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METHOD AND APPARATUS FOR PRODUCING COLD DRAWN MONOFILAMENTS

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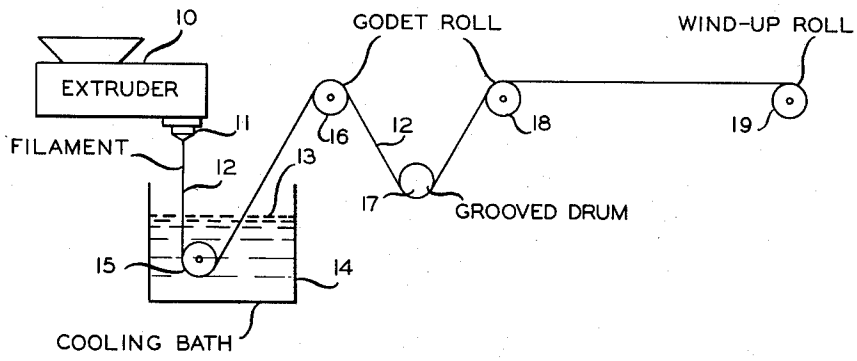


FIG. 1

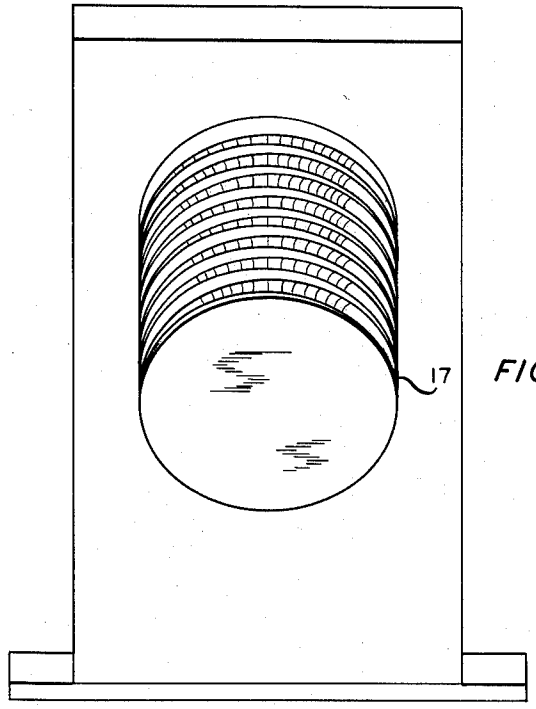


FIG. 2

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METHOD AND APPARATUS FOR PRODUCING COLD DRAWN MONOFILAMENTS

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This invention relates to a method and apparatus for producing cold drawn thermoplastic filamentous articles.

Heretofore, monofilaments of thermoplastic materials have been prepared by several different methods. However, there are certain disadvantages in the conventional techniques currently employed by monofilament producers. For example, when breakage of one strand occurs, it is difficult to retrieve this strand and "thread" it back into the equipment. Also, in many cases there is a problem with "fluid carry-over" from the hot bath to the monofilament spools. This, of course, as is well recognized in the art is very objectionable. Additionally, it is desirable to offer some snubbing action during drawing to the monofilament to prevent the drawing stress from being transmitted through the heating zone back to the cold strand. This can be generally accomplished in a water bath or steam cabinet, but is quite difficult in a hot air drawing oven, for example.

The present invention relates to a novel method and apparatus for cold drawing thermoplastic filamentous articles, especially monofilaments, wherein many of the prior art disadvantages associated with cold drawing operations are obviated.

Accordingly, an object of this invention is to provide an improved method for cold drawing thermoplastic filamentous articles.

Another object of this invention is to provide an economical and convenient method for cold drawing monofilaments of thermoplastic materials such as polyethylene.

Another object of this invention is to provide a novel apparatus for cold drawing thermoplastic monofilaments.

Other objects and advantages of my invention will be apparent to one skilled in the art upon reading the accompanying disclosure which includes a drawing comprising:

FIGURE 1, a schematic view showing my invention, and

FIGURE 2, an enlarged view of the grooved drum used as my apparatus in carrying out the process of my invention.

Broadly, the invention resides in a method for cold drawing thermoplastic filamentous articles, such as monofilaments formed from polymers of ethylene, especially polyethylene, wherein a filament of such a thermoplastic is cold drawn over a stationary heated surface, preferably a grooved surface when a plurality of filaments are being drawn simultaneously, under conditions such that an over-all reduction in diameter of the filament and substantial elongation of the filament is effected.

