FIG. 1

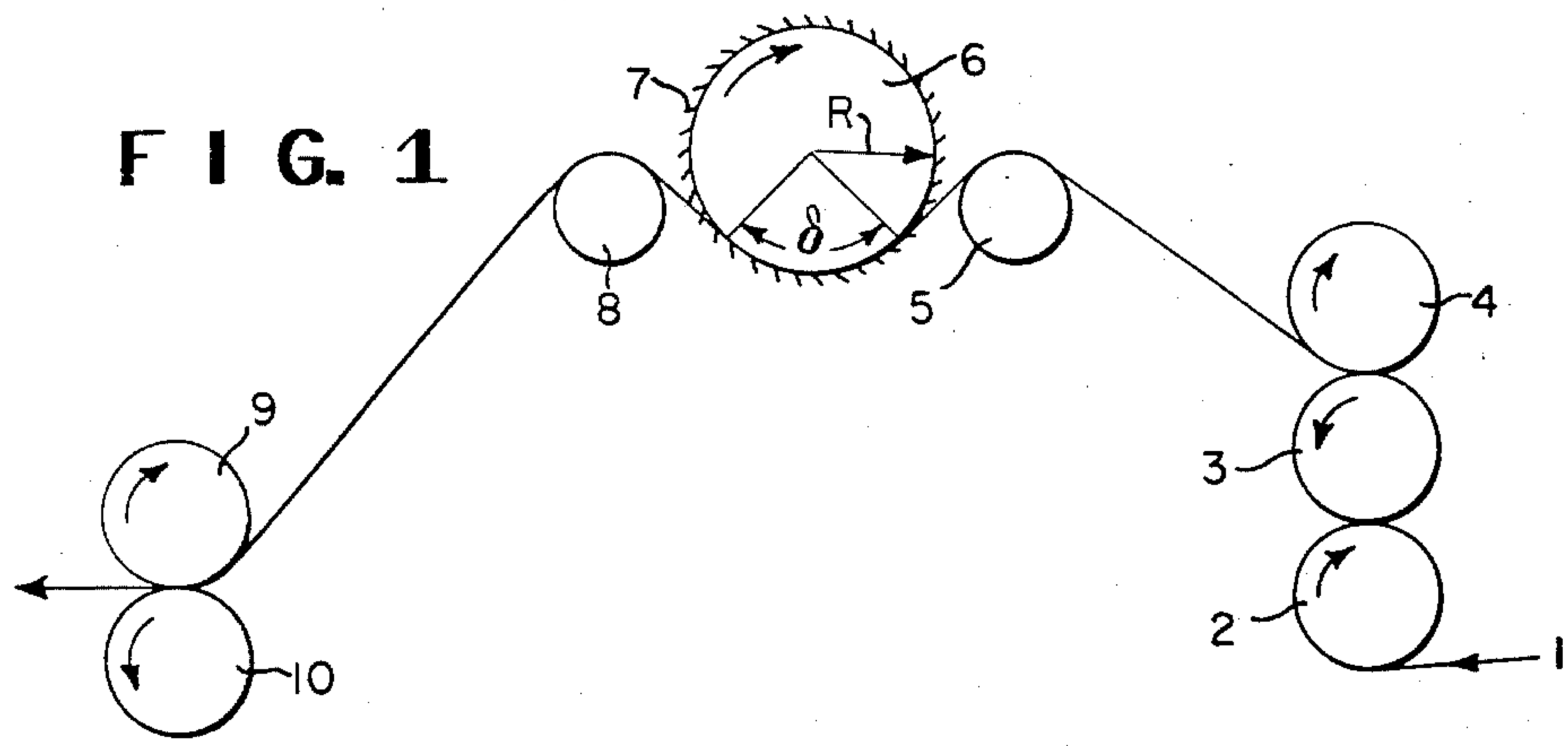


FIG. 2

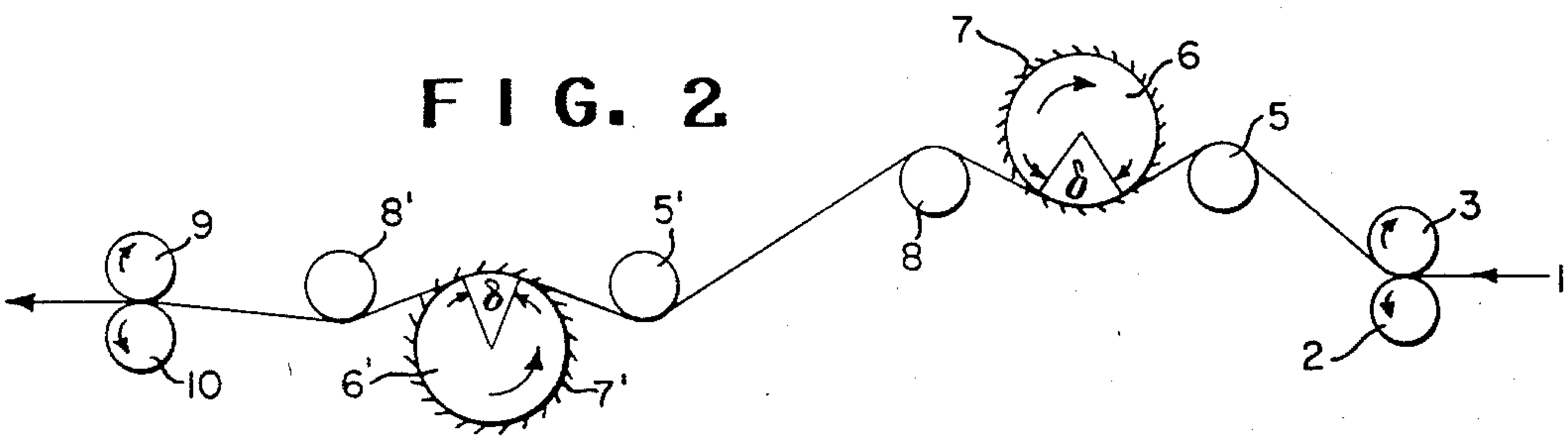


