ONLINE CHARACTERIZATION OF POLYPROPYLENE FIBERS DURING MELT SPINNING

Srinivasa Varkol, Gary C. Lickfield
SCHOOL OF MATERIALS SCIENCE AND ENGINEERING, CLEMSON UNIVERSITY
Kate Stevens
THE CENTER FOR ADVANCED ENGINEERING FIBERS AND FILMS, CLEMSON UNIVERSITY

Introduction

Polypropylene fibers are produced via melt spinning (Figure 1). The amorphous molten polymer exiting the spinneret (die) is transformed into a semi-crystalline fiber before reaching the take-up roll. The fine structure of the fiber is developed with in the length of the spin-line. The structure and properties of the fiber are dependent on the spinning conditions. Online measurements along the spinline gives insight into how the processing conditions affect the real time development of fine structure.

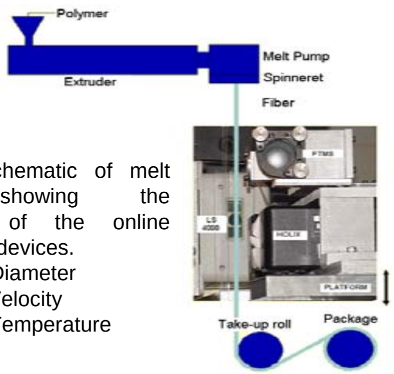


Figure 1. Schematic of melt spinning showing the arrangement of the online measurement devices.
HOLIX : Diameter
LS4000 : Velocity
FTMS : Temperature

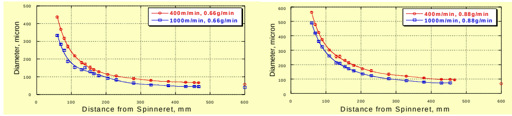
Research Objectives

Simultaneous online diameter, velocity and temperature measurement at intervals along the spin-line.
Study of the process-structure-property relation by measuring fiber properties offline.

Experimental

Resin (MFI, g/10min)	Polypropylene (35)
Throughput Rate, g/min/hole	0.66 and 0.88
Take-up Speed, m/min	400 and 1000
Extrusion Temperature, °C	220

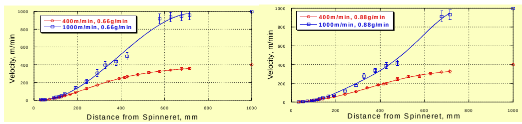
Online Measurements



(i) (ii)

Figure 2. Online diameter profiles as a function of distance from the spinneret at two different throughput rates: (i) 0.66 g/min; (ii) 0.88 g/min

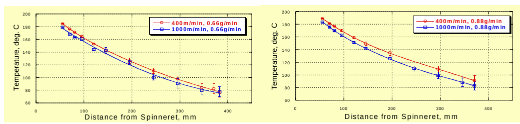
The fiber draws down rapidly up to 150 mm from the spinneret and the rate of draw down decreases thereafter. The final diameter decreases, with increase in take-up speed and decrease in throughput rate.



(i) (ii)

Figure 3. Online velocity profiles as a function of distance from the spinneret at two different throughput rates: (i) 0.66 g/min; (ii) 0.88 g/min

Fiber velocity increases at a faster rate at higher take-up speed and lower throughput rate. At higher take-up speed, fiber diameter is less and velocity is more. So, the spinline stress will be higher.



(i) (ii)

Figure 4. Online temperature profiles as a function of distance from the spinneret at two different throughput rates: (i) 0.66 g/min; (ii) 0.88 g/min

The fiber temperature does not vary much with take-up speed. With the increase in take-up speed, the fiber diameter decreases resulting in a greater heat loss. But this effect is reduced as the fibers are exposed to quench air for less time.

Structure-Property Relations

Fiber birefringence increases with increase in take-up speed or decrease in throughput rate.

The fiber tenacity obtained correlates well with the birefringence.

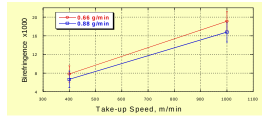


Figure 5. Fiber birefringence as a function of take-up speed. Two data sets are two throughput rates

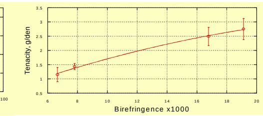


Figure 6. Tenacity of the fiber as a function of birefringence at all the processing conditions

Take-up Speed m/min	Throughput Rate g/min	Birefringence x1000	Crystallinity %	Tenacity g/den	Breaking Strain
400	0.66	7.81 (1.74)	43.9 (0.21)	1.43 (0.11)	5.93 (0.41)
400	0.88	6.66 (1.77)	43.8 (0.42)	1.15 (0.25)	6.39 (0.49)
1000	0.66	19.12 (2.05)	43.4 (0.08)	2.75 (0.37)	2.91 (0.55)
1000	0.88	16.78 (2.12)	43.1 (0.51)	2.49 (0.32)	3.32 (0.40)

Table 1. As-spun fiber properties measured at all the processing conditions. Values in parentheses are standard deviation

Crystallinity of the fiber does not vary within the processing conditions investigated.

Breaking strain of the fiber decreases with increase in take-up speed or decrease in throughput rate.

Conclusions

Simultaneous online fiber diameter, velocity and temperature were successfully measured. From these results, it was concluded that, for any given resin and extrusion temperature, spinline stress increased with an increase in take-up speed and/or decrease in throughput.

Process structure property relationships were studied by measuring as-spun fiber properties. With an increase in take-up speed spinline stress increased, and the molecules were oriented in the direction of fiber axis. Hence, birefringence and tenacity of the fiber increased and breaking strain decreased