ray diffraction (XRD) is also used for morphological study and is done using broken advanced X-ray diffractometer.

3. Results and discussion

3.1 Mechanical Properties

The tensile strength and modulus of nanocomposites moulded at three different temperatures are shown in Figure.1 and 2. The addition of clay to the fibre reinforced composites affects its strength very much. For polymer clay composites higher strength is obtained for 180^{0}C moulding temperature whereas for fibre reinforced composites it is 190^{0}C. The flexural strength or three point bending of composites with different moulding temperatures are shown in Figure 3. Similar trend as tensile strength is obtained for flexural strength also. The addition of glass fibre and nanoclay increases the flexural strength and modulus.

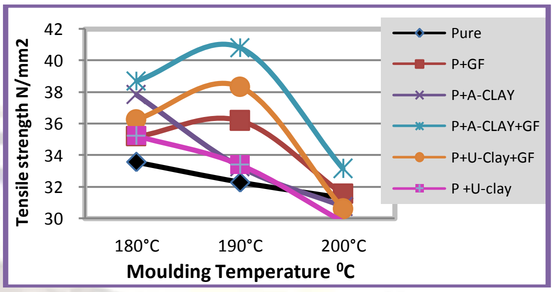

Fig.1 Tensile Strength of composites moulded at different temperatures

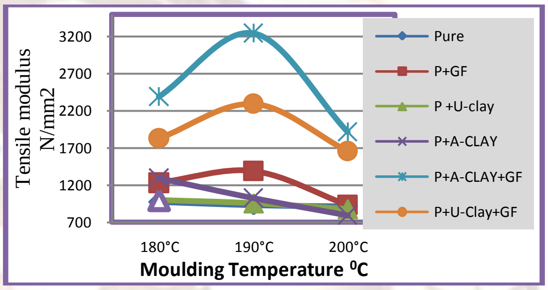

Fig.2 Tensile Modulus of composites moulded at different temperatures

For polymer/clay composites the optimum moulding temperature for high flexural strength is 180^{0}C whereas for fibre reinforced composites it is 190^{0}C. This is because the fibre loading increases viscosity and hence reduce proper flow and orientation of molecules during moulding.

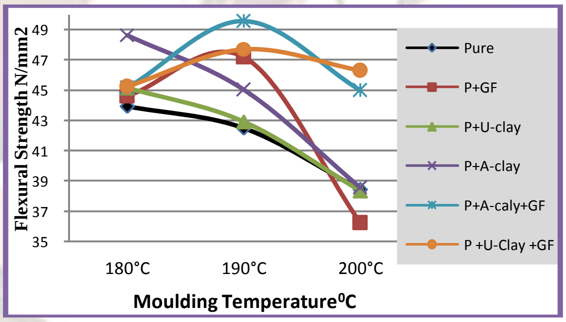

Fig.3 Flexural Strength of composites moulded at different temperatures

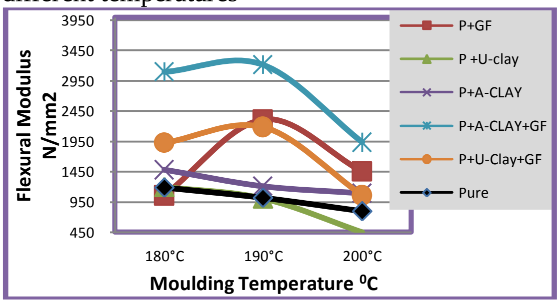

Fig.4 Flexural modulus of composites moulded at different temperatures

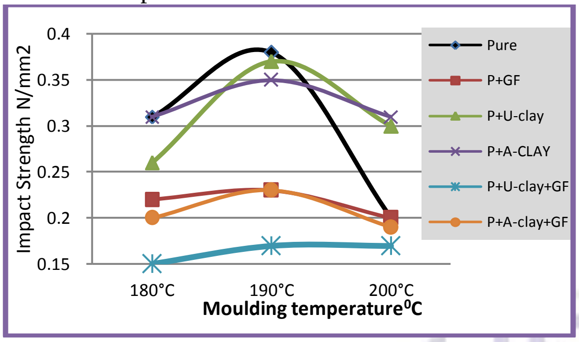

Fig.5. Impact strength of composites moulded at different temperatures

From figure.5 it is found that the impact strength is high for composites moulded at 190^{0}C. Further temperature of moulding will cause degradation of polymers which reduces the strength.