FIG. 7

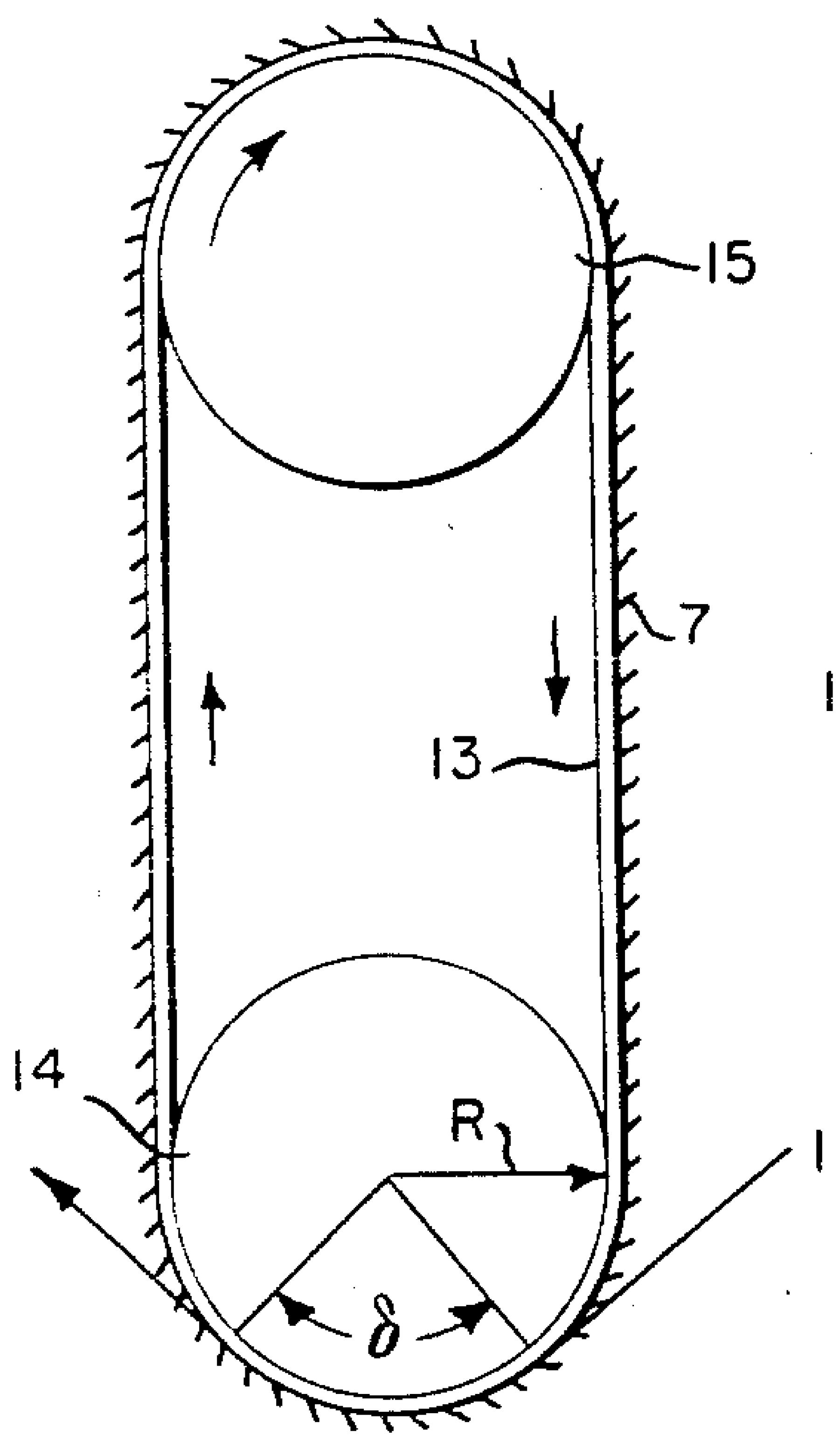
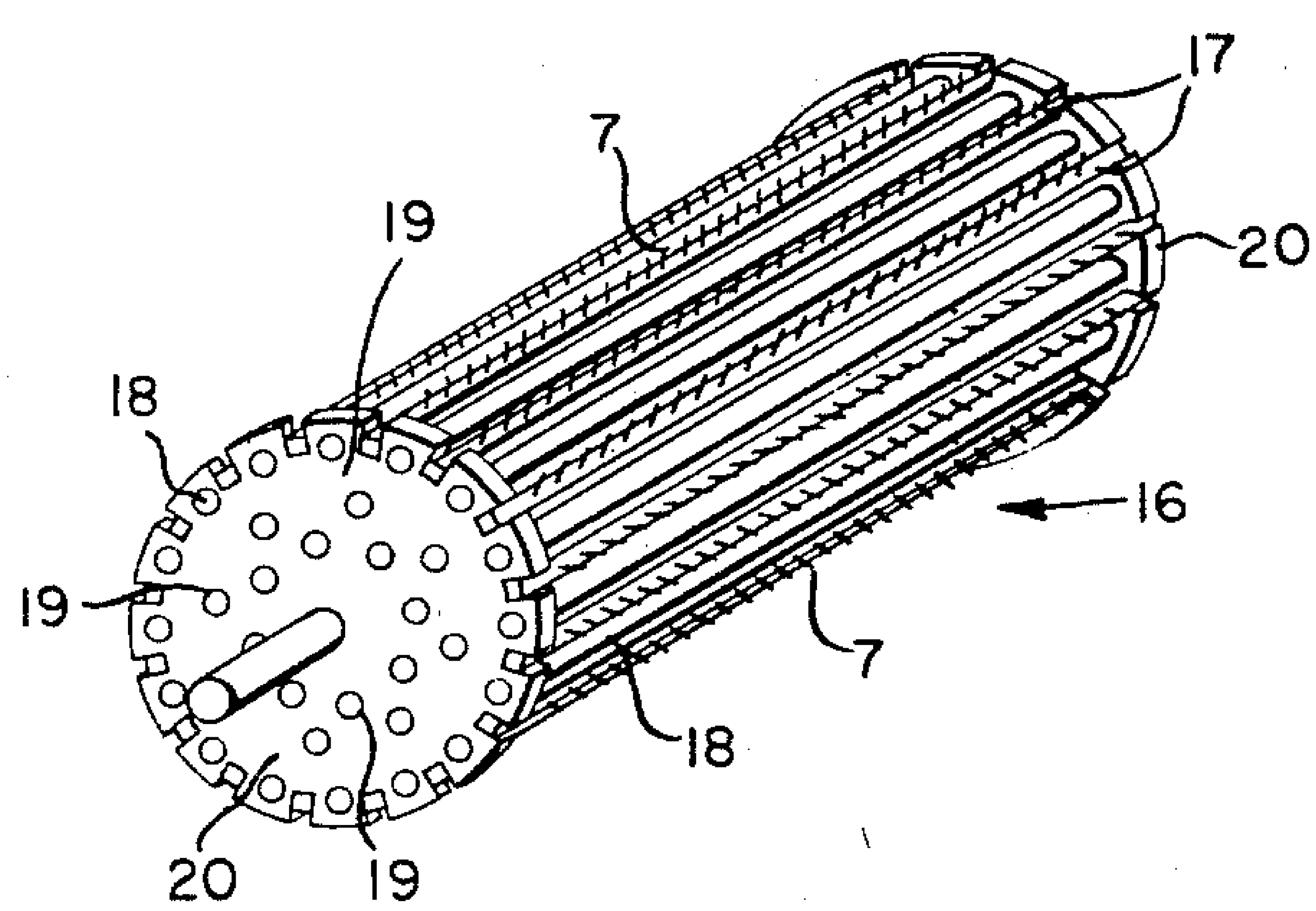


