The present invention relates to apparatus for the spinning of a synthetic funicular body. More particularly, it relates to a spinneret which is particularly useful in the formation of a longitudinally-channeled funicular body of a melt-spinnable fibrous synthetic linear polymer. By the term "funicular body" is meant a filament, fiber, staple, yarn, tow, cord or the like which is suitable for textile and other uses. It is an object of the present invention to provide a novel spinneret useful in the art of melt-spinning. Another object is to provide a novel spinneret useful in the production of a longitudinally-channeled funicular body.

These and other objects will become apparent in the course of the following specification and claims. In accordance with an invention described in copending United States patent application, Serial No. 334,457, filed February 2, 1953, longitudinally-channeled funicular bodies are produced from a fiber-forming synthetic polymer by melt-spinning through a spinneret containing single or multiple, suitably patterned arrangements of holes of such proximity and size that as the filaments emerge, coalescence occurs among the strands of each patterned arrangement. Thereafter, the extrusions are subjected to rapid quenching to arrest plastic flow. Further deviation from a circular cross-section is obtained by drawing the extruded filaments. It has been observed that the completeness with which the individual strands are coalesced to a composite filament may be improved by modifying the spinneret plate so as to reduce the web thickness (i.e., the closest distance between the circumference of adjacent holes) within the patterned arrangement. However, any such decrease in web thickness will obviously be accompanied by a corresponding loss of strength in the spinneret plate.

In accordance with the present invention, it has been found that coalescence among individual strands in the melt-spinning of a longitudinally-channeled filament as described in the aforementioned copending application may be improved by protruding the patterned arrangement on the spinneret plate so that it taper outwardly from the extrusion face. The invention will be more readily understood by reference to the figures. Figures 1 through 12, inclusive, are plan views of fragmentary sections of spinneret plates showing various typical individual patterned arrangements which may be employed in accordance with the present invention. Figure 13 is a magnified fragmentary cross-sectional view of a spinneret plate in which the patterned arrangement on the spinneret plate has been protruded from the extrusion face in a blister-like fashion.

The following examples are cited to illustrate the invention. They are not intended to limit it in any manner. By the term "relative viscosity," as used herein, is meant the quotient of the efflux time in a capillary viscometer at 25°C, of solution of 11 grams of a polymer in 100 ml of solvent divided by the efflux time of the solvent under the same conditions. This figure gives a relative indication of the degree of polymerization. The reference solvent employed in the examples for polyethylene terephthalate is a solution of 7 parts by weight of trichlorophenol and 10 parts by weight of phenol. 

Example I

A spinneret plate having a thickness of 0.312 inch and containing 170 holes, consisting of 34 of the 5-looped pattern arrangement as shown in Figure 11, is drilled. With reference to Figure 10, the holes have diameters of 0.007 inch. Within each patterned arrangement, they are spaced 0.009 inch from center to center presenting a web 5 (the shortest distance between each adjacent hole) of 0.002 inch. Prior to drilling of the holes, a counterbore, 3, of 0.300 inch on a 45° chamfer is made on the polymer melt face 1 for each patterned arrangement. Each patterned arrangement is then tapped lightly on its polymer melt face until the center of the arrangement protrudes 0.005 inch from the extrusion face 1. The extrusion face thereby assumes a multiple blistered appearance, having 34 essentially hemispherical protrusions, one at each patterned arrangement. The patterned arrangements are laid out on concentric circles. The spinneret plate is locked in conventional melt-spinning equipment similar to that disclosed in United States Patent No. 2,266,268.

Polyethylene terephthalate, prepared in accordance with the procedure described in United States Patent No. 2,465,319, having a relative viscosity of 5.8, is spun through this equipment to obtain a 252-denier, 34-filament yarn. The yarn is spun at a rate of 960 yards per minute into a cross-flow cooling chimney which extends 12 inches below the spinneret. Such an arrangement is shown in United States Patent No. 2,273,105. Air flow is maintained in the chimney at 234 cubic feet per minute. The air at the inflex is approximately at room temperature. The spinneret filler pack is maintained at approximately 270°C. A yarn of ribbon type filaments having corrugated surfaces is formed.

A series of observations is made by cutting across the yarn in several places and counting the number of filaments, the strands of which are not completely coalesced. The yarn spun as described above is found to average 2.0 filaments having strands which are not completely coalesced.

The use in the above procedure of a similar spinneret plate but having no protrusion of the patterned arrangements produces an average of about 10 split filaments.

Example II

A spinneret plate containing 10 holes consisting of 2 of the 5-looped patterned arrangement as shown in Figure 11, is drilled. Each patterned arrangement is protruded 0.002 inch. The diameters of the holes, their spacings and other dimensions are the same as described in the plate of Example I. The plate is locked in equipment as described in Example I. A yarn is spun employing the melt and technique of Example I. No split filaments are observed.

Example III

A spinneret plate containing 94 holes, consisting of 6 of the 9-looped patterned arrangement of Figure 4, is drilled. Each patterned arrangement is protruded 0.004 inch. The diameters of the holes, their spacings and other dimensions are the same as described in Example I. The plate is locked in equipment as described in Example I. A yarn is spun employing the melt and technique of Example I. A yarn having filaments of cruciform cross-section is formed. An examination of yarn cross-section disclosed no split filaments.
A spinneret plate containing 90 holes, consisting of 18 of the 5-holed patterned arrangement of Figure 11, is drilled. Six of these patterned arrangements are protruded 0.003 inch. Other dimensions of the plate are as described in Example I. A yarn is spun employing the melt and technique of Example I. The filaments from the protruded and the non-protruded patterned arrangements are collected as separate yarns. Examination of the yarn from the six protruded patterned arrangements disclosed no split filaments. An average of 9 filaments of the 12-filament yarn showed incompletely coalesced strands.

