TREATMENT OF MULTI-FILAMENT YARN
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The present invention relates to the treatment of yarn and more particularly to subjecting substantially untwisted thermoplastic synthetic high polymer multi-filament yarn to the action of a gas passing across or through the yarn in the form of a jet stream. The invention is also directed to an improved apparatus for carrying out the foregoing method.

In the textile trade, it is a well known fact that thermoplastic yarns having substantially no twist are difficult to handle in textile processes such as weaving and knitting because the parallel filaments are only loosely associated and therefore incur problems in the said handling operation. In order to overcome this problem, it is normally necessary to provide a twisting step and, if required, the twisted threads are also given a sizing operation which imparts better cohesion between the filaments of the yarn. However, the twisting operation is time consuming and therefore a costly operation, and, from the standpoint of economy, it is highly desirable to eliminate the twisting step, if the filaments can be made to cohere by other methods.

In recent years in the textile field, various methods and apparatus have been developed for modifying the characteristics of yarns consisting of a multiplicity of filaments by passing the yarn through a zone in which gas such as air and the like is introduced under pressure to effect a turbulence in the zone and thereby cause the individual filaments to form loops, convolutions, and the like and, upon withdrawing the yarn from the turbulent zone under a reduced tension, collect the same either with or without twisting depending upon whether the yarn was twisted prior to entry into the zone. Such yarn is characterized by a multiplicity of crumodal loops particularly along the outer surface of the yarn bundle and is known in the trade as Taslan. The basic patent covering this type of yarn is U.S. Patent No. 2,783,609.

Another air jet treatment of regenerated cellulose yarn is covered in Canadian Patent No. 554,150 and the object of that process is to produce a twisted yarn. It is stated therein that the thread undergoes an increase in denier and decrease in length during the treatment which in effect is making a more voluminous yarn by the said treatment. The patentee describes a treatment in which the rate of withdrawing yarn from the treatment zone is from 4% to 10% less than the rate of feed. In the case of regenerated cellulose yarn, it has been determined that it is impossible to provide that degree of overfeed because slack will occur in the yarn which will cause it to wrap around the feed roller. This is due to the inelasticity of regenerated cellulose yarn. There would be an absence of tension on the yarn and the only way to induce tension would be to maintain the withdrawal speed at least equal to the input speed. This, however, is not contemplated by the patent.

Still another method of treating filamentary yarn with gases is disclosed in U.S. Patent No. 2,985,995. However, in this case, the patentees preferably utilize several air jets of complicated construction in which the gas is directed onto the thread and impinged on a solid flat surface. Such a system is conducive to interlacings to a lesser extent and the method causes adverse optical effects in the yarn which is objectionable in a woven fabric. The patent describes in detail the various factors necessary to produce interlaced yarn, but there is no systematic method in which the optimum interlacing action is determined and effected, nor is there any disclosure to correlate the air pressure and the tension in the yarn in order to effect optimum results.

It has now been unexpectedly determined that in addition to the two basic controlling factors, which are yarn tension and air pressure, in order to obtain the desired degree of intertwining of filaments, the intensity of the sound which is measured in decibels is a critical factor to effect optimum intertwining of the filaments. In other words, for a given tension, the air pressure is chosen which gives the highest number of decibels that can be borne by the human ear for an optimum degree of intertwining. The degree of intertwining varies inversely with the tension for a given air pressure. Therefore, at very low tension, for example, below 0.05 gram per denier, loops will form around the surface of the yarn and make the Taslan type of yarn. On the other hand, tensions cannot be permitted above 0.3 gram per denier because, then in attempting to obtain a sufficient intertwining of the filaments, the air pressure must be increased to a point where the yarn will be damaged.

It is therefore an object of the present invention to provide a thermoplastic yarn composed of a multiplicity of filaments which have been treated with a gas to provide the optimum degree of intertwining or coherency effect.

It is a further object of this invention to utilize a method in which tension on the yarn and the air pressure are correlated to effect a maximum degree of sound or loudness as measured in decibels.

Another object of the present invention is to provide a simple yarn intertwining assembly which may be easily adjusted for varying yarn conditions and the efficiency of which is directly proportional to the loudness of sound produced.

A still further object of this invention is to provide a resonance or cushioning chamber for receiving a stream of gas after passage of the same through a bundle of filaments and for absorbing the initial surge of said gas to prevent disorderly secondary gas currents from interfering with yarn entanglement by the gas jets.