FIG. 8



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TOW COMBING PROCESS

Filed Oct. 3, 1966

PRIOR ART

FIG. 3a

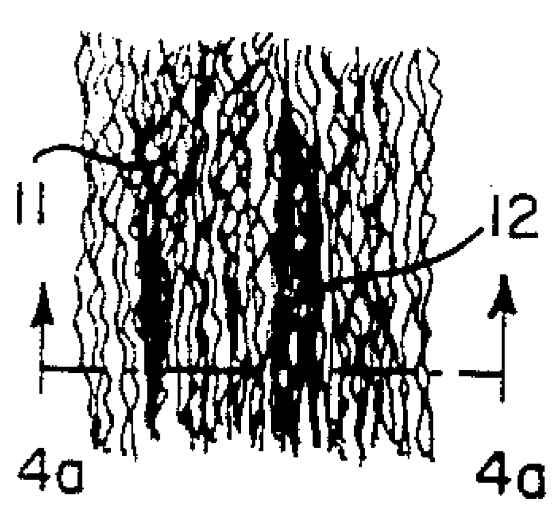
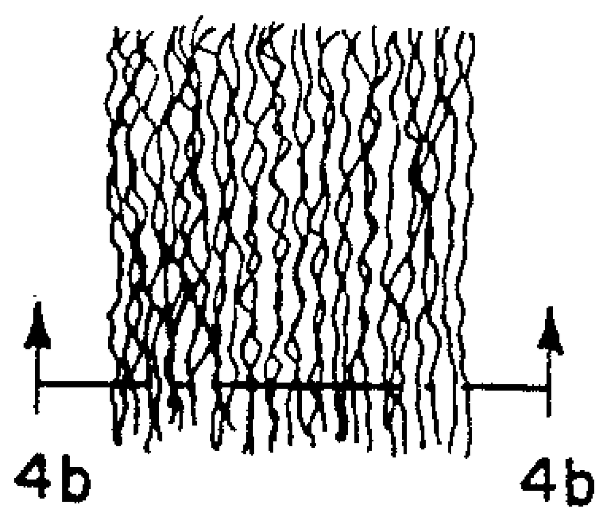