Also, according to the invention, an apparatus is provided for carrying out the above process, said apparatus preferably comprising an internally heated cylinder or drum, having on its surface a plurality of spaced parallel circumferential grooves, preferably tapered grooves, through which the filaments are drawn so as to effect an over-all reduction of diameter of the filament and substantial elongation of a filament drawn through said grooves.

In a preferred operation, the drum or cylinder described above is placed between two sets of Godet rolls and is so positioned as to cause the filament to be drawn through grooves and be forced into progressively smaller diameters or widths. The width of each groove can be

the same over its entire length, e.g. the diameter of the undrawn filament, or each groove can be of narrowing width, e.g. from the undrawn filament diameter at one end to the drawn filament diameter at the other end. Also, the filaments can be drawn through grooves either in the direction of taper or in the opposite direction. The heat from both the heated drum and the mechanical energy supplied by drawing through the grooves will cause the filament to be ductile. Furthermore, drawing the monofilament through the groove will offer the necessary snubbing action to prevent stress from being imposed on the unheated portion of filament or strand as well as providing better heat transfer from the drum to the filament. The present invention offers a completely dry process that is easily threaded and rethreaded during operation and furthermore will produce a monofilament with a higher strength than can be obtained by some of the more conventional prior art methods.

The invention is applicable to the broad class of thermoplastic materials which can be used to form filamentous articles. These include rubber hydrochloride, polyvinylchloride, copolymers of vinylchloride and another monomer such as vinyl acetate and vinylidine chloride, polystyrene, polyolefins such as polyethylene, polypropylene and copolymers of ethylene with other monomers such as propylene, 1-butene, and the like. Since my development work has been primarily directed to work with polyethylene, the major portion of this description will be directed to this material but, it will be realized, the process can be used with other thermoplastic materials as set forth above.

The preferred material for use in this invention is referred to as high density polymers of ethylene. This term signifies that the density of the ethylene polymers is at least 0.930 gram per cubic centimeter at 68° F. Usually, the density is in range of 0.940 to 0.980 and, often, within the range of 0.950 to 0.970. The term "density," as used in this specification, refers to the weight per unit volume (grams per cubic centimeter) at 68° F. These high density polyethylenes can also be characterized in terms of their melt index. Melt index is a measure of the rate at which polyethylene can be extruded under specified conditions. Melt index is inversely proportional to the molecular weight of the polymer. The melt index is determined according to ASTM–D–1238–52T. The high density polyethylene which can be used generally has a melt index of at least 0.5 and preferably from 0.9 to 25.

The polyolefins, especially polyethylenes, that can be employed in the practice of the present invention can be prepared by any of the methods which are usually employed for the preparation of these polymers. The high density polyolefins, especially polymers of ethylene, prepared by the low pressure processes now known are particularly useful in the preparation of the monofilaments cold drawn according to the invention. However, the invention is also applicable to the lower density polyolefins as well.

The filaments "cold drawn" according to the invention ordinarily have an outside diameter in the range 0.01 to 100 or more mils, usually 0.1 to 50 mils. Polyolefin filaments that can be stretched according to the invention have a tensile strength of at least 50,000 p.s.i. at room temperature and at least 15,000 p.s.i. at the temperature of boiling water. These tensile strengths often are in the order of 90,000 to 100,000 when measured at room temperature, say 65° F., and when determined by ASTM method D–638–52T.

In actual operation, the first step according to the present process is to extrude or otherwise extend the thermoplastic polymer to form a filamentous article, such

as a monofilament. This step ordinarily comprises forcing the polymer, usually in the molten state, through a small opening or die which optionally may contain a plurality of holes of similar cross-section. It is ordinarily preferred that the extruded filament be quenched before further treatment. This can be done by exposure to air, nitrogen or other fluid at atmospheric temperature, but is preferably done by immersion in an inert fluid such as water. Highly satisfactory results are produced with water at temperatures ranging from about 30° F. to about 160° F., preferably about 40 to about 100° F. for high density polyolefins.

In accordance with the invention, the quenched filament is "cold drawn" by drawing the filament over a stationary heated surface, preferably a grooved surface so as to effect an over-all reduction in diameter and substantial elongation of the filament. The term "cold drawing" generally signifies that the material is stretched, drawn, or elongated at a temperature below its softening point at a rate such that the filament does not break. The temperature of cold drawing can range from room temperature, for example 65 to 70° F., up to temperatures slightly below the softening point of the polymer, for example 260° F. The temperature is generally in the range 65 to 260° F., preferably from 100 to 260° F. Excellent results are obtained when the cold drawing is conducted at temperatures of about 210° F. or higher, preferably from 225 to 250 or 260° F. It will be understood that the upper limit of temperature will be dictated by the softening temperature of the polymer itself and should be at least a few degrees below the softening temperature.