3.2 Thermal Properties

In order to investigate the effect of different nanofillers on the degree of crystallinity, DSC curves of compounds were analysed.

Table.1 Crystallization Temperature of composites

Composite	Crystallization Temperature ^{0}C
PP/HDPE/GF	113.81
PP/HDPE/A-clay	119.08
PP/HDPE/A-clay/GF	119.98

The results show that the crystallinity increases in the presence of nanoclay and it's not affected by the processing conditions used. The presence of nanoclay platelets dispersed in the hybrid matrix promotes heterogeneous nucleation, thus increases the crystallization rate and increases the degree of crystallinity.

Thermal stability of the hybrid composite was studied using TGA. The thermogravimetric curves are plotted in figures 6 and 7. The addition of clay increases the decomposition temperature of hybrid composites.

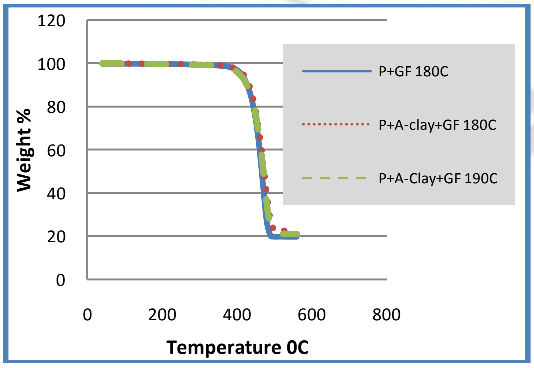

Fig.6 Temperature Dependence of Weight Loss for Composites

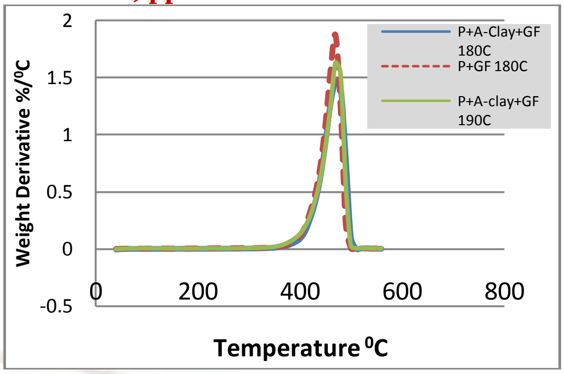

Fig.7 Temperature Dependence of Weight Derivative for Composites.

Table. 2 Results of TGA of different composites

Composites	Temperature of onset of thermal degradation, °C	Temperature of complete degradation, °C
P+GF (180°C)	345.89	470.25
P+A-Clay+ GF (180°C)	350.99	470
P+A-Clay+ GF (190°C)	331.06	474.64

These results indicate that as moulding temperature increases, thermal stability of composites decreases. Thermal stability of hybrid composites is higher than that of the composite without nanoclay (PP/HDPE/20%GF). At the same time, the hybrid composite moulded at 180^{0}C gives better performance than that moulded at 190^{0}C.

3.3 Morphological Study

The pictures do however give a much better feel of the particles in 3D space. Several SEM images were taken at various magnifications to characterize the hybrid composite. SEM results for fractured surface of moulded samples are given below. SEM micrograph of fracture surface of 80PP/20HDPE pure blend is given in the figure.8

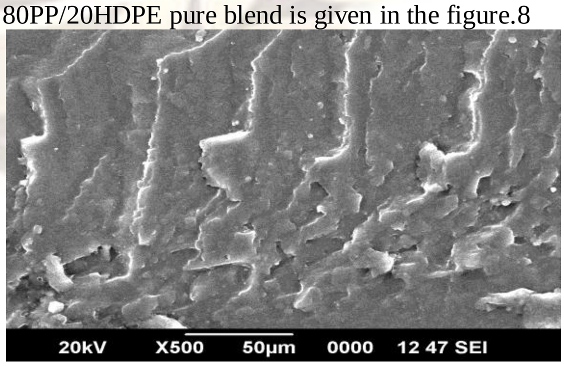

Fig.8 SEM image of fracture surface of 80PP/20HDPE pure blend.

