

Sept. 22, 1970

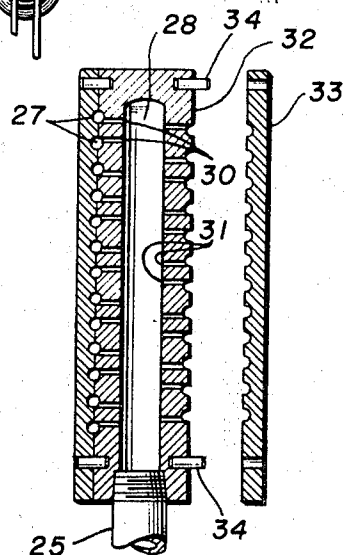
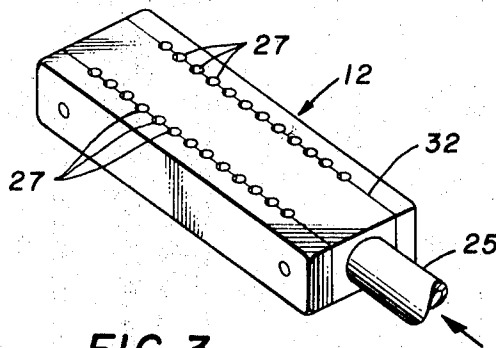
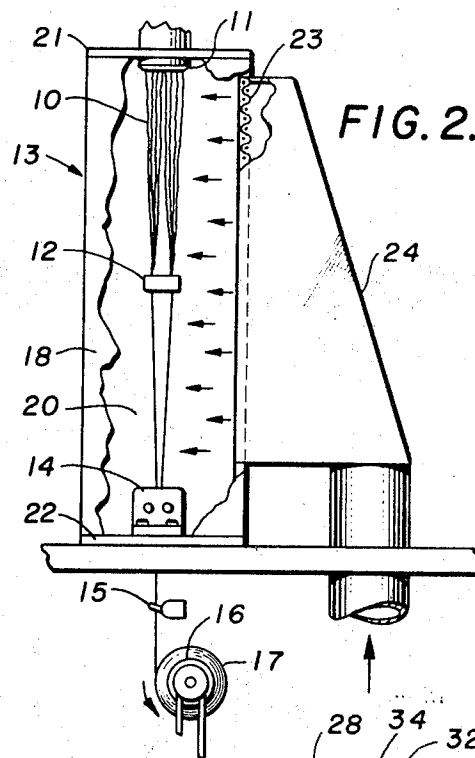
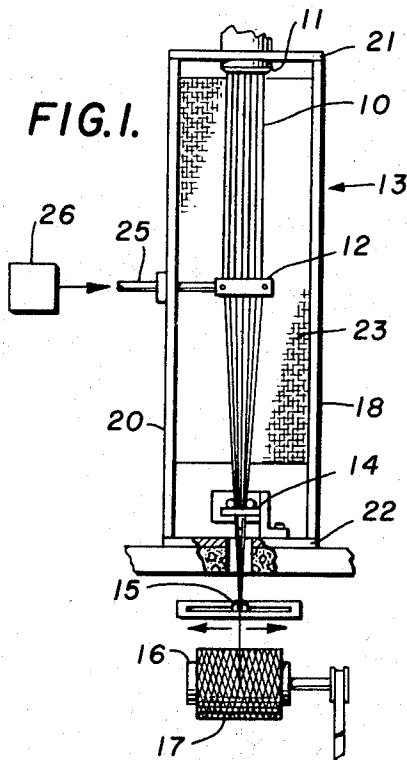
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3,529,323

APPARATUS FOR PRODUCING YARN HAVING INDIVIDUALLY AND
PERMANENTLY TWISTED FILAMENTS

Original Filed June 23, 1965

3 Sheets-Sheet 1



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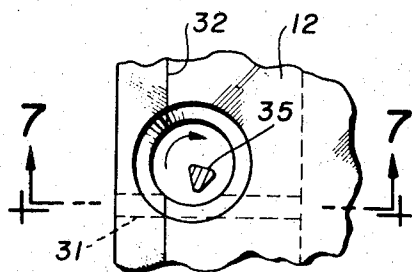


FIG. 5.

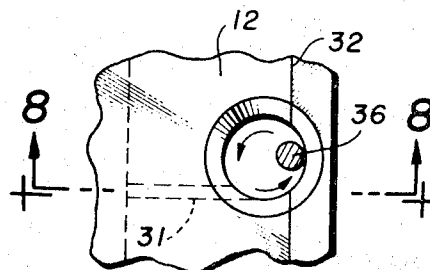


FIG. 6.

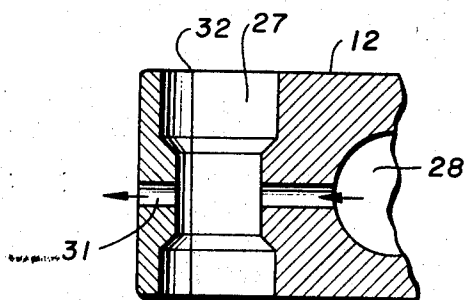


FIG. 7.

