

INJECTION MOLDING OF PREGENERATED MICROCOMPOSITES

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(ABSTRACT)

One portion of this work was concerned with injection molding pregenerated microcomposites composed primarily of poly(ethylene terephthalate) (PET) as the matrix and HX1000 as the thermotropic liquid crystalline polymer (TLCP). Several factors were examined to maximize the mechanical properties of these composites, including injection molding temperature, matrix viscosity, and nozzle tip exit diameter. In addition, concentrated strands of HX1000/PET (50/50 wt%) were diluted using both an injection molding grade of PET and an injection molding grade of PBT. From this work, it was determined that the best mechanical properties were produced when the microcomposites were processed at the lowest injection molding temperatures, diluted with PBT, and injection molded using a large nozzle tip exit diameter.

The pregenerated microcomposite properties were compared against theoretical predictions as well as glass-filled PET. It was found that the pregenerated microcomposites had tensile moduli of approximately 70% of theoretical expectations in the machine direction. Additionally, the comparisons against glass-filled PET revealed that at the same weight fraction of reinforcement, the pregenerated microcomposites had lower properties. Still, the composites were found to have smoother surfaces than glass-filled PET and at temperatures up to 150°C the storage and loss moduli of the pregenerated microcomposites were similar to those of glass filled PET. It was concluded that if the theoretically expected levels of reinforcement could be attained, the pregenerated microcomposites processing scheme would be a viable method of producing light weight, wholly thermoplastic composites with smoother surfaces than are obtained with glass reinforcement.

An additional focus of this research was to evaluate the ability to modify the crystallization behavior of a high melting TLCP (HX6000, $T_m = 332^\circ\text{C}$) with a lower melting TLCP (HX8000, $T_m = 272^\circ\text{C}$). It was found that it was possible to tailor the crystallization behavior of these TLCP/TLCP blends by varying the weight fraction of each component, as determined by rheological cooling scans and differential scanning

calorimetric cooling tests. Based on the analysis of these TLCPs at the maximum injection molding temperature of 360°C, it was speculated that they had reacted with one another.

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Original Contributions

The following are considered to be the significant original contributions of this research:

- It was determined that diluting with poly(butylene terephthalate) (PBT) rather than poly(ethylene terephthalate) (PET) yielded higher mechanical properties in the pregenerated microcomposites.
- The best processing conditions for producing pregenerated microcomposites were established. To maximize mechanical properties, the processing temperature must be kept as low as possible, the nozzle tip with a large exit diameter should be used, and the diluting resin had to possess a low viscosity.
- The crystallization temperature of a high melting TLCP (HX6000, $T_m = 332^\circ\text{C}$) was lowered by addition of a low melting TLCP (HX8000, $T_m = 272^\circ\text{C}$). This allowed the crystallization temperature to be varied over an approximately 60°C temperature range by simply varying the weight fractions of the two components in the blends.

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Index of Abbreviations

English Symbols

a - dimensionless parameter that describes the transition region between the zero shear rate region and the power law region

a_2 - second order orientation tensor

a_4 - fourth order orientation tensor

a_{ij} - components to the second rank tensorial representation of orientation

c - concentration of fibers in the suspending fluid

CR - composition ratio

d - fiber diameter

E - bending modulus of reinforcing fibers, Young's modulus

f_{or} - Herman's orientation function

HBA - 4-hydroxybenzoic acid

HDPE - high density polyethylene

HNA - 2-hydroxy-6-naphthoic acid

L - fiber length

L_n - number average fiber length

L_w - weight average fiber length

LDPE - low density polyethylene

MAGPP - maleic anhydride grafted polypropylene

MAP - maleic anhydride polypropylene; maleated polypropylene

MLFIM - multiple live-feed injection molding

n - power law exponent, flow index, power law index

N_i - number of fibers at each angle

N_1 - first normal stress difference

p - unit vector parallel to the fiber axis

p_i - components of unit vector p

PA - polyamide; nylon

PA6 - polyamide 6; nylon 6

PA6,6 - polyamide 6,6; nylon 6,6

PBT - poly (butylene terephthalate)

PC - polycarbonate

PEI - poly (ether imide)

PEEK - poly (ether ether ketone)

PEKK - poly (ether ketone ketone)

PET - poly (ethylene terephthalate)

PP - polypropylene

PPS - polyphenylene sulfide

PS - polystyrene

PSF - polysulfone

r - fiber radius

r_a - fiber aspect ratio

R_b - critical radius for breaking

TLCP - thermotropic liquid crystalline polymer

TTS - titanate coupling agent

v_i - components of the velocity vector

vol% - volume percent

wt% - weight percent

x_i - coordinate system axes

Greek Symbols

α_0 - dimensionless shape factor

$\dot{\gamma}$ - shear rate

$\dot{\mathcal{E}}$ - rate of strain tensor

η - suspension viscosity

η^0 - suspension zero shear viscosity

η_m^0 - neat matrix zero shear viscosity

η_f - viscosity of the neat suspending fluid

η_0 - zero shear viscosity

η_∞ - infinite shear viscosity

θ - angle formed between the fiber and the reference direction

κ_c - consistency index

λ - time constant, material constant that depends on fiber aspect ratio

λ_i^0 - time constant

σ_b - tensile strength

τ_y - yield stress

ϕ - volume fraction, volume fraction of solids

ϕ_m - maximum packing parameter

$\Psi(p,t)$ - fiber probability distribution function

Ω - vorticity tensor