molecular weight distribution (greater M_w/M_n value), whereas LLDPE has a narrower molecular weight distribution (lesser M_w/M_n value). These structural and compositional differences result in the rheological (melt flow) properties of LDPE being significantly different from those of LLDPE. Thus, surface melt fracture performance of LLDPE is not predictable from surface melt fracture performance of LDPE.

SUMMARY

[0006] We discovered a problem with surface melt fracture of linear low-density polyethylene (LLDPE). We found that LLDPE undergoes a slipstick transition and converts to a slip or fast-moving wavy extrudate surface at shear rates above 2,000 per second (s^{-1}) and shear stress about 0.2 megapascal (MPa). Surprisingly, however, at shear stress above 0.4 MPa, even above 0.5 MPa, and at shear rates above 1,100 s^{-1}, the problem did not worsen. In the latter higher-energy shear-stress regime a smooth surface LLDPE extrudate without surface melt fracture (SMF) unexpectedly forms.

[0007] An aspect of the present disclosure provides a method of extruding a melt of a linear low-density polyethylene (LLDPE) so as to form an LLDPE extrudate without surface melt fracture. The method comprises heating a melt of the LLDPE to a temperature from 190.0 to 260.0 degrees Celsius; extruding through a die the heated melt at a shear rate of from 1,101 to 7,000 per second and at a shear stress of greater than 0.41 megapascal, thereby forming a linear low-density LLDPE extrudate without the surface melt fracture; and cutting the LLDPE extrudate into pellets having surfaces without the surface melt fracture;

wherein a die hole of the die has a diameter from 0.5 to 1.4 millimeters (mm); and

wherein the method is characterized by any one of limitations (i) to (iv):

(i) the temperature of the melt of the LLDPE is from 190.0° to 226° C., the shear rate is from 1,201 to 1,830 s^{-1}, and the shear stress is from 0.47 to 0.49 MPa;

(ii) the temperature of the melt of the LLDPE is from 206° to 214° C., the shear rate is from 3,601 to 4,500 s^{-1}, and the shear stress is from 0.47 to 0.55 MPa;

(iii) the temperature of the melt of the LLDPE is from 226° to 234° C., the shear rate is from 3,201 to 3,500 s^{-1}, and the shear stress is from 0.47 to 0.53 MPa; or

(iv) the temperature of the melt of the LLDPE is from 246° to 254° C., the shear rate is from 2,601 to 3,600 s^{-1}, and the shear stress is from 0.44 to 0.57 MPa.

BRIEF DESCRIPTION OF THE DRAWING(S)

[0008] Figure (FIG.) 1: black-and-white photograph of a comparative LLDPE extrudate strand produced at comparative low shear rate values (less than 1,000 s^{-1}) and low shear stress values (less than 0.3 MPa). The strand has a smooth surface consistent with absence of surface melt fracture.

[0009] FIG. 2: black-and-white photograph of a comparative LLDPE extrudate strand produced at comparative medium shear rate values (1,000 to 2,500 s^{-1}) and medium shear

stress values (0.3 to 0.4 MPa). The strand has a rough, irregular surface resulting from surface melt fracture.

[0010] FIG. 3: black-and-white photograph of an inventive LLDPE extrudate strand produced at inventive high shear rate values (2,601 to 7,000 s^{-1}) and high shear stress values (0.41 to 0.6 MPa). The strand has a smooth surface consistent with absence of surface melt fracture.

[0011] FIG. 4: black-and-white photograph of inventive LLDPE extrudate pellets produced at medium shear rate values (1,000 to 2,500 s^{-1}) and inventive high shear stress values (0.41 to 0.6 MPa). The pellets have smooth surfaces consistent with absence of surface melt fracture.

CLAIMS

1. A method of extruding a melt of a linear low-density polyethylene (LLDPE) so as to form an LLDPE extrudate without surface melt fracture, the method comprising heating a melt of the LLDPE to a temperature from 190.0 to 260.0 degrees Celsius (° C.); and extruding through a die the heated melt at a shear rate of from 1,101 to 7,000 per second (s^{-1}) and at a shear stress of greater than 0.41 megapascal (MPa), thereby forming a linear low-density LLDPE extrudate without surface melt fracture; and cutting the LLDPE extrudate into pellets having surfaces without the surface melt fracture;

wherein a die hole of the die has a diameter from 0.5 to 1.4 millimeters (mm); and

wherein the method is characterized by any one of limitations (i) to (iv):

(i) the temperature of the melt of the LLDPE is from 190.0° to 226° C., the shear rate is from 1,201 to 1,830 s^{-1}, and the shear stress is from 0.47 to 0.49 MPa;

(ii) the temperature of the melt of the LLDPE is from 206° to 214° C., the shear rate is from 3,601 to 4,500 s^{-1}, and the shear stress is from 0.47 to 0.55 MPa;

(iii) the temperature of the melt of the LLDPE is from 226° to 234° C., the shear rate is from 3,201 to 3,500 s^{-1}, and the shear stress is from 0.47 to 0.53 MPa; or

(iv) the temperature of the melt of the LLDPE is from 246° to 254° C., the shear rate is from 2,601 to 3,600 s^{-1}, and the shear stress is from 0.44 to 0.57 MPa.

2. The method of claim 1 wherein the temperature of the melt of the linear low-density LLDPE is selected from: 190.0° to 226.0° C.; 206° to 234.0° C.; and 226° to 254° C.

3. The method of claim 1 or 2 wherein the shear rate is selected from: 1,210 to 1,840 s^{-1}; 1,850 to 2,500 s^{-1}; 2,650 to 4,490 s^{-1}; and 4,500 to 6,900 s^{-1}.

4. The method of any one of claims 1 to 3 wherein the shear stress is selected from: 0.43 to 0.49, 0.44 to 0.55, 0.56 to 0.70 MPa; and 0.71 to 1.0 MPa.

5. The method of any one of claims 1 to 4 wherein the die is maintained at a temperature from 140° to 240.0° C.

6. The method of any one of claims 1 to 5 wherein the linear low-density LLDPE is characterized by any one of limitations (a) to (e): (a) a melt index (I_2, 190° C., 2.16 kg) from 0.5 to 1.4 grams per 10 minutes (g/10 min.); (b) a molecular weight distribution (M_w/M_n) from 2.3 to 4.4; (c) both (a) and (b); (d) a long chain branching characterized by less than 0.008 long chain branches per 1,000 carbon atoms; and (e) both (d) and any one of (a) to (c).

7. The method of any one of claims 1 to 6 wherein cutting the LLDPE extrudate into pellets having surfaces without the surface melt fracture comprises pelletizing the LLDPE extrudate underwater to make pellets of the LLDPE without the surface melt fracture.