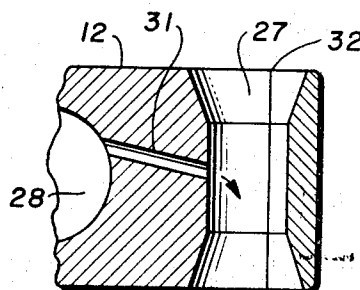


FIG. 8.

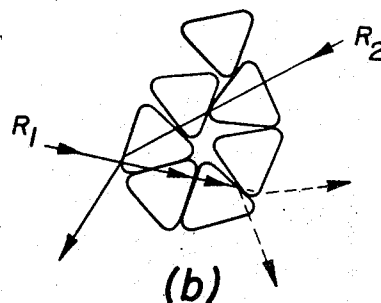
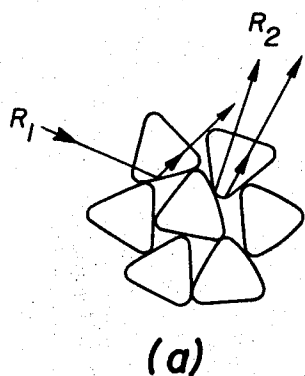


FIG. 9.

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3 Sheets-Sheet 3

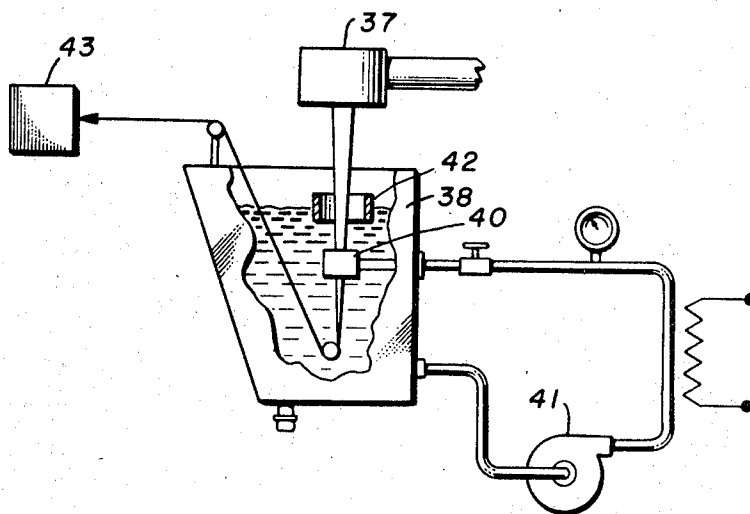
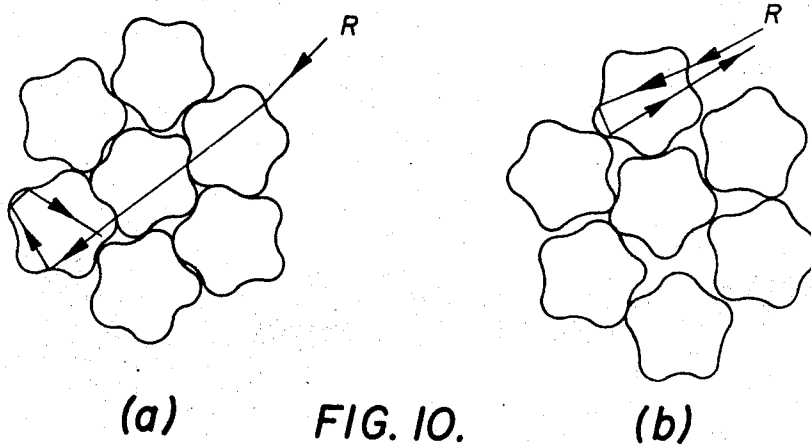


FIG. II.

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3,529,323

APPARATUS FOR PRODUCING YARN HAVING INDIVIDUALLY AND PERMANENTLY TWISTED FILAMENTS

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Original application June 23, 1965, Ser. No. 466,237, now Patent No. 3,367,100, dated Feb. 6, 1968. Divided and this application Oct. 10, 1967, Ser. No. 688,288
Int. Cl. D01d 5/22, 13/02

U.S. Cl. 18—8

4 Claims

ABSTRACT OF THE DISCLOSURE

A melt-spinning apparatus for producing a threadline of permanently and individually twisted filaments from a synthetic thermoplastic resin having a spinneret and a spinning chamber for receiving streams of resin emitted from the spinneret. At least one filament-twisting fluid jet through which a hardened filament passes en route to a collecting means is positioned within the chamber. Fluid moving through each jet at a high velocity exerts a peripheral effort on the filament to cause a twist to back up toward the spinneret beyond the point where the filament becomes hardened; the twist of some of the filaments is opposite in direction to that of the other filaments.

This is a division of application Ser. No. 466,237, filed June 23, 1965 and now Pat. No. 3,367,100.