Figure.9 shows the tensile fracture surface micrograph of PP/HDPE/20%GF. In this case the glass fibres are evenly distributed in the polymer matrix.

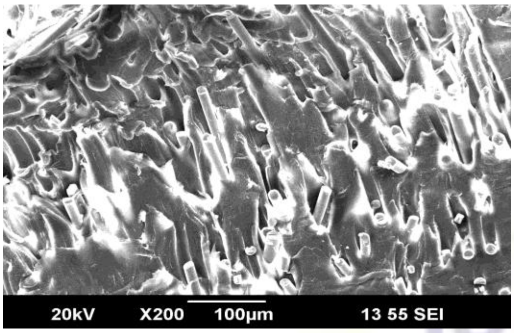

Fig.9 SEM image of fracture surface of PP/HDPE/GF composite.

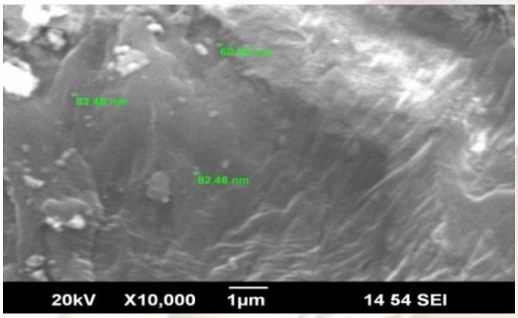

Fig.10 SEM Image of Fracture Surface of PP/HDPE/A-clay Composite

Figure.10 shows the tensile fracture surface of PP/HDPE/2% Amino-clay, in this case nanoclay is dispersed in the polymer matrix. In these figures, we can see the maximum exfoliation.

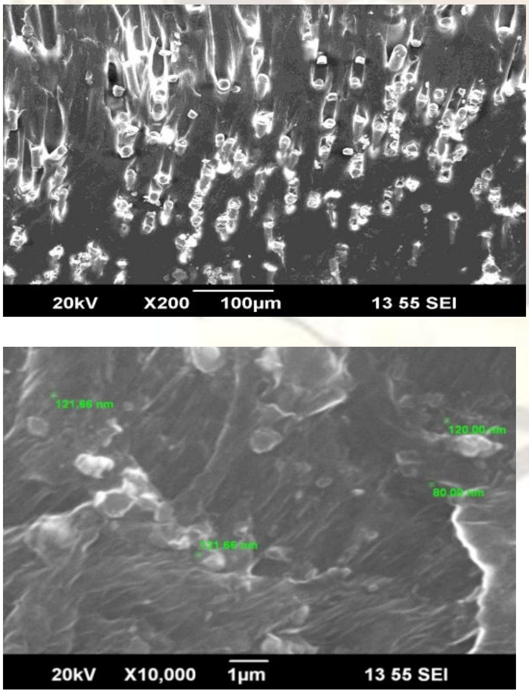

Fig.11 SEM images of PP/HDPE/2% Amino-clay/20%GF.

Figure.11 shows the tensile fracture surface of PP/HDPE/2% Amino-clay/20%GF, in this case nanoclay is there along with the short fibres in the polymer matrix and better interaction between the nanoclay and fibres can be seen. Matrix is more homogeneous and more adhesion between fibre and matrix is seen in the presence of nanoclay As the result, PP/HDPE/2%Amino-clay/20%GF hybrid composite gives better strength as compared to that of the composite with fibre alone.