FIG. 3b



PRIOR ART

FIG. 4a

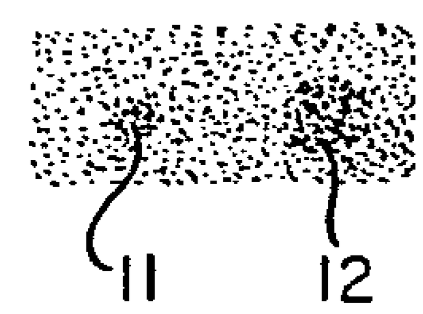


FIG. 4b

FIG. 5

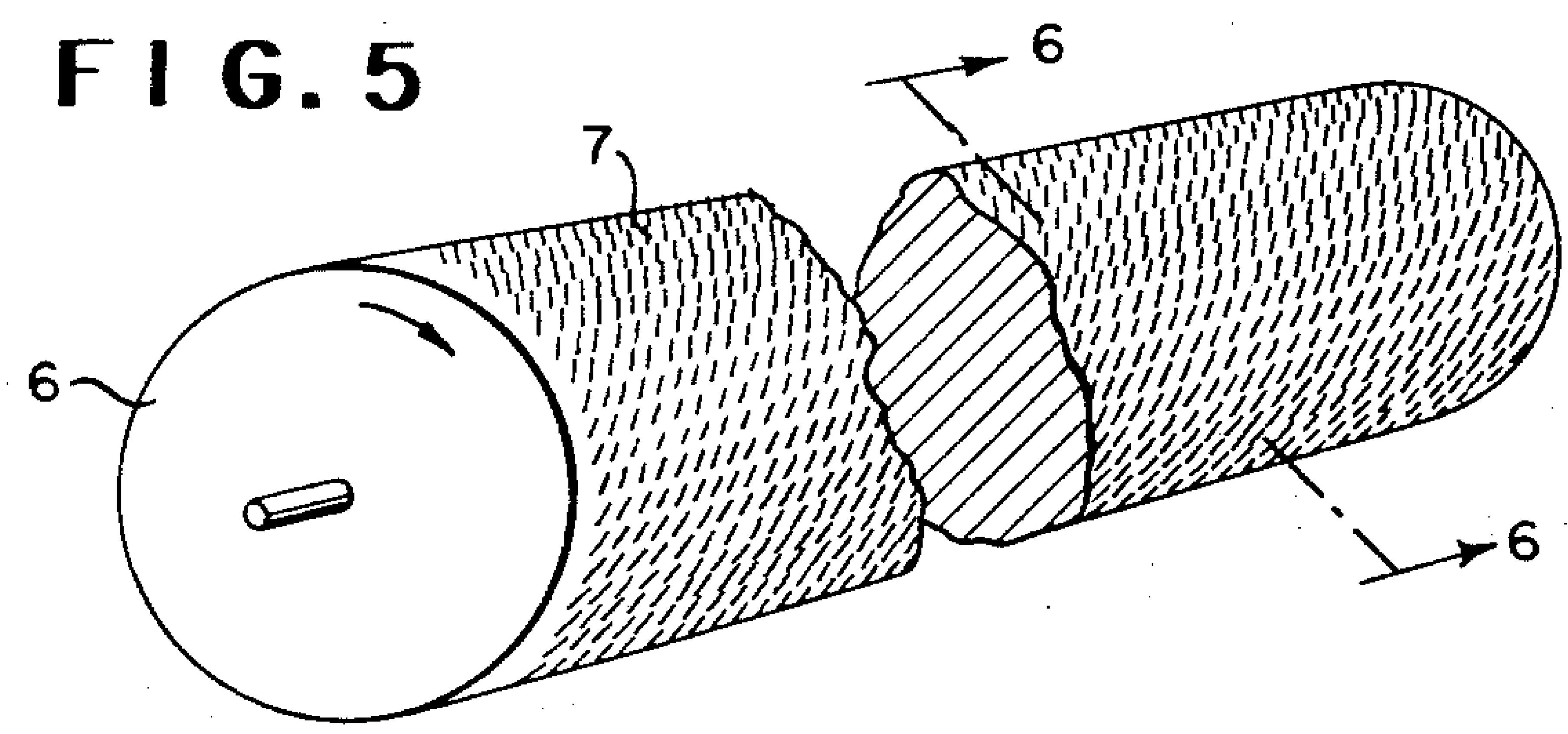
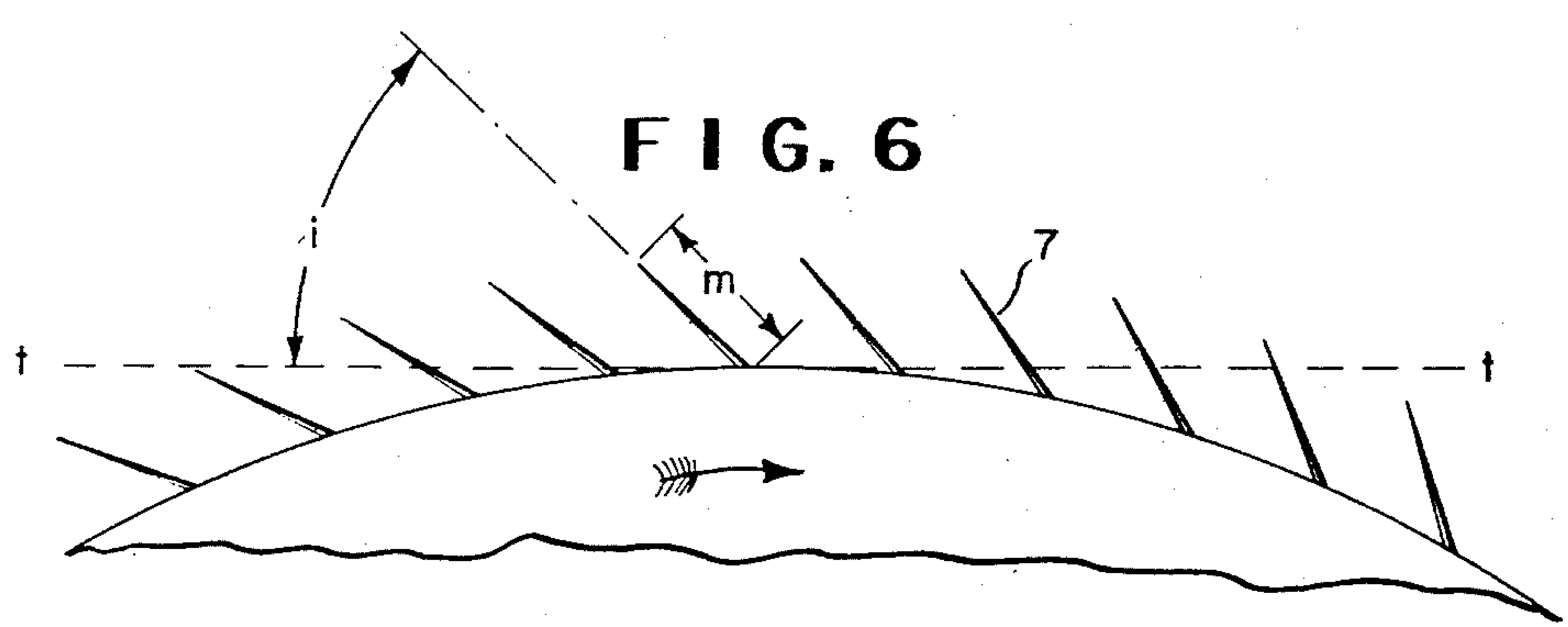


FIG. 6



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TOW COMBING PROCESS

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U.S. Cl. 19—65 9 Claims

Int. Cl. D01b 3/04

ABSTRACT OF THE DISCLOSURE

A process for combing crimped tow of synthetic fibers wherein moving tow is contacted over a curvilinear path by a moving, substantially cylindrical, needle-bearing surface. The tow feed, speed of the needle bearing surface, and length and inclination of the needles are interrelated variables.

This invention relates to treatment of a tow of man-made textile filaments, and is more particularly concerned with an improved process for opening tows to distribute the filaments in a homogeneous arrangement suitable for direct tow-to-sliver conversion with subsequent cotton system drafting and spinning into yarn.

In the commercial production of spun yarns, it is customary to cut a tow to staple, card the staple to sliver, and draft and twist the sliver to roving and yarn. The carding step is performed to clean, open, separate and somewhat parallelize the fibers, and so dispose them for subsequent formation of sliver suitable for drafting and conversion to yarn. Since carding is necessarily time-consuming and involves utilization of expensive equipment, artisans have attempted to circumvent it by use of specialized tow-to-sliver converters, such as the Pacific Converter which cuts tow to staple and converts the staple to sliver, or new stretch-break machines, such as the Turbo Stapler which breaks tow to staple and produces sliver. After doubling and drafting, the roving from these slivers may be fed to the spinning frame for spinning to yarn. Although the cutting-type converter has been highly successful when used in conjunction with worsted-system drafting and spinning, it was heretofore impossible to produce a spun yarn in this connection by cotton-system drafting and spinning. The commercially available stretch-breaking converters are less than satisfactory for large-scale production of sliver suitable for cotton-system spinning because they are unable to convert heavy-denier tow (i.e., 225,000 to 2,000,000 denier) to staple with length distribution suitable for such spinning. Thus, in large-scale production of cotton-system-spun yarn, intermediate carding was believed absolutely necessary.

It has recently been found that the quality of yarns and their ease of production by the tow-to-sliver intermediate has a critical relationship, inter alia, to the degree of separation or "openness," parallelization, and homogeneity of the fiber arrangement in the starting tow. Accordingly, attempts have been made to provide the proper combination of these characteristics in tows for conversion to a cotton-system-spun yarn by the tow-cutting sliver-preparation intermediate treatment. However, even the most modern methods of tow processing have proven inadequate for collectively changing said characteristics over their gamut of possibilities.