The present invention is concerned with producing individually twisted filament yarn. More particularly, it is concerned with an apparatus for individually twisting filaments during melt spinning thereof.

Recently it has become important to impart twist to individual filaments in a bundle thereof. Doing this gives the bundle increased bulk and different light reflectance properties. It is now common for a filament manufacturer to produce filaments having polygonal cross sections. Filaments having such cross sections, particularly where the shape is trigonal, tend to fit or nest together to form a threadline even more compact than one composed of filaments having normal round cross sections. To break up this fitting together of polygonal section filaments in order to increase the bulk and cover thereof, it has been suggested to rotate each individual filament of a threadline about its long axis by applying a positive peripheral rotational effort during melt spinning such that a twist runs along each of the filaments from a point where the filaments are solid to a point above where solidification of the filaments occurs. To do this a worm gear or like member is positioned perpendicularly to the axis of the spinning filaments. As the gear turns unidirectional permanent twist is imparted to each filament. While this known procedure represents a basically new operation for individually twisting filaments, a need for improvements has arisen in regard to having better control of the filaments and providing greater twist at the ever increasing spinning speeds being used today by filament manufacturers. Furthermore, the twist provided by the prior art is unidirectional, that is, the twist is either S or Z in all the filaments throughout the length of the threadline. It has now been found advantageous to provide a threadline in which the filaments are individually twisted and are bidirectional, that is, some of the filaments of the threadline have S twist throughout their lengths and others have Z twist throughout their lengths. The prior art procedures lack a teaching for accomplishing this in a simple and economic manner.

Therefore, it is an object of this invention to provide a new and useful apparatus for twisting individual filaments during melt-spinning.

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It is a further object to provide a new and useful apparatus for melt-spinning filaments and twisting same up to and just beyond the point of solidification of the filaments in the spinning chamber so as to provide a uniform and positive twist in the individual filaments, the twist in some of the filaments being in an opposite direction with respect to the direction of the twist in the other filaments.

It is another object to provide an apparatus for producing a bundle of filaments in which some of the filaments have a permanent uniform twist in one direction throughout their length and the remainder of the filaments have a like twist but in the opposite direction.

In general, the objects of the present invention are accomplished by providing a melt-spinning apparatus for use in the production of individually twisted filaments from a synthetic thermoplastic filament-forming polymer. This apparatus includes a spinneret for extruding said polymer in a molten condition in a yarn path extending generally downward along a vertical extrusion line and means for collecting the resulting filaments in an orderly form such as a package. An elongated spinning chamber is positioned between the spinneret and collecting means and is adapted to receive streams of polymer emitted from the spinneret upon extrusion therefrom. Within the chamber the polymer streams are cooled into hardened filaments. At least one filament-twisting fluid jet through which a hardened filament normally passes toward the collecting means is provided. A source of supply of fluid is provided, as well as means for moving the fluid at high velocity to the jet where the fluid exerts a peripheral effort on the filaments sufficient to cause the twist to back up toward the spinneret beyond the point where the filaments become hardened. A plurality of jets are employed, ordinarily sufficient in number to twist each filament individually. The jet comprises a block through which holes extend axially with respect to the yarn path and is adapted for receiving the filaments for individual confined passage therethrough. Each hole has a tangential fluid entry port so that within the holes the fluid imparts a cranking action to the filaments. Preferably, the tangential entry of the fluid is clockwise in some holes and counterclockwise in other holes. Thus, some of the filaments twist in one direction and others twist in the opposite direction back toward the spinneret.

By use of the apparatus individually twisted continuous filament yarn is provided. In operation of the apparatus each individual filament is rotated about its long axis by applying a peripheral rotational effort sufficient to back twist the filaments into a zone where the filaments are not completely hardened but are still plastic from having just been melt-spun. An improvement occurs by accomplishing the twisting by establishing a stream of fluid and directing the stream within a confined zone tangentially against a filament to provide the required rotational effort. Preferably, a plurality of fluid streams are provided. Some of these streams are directed clockwise tangentially against some of the filaments and counterclockwise tangentially against the other filaments. Hence, the apparatus provides yarn composed of filaments some of which have a permanent twist along their lengths in one direction and others of which have a permanent twist along their lengths in the opposite direction.

The apparatus further provides a threadline composed of a plurality of synthetic thermoplastic filaments exhibiting low molecular orientation. The filaments have a polygonal cross section and are characterized by each filament having a permanent individual twist along its length. The twist of some of the filaments takes a direction opposite to that taken by the other filaments. Good results are obtained when about 20–80% of the filaments assume a Z direction twist and the other 80–

20% of the filaments assume an S direction twist. A preferred polymer is nylon, particularly nylon-66 and the polymer shows a low degree of molecular orientation as indicated by a birefringence of about 0.000-0.040. After the twist has been set in the filaments, the thread then will ordinarily be drawn to increase the molecular orientation as desired by the conventional procedures.

With reference now to the drawing:

FIG. 1 is a schematic front elevational view of a melt-spinning apparatus showing filaments being melt-spun and quenched in a conventional cross-flow of cool air and incorporating one embodiment of the invention.