The nature and viscosity of the polymer to be extruded, the particular patterned arrangement employed and the size and spacing of the individual holes within each patterned arrangement are variables, the combined effect of which determines optimum operating conditions and optimum protrusion at each patterned arrangement. In general, it is desirable to extrude at as low a temperature as possible to avoid unnecessary plastic flow in the extruded mass. The individual holes within each patterned arrangement must be maintained small to present a structure having a relatively large surface area to cross-section which is easily quenched. These individual holes must be close enough together within each patterned arrangement that coalescence of the individual strands within each arrangement occurs. A protrusion of patterned arrangement of as low as 0.001 inch has been found beneficial. It is preferred to protrude within the limits of about 0.002 to about 0.005 inches. A protrusion of about 0.0035 permits a wide range of adaptability to other variables. Protrusions above about 0.0065 inch frequently will not give the effect desired.

In general, it may be stated that optimum temperature for the melt-spinning of any particular polymer will be slightly lower when practicing the present invention than is usually employed in the conventional melt-spinning of the same polymer. A pack temperature of from about 255° C. to about 290° C. is recommended for the spinning of polyethylene terephthalate having a relative viscosity of from 25 to 25 when following the teachings of the present invention. Polyhexamethylene adipamide, having a relative viscosity within the range of 25 to 45, is best spun at a pack temperature of from 245° C. to 270° C. when proceeding in accordance with the present invention.

Rapid quenching of the extruded filament assists in the arrest of its plastic flow. It is promoted by maintaining the diameter of the extruded individual strand as low as practicable in order to assist heat transfer after extrusion. In general, a hole diameter of from about 0.004 to about 0.030 inch has been found suitable for the melt-spinning of polymesters and polyamides. A relatively high velocity, low-temperature air stream is also beneficial in obtaining this result. Co-current or counter-current flow at the spinneret face may be advantageously employed. In any of these techniques, care must be taken to avoid fouling the extruded filaments, one with the other. Beside quenching in air, quenching in any inert cooling fluid may be employed.

The thickness of the spinneret plate is not critical. It should be maintained as thin as practicable in order to avoid temperature changes of the polymer melt between its polymer melt surface and the extrusion surface. Furthermore, a thick plate introduces friction losses. The matter of strength of the plate must be considered and this will depend not only on its thickness but on its material of construction. For a chromium steel plate (such as illustrated in United States Patent No. 2,341,555) a plate thickness of from about 0.2 to about 0.4 inch is sufficient. It is possible to decrease the thickness at each extrusion point by countersinking on the polymer melt face over each patterned arrangement. In this manner, it is possible to have as low an effective thickness at the point of extrusion as about 0.01 inch when using a plate of the metal described above. The thickness of the web at the extrusion face of the spinneret plate should be kept as low as practical. The maximum permissible thickness will be primarily related to the size of the extrusion orifices. However, the nature of the extruded polymer will also affect it to a certain degree. Where the orifice diameter is between the limits of about 0.004 to about 0.030 inch and the polymer is a member of the group consisting of polymesters and polyamides, the web thickness at the extrusion face is advantageously maintained at about 0.002 inches and is preferably maintained in the limits of about 0.001 and about 0.003 inch. This invention is applicable broadly in the production of all types of fiber-forming synthetic linear polymers which are capable of being melt spun. Illustrative of polyamides and copolyamides which can be spun employing the apparatus of this invention are those described in any of the United States Patents Nos. 2,071,250, 2,071,253, 2,130,523, 2,130,948, 2,190,770, 2,252,555, 2,252,557 and 2,374,137. Examples of polymesters and copolymesters are shown in United States Patents Nos. 2,071,250, 2,071,251, 2,465,150 and 2,465,319.

Many other modifications within the scope of the disclosed invention, without a departure from the inventive concept, will be apparent to those skilled in the art.

What is claimed is:
1. A spinneret plate for melt-spinning which comprises a solid plate having at least one protrusion which extends gradually outward from the spinneret face for a distance of from about 0.001 to about 0.0065 inches, each protrusion having a group of holes in which the web thicknesses between adjacent holes in the group are less than about 0.003 inch, and with each group of the said holes having on the polymer melt face of the said plate a region which is counter-sunk to a depth less than the thickness of the said plate.
2. The plate of claim 1, wherein the protrusion is within the limits of about 0.002 and 0.005 inch.
3. The plate of claim 1, wherein the web thickness is about 0.002 inches and the protrusion is about 0.0035 inch.

References Cited in the file of this patent

UNITED STATES PATENTS

2,001,000 Taylor et al. 2,148,221 Schneide Feb. 21, 1939 2,149,425 Draemn Mar. 7, 1939 2,232,689 Bradshaw Aug. 19, 1941 2,553,692 Webb May 22, 1951
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,891,277

June 23, 1959

Walter L. Sutor

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 20, for "means" read -- meant --; column 2, line 27, for "No. 2,266,268." read -- No. 2,266,368. --; column 3, line 39, for practising" read -- practicing --; column 4, line 61, in References Cited list, for "Echneider" read -- Schneider --.

Signed and sealed this 1st day of December 1959.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents