Nov. 15, 1960 R. A. CRAIG 2,959,839

LINEAR CONDENSATION POLYMER FIBER

Filed May 18, 1955

FIG 1

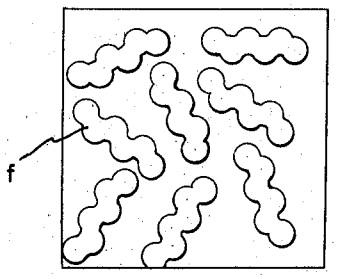


FIG 2

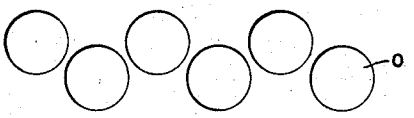


FIG 3

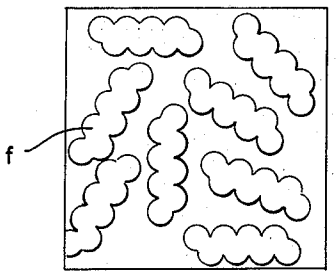


FIG 4

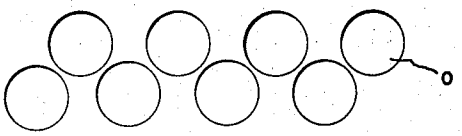
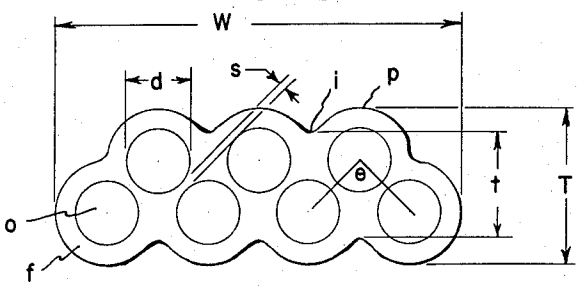


FIG 5



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United States Patent Office 2,959,839 Patented Nov. 15, 1960

2,959,839

LINEAR CONDENSATION POLYMER FIBER

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Filed May 18, 1955, Ser. No. 509,133

3 Claims. (Cl. 28—82)

This invention relates to manufacture of textiles, concerning particularly synthetic fibers of novel configuration especially useful in apparel fabrics.

Formation of filaments having non-round cross section by coalescence of extruded multiple streams of fiber-forming composition is known, although successful application of the general principle to melt-spinning technique is comparatively recent. The range of possible cross-sectional modification is bewildering, and the chances that any particular one will prove to be an improvement over earlier forms should not be overestimated, especially in apparel manufacture where any yarn variation is likely to introduce undesirable characteristics into the process or product. Among the prominent requirements for apparel fabrics, which usually are made from staple yarns (i.e., yarns composed of relatively short fibers, as compared with continuous filaments), are desirability of dyed appearance, loftiness of handle, and freedom from "pilling" (i.e., dislocation of component staple fibers to form little balls or "pills" on the fabric surface).

A primary object of the present invention is provision of melt-spun filaments productive of improved apparel fabrics. A specific object is preparation of linear condensation polymers in filamentary form having unusual surface characteristics. Other objects of this invention, together with means and methods for attaining the various objects, will be apparent from the following description and the accompanying diagrams.

Figure 1 is an enlarged transverse section through filaments of one form constructed according to the present invention. Figure 2 is a plan view of a filamentary unit pattern of orifices in the spinneret used in preparation of the filaments of Figure 1. Figure 3 shows in enlarged transverse section another form of filament according to this invention. Figure 4 shows a unit pattern of the spinneret employed to prepare the filaments of Figure 3. Figure 5 is a schematic representation of the transverse cross section of a filament of this invention superimposed upon an orifice pattern of the corresponding spinneret, with indication of pertinent dimensional characteristics.

In general, the objects of the present invention are accomplished through melt-extrusion of fiber-forming linear condensation polymers by means of spinnerets having in zigzag configuration at least a half dozen orifices per resulting filament, whose transverse cross section is characterized accordingly by at least two indentations on each side corresponding to an angle of at least about 90° and at most about 120° included at each zigzag by a successive trio of orifices. Figure 5, in which the reference characters have the significance attributed to them in the following table, facilitates more detailed characterization and understanding of the product of this invention and means for producing it, which are exemplified variously in the preceding four drawings.

TABLE

Reference Character	Corresponding Dimension or Element
o	Orifice of spinneret.
d	Diameter of spinneret orifice.
s	Spacing between adjacent orifices.
θ	Included angle (subtended at center of orifice by centers of flanking orifices).
f	Filament.
i	Indentation of filament surface (in direction of minor axis).
p	Protrusion of filament surface (between identations).
W	Over-all width of filament (major axis).
T	Over-all thickness of filament (minor axis).
t	Minimum thickness of filament (provided by indentations).