FIG. 2 is a side elevation showing more clearly the flow of cooling air across the spinning filaments.

FIG. 3 is a perspective view of the filament whorl or filament-twisting fluid jet illustrating a parallel arrangement of two lines of holes suitable for use with filaments quenched by cross-flow air as illustrated in the preceding figures.

FIG. 4 is a central longitudinal section with parts separated for illustrative purposes of the whorl assembly shown in FIG. 3, the fluid jet arrangement and the split plate construction being more clearly illustrated.

FIGS. 5, 6, 7 and 8 illustrate on an enlarged scale details of structure in two preferred methods of the apparatus.

FIGS. 9 and 10 show transverse cross sections of high luster multifilament non-circular filament yarns and the distribution of a ray of incident light falling upon such yarns.

FIG. 11 schematically illustrates the use of the filament whorl with melt-spun filaments quenched by a liquid bath, such as water.

As shown in FIGS. 1 and 2, spinning filaments 10 issuing from a spinneret 11 pass individually through the eyelets of a filament whorl or filament-twisting fluid jet 12. The jet may be adjustable vertically. Ordinarily the whorl or jet is positioned within spinning chamber 13 only a few inches below the solidification point (stick-point) of the filaments in order to reduce the unsupported length of filaments between the spinneret and whorl. The filaments are combined at a convergence guide 14 and subsequently are wound up in a conventional manner on the spinning machine. As illustrated the yarn wind-up includes a reciprocally mounted traverse guide 15 adapted to lay the melt-spun filaments on a bobbin 16 or the like suitably driven to form a filament package 17. It will be appreciated that the speed of filament take-up on bobbin 16 will be coordinated properly with the extrusion speed of the polymer so that proper melt-spinning is accomplished. Ordinarily the collection rate is considerably higher than the extrusion rate.

The spinning chamber 13 having an open or partially closed front comprises two solid vertical side walls 18 and 20 in spaced apart relationship, a top panel 21 and a bottom panel 22 provided with an opening therein through which the gathered bundle of filaments pass in operation. The back wall 23 of the chamber bridging the side walls and the panels is made of material pervious to gas, such as gauze fabric, felt material, or, as illustrated, a fine mesh wire screen. The screen will impart a diffused but substantially straight line flow from plenum chamber 24 so that the cooling gas contacts laterally the vertically moving streams of polymer to cool same into solid filaments. Often it is desirable to contact the filamentary streams with a force sufficient to cause the stream to assume an arcuate path during part of their travel down the spinning chamber.

In the yarn path between the spinneret and the take-up means there is positioned the filament whorl 12 shown in more detail in FIGS. 3 and 4. Fluid is moved to the whorl through a conduit 25 from a fluid impeller 26.

The filament whorl 12 comprises a plurality of apertures or eyelets 27 through which the individual filaments pass. A jet stream of compressed gas, usually air, is intro-

duced into each eyelet in a plane approximately normal to the axis of the moving filaments. The gas jet enters either tangentially to the inner surface of the eyelet to generate a vortex or it passes across the eyelet substantially tangential to the inner surface to form a high-velocity drag stream. The interaction of the vortex or drag stream with the axially moving filament generates a torque in each filament about its own axis. The impressed torque is resisted by twisting of the filament, the twist deformations extending up the plastic filament toward the spinneret. While in the twist-deformed state the filament solidifies, retaining the permanent unidirectional twist. Each filament in the threadline may be given the same twist direction, such as S; but it is usually preferable to have mixed filaments of both S and Z twist. The direction of twist is determined by the location of the air jet relative to the axis of the whorl eyelet.

For multifilament yarns cooled by a transverse flow of air it is preferable to have the whorl eyelets arranged in straight rows. For other methods of quenching, such as a concurrent or countercurrent flow of air, the whorl eyelets are arranged in concentric circular or elliptical arrays similar to the circular array of holes in the spinneret often used to spin the filaments.

FIGS. 3 and 4 further show the design of a particular whorl used with melt-spun filaments quenched by a cross-flow of cooling air or by a static bath of liquid, such as water. Eyelets 27 are arranged in two parallel straight rows. Compressed fluid enters the whorl near conduit 25 through a large axial bore 28 from whence it flows tangentially into each eyelet through jet capillaries 30 and 31. As shown, the eyelets alternate clockwise and counterclockwise vortices by introducing the jets on opposite sides of the eyelets; thus, yarns spun through the whorl contain S twist filaments and Z twist filaments.

For convenience in threading filaments through the eyelets, the eyelets are cut by a parting plane 32 which passes through all eyelets in a given row, as more clearly shown in FIG. 4. With no air flowing in the whorl, the plate 33 is removed and each individual filament is inserted into its respective eyelet and the plate is replaced to complete and close the eyelet. Locating pins 34 engage mating holes in a plate to insure ready positioning thereof. The plate may be retained in place by a cap screw, or the like.

As clearly shown in FIGS. 5-8, the parting plane 32 preferably does not divide the eyelet exactly in half along a diameter. Rather, the plane passes through a chord about $\frac{3}{4}$ of a diameter from the opposite inner wall of the eyelet. In this case, with the plate portion off, each eyelet on the fixed piece functions efficiently as a filament guide while the filaments are being threaded through the eyelets; when the parting plane exactly divides the eyelets in half, filaments tend to jump out of the half-eyelet during string-up prior to closure with the plate.

On a much enlarged scale, two preferred designs for the whorl eyelets are illustrated in FIGS. 5-8.

FIG. 7 is a section taken along plane 7-7 of FIG. 5. The distinctive feature of the structure in FIG. 5 is that only the central axis of the jet capillary 31 is tangent to the inner wall of the eyelet and the capillary opens directly into the atmosphere. A high velocity fluid stream ("dragstream") thus passes across one side of the eyelet with only a weak vortex being developed directly in the eyelet. This arrangement is especially effective with filaments having non-circular cross-section, the filament apparently rotating in the "dragstream" like an undershot water wheel. In FIG. 5 a triangular section filament 35 is illustrated.

FIG. 8 is a section taken along plane 8-8 in FIG. 6 which illustrates an embodiment of the whorl which is especially suitable to filaments with circular sections. One such filament 36 is shown. The jet capillary 31 enters the eyelet 27 such that the capillary wall is tangent to the inner wall of the eyelet, and all fluid entering the

capillary passes out through the eyelet, generating a strong vortical motion in the process. As shown in FIG. 8 it is preferable to position the jet capillary such that it is directed downward at a small angle on the order of 10° – 35° . This provides a small consistent component of velocity downward in the direction of the axial movement of the filament, which tends to stabilize the lateral motion of the unsupported free filament above the whorl.

The degree of twist actually generated in the spinning filament is dependent upon the jet velocity entering the whorl eyelet and the axial velocity of the moving filament (spinning speed). To obtain sufficient twist to provide a high natural bulk to yarn, the filaments must rotate on the order of 30,000 r.p.m. or more, and such speeds are feasible with the filament whorl. One application to which the filament whorl is especially suitable is non-circular filament yarns.

With circular filaments a low degree of twist, on the order of one turn per foot per individual filament, has little discernible effect upon the appearance or performance of the yarn. Non-circular filament yarns, however, gain in natural bulk by the introduction of even a small degree of twist when the twist is applied to each filament independently. This arises from the fact that non-circular filaments can pack together in a very compact arrangement, as well as in more distributed patterns; circular filaments, on the other hand, have a relatively unique and constant mode of packing irrespective of simple twist.

A further important factor comes into play with high luster or "sparkle" yarns composed of non-circular filaments, such as those having substantially straight-sided polygonal cross sections. A principal component of the scintillating sparkle is due to refraction and total internal reflection of incident light. A substantial fraction of the light falling on the face of a "sparkle" fabric must be reflected back from the face side if the brillanté effect is to be apparent.

Reflection of light can only occur at the air-polymer interface as in surface reflection or at a polymer-air interface as in the case of internal reflection. A small degree of twist to the individual filaments assures many polymer-air interfaces at a given section of the yarn while lack of individual twist tends to reduce the number of interfaces, and twisting of all filaments together as a bundle further reduces the polymer-air interfaces, thus diminishing the possibility of sparkle luster. This situation is illustrated in FIGS. 9 and 10.

FIG. 9(b) shows a typical cross section of an untwisted 7-filament yarn composed of undelustered nylon-66 triangular filaments. As indicated, the facets of several filaments register with one another to form a compact bundle. The packing is even more compact when such filaments are all twisted together as a threadline. A ray of incident light R_1 enters the filaments as shown and passes through three filaments successively without significant internal reflection because of the absence of a polymer-air interface; the ray finally emerges with practically no light reflected or scattered in the front direction. Light ray R_2 similarly passes through three filaments without internal reflection to create sparkle.

FIG. 9(a) is a section of the same type of triangular filament yarn but each individual filament has approximately 0.15 turn per inch, some filaments with S twist and some with Z twist. The facets of the filaments no longer register to permit close packing, and the polymer-air interfaces are preserved in many directions. The incident ray of light R_1 is internally reflected totally at the first polymer-air interface and emerges with high intensity to create a scintillating effect. Similarly, ray R_2 is totally reflected twice at polymer-air interfaces and emerges almost in the same direction as the incident ray.

FIG. 10(a) illustrates the situation with untwisted pentagonal section filaments. Because of close packing the polymer-air interface is greatly reduced and the incident light ray R is completely scattered within the yarn,

yielding no front-reflected emerging light. FIG. 10(b) shows a group of similar filaments each having about 0.2 turn per inch of individual twist which prevents close packing. Here the incident ray R is internally reflected twice and emerges to the front in almost the same direction as the incident ray.

An analogous situation occurs with all non-circular filament yarns. The sharply defined sections such as Y-sections benefit from individual twisting to the filaments by gaining more natural bulk because close packing is reduced. Sparkle type yarn gains in addition to the greater bulk a distribution more favorable for reflections providing the desired scintillating luster.