The source of difficulty in achieving openness and homogeneity in fiber arrangement in tows lies in the general quality of the as-produced tows. In producing crimped tows, the constituent filaments are drawn as a bundle and then crimped, either mechanically, e.g., by the stuffer-box treatment shown in Hitt U.S. Patent No. 2,747,233, dated May 29, 1956, or with hot fluids, e.g., as disclosed in Claussen et al. U.S. Patent No. 3,055,080,

dated July 19, 1960. Such processing of heavy-denier tow invariably results in a considerable number of filaments stuck together, crimped in phase, or otherwise in intimate contact over a portion of their length. Such "clumps" or "caterpillars," as they are frequently called, are not easily removed. Processes for opening tow have been proposed, but until now no process has effected substantially complete removal of caterpillars in high-denier tows.

The present invention has, as its most important object, the provision of an open, high-denier tow, the constituent filaments of which are parallelized and homogeneous in arrangement, which is readily amenable to direct tow-to-sliver conversion and subsequent cotton-system processing to spun yarn. Another object of this invention is to provide an open tow which is essentially free of defects such as caterpillars. A further object is a quick, simple and economical method for producing such a tow. Other objects will appear hereinafter.

These and other objects are accomplished by processing with stiff needles (as defined hereinafter) protruding from a surface moving in a substantially curvilinear path, e.g., with a needled roller, a heavy-denier tow of 225,000 to 2,000,000 denier (25,000 to 222,000 tex) to provide an essentially homogeneous arrangement of crimped, parallelized, nonelastomeric man-made textile filaments of from 1.0 to 40 denier (0.11 to 4.44 tex) per filament.

The present invention includes a method for effecting homogeneous interfilament separation in a heavy-denier tow (225,000 to 2,000,000 denier) of crimped, manmade, continuous filaments, comprising the steps of (A) feeding the tow at a speed (V) of approximately from 6 to 400 yards per minute (5.5 to 366 meters per minute), in the general direction of constituent-filament orientation, peripherally to a curved, needled surface, (B) subjecting the advancing tow to combing action by making intimate arcuate contact with the stiff needles while the surface moves, in said contact area, in the general direction of tow feed at a peripheral speed of from approximately 1.1 (V) to 15 (V), the line of contact in a plane along the feed direction and perpendicular to the tow width is substantially an arc of a circle subtended by a central angle of up to approximately 180°, (C) withdrawing said tow at a speed of from 1.0 (V) to 1.2 (V), with the proviso that the sum of angles α and β as herein defined is in the range of from approximately 90° to 270°.

The invention will become clearer from the following description and the accompanying drawings and photographs wherein:

FIGURE 1 and FIGURE 2 are schematic illustrations of preferred embodiments of the present invention;

FIGURE 3*a* represents a heterogeneous arrangement of fibers indicative of tows of the prior art;

FIGURE 3*b* represents an open, homogeneous arrangement of fibers according to this invention;

FIGURE 4*a* is a cross-sectional view of the tow of FIGURE 3*a*, taken along the line **4*a*—4*a***;

FIGURE 4*b* is a cross-sectional view of the tow of FIG. 3*b* taken along the line **4*b*—4*b***;

FIGURE 5 is an isometric view of the needled roller of FIGURE 1;

FIGURE 6 is an enlarged partial cross-sectional view of the needled roller of FIGURE 5, taken along the line **6—6** of that figure;

FIGURE 7 is a schematic illustration of another embodiment of this invention showing a needled surface engaging a tow;

FIGURE 8 is an isometric view of an alternate embodiment of a comb roller which can be used in accordance with this invention.

Referring to the drawings in more detail, FIGURE 1 shows tow **1** being fed to and passing between feed rollers

2, 3 and 4. Upon leaving the feed rollers, the tow passes partly around guide bar **5** and subsequently makes contact with roller **6**, of radius R, having needles **7** protruding from its surface. The roller is contacted over an arc subtended by angle δ. Upon leaving the needle roller, the combed tow passes partly around guide bar **8** and subsequently passes between delivery rollers **9** and **10**. FIGURE 2 shows a process similar to the process shown in FIGURE 1, but with two comber rollers: a first roller **6** and a second roller **6'**; the numbers corresponding to the numbers of FIGURE 1 except that the elements of the second roller and apparatus closely associated therewith are designated with primes.

FIGURE 3*a*, FIGURE 3*b* and FIGURE 4*a*, FIGURE 4*b* show representative portions of tows before and after treatment. The tow of FIGURE 3*a* and FIGURE 4*a* has "caterpillars" **11** and **12** which characterize it as having the heterogeneous filament arrangement typical of tows of the prior art. The tow of FIGURE 3*b* and FIGURE 4*b* has an essentially homogeneous fiber arrangement typical of the present invention.

FIGURE 5 is an enlarged isometric view of the roller **6** of FIGURE 1, having needles **7** protruding from its surface. FIGURE 6 shows a cross section of roller **6** having needles **7** protruding from its surface at an angle of inclination i measured from a tangent t to the roll surface, each needle having a length m measured from the point of said tangency to the needle point.

FIGURE 7 shows an alternate embodiment of the present invention wherein tow **1** contacts a moving needle-carrier belt **13** having protruding needle **7**, the carrier being driven and guided by rollers **14** and **15** in such a manner that the tow contacts the needles during its curvilinear movement with roll **14**. The roll has a radius R, and contact is made with the needled surface over an arc subtended by angle δ. FIGURE 8 is an isometric view of an optional low-friction roller **16** having needles **7** protruding from bars **17** which are affixed to end flanges **20**. An endless flexible film (not shown) is looped over and under a series of outer supporting rods **18** and inner supporting rods **19** which are rotatably mounted in end flanges **20**.

The use of such apparatus in the process of this invention involves a subsequently defined critical combination of process variables for providing effective combing of a tow by a needled surface. It was entirely unexpected that an endless tow of such a heavy denier (above 225,000) would yield to continuous combing action, resulting substantialy complete "caterpillar" removal to provide parallelization of filaments and homogeneous interfilament separation.

A tow as used herein is defined as a group of continuous, nonelastomeric, man-made filaments which possess a certain amount of crimp. Useful tow-deniers may be from approximately 225,000 to 2,000,000, and the individual filaments may be in the textile denier range from approximately 1 to 40 denier, with approximately 1.5 to 6 denier per filament being most common when the end use is in spun staple yarn.

