Unlock new opportunities in packaging

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Abstract

A unique polymer design gives Achieve™ Advanced Polypropylene exceptional properties in packaging. The higher stiffness and broader molecular weight distribution of the polymer help unlock opportunities for downgauging, high temperature resistance and process window improvement in applications including thermoformed rigid cups and containers.

Introduction

Since the latter half of the 20th century, polypropylene (PP) production and use has been growing phenomenally, at the same time polypropylene has been rapidly penetrating the packaging field, as well as many other applications, due to its excellent combination of physical, thermal and chemical properties. [1] While the semicrystalline nature of PP gives PP the advantage of these properties in packaging applications, it also leads to challenges in processing for PP converters. Thermoforming has traditionally been used with amorphous polymers such as polystyrene as they can be relatively easy to process above the glass transition temperatures with a large process window. [2] PP is traditionally more difficult to process due to its low melt strength, which makes it easier to sag during thermoforming. [3]

The goal of this paper is to give an overview of Achieve™ Advanced PP in packaging applications and the improved process window and part quality thanks to higher stiffness and melt strength.

Materials

Two PP resins manufactured by ExxonMobil Chemical Company were used for the experimental work. Both resins had a solid density of 0.900 g/cm3. Other properties could be found in Table 1.

	Test based on	ExxonMobil™ PP6272NE1	Achieve™ Advanced PP6282NE1
Melt Mass-flow Rate (230°C/2.16 kg), g/10 min	ASTM 1238	2.8	1.8
Tensile strength at yield 2.0 in/min, MPa	ASTM D638	37.2	38.3
Flexural Modulus (1% Secant), MPa	ASTM D790A	1700	2020
Thermal Deflection Temperature at 66psi, °C	ASTM D648	110	116

Table 1. Selected properties of ExxonMobil™ PP6272NE1 and Achieve™ Advanced PP6282NE1

Discussions

Due to its unique molecular design, Achieve™ Advanced PP6282NE1 has a broader molecular weight distribution, compared to ExxonMobil™ PP6272NE1 and a competitive PP grade, as shown in Table 2.

	Achieve™ Advanced PP6282NE1	ExxonMobil™ PP6272NE1	Competitive grade PP
Mw/Mn	14.1	8.4	8.1

Table 2. Molecular weight distribution of Achieve™ Advanced PP6282NE1, ExxonMobil™ PP6272NE1 and a competitive grade PP.

A Rheotester 1000 capillary rheometer in combination with the Rheotens 71.97 (Göttfert) was used for melt strength testing at 190°C and 300 s melting time. Material present in the barrel of the Rheotester is extruded through the die and is picked up by the rolls of the Rheotens. Once the strand is placed between the rolls, the roll speed is adjusted till a force 0 is measured. This beginning speed Vs is the speed of the strand through the nip of the wheels at the start of the test. Once the test is started, the speed of the rolls is increased with a 12.0 mm/s² acceleration and the force is measured for each given speed. After each strand break, or strand slip between the rotors, the measurement is stopped and the material is placed back between the rolls for a new measurement. A new curve is recorded. Measuring continues until all material in the barrel is used. Achieve™ Advanced PP6282NE1 has a much higher melt strength of 46.5 cN, compared to the other two commercial PP grades, as shown in Figure 1.

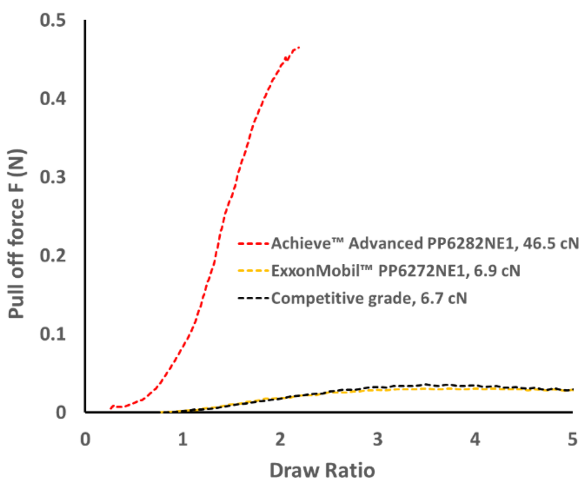


Figure 1. Melt strength comparison of Achieve Advanced PP6282NE1, ExxonMobil PP6272NE1 and a competitive commercial PP grade

A sheet temperature window study was done on an in-line thermoforming machine with a single cavity 16-ounce cup tool at 1.9 mm sheet gauge. The result is shown in Figure 2. Oven temperatures were changed to determine the upper and lower limit of sheet temperature while maintaining cup quality. Sheet temperature was determined by an infrared temperature sensor before entering the former. Achieve Advanced PP6282NE1 has a wider sheet temperature window. Sheet sag has been a challenge for polypropylene in thermoforming as general purpose PP has low melt strength and cannot hold the weight while being heated in the oven. High melt strength of Achieve Advanced PP6282NE1 helps to keep sheet sag at a minimal level while being heated. Thus providing thermoformed parts with more uniform material distribution and wider process window.