As indicated above, the cold drawing is conducted at a rate which is insufficient to effect breakage of the filament. The maximum rate will vary depending upon the temperature of the filament. At relatively low temperatures it will necessarily be relatively low. The rate can be much higher at higher temperatures within the range discussed. The maximum or optimum rate of cold drawing is readily determined by mere routine tests in a given set of circumstances by one skilled in the art. The cold drawing will be sufficient to orient the polymer and the polymer will generally be drawn to a length which is from five times the length of the undrawn filament up to just short of the breaking point and will most generally be drawn from 5 to 10 times the length of the undrawn filament.

It is believed that the invention can be best understood from the accompanying drawing. Directing attention thereto, FIGURE 1 illustrates a schematic presentation of this invention. In this figure, an extruder **10** is connected to a die **11** which has a single hole at the end thereof; however, the die may optionally contain a plurality of holes of similar cross-section. Molten polymer is extruded through die **11** to form monofilament **12**, only one being shown for clarity, and passed into quench bath **14** containing a quench liquid **13**. The quench bath is generally filled with water but other suitable fluid materials can be used. The coolant can be any liquid which is both physically and chemically inert toward the filament extruded, i.e., the liquid which neither dissolves, plasticizes, hardens, softens, nor chemically reacts with the extruded filament. In addition to the water mentioned, other liquids that can be employed include ethylene glycol, diethylene glycol, ethers of these materials, glycerin and the like. The particular liquid used in the quench is not a part of my invention.

The extruded monofilament **12** passes under a roller **15** in cooling bath **14**, over and around Godet roll **16**, over the heated surface of stationary drum **17**, which constitutes an essential feature of my invention, over and around Godet roll **18**, and then to wind-up roll **19** where the drawn filament is stored. Drum **17**, which is internally heated, preferably has at least one tapered groove around a portion of its circumference. Each groove can vary from the undrawn filament diameter on one side to near the drawn filament diameter on the other side. Drum **17** is so positioned between Godet rolls **16** and **18** as to cause each filament to ride in a tapered or milled groove and be forced into progressively smaller diameters, thereby effecting an over-all reduction in diameter of the filaments. Godet roll **18** rotates at a higher rate of speed than Godet roll **16**, thereby effecting a substantial elongation, for example 5:1, of each filament drawn through a groove on drum **17**.

It should be realized that a plurality of spaced parallel circumferential grooves can be provided on a portion of the surface of the drum so that a plurality of filaments can be cold drawn simultaneously. Although milled grooves of decreasing diameter are shown in a preferred embodiment on the surface of a drum or cylinder, it is obvious that the grooves can be milled on other surfaces including flat, slightly curved, etc. so long as the grooves are so positioned as to cause the filament to ride in the milled grooves and be forced into progressively smaller diameters. If, for example, a flat surface having grooves is employed, it is preferred to have curved or radiused ends on the grooves to avoid sharp edges cutting the strands being drawn through the grooves.

In FIGURE 2, drum **17** is shown attached to a support and the unit is tilted forward toward the viewer so that the grooves in top of the drum can be readily seen. Drum **17** preferably has a plurality of spaced parallel circumferential grooves of narrowing width from one end of each groove to the other on a portion of its surface. The base or channel of each groove is preferably semicircular, thus being adapted for cold drawing of filaments that are circular in cross-section. It is preferred that the channel or root of each groove has substantially the same shape as the cross-sectional shape of the filament being drawn through the groove and contacting the base of each groove. Although a semicircular base or root has been shown as being preferred, it is obvious that other configurations including V-shaped grooves for triangular articles, rectangular grooves wherein the sides are normal to the axis of the drum for square filaments or articles, and the like can be employed.

In one apparatus that I have used for cold drawing polyethylene filaments, the length of the grooves were 180° on a 9-inch outside diameter drum heated internally with steam. The width of each groove was decreased at each 45° interval. However, if desired, a uniform taper or decrease in width from one end to the other end of each groove can be employed if desired. In the drum I have used for cold drawing polyethylene monofilaments, the initial width of the groove was about 0.047 inch for 45° of travel, about 0.037 for the next 45° of travel, about 0.027 for the next 45° of travel, and about 0.017 for the last 45° of travel.