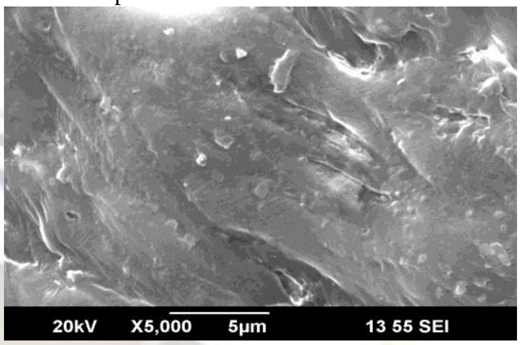

Fig.12 SEM images of Hybrid composite moulded at 180^{0}C

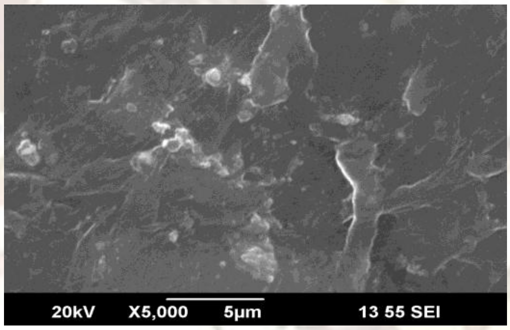

Fig.13 SEM image of PP/HDPE/2% Amino-clay/20%GF

Figure.12 and figure.13 represents the SEM images of PP/HDPE/A-clay/GF hybrid composites moulded at 180^{0}C and 190^{0}C respectively. There is not much variation found in the dispersion of clay particles in the polymer matrix. These results show that the moulding conditions do not affect the morphological features of the composites.

X-ray diffraction is used to determine crystal morphology of the nanoparticles in the composite. Nanoclay is in the form of layers or stacks of platelets. This leads to isomorphic substitution within layers and generates a negative charge exchange capacity. During melt mixing, polymer precursor or preformed polymer penetrated in to the gallery space between the layers. In the composite, the gap between the single sheets (d-spacing value) should be widened to get enhanced properties.

In this study the XRD analysis is performed for pure Amino-clay, PP/HDPE/A-clay composite and PP/HDPE/A-clay/Glass Fibre composites. The results obtained are plotted in the figure 12. It is shown that the d-spacing value of the PP/HDPE/A-clay composite is higher than that of amino-clay.

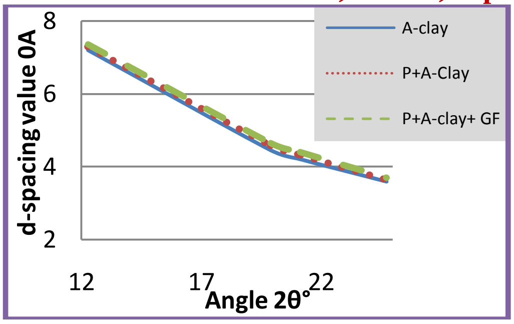

Fig.14 Results of XRD- Comparison of d-spacing value of composites.

In hybrid composite the d-spacing value is further increased, which indicate the complete dispersion of nanoclay and glass fibres in the polymer matrix. This increased d-spacing value explains the enhanced properties of hybrid composites compared to others.

Table.3 Results of XRD showing d-spacing values of Amino clay and composites

Angle 2θ°	d-spacing value, °A		
	Amino Clay	PP/HDPE/ A-clay	PP/HDPE/A-clay/Glass Fibre
12.28	7.204	7.29	7.351
19.89	4.459	4.582	4.654
21.13	4.201	4.317	4.397
24.74	3.595	3.634	3.697

4. Conclusions

The effect of moulding temperature on the properties of composite based on PP/HDPE (80/20) was studied in this work. The study shows that the moulding temperature has significant effect on the mechanical and thermal properties of the composite. The optimum moulding temperature depends on the desired mechanical/thermal properties of the composite for its application. The incorporation of nano clay and glass fibres improves the properties of PP/HDPE blends. The enhancement in physical properties is well explained by morphological characterization.

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