These objects may be accomplished, in accordance with the present invention, by providing an intertwining method based upon an air pressure system using a resonance chamber constructed in different dimensions from which one dimension specifically will give the optimum intertwining effect while, with the change of the dimensions of the resonance chamber in cooperation with a range of air pressure, overfeed and tension will cover a broad spectrum of intertwining effects sufficient for a filament cohesion ranging from twist imitating draw twist up to a twist avoiding twist slashing.

The foregoing, as well as other objects and advantages of the present invention, will become apparent to those skilled in this art upon study of the following description taken in conjunction with the accompanying drawings, wherein
FIGURE 1 represents in perspective a preferred embodiment of the apparatus of this invention with the coverplate opened for inspection;

FIGURE 2 is a cross sectional view taken along line 2-2 of FIGURE 1, but with the coverplate closed to illustrate alignment and tensioning of yarn within the apparatus; and

FIGURE 3 is an enlarged schematic view showing the alignment and relative disposition of significant elements, taken generally along the line 3-3 of FIGURE 1 but omitting the housing structure for purposes of clarity.

With attention now directed to the drawings, particularly FIGURE 1, it will be seen that housing 10 is provided for supporting and maintaining in proper position a jet assembly 11 and a cylindrical plug 12. The jet assembly 11, including gas supply tube 13, is removable and adjustably clamped within housing 10 by any suitable means such as set screw 14. Likewise, cylindrical plug 12 is also adjustably positioned by set screw 15.

As will be seen from the drawing, housing 10 is provided with a hollow opening 16 to provide an area or zone for receiving the discharge end of jet assembly 11 and the free end of cylindrical plug 12. Thread guides 17, 17 are secured to housing 10 by any suitable means and extend diametrically across hollow opening 16. Although these thread guides may be of conventional V-slot construction, it is important that the slots in each be sufficiently small to prevent lateral vibration of yarn 18 passing therethrough. Moreover, as will be seen from FIGURE 2, thread guides 17, 17 should be adjusted to provide precise alignment between yarn 18 and jet orifice or nozzle 20 formed in the terminal end of the jet assembly.

In order to produce the desired effect on yarn processed by the present invention, a resonance or cushioning chamber 21 is formed in the free end of cylindrical plug 12. A reduced entrance passageway 22 provides access between chamber 21 and the atmosphere within the area defined by hollow opening 16. Although the exact shape of resonance chamber 21 is not critical, the capacity or volume of the same is very important as will be discussed infra.

Coverplate 23 performs the functions not only of enclosing hollow opening 16 and reducing the accumulation of foreign matter, but also supports yarn vibration dampening members 24, 24. Each of members 24, 24 cooperates with its corresponding thread guide 17, 17 as shown in FIGURE 2 to position yarn 18 precisely within the thread guide slots in order to insure alignment with jet orifice 20 without imparting excess tension. Thread guides 17, 17 and dampening members 24, 24 additionally define, within hollow opening 16, the operating portion of yarn undergoing treatment. The intertwining effect produced by gas discharging under pressure from orifice 20 will occur only in that unsupported portion of yarn extending between cooperating thread guides and dampening members.

Coverplate 23 also serves to support sound insulating or absorbing material 25. As shown in FIGURE 1, a blanket of material 25 overlaps the entire exposed surface of housing 10 and also surrounds the operating zone defined within hollow opening 16. As will be seen presently, the operating efficiency or effectiveness of the present invention increases directly in proportion to noise produced by gas discharging through orifice 20 and resonating within chamber 21. It has been determined, for example, that certain results are obtained with jet pressure increased to such an extent that the sound produced is unbearable unless the operators wear ear plugs. Accordingly, the sound insulating or inhibiting material 25, which may be formed from foam rubber, felt, or porous plastics such as relatively stiff polyurethane foam, is considered an indispensable element for preferred operation of this invention.

Attention is now directed to FIGURE 3 which indicates more clearly the relative size and disposition of parts found to be necessary for satisfactory operation of this invention. The diameter b of entrance passageway 22 should lie in the range between 1.0 and 1.8 times the exit diameter a of jet orifice 20. With a jet orifice diameter a of unity measured in millimeters, therefore, the entrance b should lie between 1.0 and 1.8 millimeters in diameter.

Although the exact shape of resonance chamber 21 is not critical, the capacity or volume of the same is very important as will be discussed infra. With attention now directed to the drawings, particularly FIGURE 1, it will be seen that housing 10 is provided for supporting and maintaining in proper position a jet assembly 11 and a cylindrical plug 12. The jet assembly 11, including gas supply tube 13, is removable and adjustably clamped within housing 10 by any suitable means such as set screw 14. Likewise, cylindrical plug 12 is also adjustably positioned by set screw 15.