For added convenience in discusstion of the filaments of this invention, various of the dimensional reference characters presented in the above table and in Figure 5 are grouped to define two ratios especially useful in characterizing important properties of the filaments, as follows:

Width-to-thickness ratio ..... $WTR=W/T$.
Indentation-to-thickness ratio ..... $ITR=1-t/T$.

Thus, a flat ribbon-like filament would have a high WTR but negligible ITR; a round filament would have $WTR=1$ and $ITR=0$; two identical round filaments just barely fused together would have $WTR=2$ and $ITR=1$; and a filament corresponding to that of Figure 5 (which otherwise is intended to be a general, rather than specific, representation) would have $WTR=3$ and $ITR=⅓$, each indentation penetrating the filament to a depth equal to about ⅙ the maximum thickness.

Experience with filaments made with melt-spun linear condensation polymers has shown that yarn composed of round staple fibers is an undesirable constituent of apparel or other fabrics subjected to rubbing in use because of the facility with which such fibers dislodge, twist, and tangle to form unsightly pills on the surface of the fabric. Ribbon-shaped fibers, though resistant to pilling, have when dyed in dark shades the undesirable attribute of "glittering," i.e., reflecting light in a sparkling manner somewhat as the ocean does on a sunny day. Except in some novelty fabrics this glitter is extremely objectionable, being considered a quality defect by discriminating purchasers.

In fibers composed of linear condensation polymers, such as polyhexamethylene adipamide or polyethylene terephthalate, both pilling and glittering can be precluded according to the present invention in a filamentary configuration having a width-to-thickness ratio of at least three and an indentation-to-thickness ratio of at least one-third; fabric so constructed also exhibits a desirable lofty handle and is free from defects that otherwise might inhibit commercial acceptability. Filaments having fewer than two indentations on each side are substantially incapable of formation with a value of WTR sufficient for pill resistance, and the term "corrugated" as applied herein to fibers and filaments signifies presence of at least two indentations running on each side the length of a filamentary structure that is much wider than it is thick.

In the design of zigzag orifice patterns in spinnerets for producing corrugated filamentary configurations, included angles below about 90° or above about 120° usually decrease, rather than increase, the actual indentation because of fusion along the width of the filament at the lower angular extreme and because of formation of secondary protrusions within the indentations at the higher angular extreme. A zigzag configuration is em-

ployed to offset the indentations on opposite sides of the filament; in the absence of such offsetting, sufficiently high ratios of indentation to thickness to prevent glitter impair the structural integrity enough to foster splitting of the filaments during processing and use, an obviously undesirable characteristic. The practice of the present invention is exemplified below.

Example I

A flat circular steel spinneret plate is drilled with 216 orifices arranged in a filamentary unit pattern like that of Figure 2 (6-hole, 120° included angle) with 36 such patterns grouped radially, the orifices having an individual diameter of 6 mils (thousandths of an inch) and being spaced 7 mils between centers. Assembled in a filter pack like that described by Hull et al. in Patent 2,266,-368, the spinneret is employed to spin molten polyethylene terephthalate having a relative viscosity of 31±1 prepared according to the procedure described by Whinfield and Dickson in Patent 2,465,319. The melt is extruded through the spinneret with the pack maintained at 280° C. into a cross-flow chimney in which air flow is about 105 cubic feet per minute to obtain at about 1200 yards per minute a continuous multifilament of about 300 denier, like that represented in cross section in Figure 1. For these filaments, *WTR*=3.4 and *ITR*=0.46. The continuous multifilament is drawn to three times its original length, giving a final denier of about 100, whereupon it exhibits tenacity of about 3.4 grams per denier and elongation of 41%, it is cut into 2½-inch staple lengths and formed conventionally into 30/1 yarn (cotton count), which is doubled and woven into 2 x 2 lightweight twill suiting. The fabric is crabbed, beck-scoured, and beck-dyed navy blue. The fabric proves free from objectionable glitter, closely approximating in appearance a control fabric woven from yarn made up from staple fibers of the same denier having round transverse cross section. Upon being brushed for 5 minutes and sponged for 5 minutes in a conventional pilling test, the fabric of this example shows an average of one pill per 15 square inches, while the control fabric upon being subjected to the same procedure shows an average of 68 pills per same area unit. Comparison of both fabrics in handle, weight, bulk, thickness, and crease recovery reveals them to be equivalent in every regard.

