EFFECT OF THE CONDITIONS OF FILM PROCESSABILITY OF LOW DENSITY POLYETHYLENE IN THE MECHANICAL PROPERTIES

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Introduction

Production of polymer films is of great importance from a commercial point of view, especially in packaging [1]. In film blowing, the polymer is biaxially oriented in the melt state and rapidly cools down in order to freeze the oriented structure [3]. Several studies [2– 4] focused on the structure of polyethylene blown films, especially orientation and anisotropy of polyethylenes. The main parameter controlling anisotropy, for example MD/TD tear resistance, is the lamellar structure of the film (morphology). Molecular orientation imparted during film blowing is known to have a major effect on the mechanical properties. Therefore, characterization of film morphology is crucial to predict the final properties of the films.

The main objective of this work was to study the tensile properties of LDPE blown films. Tensile modulus both MD and TD are reported and the results are related changing the following parameters: the bubble differential pressure (25, 50 y 100 mmH_2O); the extrusion velocity (20, 30 y 40 rpm); The angular velocity of the take-up rollers (60, 80, 100, 120, 140 y 160); the freeze-line height, the angular velocity of the take-up rollers, and the final film diameter were also measured in order to calculate the polymer flow rate, to determine the variants in the mechanical properties.

Experimental

Low density polyethylene (LDPE) PX20020 by PEMEX was used.

Preparation of Tubular Films

A single-screw extruder (Haake Rheomix 254) coupled with a blown-film device was used to prepare tubular films. Technical specifications of the experimental setup are reported in Table 1.

Figure 1 shows a schematic of the system used. A water manometer was fixed with the blowing air feed to measure the bubble differential pressure and a bypass line was used to mitigate pressure variations inside the bubble. A digital camera and a squared pattern were used to measure the freeze-line height. The angular velocity of the take-up rollers and the final film diameter and thickness were also measured in order to calculate the polymer flow rate. Different draw ratios (DR¼V_f/V_0), defined as the take-up roller velocity (V_f) divided by the extrusion velocity (V_0), were used to study the effect of this parameter on morphology, barrier, and tensile properties. One important parameter in the film blowing process that is seldom reported is the stretching force (F) [5–7]. Similar to earlier investigations [6,7]. The stretching force was measured using a device based on the principles of a torque wrench and consisting of two rubber rolls. The processing conditions are given in Table 2 and further details of the equipment can be found elsewhere [8].

Table 1. Specifications of the film blowing equipment used (single-screw extruder Haake Rheomix 254).

Barrel	
Screw diameter, D	19mm
Screw length, L	25 D
Heating zones	3
Annular die	
Diameter	25mm
Pin diameter	24mm
Gap width	0–0.8mm
Functionality	
Heater capacity/zone	1000W

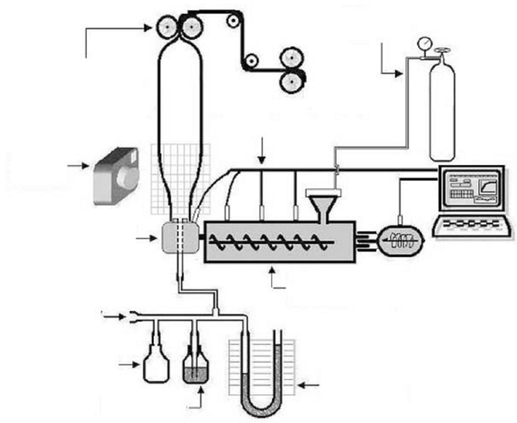

Figure 1. Schematic diagram of the film blowing experimental set-up.

Tensile Tests

Tensile properties were determined at room temperature using a United machine (model Instron 4411) in accordance with ASTM D882-02 method. In order to study anisotropy, two sets of specimens were prepared having their longer axis parallel and normal to the suspected direction of anisotropy (TD and MD), respectively.

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Table 2. Processing parameters for film blowing of LDPE.

