

PATENT SPECIFICATION

(11) 1 515 968

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- (21) Application No. 32455/76 (22) Filed 4 Aug. 1976
 (31) Convention Application No. 50/095 382
 (32) Filed 7 Aug. 1975 in
 (33) Japan (JP)
 (44) Complete Specification published 28 June 1978
 (51) INT CL² B29D 23/04
 (52) Index at acceptance
 B5A 1G3B 1R314C1C 2A3 2C1 2C3 2P2
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(54) METHOD OF SHAPING TUBULAR FILM

(71) We, IDEMITSU PETRO-CHEMICAL CO., LTD., of No. 1-1, Marunouchi 3-chome, Chiyodaku, Tokyo, Japan, a Japanese body corporate do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 The present invention relates to a process for the production of a tubular film by melt-extruding a resin, particularly a high molecular weight polyolefin resin, through an annular die.

15 In the air-cooling inflation process, air is blown into the extruded tubular film to blow up the film and form a resin bubble, thereby stretching the tubular film in directions transverse to the extrusion direction. The requirements of high productivity mean that the tubular film should be extruded at a speed as high as possible, but it has been extremely difficult to produce very thin films by the air-cooling inflation method from high molecular weight polyolefin resins and particularly from high density polyethylene and, even when shaping of the resin into a film has been carried out at high speed, it has been extremely difficult to obtain a thin film having good mechanical properties.

20 Amongst the proposals for overcoming the disadvantages of the air-cooling inflation method, a method of reducing the unevenness in the thickness of the resulting film by employing a rotating die has been proposed.

25 However, this method has the disadvantages that the apparatus required is complicated and limits are imposed on the take-up speed of the film. Another method involves stabilizing the resin bubble by contacting it with a mandrel inside the bubble, but this method is unsuitable for high speed take-up. Yet another method is described in Japanese Patent Application No. 61252/1974, as laid open to public inspection, and involves contacting a constricted portion of a tubular extrudate with a cylindrical member for stabilizing the resin bubble, the member having a diameter substantially smaller than the inner diameter

of the lip of the die. However, preparation of such a constricted part is difficult to carry out and, when the constricted part is contacted with the cylindrical member and cooled, there often occur rub streaks, adherence, injury or even breakage of the film.

55 In general, when a tubular film is shaped by the air-cooling inflation method, a film having a satisfactory mechanical strength is obtained by stretching the film biaxially, thus orienting the resulting resin crystals, under an appropriate set of conditions, including melting temperature of the resin, shape of the cooling ring slit, cooling conditions (such as the amount of cooling air), blow-up ratio of the resin bubble and the take-up speed of the film. However, since the molten resin tube extruded through the die is cooled by air and inflated at about the point where crystallization is initiated, the shape of the resin bubble at this point is very unstable and is susceptible to variation. If the take-up speed of the film is increased in order to shape the film at a higher speed, the shape of the resin bubble becomes even more unstable, resulting in uneven thickness, wrinkles, sagging of the film and fluctuation in the folded width of the film. Further, at high take-up speeds, since the stretching of the film and thus its orientation in the machine direction (direction of extrusion) is so great, orientation in the transverse direction must also be increased by increasing the blow-up ratio of the resin bubble, in order to balance the strength of the film in the longitudinal and transverse directions. This, however, makes the resin bubble even more liable to variation. In summary, if the shape of the resin bubble varies significantly, cooling becomes uneven and the frost line becomes liable to fluctuate and not only is the balance of the strengths of the film in the longitudinal and transverse directions lost but also film shaping itself becomes difficult.

85 We have now discovered that the provision of a cylindrical member within the tubular film immediately after the film has been extruded stabilizes the resin bubble even when the take-up speed is high and allows a higher blow-up ratio of the bubble. It is necessary

that the cylindrical member should have an outer diameter the same as or substantially the same as the inner diameter of the lip of the annular die through which the tubular film is extruded, except at the end of the member adjacent the die, where the diameter should be less than the inner diameter of the lip of the die. The process of the invention enables stretching of the tubular film to be carried out in the machine direction whilst the resin is still molten before forming the resin bubble and subsequently stretching in the transverse direction to be effected by blowing air into the tubular film to form a resin bubble.