Repetition of the above procedure with the sole substitution of a spinneret plate in which each filament unit consisted of four 7 mil orifices spaced in a straight line on 8 mil centers produced filaments having *WTR*=3.3 and *ITR*<0.20. Resultant staple fabric was pill-free but glittered excessively. In an attempt to overcome this difficulty the indentation-to-thickness ratio was increased by utilizing a spinneret with a like filamentary unit except for doubling of the spacing between adjacent orifices, thus leaving WTR substantially unchanged but increasing ITR to 0.40; however, so much difficulty was encountered with separation or splitting of the individual filaments along the corrugations that fabric manufacture from the yarn so produced (with great difficulty) was not at all practicable.

Attempts to eliminate the splitting of corrugated filaments produced by spinnerets having widely spaced in-line orifices by grooving the face of the spinneret to a depth of about 2 mils to connect adjacent orifice outlets reduced the incidence of split filaments somewhat without impairing the ratio of indentation to thickness by more than a few percent and without affecting the ratio of width to thickness, but this experiment failed to alleviate the undesirable structural discontinuity sufficiently for commercial production.

Example II

The procedure of the above example is repeated except for substitution of a spinneret plate having a filamentary unit of 8 orifices with 90° included angle. No difficulty is encountered during the processing of the filaments, which proved to have *WTR*=3.5 and *ITR*=0.50. Fabric composed of staple yarn made from these filaments as in the first example is free from pilling and from glitter in dark dye shades and is otherwise acceptable for apparel use.

Although the above examples are drawn to filaments made of polyethylene terephthalate, other melt-spun fiber-forming linear condensation polymers are similarly useful. In the manufacture of nylon filaments, for which the general procedure is much better known than for polyethylene terephthalate (and, thus, omitted here), it is helpful to increase the melt viscosity to at least about 3000 poises to ensure proper formation of the corrugated filaments of the present invention. Illustrative of polyamides and copolyamides which can be employed in the process of this invention are those described by Carothers in any of the following: Patents 2,071,250, 2,071,253, 2,130,523, 2,130,948, 2,190,770, and 2,252,555; by Czerwin in Patent 2,252,557; and by Salisbury in Patent 2,374,137. Some of the useful examples of polyesters and copolyesters are shown by Carothers in Patents 2,071,250 and 2,071,251; by Dickson in Patent 2,465,150; and by Whinfield & Dickson in Patent 2,465,319.

As suggested above, excessive spacing of orifices for an in-line filamentary unit is conducive to splitting of the intended unitary filament; this is true also for the corrugated configuration of the present invention. In general, with the usual sizes of orifices having diameters in the range of from about 4 to about 10 mils, the separation of adjacent orifices should not exceed 1½ mils appreciably; widthwise continuity of resulting filaments diminishes rapidly with orifice separation increasing from 1.6 to 2.0 mils. The general technique of forming a filament by coalescence of multiple streams of extruded polymer melt is described by Hayden in French Patent 1,096,943 published June 28, 1955. Of course, the minimum separation is dependent upon the desired ratio of indentation to thickness, and spacings less than about ¾ mil are conducive to such complete coalescence or fusion of the extruded streams of polymer as to reduce the indentation sufficiently to give rise to objectionable glitter.

The major axis of the corrugated filaments of this invention need not be straight but is shown that way for simplicity and because filaments so constructed have performed satisfactorily. If desired, the unit pattern of orifices may zigzag about an arc, S curve, or other more complex configuration. More than two adjacent orifices may lie in a straight line so long as the resulting filament is free from wide expanses of surface either flat or only so slightly indented as to mirror incident light to an objectionable extent. In general, the orifices within each unit group will be of the same size, although they may vary somewhat if desired, and all the filamentary unit groups in one spinneret will be alike where uniformity of the product is required, although various patterns may be employed together where variety is permissible.

Despite emphasis above of the particular suitability of the corrugated filaments of this invention in dark-dyed apparel fabrics, these filaments are useful also in undyed fabrics and those dyed in light shades. Of course, titanium dioxide or other delusterant may be present in the product, and some delusterant often will be desirable in the lighter-colored materials. The advantages and benefits of the present invention will be apparent despite employment of added steps, ingredients, or apparatus or other variations from the invention as described.

The claimed invention:

1. Fiber composed of linear condensation polymer and characterized by transverse cross section having an over-all width at least 3 times the maximum thickness and outlined by successive abutting arcuate protrusions defining indentations therebetween, with at least two indentations uniformly running the length of the fiber on

each side, each indentation being located opposite a protrusion on the opposite side and having a depth of at least ⅙ the maximum thickness of the fiber.

2. Staple yarn composed of the fiber of claim 1.

3. Fabric composed of the yarn of claim 2 and characterized by freedom from pilling and from glittering in dark dye shades.

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