Although main emphasis has been given to the use of the filament whorl with air-quenched melt-spun filaments, the whorl is particularly suited to filaments spinning from a spinneret 37 into a liquid quench bath 38, such as a tank of water as shown in FIG. 11. In this application the structure of the whorl 40 is normally unchanged except that dimensions are usually enlarged because only heavy denier yarns (i.e., 200 denier per filament) are normally spun in liquid quenchers. The whorl is mounted several inches below the surface of the liquid, and water under pressure is forced through the jet capillaries. The most economical arrangement is to have a small pump 41 capable of maintaining 40–50 p.s.i.g. to deliver water to the jet capillaries of the whorl in a closed recirculation system from the quench bath. A ring baffle 42 at the surface of the bath encloses the group of filaments in order to control the standing waves and eddies set up by the rotating filaments. The twisted filaments leave the bath and are forwarded to stretching and collecting means 43.

The following examples will illustrate further the invention. However, it is understood that the invention is not limited thereto, since many other embodiments are apparent.

EXAMPLE I

Nylon-66 polymer was spun on a conventional inert gas-blanketed spinning machine, the polymer having nominal relative viscosity of 39, and the spinning temperature was 293° C. Polymer was extruded through a spinneret having 6 holes. Each hole was composed of five equispaced slots radiating from a common intersection, the slots being 0.003 inch wide by 0.026 inch long. The extruding filaments passed over a pin guide about 45" below the spinneret and from thence were wound conventionally on a bobbin at the rate of 517 y.p.m. In a spinning chimney the filaments were quenched by a transverse flow of air between the spinneret and the pin guide, and the air temperature was 23° C. Cross-sectional photomicrographs showed that the filaments had a distinct pentalobal section somewhat akin to those illustrated in FIG. 10 except that lobes were much more pronounced, resembling a 5-pointed star.

A filament whorl was made in brass with an arrangement similar to that shown in FIG. 3 but having only two eyelets, one eyelet being of the form shown in FIGS. 5 and 7, and the other eyelet being of the form shown in FIGS. 6 and 8. The axial length of each eyelet was $\frac{7}{32}$ ". The "dragstream" eyelet (FIG. 5) had a diameter of 0.05" and the jet capillary diameter was 0.032". The vortex type eyelet (FIG. 6) had a diameter of 0.094" with jet capillary diameter of 0.020".

The two-eyelet whorl was mounted on a vertical slide bracket in the chimney of the machine spinning pentalobal filaments. With the whorl in a low position some 30" below the spinneret, one filament was placed in each eyelet and the plate replaced to close the eyelets. The whorl was then raised up to within 20" of the spinneret but below the solidification region of the filaments ("stick point"). Compressed air from an air-heater at 90 p.s.i.g. was led through flexible hose and a needle valve to the whorl eyelets.

As air flow to the whorl was increased, twist rapidly developed in the filaments passing through the whorl. Above a certain flow rate the filaments began to "whip" erratically, depending also upon the length of unsupported filament between the spinneret and the whorl. The most stable position for the whorl was a few inches below the stickpoint of the filament; in this location, air flow rate to each jet capillary was approximately 0.008 std. cubic feet per minute with good lateral stability in the filaments. Twist development as well as lateral stability was greatest in the drag stream type of eyelet (FIG. 5); apparently the Bernoulli pressure difference tends to keep the filament partially immersed in the drag stream at all times. This suggests that even greater stability would be achieved by admitting a second drag stream to the eyelet diametrically opposite but parallel to the first and directed in the opposite direction of the first; in this way the rotating filament would be supported almost entirely by the air streams with only occasional contact with the eyelet inner wall.

By use of a stroboscopic light source the twist generation was observed to be quite regular. By counting the highlights reflected from each lobe of the yarn, the actual twist could be estimated. In the first 4-5 inches below the spinneret no twist was discernible in the filaments, the fluidity of the filaments evidently being too great to sustain a significant torque. At about 4-5 inches from the spinneret, twist became apparent and the first two highlights were spaced about 2 inches apart, indicating about one complete turn per 10 inches. The lateral spacing of highlights rapidly decreased until the spacing was about $\frac{1}{4}$ inch at some 3 inches above the whorl; i.e., at the stick point. Thereafter, the spacing of the highlights did not change until well below the whorl where fluctuating random twist caused by the pin guide was superimposed on the twist generated by the whorl. In filaments spinning directly without passage through the whorl only random twist was observable and this twist began to appear a few inches below the stick point. It is apparent that under the given operating conditions one turn of twist per $\frac{1}{4}$ inch of axial length of filament was formed by the action of the whorl; upon drawing the yarn about 400% the twist level in the drawn yarn becomes about 0.2 turn per inch.

