PP-Blends with Tailored Foamability and Mechanical Properties

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ABSTRACT

The optimisation of physical foaming of branched Daploy™ WB130HMS polypropylene foam resin and corresponding blends with a Polypropylene Blockcopolymer are described in this paper. The resulting foam morphologies of blends consisting of linear and branched polypropylene materials produced at various processing temperatures were studied using a single-screw tandem foam extrusion system and their volume expansion behaviours were compared. Three different die geometry's were tested for physical foaming of PP-blends using 5 and 10 wt% of butane. A correlation between extensional rheology and lower limit of foam density for blends was found. Depending on die geometry the use of different concentrations of branched polypropylene resin in the blends was required to achieve foam densities < 50 kg/m^3. The influence of foam density and blend ratio on mechanical properties of foams will be discussed on a model and representative samples.

1. INTRODUCTION

Polypropylene foams are considered as a substitute for other thermoplastic foams in industrial applications due to several reasons beyond its lower costs. They have a higher rigidity compared to other polyolefins, offer higher strength than polyethylene, better impact strength than polystyrene, and they provide higher service temperature range and good temperature stability compared to both classes of materials.

However, since standard linear polypropylene shows low melt strength, low extensibility and thus poor foamability, another class of polypropylenes must be

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used. Technologies were established for the production of long-chain branched polypropylene which led to the high-melt-strength polypropylene resins for the production of low density foams. Reasons for their better performance in foaming are their enhanced extensional flow properties, i.e. increased melt strength and increased extensibility of the melt. HMS-PP materials can be foamed either in its pure form yielding rigid foams, or as a blend with other polyolefins in order to tailor the mechanical properties of the foams.

This publication investigates the influence of blending HMS-PP with a polypropylene block-copolymer. The interrelations of blend ratio on the extensional rheology, on foamability, and on the mechanical properties of final polypropylene foams are discussed.

2. EXPERIMENTAL

2.1 Materials

Two Borealis polypropylenes were used in the present work. One of them, Daploy™ WB130HMS is a branched homopolymer with high melt strength and high extensibility. The second material, BC250MO, is a standard Polypropylene Block-copolymer with ethylene commonly used for injection molding.

Table 1 Material data

		HMS-PP	PP Block Copolymer
Manufacturer		Borealis	Borealis
Trade name		WB130HMS	BC250MO
$MFR_{230/2.16}$	g/10min	2	4
Melt Strength	cN	34	5,3
Extensibility	mm/s	224	133
Tensile Modulus	MPa	2000	1250
Tensile at Yield	%	6	6
Elongation at Break	%	12	460

2.2 Testing of Material Properties

The extensional flow properties of the melt and the mechanical properties of injection molded test specimen were investigated with the Rheotens test, and the tensile test according to ISO527, respectively. The Rheotens experiment simulates industrial spinning and extrusion processes. In principle a melt is pressed or extruded through a round die and the resulting strand is hauled off. The stress on the extrudate is recorded, as a function of melt properties and measuring parameters (especially the ratio between output and haul-off speed, practically a measure for the extension rate).

For the results presented below, the materials were extruded with a lab extruder HAAKE Polylabsystem and a gear pump with cylindrical die (L/D = 6.0/2.0 mm). The gear pump was pre-adjusted to a strand extrusion rate of 5 mm/s, and the melt temperature was set to 200°C. The Göttfert Rheotens tester was operated at constant acceleration of the pulleys (120 mm/s^2). The end points of the Rheotens curve (force versus pulley rotary speed) is taken as the melt strength and extensibility values.

2.3 Experimental Setup for Foaming

This setup is intended to determine the processing window of the selected materials and its blends with butane as a foaming agent in a broad range of melt temperatures with different die geometries. The achieved minimum densities are around 30 kg/m^3.

A tandem foam extrusion setup was used for this purpose. It consists of a 5-hp extruder drive with a speed control gearbox (Brabender, Prep Center), a first 3/4" extruder (Brabender, 05-25-000) with a mixing screw (Brabender, 05-00-144) of 30:1 L/D ratio, a second 1 1/2" extruder (Killion, KN-150) with a built-in 15-hp variable speed drive unit with a 18:1 L/D ratio. The other systems include a positive displacement pump for butane injection, a diffusion enhancing device containing static mixer (omega, FMX-84441-S), a gear pump (Zenith, PEP-II 1.2 cc/rev) where the volumetric displacement is properly controlled by the motor, a heat exchanger for cooling the polymer melt that contains homogenizing static mixers (Labcore Model H-04669-12), a cooling sleeve for the precise control of die temperature. The first extruder is used for the plastication of the polymer resin while the second extruder is responsible for mixing and initial cooling of the polymer melt. The gear pump controls the polymer melt flow rate and the heat exchanger further homogenizes and cools the melt. Three different dies (1) L/D = 0.1"/0.018", (2) L/D = 0.3"/0.040", and (3) L/D = 0.5"/0.040") were used in this study.

The polypropylene material pellets blended with 0.8 wt% talc as cell nucleating agent were first fed into the barrel through the hopper and were completely melted by the screw rotation. Then a metered amount of butane was injected into the extrusion barrel by a positive displacement pump and mixed intensively with the polymer melt stream. The single-phase polymer/gas solution passed through the gear pump and was fed into the heat exchanger where it was cooled to a designated temperature. The cooled polymer/gas solution entered the die and foaming occurred at the die exit through a process of thermodynamic instability induced via rapid pressure drop. The melt and die temperatures were synchronized for simplicity in this study. While optimizing all the parameters, the melt and die temperature were lowered gradually and samples were randomly collected at each designated temperature when no further change was observed in the pressure.

2.4 Characterization of the Foams

The density of the foams was determined by measuring the weight and volume of the sample.

For representative samples made from defined blends of WB130HMS and BC250MO with industrial foaming lines, tensile tests according to ISO527 and falling dart tests were performed.

3. RESULTS AND DISCUSSION

3.1 Mechanical Properties of Blends

Daploy™ WB130HMS is a homopolymer based material. Although it enables the production of very low density foams, these tend to be rather stiff. However, because it is pure PP material, it can be blended with the full range of other standard PO materials to modify the final foam properties to fit the requirements of the particular end-use application (see Table 2).

As with all polymer blends, the final blend properties depend on the properties of the individual materials and the blend ratio.

For our particular system, tensile tests have been performed with the pure materials, as well as with a 50/50 blend of WB130HMS and BC250MO. It shows, that the block-copolymer has lower tensile modulus with 1250MPa, while the pure HMS-PP homopolymer has a tensile modulus of 2000MPa. The blends show tensile modulus right between the two pure materials. In terms of elongation at break, the pure block-copolymer has an elongation at break of 450%, while the HMS-PP homopolymer shows elongation at break values of 12%. No linear relationship of elongation at break and blend ratio was found. This is indicated in Figure 1.

Table 2 Effect of Blend Partners to Daploy™ WB130HMS

Blend Partner	Foam Property Modifications
Block Copolymer	• Improved Low Temperature Impact • Reduced Stiffness • Increased Toughness
Random Copolymer	• Softer Foams • Improved Toughness
Borsoft™ PP's	• Soft Foam • Good Low Temperature Impact
m-PE's	• Very Soft Foams • Good Low Temperature Impact

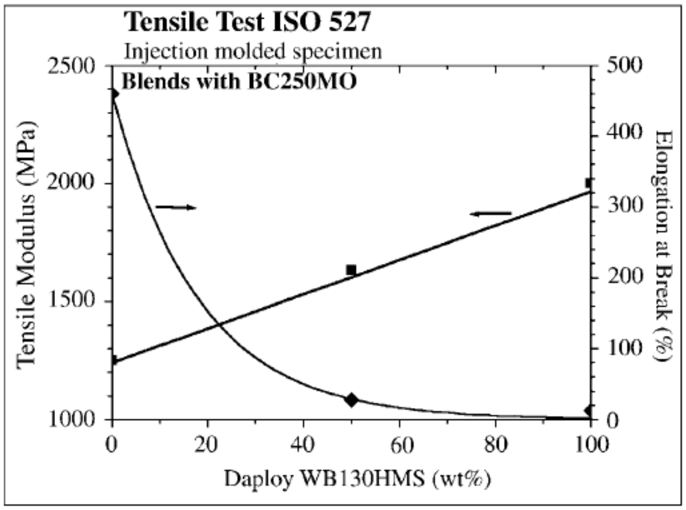

Figure 1 Mechanical properties of HMS-PP blends

3.2 Extensional Rheology of Blends

The most important consideration for foam production is the effect of the blend partner on the achievable foam density at a given production set up. In this respect the linear blend partner will have a "diluting" effect on the benefits of the pure HMS and reduce its effectiveness. The reason for this is a changed

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