

**MELT RHEOLOGICAL, EXTRUDATE SWELL AND MELT FRACTURE  
BEHAVIOR OF CALCIUM CARBONATE AND TITANIUM (IV) DIOXIDE  
NANOPARTICLE-REINFORCED POLYPROPYLENE COMPOSITES**



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## ABSTRACT

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Melt rheology, extrudate swell and melt fracture of isotactic polypropylene (iPP) filled with  $\text{CaCO}_3$  or  $\text{TiO}_2$  nanoparticles in various amounts (i.e., from 0 to 30 wt.%) during capillary melt-extrusion were investigated. The wall shear stress for both neat iPP and iPP compounds increased in a non-linear manner with increasing the apparent shear rate. The stearic acid – treated nanoparticles exhibited the hydrophobic characteristic that resulted in a significant reduction in the wall shear stress when the amount of the fillers increased when comparing with the nanoparticles having a hydrophilic surface. The percentage of extrudate swell was found to increase with increasing the apparent shear rate in a non-linear manner, while it was found to increase linearly with increasing the wall shear stress. The extrudate swell decreased with increasing the amount of the fillers. Lastly, The severity of the melt fracture was found to increase with increasing the apparent shear rate. The maximum  $\text{TiO}_2$  content of 30 wt.% showed no evidence of the melt fracture. With increasing the L/D ratio, the critical shear rate at which the melt fracture was observed and shifted toward a higher value, possibly a result of the partial molecular relaxation during the flow through a longer die.

## บทคัดย่อ

ระพีพันธ์ แดงตันกี : พฤติกรรมการไหล การบวมตัว และการเสีรูปร่างของ พอลิเมอร์พอลิพรอพิลีนผสมอนุภาคนาโนแคลเซียมคาร์บอเนต และ ไทเทเนียมไดออกไซด์ (Melt Rheological, Extrudate Swell and Melt Fracture Behavior of Calcium Carbonate and Titanium (IV) Dioxide Nanoparticle-Reinforced Polypropylene Composites) อ. ที่ปรึกษา : รศ. ดร. พิชญ์ สุภผล 127 หน้า

งานวิจัยนี้เป็นการศึกษาสมบัติการไหล พฤติกรรมการบวมตัว และการเสีรูปร่างของพอลิเมอร์หลอมเหลวพอลิพรอพิลีนผสมอนุภาคนาโนแคลเซียมคาร์บอเนตและไทเทเนียมไดออกไซด์ ในปริมาณตั้งแต่ 0 ถึง 30 เปอร์เซ็นต์โดยน้ำหนักโดยใช้เครื่องคาปีลารีรีโอมิเตอร์เป็นเครื่องมือในการทดลอง ผลการทดลองพบว่าค่าความเค้นเฉือนของพอลิพรอพิลีนและพอลิพรอพิลีนผสมมีค่าเพิ่มขึ้นเมื่อเพิ่มอัตราเฉือน ค่าความหนืดมีค่าลดลงเมื่อเพิ่มอัตราเฉือนเช่นเดียวกัน ในส่วนของพอลิพรอพิลีนผสมอนุภาคนาโนที่มีผิวภายนอกเคลือบด้วยกรดสเตียริกทำให้มีสมบัติเป็นไฮโดรโฟบิก ทำให้ค่าความเค้นเฉือนมีค่าเพิ่มขึ้นไม่มากนักเมื่อเทียบกับผิวภายนอกที่มีสมบัติเป็นไฮโดรฟิลิก เมื่อให้ความสนใจไปที่การไหลแบบยืดคั้งพบว่าในทุกๆส่วนผสมของพอลิเมอร์ผสมค่าความเค้นแรงคั้งมีค่าเพิ่มขึ้นตามอัตราการยืดคั้งดังนั้นค่าความหนืดจากการยืดคั้งจึงมีค่าลดลงตามอัตราการเพิ่มการยืดคั้งเช่นเดียวกัน พฤติกรรมการบวมตัวของพอลิเมอร์ผสมในทุกๆอัตราส่วนผสมพบว่าการบวมตัวมีค่าเพิ่มขึ้นตามความสัมพันธ์แบบไม่เป็นเส้นตรงเมื่อเพิ่มอัตราเฉือนแต่มีความสัมพันธ์แบบเส้นตรงกับค่าความเค้นเฉือน ค่าการบวมตัวมีค่าลดลงเมื่อเพิ่มปริมาณอนุภาคนาโนเนื่องมาจากเมื่อเพิ่มปริมาณอนุภาคสารเติมเต็มทำให้เกิดการขัดขวางการเคลื่อนที่ของสายโซ่โมเลกุลของพอลิเมอร์ ในผลการทดลองสุดท้ายเกี่ยวกับการเสีรูปร่างของพอลิพรอพิลีนผสมนาโนไทเทเนียมไดออกไซด์พบว่าการเสีรูปร่างเกิดมากขึ้นเมื่อเพิ่มอัตราเฉือนและในช่วงของอัตราเฉือนที่ทำการศึกษาที่อัตราส่วนผสม 30% ไม่พบการเกิดการเสีรูปร่าง ค่าความถี่ของการเสีรูปร่างมีค่าต่ำสุดเมื่อใช้อนุภาคไทเทเนียมที่เคลือบผิวด้วยกรดสเตียริก เมื่อเพิ่มขนาดความยาวสายโซ่โมเลกุลที่เริ่มเกิดการเสีรูปร่างมีค่าเพิ่มขึ้นทั้งนี้เนื่องจากการคลายตัวของสายโซ่โมเลกุลในระหว่างอยู่ในคาย

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**ABBREVIATION**

L/R	Length per radius of die
iPP	Isotactic polypropylene
sPP	Syndiotactic polypropylene
Wt%	Percentage by weight
MFR	Melt flow rate
CaCO	Calcium carbonate
TiO <sub>2</sub>	Titanium dioxide
PN	Polyoxyethylene nonphenol
SEM	Scanning electron microscope
HIPS	High impact polystyrene



## LIST OF SYMBOL

$\tau$	Shear stress
$\gamma$	Shear strain
$\dot{\gamma}$	Shear rate
$V$	Velocity
$\eta$	Shear viscosity
$\sigma$	Tensile stress
$\varepsilon$	Engineering strain
$\eta_e$	Elongational viscosity
$\tau_{app}$	Apparent shear stress
$\dot{\gamma}_{app}$	Apparent shear rate
$Q$	Volumetric flow rate
$\tau_{real}$	Real shear stress
$\dot{\gamma}_{real}$	Real shear rate
$Pe$	Exit pressure
$\dot{\varepsilon}$	Elongational rate
$\eta_{elong}$	Elongational viscosity
$D, D_{ex}$	Diameter of the extrudate
$D_0$	Diameter of the die
$B$	Extrudate swell
$\nu$	Frequency