Examples of some nonelastomeric man-made filaments useful in the practice of this invention include polyamides such as polyhexamethylene adipamide and copolymers thereof, polyesters such as polyethylene terephthalate and copolymers thereof, acrylics such as polyacrylonitrile and copolymers thereof, cellulosics such as rayon and cellulose acetate and polyolefins such as polyethylene and polypropylene.

The crimp of a fiber refers to its waviness or nonstraight configuration. The crimps may be of any type, e.g., of "sawtooth" type or helical three-dimensional type, or a combination of these along the fiber length. The crimps may be arranaged either regularly or randomly. The crimp frequency, i.e., the frequency of occurrence of crimps along the length of the fibers in the new tow may be from approximately 1 to 50 crimps per inch (0.4 to 20 crimps per cm.) of relaxed fiber length.

The tow of the present invention possesses a homogeneous structure which is free from caterpillars. It has a generally parallelized fiber arrangement. By this is meant not only that the filament ends in a representative whole cross-section of the tow display themselves randomly as shown in FIGURE 3*b*, but that the individual filaments run substantially in the same direction in the tow. The latter is not necesarily to be construed as meaning that the crimps are in phase. The general direction of the filaments is not crisscross but is substantially parallel.

The first step in the new process is to feed a tow, in the same direction as the general orientation of its constituent filaments, to the periphery of a moving needled surface. The feed speed may be from about 6 to 400 yards per minute (6 to 60 y.p.m. are generally useful). This step is conveniently accomplished by passage of the tow between the nip of communicating, rotating, feed rollers.

The second step in the new process is to contact the advancing tow with a moving needled surface. The surface is preferably that of a cylinder having protruding needles, such as shown in FIGURE 5, but other suitable arrangements include a needled lattice or belt driven by rotating cylinders as shown in FIGURE 7. To insure adequate treatment of the tow by the needles, it is important that the path of contact of the tow with the surface be substantially curvilinear. If the contact is made in an extended straight path, as would be the case, for instance, if the tow passed in vertical contact with the belt illustrated in FIGURE 7, it would not be possible to insure adequate contact.

A path of substantially curvilinear contact also includes the type of path the tow makes over a surface such as that provided by the low-friction roller of FIGURE 8. Although this type of path is not as smoothly contoured as the arc the tow makes over the roller of FIGURE 5, it is substantially equivalent for present purposes and the line of such contact will herein be called an arc.

The path of contact of the tow with the needled surface must be substantially arcuate, the arc being that subtended by a central angle of up to approximately 180° and preferably from 20° to 150°. The speed of the needled surface-contact area is from 1.1 to 15 (preferably from 3 to 9) times the tow feed speed, and the direction of movement of the surface in the contact area is in the same direction as the movement of the tow.

The frequency of occurrence of the needles on the carrying surface and the diameters of the needle wires are chosen to accommodate the tow to be treated, the choice depending on the denier and number of filaments in the tow. For example, with a 1,000,000-denier tow of 1.5 d.p.f., the preferred needle frequency is from 100 to 300 needles per square inch (15 to 46 needles per square cm.) of surface, and preferred needle diameter is from 0.010 to 0.020 inch (0.25 to 0.51 millimeter). The needles are preferably arranged in rows which run perpendicular to their direction of travel, but they may be spaced in other configurations. Preferably, the needle frequency per row, i.e., the number of needles per unit row-length, differs from row to row along the circumference of the curved surface. Best results are obtained by using different prime-number needle-frequencies (needles per inch) for adjacent rows, as for example 53 needles per inch for the first row, 61 needles per inch for the second row, etc.

The needles must be stiff. For the purposes of the present invention a stiff needle is defined as one having a bending stiffness resistance EI/m^2 of greater than 0.15 pound (68 grams), where E is the modulus of elasticity, I is the moment of inertia of the needle cross-section and m is the protruding needle length. The bending stiffness resistance of the needle is equivalent to the value of transverse load applied to the tip which will produce a tip deflection of one-third the cantilever length (m) of the needle; a stiff needle will deflect less than $m/3$ under a load of 0.15 pound.

The length of the needles (depicted as m in FIGURE 6) should be sufficient to treat the full thickness of the tow. Preferably the needles are of sufficient length to penetrate completely through the tow. However, when two needled surfaces are provided as shown in FIGURE 2, one to comb the full width of the tow from one side and the other to comb the full width from the other side, the needles only need to penetrate about ½ of the tow thickness for each contact. The needles may be straight or slightly curved in the direction opposite to the direction of movement of the surface. The orientation of the needles must be in a plane perpendicular to the axis of rotation of the needled surface in the area of contact and must be inclined from the tangent to the arc of contact at the needle base. The angle of inclination of the needles (designated i in FIGURE 6) relative to the tangent as herein described may be from approximately 20° to 140° and is preferably from 30° to 70°, and just as important, must be within the limitations of the equations to follow which include as a variable the needle inclination.

After achieving proper tow contact with the needle-bearing surface, the next step is to withdraw the tow from the surface. The take-off speed is from approximately 1.0 to 1.2 and preferably 1.05 to 1.15 times the tow feed speed. To insure needle disengagement from the tow and prevent roll wraps, it may be desirable to introduce assisting means, such as an air-jet, a doffer-bar, or a rotating and/or vibrating doffing member, in the space between the tow and the needles just subsequent to the curvilinear contact.

Within the limitations described above in the practice of the present invention, it has been found that the process variables consisting of tow feed speed, speed and radius of curvature of the needled surface in the area of tow contact, needle length, and needle inclination angle must be interrelated, as defined below, such that the sum of angle α and an angle β is from about 90° to 270°. The angle α is obtained by means of the equation,

$$Q=\frac{\cos i \pm (f+\sin i)\sqrt{f^2+2f\sin i}}{1+f^2+2f\sin i}$$

Q will have two values. When both values are positive, the smaller of which is, e.g., g, then $\alpha=\arccos g$; when the two values are positive and negative, e.g., $+k$ and $-y$, then $\alpha=\arccos(-y)$; when both values are negative, the numerically larger (absolute value) of which is e.g., $-h$, then $\alpha=\arccos(-h)$. The angle β is obtained by the equation,

$$\beta=\arccos\frac{1-X[1+f^2+2f\sin i]^{-1/2}}{\sqrt{1+X^2-2X[1+f^2+2f\sin i]^{-1/2}}}$$

In the above equations:

X=peripheral speed of the needled surface divided by the tow feed-rate,

f=the protruding needle length divided by the radius of curvature of the needled surface in the contact area, and

i=the needle inclination angle in degrees, measured as defined above.