Thus, the present invention consists in a process for the production of a tubular film, in which a resin is melt-extruded through an annular die and air inflated and air-cooled, wherein the tubular film, immediately after extrusion, and before inflation is passed over at least part of the length of a cylindrical member having an opening at its end remote from said die, having a plurality of holes towards its end adjacent said die which holes communicate with said opening, and having an outer diameter the same as or substantially the same as the inner diameter of the lip of said annular die except at its end adjacent said die where its outer diameter is smaller than the inner diameter of the lip of the die, a minimal clearance being maintained between the uninflated film and said member without their coming into contact by passage of air through said holes.

The extrusion process is preferably carried out upwardly, the cylindrical member thus being mounted above the annular die, the narrower end and the plurality of holes thus being at the bottom.

The tubular film produced by the process of the invention may be folded by means of pinch rollers and withdrawn, preferably upwardly, at high speed to maintain a suitable air pressure inside the resin bubble. Seemingly, part of the air which is blown in to achieve inflation descends outwardly from the top of the cylindrical member, reaches the plurality of holes, which are preferably uniformly distributed about the periphery of the end of the member adjacent the die, but is readily pushed back in the machine direction to form a small clearance between the cylindrical member and the tubular film of molten resin, as a result of the aspiration effect resulting from the motion of the tubular film; this descending and ascending motion of the air is believed to be continuously repeated. This condition can be maintained by adjusting the amount of cooling air supplied. Maintenance of as small a clearance as possible between the tubular film and the cylindrical member without allowing the member and the film to come into contact ensures that the resin bubble

swings very little and that it is thereby stabilized.

In order that the resin bubble should be stabilized as described above, it is necessary that the outer diameter of the cylindrical member at the end adjacent the die should be smaller than the inner diameter of the lip of the die but that the outer diameter of the cylindrical member elsewhere than that end should be the same as or substantially the same as the inner diameter of the lip of the die. Thus, the outer diameter of the cylindrical member may be the same as or slightly larger or slightly smaller than the inner diameter of the lip of the die. The cylindrical member must have a diameter smaller than the inner diameter of the lip of the die at the end adjacent the die in order to prevent the tubular extrudate of molten resin from adhering to the member immediately after extrusion, which would result in the cylindrical member becoming an obstacle to the extrusion path of the tubular film. We prefer that the length of the cylindrical member should be somewhat greater than the length of the tubular film before the tubular film is expanded in the transverse direction.

Of course, as in all air-cooling inflation methods, cooling air is blown, preferably upwardly, from outside the die and air for forming the resin bubble is blown into the tubular film from the inside of the die at the initial stages of the shaping operation.

The tubular extrudate of molten resin has the same diameter as the lip of the die or is expanded so as that it has a diameter slightly greater than that of the lip of the die, in relationship with the mutual locations of the tubular extrudate and the cylindrical member. However, when the resin bubble is formed, rapid expansion takes place to form a bubble having a large blow-up ratio, preferably a blow-up ratio of from 2.5 to 6.0 times in the transverse direction; this is followed by crystallization of the resin and take-up of the tubular film. The process of the present invention enables an extremely thin film of high molecular weight resin to be prepared at high speed, the quality of the resulting film being superior to that obtainable by prior art methods.

The invention is further illustrated with reference to the accompanying drawings, in which:

Figure 1 shows a cross-sectional view of part of the apparatus employed in the process of the invention and

Figure 2 is similar to Figure 1, but showing a differently shaped bubble.

In the drawings, a tubular film of molten resin is extruded through an annular die 1. A cylindrical member 2 for stabilizing the resin bubble 5 is provided immediately above the die 1, the bottom 3 of the cylindrical mem-

ber being substantially narrower than the inner diameter of the lip of the annular die 1, whilst the remainder of the cylindrical member 2 is of approximately the same external diameter as the internal diameter of the lip of the die. A plurality of small holes 4 are formed in the lower end of member 2, which has an opening at its upper end. The extruded resin film is inflated using air blown in from the inside of the die. The molten resin is cooled by means of an external cooling air ring 7, the frost line being shown at 6.