In order to illustrate my invention, reference is made to the following specific example, wherein an ethylene polymer is utilized which was prepared by copolymerization of ethylene with 1-butene in the presence of cyclohexane and a heat activated (950° F. for 10 hours in anhydrous air) catalyst comprising chromium oxide supported on a silica-alumina in which the weight ratio of silica to alumina was about 9:1. The total chromium content was about 2.5 weight percent of which a portion was in the hexavalent state. The polymerization was conducted at a temperature of about 300° F. and a pressure of about 450 p.s.i.g. The ethylene polymer thus obtained was formed into pellets. The polymer had a density of 0.950 and a melt index of 0.3. The polymer was extruded into a filament and cold drawn according to the process of FIGURE 1.

Specific Example

The pellets obtained above were fed to an extruder which was heated to a temperature ranging from 500 to 535° F. and molten polymer was extruded at a temperature of about 525° through the die head. The mono-

filament extruded had a diameter of about 0.042 inch and was then passed through quench tank **14** containing water at a temperature of about 40° to 100° F. The filament was removed from quench bath **14** and passed over and around Godet roll **16** operating at a speed of 20 f.p.m. and then over and around Godet roll **18** operating at a speed of 200 f.p.m. Interposed between Godet rolls **16** and **18** was stationary drum **17** having tapered grooves thereon and so positioned as to pass the filament through approximately 180° of contact with the groove on drum **17**. The drum was internally heated with steam and was maintained at a temperature of 210 to 230° F. The filament was drawn through the groove in the direction of taper.

The drum was 9 inches in diameter and had grooves with an initial width of 0.045 for 45°, 0.035 inch for the next 45°, 0.025 inch for the next 45°, and 0.015 for the last 45° travel of the filament through the groove. The filament was drawn at a ratio of 10:1 and the diameter of the filament was reduced from 0.042 inch to 0.12 inch.

While I have illustrated my invention using a copolymer of ethylene and 1-butene prepared using chromium oxide supported on silica-alumina, it is as stated applicable to many other materials. As an additional example, I can mention polymers of ethylene, especially polyethylene, prepared in the presence of an organometallic catalyst which can be produced, for example, by mixing an aluminum trialkyl with titanium halide or an aluminum alkyl halide with a titanium halide.

The thermoplastic material used can contain additives such as antioxidants, pigments, plasticizers, and the like without changing the effectiveness of my invention.

As will be evident to those skilled in the art, many variations and modifications of this invention can be practiced in view of the foregoing disclosure. Such variations and modifications are clearly believed to come within the spirit and scope of the invention.

I claim:

1. An apparatus for cold drawing thermoplastic monofilaments which comprises an internally heated cylinder having on the outer periphery thereof a plurality of spaced, parallel, and circumferential tapered grooves through which separate filaments can be drawn, said grooves extending in length at least approximately one-half the circumference of said cylinder and lying in spaced planes, which planes are perpendicular to the longitudinal axis of said cylinder, each of said grooves being adapted to apply circumferential pressure to filaments ranging in diameter from 0.01 to 100 mils drawn therethrough by having a semicircular base wherein the radius of said base varies from one-half the undrawn filament diameter at one end to one-half the drawn filament diameter at the other end.

2. In an apparatus for producing a plurality of cold drawn thermoplastic filaments simultaneously which comprises, in combination, an extruder having a die to form said filaments, quenching means for cooling the extruded filaments, first roller means for removing quenched filaments from the bath, second roller means for drawing said filaments from said first roller through a drawing means, means for storing said drawn filaments, and a grooved, stationary, and cylindrical drawing means disposed between said first and second roller means so positioned as to apply simultaneous stretch to each filament drawn through separate grooves on said drawing means, said drawing means comprising an internally heated cylinder having on the outer peripheral surface thereof a plurality of circumferentially spaced, parallel tapered grooves lying in spaced planes, which planes are perpendicular to the longitudinal axis of said cylinder, extending in length at least approximately one-half the circumference of said cylinder, the number of grooves provided on said cylinder being sufficient to allow drawing a separate filament through each groove, each of said grooves having a channel shape corresponding substantially to the cross-sectional shape of the filament being drawn through the groove and having a width varying from the undrawn filament diameter at one end to the drawn filament diameter at the other end so as to apply circumferential pressure to the filament.

3. An apparatus according to claim 2 wherein said cylinder is so positioned with respect to said roller means that each filament is drawn through approximately 180° of length of said circumferential grooves and wherein the cross-section of each said groove is such that circumferential pressure can be applied to filaments ranging from 0.01 to 100 mils in diameter drawn through each groove.

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