Processing parameter	Nomenclature	Value	Units
Die radius[a]	R_0	12.15	mm
Die gap[a]	H_0	2.9	mm
Volumetric flow[a]	Q	10.86	m^3/min
Bubble pressure[a]	P	245,	Pa
		490,	-
		980	-
	$DR = V_f / V_o$	12-112	-
Draw ratio[a]	$TR = H_o / H_f$	30-210	cm
Thickness ratio[b]	$BUR = R_f / R_o$	1.8-2.4	^{0}C
Blow-up ratio[b]	Z	0.1-8.5	g/cm^3
Freeze-line height[b]	T_d	250	
Die temperature[a]	ρ_S	0.92	g/cm^3
Solid density of LDPE at 25 ^{0}C[c]	ρ_m	0.73	
Melt density of LDPE at 250 ^{0}C[c]			

Results and Discussion

Film Processability

Figure 2 shows the regions where it was possible to collect experimental data; i.e., stable bubble operation. Considering mass conservation, it is possible to calculate the mass flow (*w*) as [9]:

$$w = \pi[(R_o + H_o)^2 - R_o^2]V_o\rho_m = 2\pi R_f H_f V_f \rho_s \quad (1)$$

where V_0 and V_f are the velocities of the material at the die level and freeze-line level, respectively; and ρ_m and ρ_s are the melted and solid polymer densities, respectively. Using dimensionless parameters as defined in Table 2, Equation (1) can be written as:

$$\frac{1}{TR} = \frac{(R_0+H_0)-R_0^2}{2R_0H_0}\left(\frac{\rho_m}{\rho_s}\right)\frac{1}{DR\ BUR} \quad (2)$$

From Equation (2), a linear relationship exists between TR^{-1} and $(DR \& BUR)^{-1}$. Figure 3 shows that Equation (2) holds true for all the film produced. From the data presented in Figure 4, a slope of 0.95±0.02 was obtained by linear regression. This value is in agreement with the theoretical value calculated from Equation (2) using the geometry and physical properties of the polymers [8].

Conclusion

The processing conditions were found to modify substantially the mechanical and barrier properties of LDPE blown films. Draw ratio was found to affect directly the structure, providing orientation predominantly in the MD (fiber alignment). These morphologies produced a difference in the normal stresses, which make the material anisotropic. The degree of anisotropy was quantified in relation with the tensile strength in the MD and TD. It was found to depend on processing conditions.

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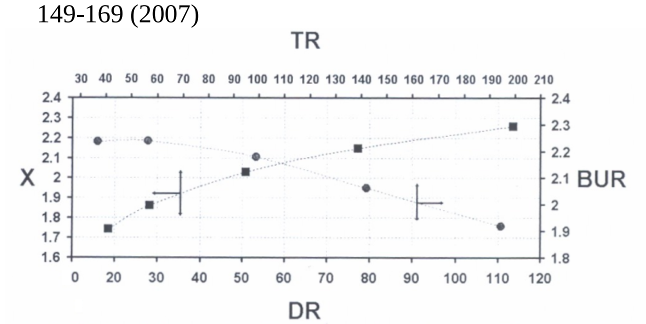

Figure 2. Experimental geometric data from LDPE blown film process.

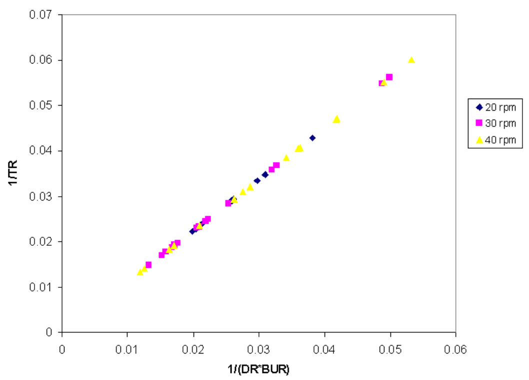

Figure 3. Relationship between TR"1 and (DR & BUR)" 1 for LDPE blown films.

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