The values of X, f and i should be such that the calculated value of α is within the range of 20° to 160° and the value of β is within the range of 55° to 179°.

In the practice of the present invention, the sum of the angles α and β must be within the range of approximately 90° to 270°. If higher or lower values are used the objects of this invention will not be accomplished.

The new tows may be converted to spun yarns by the tow-to-sliver route followed by conventional spinning on the worsted or even the cotton system. A caterpillar-free tow converted to sliver by tow cutting, e.g., on the Pacific converter, will require fewer passages of gilling and pin drafting than conventionally used to spin worsted yarns,

with a consequent economical advantage. Similarly, in sliver preparation by tow stretch-breaking methods, e.g., Turbo stapler, the new tow readily provides a better staple length distribution and randomized (nonphasing) breaks. Furthermore, these tows find use as bonded or unbonded structures such as stuffing materials for pillows, cushions, or the like.

This invention is further illustrated by the following examples of preferred embodiments although it is not restricted thereto.

EXAMPLE I

This example illustrates the preparation of a tow according to this invention.

One end of poly(ethylene terephthalate) tow is produced by methods well known in the art (involving melt-spinning, drawing the resulting filaments, and stuffer-box crimping). The tow is 800,000 denier and consists of approximately 533,000 filaments. The tow contains a considerable number of caterpillars, of the order of 50 per linear foot (164 per meter). Each caterpillar contains approximately 300 to 10,000 filaments.

A combing apparatus similar to that shown in FIGURE 2 is fabricated according to the following specifications:

(1) *First needle roller.*—4-inch (10.2 cm.) diameter, 14-inch (35.5 cm.) long steel cylinder containing 24 equidistantly spaced rows of sharp-pointed steel needles, each row being parallel to the cylinder axis; needle frequency of the first row is 47 needles/inch (18.5 needles per cm.); needle frequency of each subsequent row is 53, 61, 73, 67 and 59 needles per inch (20.8, 24, 28.7, 26.4 and 23.2 per cm.), in that order, the number pattern being repeated four times around the circumference of the roller; wire diameter of needles in each row being 0.015, 0.012, 0.012, 0.010, 0.010 and 0.012 inch (0.381, 0.305, 0.305, 0.254, 0.254 and 0.305 millimeter), respectively; needle inclination angle i is 45°. Needle length m for the respective rows is 0.141, 0.125, 0.125, 0.109, 0.125 and 0.125 inch (3.572, 3.175, 3.175, 2.778, 3.175 and 3.175 millimeters); surface spacings between each pair of rows are partially recessed.

Second needle roller.—Same as the first with the exception that needle frequency of the rows along the roller circumference conforms to the pattern 53, 61, 68, 54, 67 and 59 needles per inch (20.8, 24, 26.8, 21.2, 26.4 and 23.2 per cm.), repeated four times around roll circumference; wire diameter of needles in each row being 0.012, 0.012, 0.010, 0.012, 0.010 and 0.012 inch (0.305, 0.305, 0.254, 0.305, 0.254 and 0.302 millimeter), respectively; and needle length m being 0.125 inch (3.175 millimeters) throughout.

The tow is fed to the first roller at a speed of 6 y.p.m. (5.49 meters/minute). Each roller is driven at a peripheral speed of 44.4 y.p.m. (40.7 meters per minute) in the direction of tow feed at the area of contact. The tow contacts each roller over an arcuate path subtended by a central angle of 60° and is withdrawn from the second roller at a speed of 6.42 y.p.m. (5.87 meters per minute). The sum of the angles α and β is 224.4° for each roller contact.

The resulting tow is an open homogeneous array of parallelized filaments notably characterized by the complete absence of caterpillars.

EXAMPLE II

This example illustrates the preparation of another tow of the present invention and the cotton-system preparation of a useful textile yarn therefrom by way of tow-to-sliver conversion.

One end of poly(ethylene terephthalate) tow is produced by methods well known in the art (involving melt-spinning, drawing the resulting filaments, and stuffer-box crimping). The tow is 600,000 denier and consists of approximately 400,000 filaments. The tow contains a considerable number of caterpillars, of the order 50 per linear foot (164 per meter), each caterpillar containing approximately 300–10,000 filaments.

The apparatus is identical to Example I with the following exceptions: Needle frequency of each needle row of the first roller is 40 needles/inch (15.75 needles per cm.), needle wire diameter being 0.015 inch (0.381 millimeter); needle frequency of each row of the second roller is 54 needles per inch (21.2 needles per cm.), needle wire diameter being 0.012 inch (0.305 millimeter); length of the needles of the first roller is 0.172 inch (4.366 millimeters); of the second roller, 0.125 inch (3.175 millimeters), the surface spaces between needles are not recessed but the needle rows are fitted in recessed slots with a needle inclination angle *i* of 45°. The tow processing conditions are the same as Example I with the following exceptions: Tow feed speed is 6 y.p.m. (5.49 meters/minute); roller surface speed is 22.2 y.p.m. (20.3 meters/minute); contact with first and second rollers is over an arc subtended by 75° and 60° angles, respectively; sum of α plus β for contact with first roller is 221.6°; sum of α plus β for contact with second roller is 221.9°.

The resulting tow is an open homogeneous array of parallelized filaments and notably characterized by the substantially complete absence of caterpillars.

Sliver is prepared from the treated tow by processing it on a Pacific Converter, fitted with a 2.5-inch (6.35 cm.) staple-cutter roll. The converter sliver is given 3 passages of drawing, each with a draft of about 11, using 4 ends, 4 ends, and 5 ends for the feed to the first, second, and third passages of drafting, respectively. The resulting drawn sliver is of about 33 grains/yard (2340 tex) weight. A 4-hank (148 tex) roving is produced from the drawn sliver by processing it on a roving frame with a draft of 15.8. Two ends of this roving are fed to a spinning frame with a draft of 14.1 to spin a 30/1 cc. yarn (19.7/1 tex) with 9.8 turns/inch (3.86 turns/cm.). The spun yarn is strong, useful and shows a Cotton Count times Lea Strength (lbs.) product of 4290.

