

OBSERVATION OF FAILURE CHARACTERISTICS OF NOTCHED INJECTION MOLDED PP/TPO/MMT NANOCOMPOSITES

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Introduction

Various polymer nanocomposites have been proposed to give improved stiffness while maintaining the practical toughness of the polymeric system. This has been shown for Organoclay based nanocomposite system [1, 2] where the stiffness was improved at low levels of clay addition. This finding has prompted many researchers to develop new improved stiffness while maintaining the toughness for various polymeric systems such as polystyrene, polycaprolactone, polyurethane, epoxies and polyolefins. It is the superior characteristics as compared to other inorganic fillers that generated great interest in developing nano-filled polypropylene and Thermoplastic polyolefins (TPO). Nano-filled PP and TPOs are designed for engineering applications, such as in automotive cladding and bumper fascia.

In the past, Chow et al. [3] had shown that the improved toughness of polypropylene (PP) and TPO nanocomposites depends greatly on the dispersion of the nano-fillers within the matrix. The mechanism of failures were also found to initiate from the filler interfaces (both polymer/filler and filler/filler interphase) and propagate through the matrix. Chow et al. reported the very same tendency for polyamide 6/polypropylene/clay nanocomposites, and they also reported that using a compatibilizer they could get finer dispersions of clay in the PP matrix and by so doing could enhance the mechanical properties.

In this study, the effect of the nano-filler clusters on the fracture behavior of injection molded PP and TPO nanocomposites with/without notches are investigated. The particle trace distribution and injection molding flow profile are also discussed with respect to the effect of filler morphology on the tensile fracture toughness.

Experimental

Materials

In this experiment, nanocomposites were prepared using polypropylene/ethylene copolymer and PP homopolymer with Clayton HY organoclay-MMT. In Table 1, the chemical composition of the specimen is shown. There are two kinds of specimen used in the experiment, specimen A (13-3) and specimen B (29-3). The fabrication conditions are shown in Table 2.

Table 1 Chemical composition of nanocomposite

Materials	Weight %
Irgafos 168	0.2%
Propylene/Ethylene RCP	69.8%
PP [1-propane homopolymer]	20%
Clayton HY organo-MMT	10%

Table 2 Condition of specimen fabrication

Specimen type	Fabrication
Specimen A	1 pass through 30mm WP extruder
Specimen B	filtered through a 10u retention mesh)

Specimen preparation

The dog-bone specimen is fabricated by an injection molding process. Un-notched, smooth specimen and two different notch specimens having notch depths of 5% and 10% of their width were used. The notch was made by using vertical notcher with razor blade accompanied by micrometer.

Apparatus and procedures

Tensile test was executed on a high speed MTS machine at room temperature and low temperature (0°C). The rate of loading for each test was 50 mm/min which is defined as ASTM D638. According to notch depth and specimen type, specimen name is applied as A00, A05, A10, B00, B05, and B10. Because of the different response for tensile test, specimen A was tested only at room temperature, and specimen B was tested at both room temperature and low temperature. Since for brittle fracture, specimen B showed much better performance, fractographic analysis is applied for specimen B

Result and discussion

In case of tensile testing at ambient temperature, both specimen A and B showed very ductile fracture. In this experiment, tensile data for ambient temperature are obtained only for specimen A. In Fig. 3, tensile test results are shown. There is not a significant difference between unnotched and the 5% notched specimen; however, the 10% notched specimen shows the much brittle behavior. tensile toughness for each specimen is

shown, because of the shorter elongation to break of the 10% notch specimen, this value for the 10% notched specimen is much lower than the unnotched specimen and the 5% notched specimen.

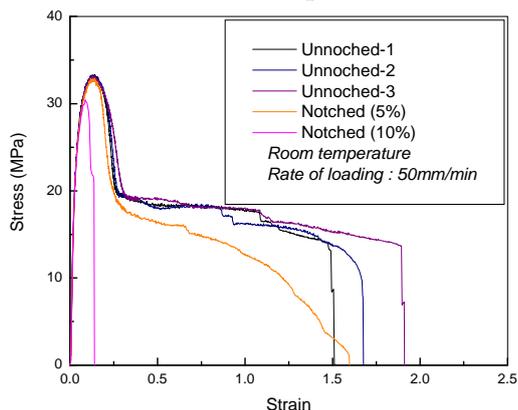


Fig. 1 Stress-strain curves of specimen A

Until the maximum loading, there are many micro craze clusters observed that looked like black dots. Necking happened after the engineering stress had decreased. During the drawing region, skin breakup starts in certain areas, followed by delamination between the core and skin. Because of these last two steps, the tensile properties for this material are not as good as expected. This phenomenon may be due to injection molding process, so compression molding or annealing of this materials may help. At ambient temperature, the tensile behavior of the sample is too ductile to observe the effect of nanoparticles. So, the low temperature test is set up for observing the effect of nanoparticles.

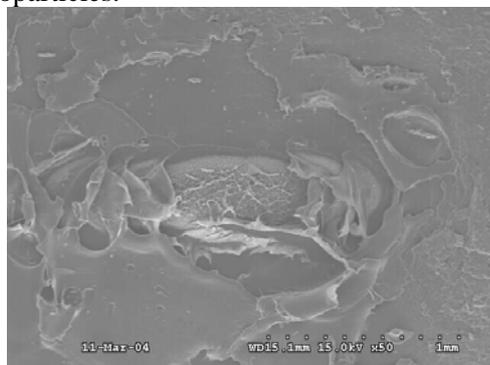


Fig. 2 SEM photo at the core of fractured specimen B

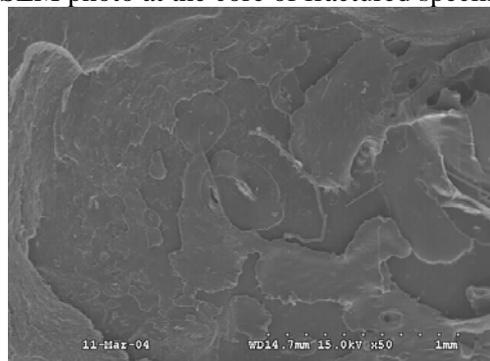


Fig. 3 SEM photo at the side of fractured specimen B

For the low temperature test, temperature was controlled to maintain at 0 °C. There was a lot of microcrazing (whitening area) around the actual

fracture point without large deformation. At lower temperature, the notch sensitivity is much more distinct, so most of energy applied to the notched specimen is used for narrow process zone and crack propagation. Nathani et al. [4] reported a reduction of stress whitening of polybutylene nanocomposites filled with 5% clay compared with that of neat polybutylene. Core microcrazes' clusters are well-defined when compared with those outside of the core (Fig. 2 and Fig. 3). It looks like an elliptical hill, and it is composed of many cracks and stretched fibrils. Cracks at outer location have elliptical shape but cracks at the core clusters are close to circular in shape.

Statistical analysis of the trace of particles from SEM was executed by a 2D image analyzer, and the average diameter of particles was calculated assuming all particles have a circular shape. The maximum size obtained from core clusters is larger than that from outer locations, and that is caused by the large deformation of core clusters, and the total number of particles of core clusters is much larger than that of outer locations.

Conclusion

1. After the tensile test at ambient temperature, all specimens show very ductile failure with a large whitening zone. There are four different stages observed before final failure: the appearance of clusters, necking, skin breaks and delamination
2. For the unnotched specimen, an obvious skin-core effect is observed due to injection molding process. Concentration of nanoparticles as clusters was observed at the center of the specimen, and the side area of the specimen shows the clusters flow around the skin-core interface.

References

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