



Twisted lamellae in water-assisted injection molded high density polyethylene

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ABSTRACT

A distinct skin-core-water-channel structure was formed in water-assisted injection molded low molecular weight high density polyethylene. A large number of well-developed banded spherulites were observed in core region. Two types of shish-kebabs, i.e., shish-kebabs without and with twisted lamellae, were appeared in both skin and water-channel region. The results imply that the formation mechanisms of twisted lamellae in banded spherulites and shish-kebabs are different, but both depend on the level of applied shear stress.

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1. Introduction

During practical polymer processing, polymer products consist of two distinct crystalline morphologies: spherulites and shish-kebabs [1–10]. Non-banded spherulites are commonly obtained in polymer processing, but banded spherulites are scarcely found. Some researchers have reported that banded spherulites can be formed in injection molded polyethylene parts under flow fields with certain intensity [3,4]. Although the formation mechanism of banded spherulites has been widely investigated in the quiescent polymer melt, there is still no general agreement about how and why the crystalline lamellae twist in spherulite. On the other hand, researches on the flow induced shish-kebabs have attracted extensive attention because the shish-kebab structures can bring out notable reinforcement on polymer products [5–10]. Recently, the X-ray exploring indicated a twisted kebab growth mode after the formation of the early shish scaffold structure in the entangled high density polyethylene (HDPE) melts which seemed to be connected with the shear rate [10], nevertheless, its nature is still

unclear and controversial.

Recently, we have carried out intensive investigation on polyolefin achieved by water-assisted injection molding (WAIM) [5–7]. During WAIM process, melt is compelled to successively flow twice, i.e., melt filling and water penetration. More importantly, the injected water can significantly accelerate the cooling rate of the interior melt. In order to systematically understand the crystal morphologies of WAIM samples, in this work, the crystalline morphology and orientation of low molecular weight HDPE obtained via WAIM is investigated and analyzed.

2. Experimental section

Commercial HDPE 2911 with number-average molecular weight of 1.2×10^5 g/mol was purchased from Fushun Petro Co., China. Injection molding machine (HTF80B-W2) with a controllable water injection unit was used for preparing WAIM specimens with cylindrical shape. The melt injection temperature was 180 °C, and the melt and water injection pressures were 75 and 15 MPa, respectively. The detailed information for devices and processing parameters were described elsewhere [5–7]. The morphology of WAIM specimens was examined using scanning electron microscopy (SEM, FEI/Phillips Quonxe-2000). The specimen preparation and selected region for SEM measurement are

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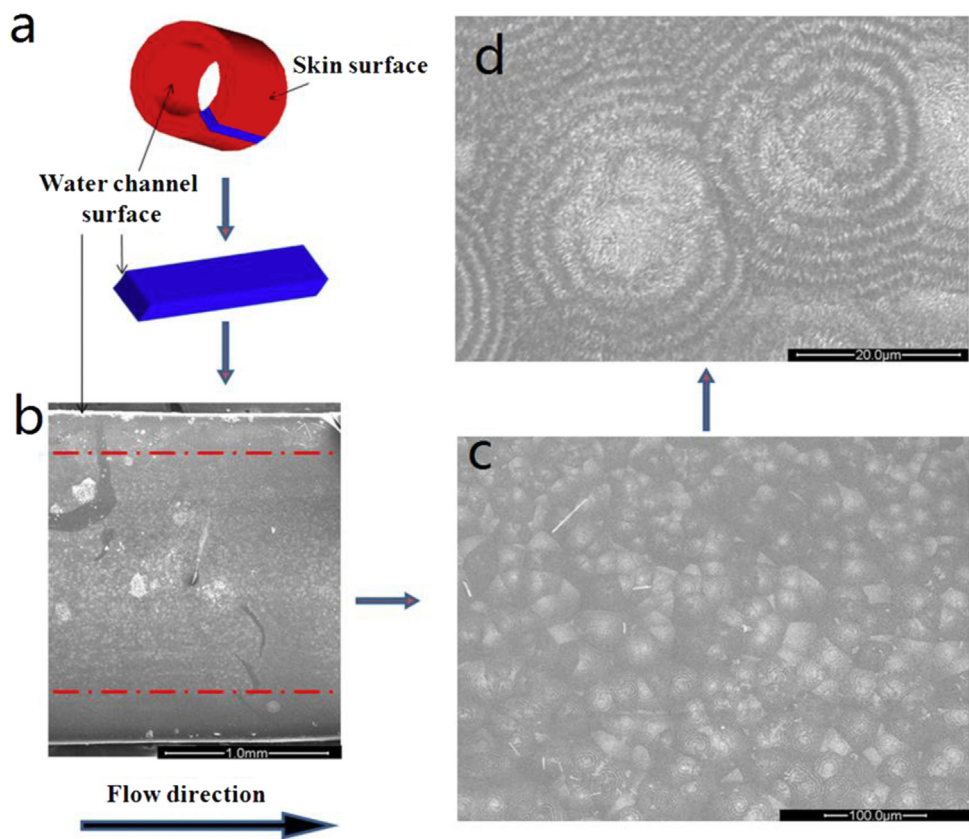


Fig. 1. (a) Schematic of WAIM parts for SEM observation and (b) the crystalline morphology across the thickness and (c, d) the high magnifications SEM images in core region.

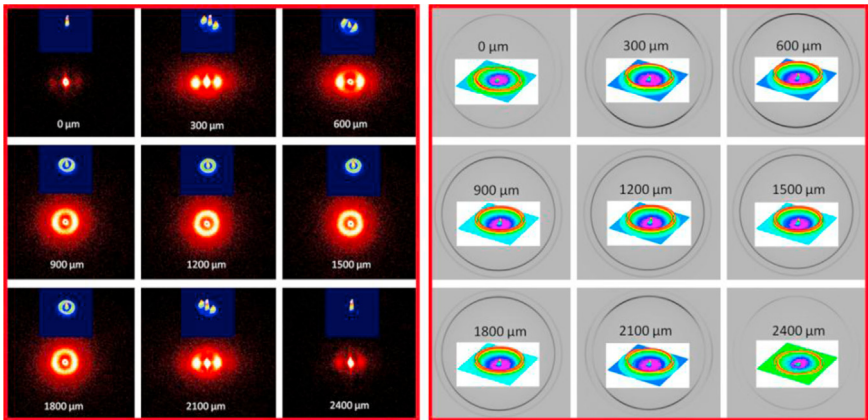


Fig. 2. SAXS (Left) and WAXD (Right) patterns of WAIM parts at selected positions from skin surface to water-channel surface.

Table 1
Orientation parameters (f_{SAXS} , f_{WAXD}), long period (L) and crystallinity (X_c).

Distance/ μm		0	300	600	900	1200	1500	1800	2100	2400	5000
f_{SAXS}	CIM	0.58	0.65	0.51	0.11						
	WAIM	0.80	0.67	0.51	0.14			0.05	0.64	0.69	
f_{WAXD}	CIM	0.45	0.63	0.36	0.11						
	WAIM	0.48	0.78	0.59	0.19			0.24	0.57	0.27	
L	CIM	21.3	21.6	23.5							27.6
	WAIM	19.0	20.5	21.9	22.8	23.1	23.1	22.8	21.0	21.0	
X_c	CIM	0.61	0.73	0.76							0.76
	WAIM	0.60	0.68	0.71	0.72	0.73	0.73	0.67	0.72	0.58	

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