EXAMPLE II

A filament whorl similar to the structure in FIG. 3 is made of magnesium-aluminum alloy and has 13 eyelets of the drag-flow design shown in FIG. 5; the eyelet length is $\frac{5}{32}$ inch, eyelet diameter 0.040 inch, and jet capillary has a diameter of 0.020". Jet capillaries enter on opposite sides of the successive eyelets to provide S or Z twist, there being seven Z eyelets and six S eyelets.

The above-mentioned whorl is mounted on a vertically adjustable bracket in the spinning chimney of a conventional steam-blanketed type melt-spinning machine. A spinneret with 26 holes divided to produce two 13-filament threadlines is installed in the machine; each spinneret orifice is designed for spinning triangular section filaments. Undelustered nylon-66 polymer is extruded through the spinneret at a rate to yield 320 denier per 13-filament threadline as the two threadlines are wound up on a conventional bobbin at 300 y.p.m. Filaments are cooled by a cross flow of air at 22° C.

After both theadlines are spinning in a steady state, the 13 filaments of one threadline are placed individually in the whorl eyelets. A check shows that the "stickpoint" of the yarn is about 13" from the face of the spinneret; the whorl is positioned about 18" from the spinneret. Compressed air from an air header is passed through a needle valve and small rotameter to the plenum bore of the whorl. By means of the needle valve the air flow rate to the whorl is varied; above about 0.007 std. cubic foot per minute per eyelet, the filaments begin to whip violently. At about 0.005 std. cubic foot per minute per eyelet, filament motion is quite stable.

Triangular filaments in the free threadline are seen to have the usual highly fluctuating random twist accumulated at the pin guide, several filaments at a time sporadically twisting together and releasing this random twist "backs up" to within about 17" from the spinneret, at which position some slight twist is discernible. Filaments passing through the whorl clearly show twist up to within about 3" of the spinneret. With a stroboscopic light source the period of the twist is seen to decrease rapidly. At about 11" from the spinneret the axial spacing of the highlights becomes constant at about $\frac{1}{2}$ ", which corresponds to one complete turn per $1\frac{1}{2}$ " of axial length of filament. The slight oscillation of the filaments in the stroboscope clearly shows that the S and Z whorl eyelets develop opposite rotations in the spinning filaments.

Samples of spun yarn are drawtwisted on a standard Whitin drawtwister at a 3.17 draw ratio with 0.41 Z twist being added on the yarns. Knit fabrics are knitted on a circular knitting machine. Examination in a strong light source shows that fabric of test yarn and the non-twist yarn are both highly lustrous, but the test yarn is decidedly more scintillating. This is somewhat surprising since the net twist in the Z and S filaments of the test yarn is only about 0.21 turn per inch; however, the difference in net twist in the Z and S filaments is 0.42 turn per inch, since the twists are of opposite sign and the twist superimposed in drawtwisting does not change this difference in twist.

Samples of yarn embedded in Canadian Balsom and cross sectioned are examined under the microscope. Test yarn filaments are generally separated somewhat as illustrated in FIG. 9(a) while non-twist control yarn tends to have the triangular filaments stacked even more markedly than those illustrated in FIG. 9(b). It is evident that the better preservation of the polymer-air interface accounts for the greater scintillation luster in the test yarn.

EXAMPLE III

A standard plastics extruder with spinning head mounted over a water tank quench bath, as illustrated in FIG. 11, is used to extrude nylon-6 filaments. A spinneret having 7 circular orifices 0.035" in diameter is installed in the spinning head. Nylon-6 polymer with a relative viscosity of 62 is charged to the extruder and the spinning head is maintained at 295° C. Filaments extrude downward into the water bath, the level of which is about 2" below the spinneret face; water temperature is about 48° C. Filaments are extruded at a rate of 115 y.p.m. with a spun denier of 810 denier per filament. The filaments are carried under a submerged notched guide bar and out over a rotatable guide cylinder, the filaments being kept separate. The filaments are continuously stretched 400% between heated godets on a conventional monofilament stretching machine, the 7 filaments finally being brought together and wound on a spool.

A 7-eyelet whorl is made having the design indicated in FIGS. 6 and 8. Eyelet diameter is 0.20" and capillary jet diameter is 0.063". The whorl is mounted in a horizontal position about 4" below the surface of the water bath and each filament is threaded through an eyelet. Water from a water main is piped through a small rotameter and needle valve to the jets of the whorl. Because of the short unsupported length of filament and the damping effect of the water bath, a wide range of flow rates to the jets proves feasible. A water rate of about 0.0025 gallon per minute per eyelet is selected. Twist generation is not readily apparent in the round filaments except at a very high degree of twist, although swirling eddies about each filament indicate a high rate of rotation.

To control the wide fluctuations in eddy currents at the water surface near the filaments, a collar is formed of a 2" strip of 32 gauge aluminum sheet to encircle the filaments and is submerged about an inch into the water surface as indicated in FIG. 11. The standing wave pattern in combination with the eddies shed by the rotating filaments greatly affect the exact position at which water

first contacts the molten filament; by bending the collar into a rectangular shape, triangular shape, etc., the standing wave pattern and water surface contour is readily changed.