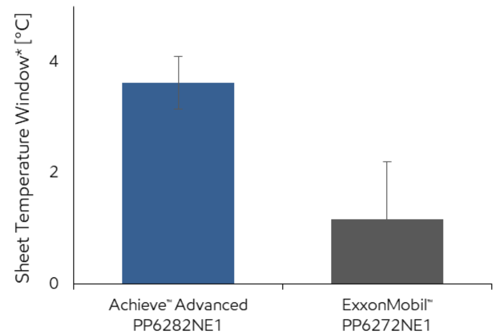


Figure 2. Sheet temperature window during thermoforming of Achieve™ Advanced PP6282NE1, ExxonMobil™ PP6272NE1, average of multiple trials

Improving thermoforming cycle speed has been a key focus for thermoformers to improve their production efficiency. A sheet with a 1.6mm gauge and 750 mm width PP sheet and a roll fed thermoforming machine with a single cavity 16-ounce cup tool was used for the thermoforming cycle speed study. Process parameters were optimized for each sample to determine maximum cycle speeds which maintained cup quality. The results are shown in Figure 3. Achieve Advanced PP6282NE1 has the fastest cycle speed among the three commercial PP grades. The relatively high process temperature could contribute to the improvement. [4]

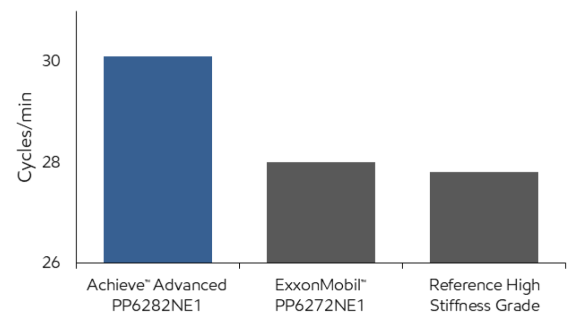
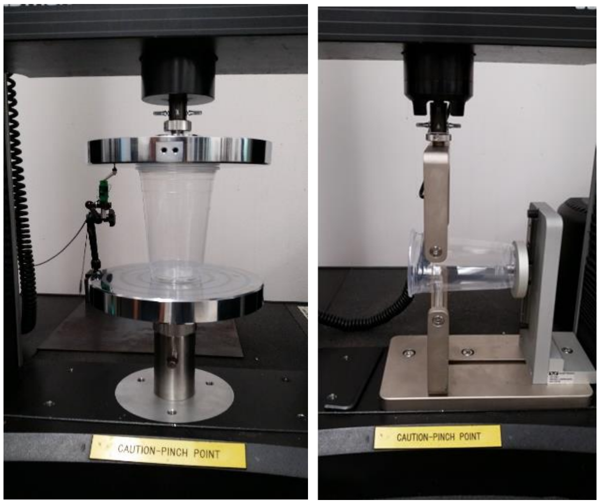


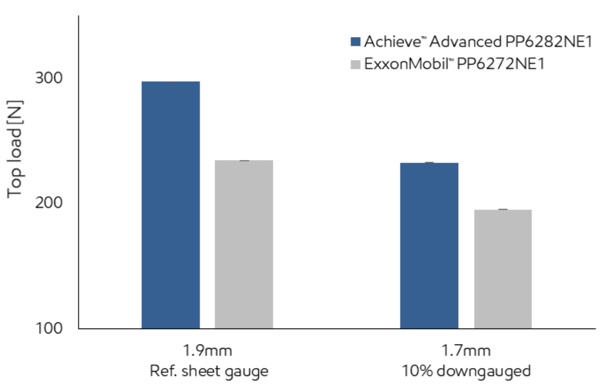
Figure 3. Thermoforming cycle speed study of three commercial grade PP

Due to the high stiffness of Achieve Advanced PP6282NE1, the thermoformed parts also present better rigidity at different dimensions. Top load and side load test of 16 oz thermoformed cups were performed using a specially designed setup as shown in Figure 4.

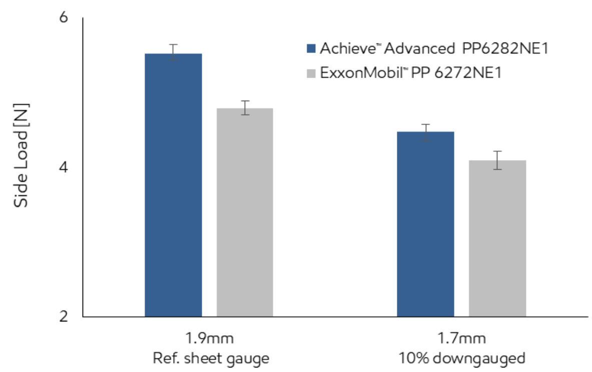


(a) (b)

Figure 4. Experimental setup of (a) top load test and (b) side load test (Photos taken from Product Technology Lab in ExxonMobil Chemical Baytown Technology and Engineering Complex)



(a)



(b)

Figure 5. (a) Top load and (b) side load test result for 16 oz thermoformed cups from Achieve™ Advanced PP6282NE1 and ExxonMobil™ PP6272NE1.

Test were done on an Instron® 5566. The bottom part is kept still and the top part moves down at a constant speed. Top load and side load test results are shown in Figure 5. Achieve Advanced PP6282NE1 and ExxonMobil PP6272NE1 were used for in line thermoforming at 1.9 mm and 1.7 mm gauge thickness. The cups made from Achieve Advanced PP6282NE1 have higher top load and side load at both gauges. While Achieve Advanced PP6282NE1 at 1.7 mm thickness has similar top load with ExxonMobil PP6272NE1 at 1.9 mm thickness, which indicates a potential 15% of downgauging capability.

Conclusions

Achieve™ Advanced PP6282NE1 is a high melt strength homopolymer that can provide uniform wall distribution in thin wall packaging and excellent processing characteristics in extrusion and thermoforming processes. Due to its higher stiffness and higher melt strength, Achieve Advanced PP6282NE1 has an improved process window and faster cycle speed during thermoforming process. The thermoformed cups from Achieve Advanced PP6282NE1 also have better stiffness at different dimensions and up to 15% downgauging capability compared to conventional commercial grade PP.

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