The shapes of the resin bubble can readily be controlled by adjusting the pressure of the cooling air, the temperature of the molten resin or other factors.

The invention is further illustrated by the following Examples, in association with the accompanying drawings.

EXAMPLE 1.

A tubular film was prepared using a high density polyethylene sold under the trade name "Idemitsu Polyethylene 640 UF" and having a melt flow index of 0.05. The extruder employed was manufactured by Placo Company Limited, Japan, had an internal diameter of 50 mm and was provided with a spiral type die whose lip had an inner diameter of 50 mm. The extrusion was carried out under the following conditions:

Temperature at exit of die	200° C
Blow-up ratio	4
Take-up speed	50m/min
Speed of cooling air blown from external air ring	about 3 m/sec
Height of frost line to be established	200 mm

The process was carried out substantially as shown in Figure 1, employing a cylindrical member 2 having an outer diameter the same as the inner diameter of the lip of the die, i.e. 50 mm. Its outer diameter at the bottom was 20 mm. 30 mm above the bottom of the cylindrical member, 4 small air passage holes, each 3 mm in diameter, were provided uniformly around the peripheral wall of the cylindrical member. The clearance between the tubular extrudate of molten resin and the cylindrical member was maintained at about 0.5 mm by adjusting the flow of cooling air.

The resulting tubular film had a thickness of 10 microns. Various of its physical properties were measured and the results are shown in the following Table.

EXAMPLE 2.

The apparatus and materials described in Example 1 were employed. Cooling air from the outside air ring was blown at a speed of about 4 m/sec. The height of the frost line was 100 mm. The procedure was otherwise the same as in Example 1, except that the shape of the resin bubble was that shown in Figure 2. The tubular film obtained had a thickness of 10 microns and the physical properties shown in the following Table.

COMPARATIVE EXAMPLE.

The procedure described in Example 1 was repeated, except that the cylindrical member was omitted and the height of the frost line was established at 50 mm. The tubular film obtained had a thickness of 10 microns and the physical properties shown in the following Table.

TABLE

	Example 1	Example 2	Comparative Example
Deviation in thickness (microns)	2	2	4
Elmendorf's tear strength (kg/cm):			
machine direction	16.5	13.8	3.5
transverse direction	26.8	45.3	71.6
Impact strength (kg cm/cm)	6,500	4,500	1,830

75 WHAT WE CLAIM IS:—

1. A process for the production of a tubular film, in which a resin is melt-extruded through an annular die and air inflated and air-cooled, wherein the tubular film, immediately after extrusion and before inflation is passed over at least part of the length of a cylindrical member having an opening at its

end remote from said die, having plurality of holes towards its end adjacent said die which holes communicate with said opening, and having an outer diameter the same as or substantially the same as the inner diameter of the lip of said annular die, except at its end adjacent said die where its outer diameter is smaller than the inner diameter



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end remote from said die, having plurality of holes towards its end adjacent said die which holes communicate with said opening, and having an outer diameter the same as or substantially the same as the inner diameter of the lip of said annular die, except at its end adjacent said die where its outer diameter is smaller than the inner diameter

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of the lip of said die, a minimal clearance being maintained between the uninflated film and said member without their coming into contact by passage of air through said holes.

5 2. A process according to Claim 1, in which said tubular film is extruded upwardly, said cylindrical member being mounted above said die.

10 3. A process according to Claim 1 or Claim 2, in which said resin is of a high molecular weight polyolefin.

4. A process according to Claim 3, in which said polyolefin is a polyethylene.

5. A process according to Claim 1, substan-

tially as hereinbefore described with reference to either of the accompanying drawings.

6. A process according to Claim 1, substantially as hereinbefore described with reference to either of the foregoing Examples.

7. A tubular film when produced by a process according to any one of the preceding Claims.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1978.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.