The stretched heavy denier yarn with filament twist does not appear superficially much different from the untwisted yarn. When single twisted filaments a foot or two long are laid out on a surface there is some slight indication of a serpentine or helical configuration. However, when the untensioned filament is heated to a temperature above about 120° C. for about 2 seconds or longer, the filament curls and kinks into a highly irregular helical form. Many small-scale crimps in random planes are superposed on the helical configuration. Examination of segments of the spun filaments at low magnification under crossed polarizers indicates a highly random distribution of inhomogeneous stressed regions that were not relieved in the hot-stretching operation. The peculiar random small scale stresses which give rise to the highly crimped-helical configuration is believed to be caused by the fluctuating position of the first contact of the water with the hot filament as it enters quench bath. This idea seems borne out by the fact that the degree and scale of tandom crimp is changed significantly by the presence or absence of the wave baffle surrounding the filament bundle at the water surface. The degree of true twist is controllable by the rate of rotation by the filament whorl, and the degree of superimposed random crimp is determined primarily by the size and shape of the wave baffle.

The invention is generally applicable to any substance that can be suitably melt spun. Specific polymeric materials capable of being melt spun include: nylon-66, nylon-4, nylon-610, nylon-11, and their filament-forming copolymers, e.g., 6/66, 6/610/66, etc.; polyesters derived from terephthalic acid and ethylene glycol and from terephthalic acid and bis-1,4-(hydroxymethyl)cyclohexane; polyethylene and polypropylene; and other substances.

The apparatus is most suitable for twisting yarn whose filaments have a non-circular cross section such as that produced where a spinneret having non-circular shaped orifices is employed during the manufacture thereof. Yarns of X- or Y-shaped cross section are examples of yarns having a non-circular cross section. The yarns may have a triangular cross section or may have a square cross section or other polygonal or multilobal shape.

There has just been described above an apparatus for producing a yarn that has a persistent twist imparted to the individual filaments thereof. The resulting yarn is bulky, that is, it has greater covering power and warmth due to enhanced lateral spacing of the filaments. Among other advantages of the present invention is the fact that the apparatus may be run at high speed and requires little operator attention. The construction and arrangement of the apparatus make it possible to convert at moderate expense existing melt-spinning equipment into a machine of the type disclosed and claimed herein. The inherent properties of the yarn twisted in accordance with this invention are such that they impart numerous and desirable effects in woven, non-woven, and knitted fabrics made therefrom.

What is claimed is:

1. A melt-spinning apparatus for use in the production of permanently and individually twisted filaments from a thermoplastic filament-forming polymer comprising:

- (a) a spinneret for extruding said polymer in a molten condition in a yarn path extending generally downward along a vertical extrusion line;
- (b) means for collecting the resulting filaments;
- (c) a spinning chamber positioned between the spin-

neret and collecting means and adapted to receive streams of polymer emitted from the spinneret upon extrusion thereof, wherein the streams are cooled into hardened filaments;

- (d) a jet block positioned in the yarn path within the spinning chamber at a point where the filaments have normally become hardened;
 - (e) means defining a plurality of holes in said block extending axially with respect to the path and adapted to receive the filaments for passage therethrough;
 - (f) means defining clockwise tangential fluid entry ports in some of the holes and counterclockwise fluid entry ports in the other holes;
 - (g) a source of supply of fluid; and
 - (h) means for moving the fluid through the ports into the holes of the jet block where the fluid exerts a peripheral effort on the filaments sufficient to cause some of the filaments to twist in one direction and others to twist in the opposite direction back toward the spinneret beyond the point where the filaments become hardened.
2. A melt-spinning apparatus for use in the production of permanently and individually twisted filaments from a thermoplastic filament-forming polymer comprising:
- (a) a spinneret for extruding said polymer in a molten condition in a yarn path extending generally downward along a vertical extrusion line;
 - (b) means for collecting the resulting filaments;
 - (c) a quenching bath normally containing a liquid spaced below the spinneret and positioned between the spinneret and collecting means, said bath being adapted to receive streams of polymer emitted from the spinneret upon extrusion thereof, wherein the streams are cooled into hardened filaments;
 - (d) a jet block positioned within the bath and through which hardened filaments normally pass toward the collecting means;
 - (e) means defining a plurality of holes in said block extending axially with respect to the path and adapted to receive the filaments for passage therethrough;
 - (f) means defining clockwise tangential fluid entry ports in some of the holes and counterclockwise fluid entry ports in the other holes;
 - (g) a source of supply of a liquid;
 - (h) a member encircling the filaments at the surface of the liquid in the bath for controlling eddy currents in the liquid at this point; and
 - (i) means for moving a liquid to the jet block where the fluid exerts a peripheral effort on the filaments sufficient to cause some of the filaments to twist in one direction and others to twist in the opposite direction back toward the spinneret beyond the point where the filaments become hardened.
3. The apparatus of claim 1 wherein each hole of said block receives a single filament.
4. The apparatus of claim 2 wherein each hole of said block receives a single filament.

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