The above Lea Strength product is surprising for cotton-system spun yarn and shows another advantage of the new tow. Lea Strength product of the same count yarn produced from the same type starting tow (not combed) cut with a staple-cutter setting of 2.5 inches (6.35 cm.), carded and spun in the same manner as above has a Lea Strength product of about 3700. The increased strength of yarn produced from the new tow by the tow-to-sliver intermediate is most likely the result of the high degree of filament openness and parallelization in the new tow.

EXAMPLE III

This example shows the effect of processing tow by a process identical to the process used in the preceding examples but with no comb-roller contact.

The starting tow is identical to the starting tow of Example I. The process is identical with the process of Example I with the exception that the comber-rollers are absent. The tow feed speed to the first guide bar is 5.6 y.p.m. (5.12 meters/minute) and the withdrawal speed from the last guide bar is 6 y.p.m. (5.49 meters/minute). The characteristics of the resulting tow are substantially the same as those of the starting tow.

EXAMPLE IV

This example shows high-speed operation of the new process.

The starting tow is identical to the starting tow of Example I.

The apparatus is substantially similar to the apparatus of Example I with the following exceptions: Tow feed speed is 55.7 y.p.m. (51 meters per minute) instead of 6 y.p.m. (5.49 meters per minute); the surface speed of each roller is 287 y.p.m. (263 meters/minute). The tow contacts each roller over an arc subtended by central angle of 60°. Withdrawal speed after contact with the first and second rollers is 307 y.p.m. (281 meters/minute). The sum of the angles α plus β for each contact is 223.4°.

The resulting tow is substantially similar to the resulting tow of Example I.

EXAMPLE V

This example shows a tow of polyacrylonitrile fibers produced in accordance with the present invention.

One end of a tow comprising filaments of an acrylic terpolymer (93.6% acrylonitrile, 6.0% methyl acrylate and 0.4% sodium styrenesulfonate) is produced by methods well-known in the art (involving dry-spinning, drawing the resulting filaments and stuffer-box crimping). The tow is 470,000 denier (52,200 tex) and consists of 235,000 filaments. The tow contains a considerable number of caterpillars, of the order of approximately 50 per linear foot (164 per meter), each caterpillar containing approximately 300 to 10,000 filaments.

The apparatus is the same as used in Example IV and the process is identical to the process of Example IV with the exception that tow feed speed is 6 y.p.m. (5.49 meters/minute) and rollers surface speed is 30.9 y.p.m. (28.3 meters/minute) and tow withdrawal speed after contact with the second roller is 6.42 y.p.m. (5.87 meters/minute).

The sum of the angles α and β for the first contact is 223.4°; for the second contact is 223.4° also.

The resulting tow is open and substantially free of caterpillars.

EXAMPLE VI

This example shows the effect of combing tow in general accordance with this invention but when the sum of angles α and β is not within the specified range.

Example I is repeated with the following exceptions: Only the second needle roller is used and its needle frequency is of the pattern 54–68–84 needles/inch (21.2–26.8–33.1 needles/cm.) repeated 8 times around the roller circumference; the roller is driven at a peripheral speed of approximately 2.78 y.p.m. (2.54 meters per minute); tow contact with the roller is over an arc subtended by an angle of 120°; the sum of α and β is 78.2°.

In the operation, many filaments of the tow do not withdraw properly from the needles and severe needle bending and damage take place. Only about 3 yards (2.75 meters) of tow can be processed and these are obtained with considerable difficulty involving the necessity of stopping and restarting the operation many times. The quality of the resulting tow is extremely poor.

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the exten defined in the following claims.

I claim:

1. In the processing of heavy-denier tows of man-made, nonelastomeric, continuous filaments, wherein the filaments are drawn and crimped as a tow to prepare them for subsequent textile manufacture, the improvement for treating a 225,000 to 2,000,000 denier tow of crimped, textile-denier filaments to provide an open homogeneous array of parallelized filaments characterized by freedom from caterpillar filament clumps, which comprises (A) feeding the tow of crimped textile filaments at a speed of approximately 6 to 400 yards per minute to a surface bearing stiff needles of sufficient length to treat the full thickness of the tow and moving in a curvilinear path in the general direction of the advancing tow at a speed of 1.1 to 15 times said feed speed, contacting the tow with the needles along an arc of up to 180° around said curvilinear path, and withdrawing the tow from the needles at a speed of 1.0 to 1.2 times said feed speed, the process being conducted under such conditions that, when calculated in accordance with the following formulas, the value of the angle α is within the range of

20° to 160°, the value of the angle β is within the range of 55° to 179°, and the sum of the angles α and β is from 90° to 270°:

α=arc cos Q, where Q is selected from the pair of values defined by the equation,

$$Q=\frac{\cos i \pm (f+\sin i)\sqrt{f^2+2f\sin i}}{1+f^2+2f\sin i}$$

the value of Q being the smaller of a pair of positive values, the negative of a pair of negative and positive values, and the numerically larger of a pair of negative values, and

$$\beta=\text{arc cos}\,\frac{1-X[1+f^2+2f\sin i]^{-1/2}}{\sqrt{1+X^2-2X[1+f^2+2f\sin i]^{-1/2}}}$$

wherein X is the speed of the needle-bearing surface divided by said tow feed speed, f is the protruding needle length divided by the radius of said curvilinear path of the surface, i is the angle of inclination of the needles measured from a tangent to the curvilinear path at the base of the needle which extends backward from the direction of movement of the needle and the angle i is within the range of 20° to 140°.

2. A process as defined in claim **1** wherein said filaments are approximately 1.5 to 6 denier per filament.

3. A process as defined in claim **1** wherein the crimped filaments of said tow have been stuffer-box crimped to have 1 to 50 crimps per inch of relaxed filament length.

4. A process as defined in claim **1** wherein said needles move in a circular path and contact the tow along an arc subtended by a central angle of 20° to 150°.

5. A process as defined in claim **1** wherein said needle-bearing surface moves at a speed of 3 to 9 times the tow feed speed.

6. A process as defined in claim **1** wherein said needle-bearing surface has from 100 to 300 protruding needles per square inch and the needles have a diameter of 0.010 to 0.020 inch.

7. A process as defined in claim **1** wherein said angle of inclination of the needles is from 30° to 70°.

8. A process as defined in claim **1** wherein said needles are arranged in rows perpendicular to the direction of needle movement at a needle frequency per row which differs from row to row.

9. A process as defined in claim **1** wherein said tow feed is from 6 to 60 yards per minute.

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