Processing, MD and TD Stretching of Cast Polypropylene Film and Evaluation of Film Performance

Bayazian H, Morshedian* J, Jamshidi A, Razavi-Nouri M
Iran Polymer and Petrochemical Institute, P. O. Box: 14965-115, Tehran, Iran
**j.morshedian@ippi.ac.ir*

Abstract

Not all the polypropylene of film grades are suitable for manufacturing of biaxially stretched film. Material selection was implemented via hot tensile and rheological tests. Processing conditions were optimized for producing very thin uniform oriented film in machine and transverse directions. Different physical and mechanical properties pertaining to performance of the film in packaging application were measured and compared to the undrawn film. The enhancement in properties arises from stress induced crystallization and formation of row-nucleated lamellar structure.

Keywords: Polypropylene, Cast Film, Biaxially Stretching, Orientation.

Introduction

Biaxially oriented polypropylene film is produced when polypropylene film is stretched in both machine and transverse directions directly following cast film extrusion. BOPP film is used in wide variety of applications including food, beverage and medical packaging. Many isotactic polypropylenes of film grades have relatively low melt strength and a micro structure not suitable to withstand high stretch ratios. On the other hand optimizing processing variables is very important to obtain a uniform film of high clarity. The morphology of the oriented isotactic polypropylene may change from spherulite shape to row-nucleated lamellar structure [1]. The present work attempts to select a polypropylene grade of appropriate structure to undergo high biaxial extension under various conditions in an optimized processing machine. Then performance of the produced film is evaluated.

Experimental

Material used

Five commercial grades of isotactic polypropylene with characteristics listed in table 1 were used for hot stretchability test. The grade which was qualified was employed on the BOPP film production line.

PP grades	Company	MFI (g/10min)	Main application
HP	Jam	3.0	Film
570P	Sabic	8.0	Film, Injection
510M	Jam	9.0	Film
D50S	Arak	6.0	Film
510L	Jam	6.5	Film

Table 1: Used polypropylene grades: MFI and main applications.

Processing

Cast film extrusion of PP implemented in an extruder of L/D = 34 between 220°C to 250°C, screw speed of 190 rpm with a coat hanger type of die of 900 mm in width. The screw metering zone was chosen long and shallow to ensure melt homogenization. Chill roll casting technic was employed to make a film which was fed in to a preheating zone at 120°C followed by longitudinal stretching with draw ratio of 5 achieved by combination of rollers at a temperature near the recrystallization temperature (~110°C). After annealing at 130°C and second preheating, transverse stretching with draw ratio of 10 was carried out in a frame of diverging chain (rotary clamps) fitted with clips at temperature of 150°C. In order to reduce the tendency of the film to shrink, final film was annealed at 160°C while under tension immediately after transverse drawing. The schematic of the production line is shown in Figure 1. This assembly is made by Brückner Maschinenbau German Company.

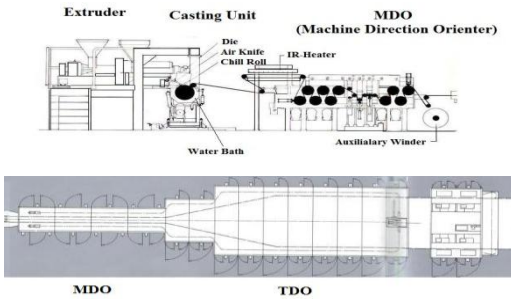

Figure 1: Schematic of casting unit and machine direction orienter (MDO) unit (side view) and transverse direction orienter (TDO) unit (top view).

Results and Discussion

The result of different polypropylene grades uniaxially drawn at the maximum speed of the present tensile testing machine, corresponding to the machine direction speed in our film stretching unit at the recrystallization temperature is shown in Table 2.

Table 2: Elongation at break (%) for different polypropylene grades.

%	HP	570P	510M	D50S	510L
25°C	1206.82	11.58	14.86	36.39	20.68
90°C	Didn't break	3300	4200	Didn't break	3600

This result demonstrated that only one of the tested PP film grades withstood high draw ratio stretching at different conditions. The HP grade with excellent respond to high elongation was put into trail test in our BOPP film production line. With optimization of different processing conditions, a uniform biaxially stretched film of about 20 microns in thickness was produced. The DSC thermogram of this film in comparison with that of the hot pressed film is depicted in Figure 2. Apart from increased crystallinity appearance of a shoulder on the melting endotherm at about 160°C is a clear indication of formation of the β crystalline phase arising from orientation induced row-nucleated lamellar structure. The main endothermic peak at 166°C is due to the α crystal form of conventional spherulitic structure encountered under quiescent condition. Table 3 compares the physical properties pertaining to packaging performance of the produced film with those of the undrawn film. It is observed that all the properties are enhanced due to chain orientation [3]. The oriented film has less haze, more gloss and higher degree of clarity due to lesser variation in refractive index across the layered crystalline structure of the film. It also has higher tensile strength and less permeability due to chain orientation, developed lamellar morphology and strain induced crystallization with smaller crystallites [2]. Rheological measurements revealed the major difference in microstructure between the stretchable HP grade and the other grades, the report of which is given elsewhere.

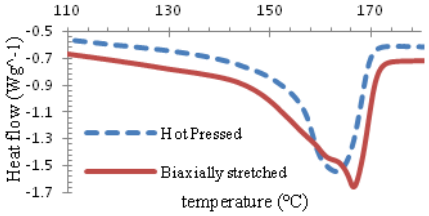

Figure 2: DSC curves for hot pressed and biaxially stretched films of HP grade PP

Conclusion

Relying merely on the manufacturer's information sheet, such as MFI and type of application, is not enough to select a polypropylene grade qualified for the biaxially film stretching process. As among five film grades of PP with MFI's falling in the same range, only one grade did not fail and responded satisfactorily to high stretching in the machine and transverse directions. Hot tensile and rheological measurements are powerful screening tests in this regard. Partly formation of row-nucleated lamellar structure with characteristic β crystals as well as stress induced crystallization is consequence of biaxially chain orientation over conventional spherulitic structure of iPP with α crystal. Improvement in clarity, permeability and other physical/mechanical properties owe to chain orientation and crystal size and structure modification.

References

1. Mollova A., Androsch R., Mileva D., Gahleitner M., Funari S.S., Crystallization of isotactic polypropylene containing beta-phase nucleating agent at rapid cooling, *Europian Polymer Jurnal.*, 49, 1057–1065, 2013.
2. Tabatabaei S.H., Carreau P.J., Ajji A., Effect of processing on the crystalline orientation, morphology and mechanical properties of polypropylene cast films and microporous membrane formation, *Polymer*, 50, 4228-4240, 2009.
3. Capt L., Kamal M.R., Münstedt H.Stopperka K. Sänze J., Morphology Development during Biaxial Stretching of Polypropylene Films.

Table 3: Some physical properties of hot pressed and biaxially stretched films of HP grade PP.

	Meting point (°C)	ΔH (crystallinity) (J/g)	Permeability (cm^3/m^2d bar)	Elongation at break (%)	Tensile strength (N/mm^2)	Gloss (GU %)	Haze	Printability	Heat seal ability
Hot pressed film	163	95	3450	392.39	4.86	40%	0.9	Poor	Poor
Biaxially Stretched film	160, 166	107.32	2110	149.28	11.68	95%	0.5	Improved	Improved