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thermoplastic and therefore of a synthetic high polymer type such as polyamides, polyesters, polyalkylenes, polyacylonitriles, polyurethanes, etc. The cross section of the filaments may be circular, multi-lobe, triangular, etc. Moreover, it has been found that this system operates satisfactorily on yarns ranging in denier from 10 to 2000 or above, and satisfactory results have been found to obtain at yarn speeds from 150 meters to 500 meters per minute. It is believed that the apparatus disclosed herein may be used equally effectively with various types of gas mediums such as carbon dioxide, nitrogen, unsaturated or saturated steam, and air. For purposes of economy, air is preferred. Generally speaking, however, use of steam necessitates less pressure than use of air. It should be pointed out in this connection that use of any gaseous medium which might impart shrinkage to the yarn treated, for example, steam or heated air, must be compensated for by a slight overdraft of yarn into the system. Only that amount of overdraft necessary to compensate for shrinkage should be provided, however, since any excess amount results in formation of surface loops explained earlier. Moreover, it is essential to satisfactory operation that the thread be maintained under a low tension during treatment whether or not overdraft occurs. Finally, any tendency toward development of electrostatic charges which arises may be obviated through use of conventional procedures such as wetting the thread with either water or a sizing agent or both.

The use of sound insulation or absorbing material has been found to be an essential ingredient of the present invention, not because of the direct participation there of in the intertwining of filaments, but because of the unbearable sound inherently produced at air pressures necessary for providing the desired results. Although precise sound measurements are difficult to achieve, and the maximum bearable loudness depends upon the operator, experiments have shown, and this is believed to be unexpected, that optimum results cannot be obtained at low noise levels. Conversely, it has been found that best results are obtained by tuning the device, through use of any conventional air pressure adjustment, to provide maximum sound. The tangling assemblies are calibrated, so to speak, by relying upon the sound produced, and any system for alleviating the loud noise involved permits use of higher gas pressure and thereby improves the overall operation and results obtained. It has been found that a noise level of 124 decibels, for example, can be effectively reduced through use of sound insulation such as that shown herein to a level of 80 decibels without impairing efficiency of the entangling assembly. Consequently, the assembly may be tuned, so to speak, for maximum efficiency at a more satisfactory sound level of operation.

### EXAMPLE

A number of experiments were conducted with an apparatus substantially similar to that shown and described herein. A nylon 6 type yarn having a denier of 70 and filament count of 24 was fed through the assembly and treated with compressed air while maintaining a tension of about 6 grams. The feed rate and draw-off rate were maintained at about 150 meters per minute (no overhead), although the rate could have been adjusted up to about 500 meters per minute or higher. During these experiments, the results of which appear hereinbelow in table form, the distance c between the nozzle exit and the resonance chamber inlet, the distance d between thread guides, the diameter of entrance passageway 22, the capacity, diameter and depth of resonance chamber 21, and the gauge pressure of compressed air used were varied. These variations appear in the table and are recorded under various runs.

<table>
<thead>
<tr>
<th>Run</th>
<th>Nylon 6 thread 70 den./24 fil.</th>
<th>Distance exit nozzle to inlet resonance chamber in mm. (c)</th>
<th>Distance between thread guides in mm. (d)</th>
<th>Capacity resonance chamber in mm.³</th>
<th>Dia. resonance chamber in mm.</th>
<th>Depth of resonance chamber in mm.</th>
<th>Gauge pressure of air in atm.</th>
<th>Tension in the thread in grams</th>
<th>Coherency factor</th>
</tr>
</thead>
</table>
The first five runs reported herein illustrated that at any given distance $c$ of between 1 and 3 mm., satisfactory entanglement may be obtained. Runs 1 to 5 respectively indicate the poor entangling results obtained when the orifice diameter is too large. Entanglement begins at the distance $c$ above or below the aforementioned critical range.

In runs 6 to 16, inclusive, the jet orifice diameter, entrance passageway 22, and resonance chamber capacity are maintained constant while varying progressively the distance $d$ between thread guides. Runs 6 to 11, inclusive, were made at a constant gauge pressure of 4 atmospheres, and runs 12 to 16, inclusive, were made at 5 atmospheres pressure. In each of these runs, the tension was maintained at 6 grams. As the table will indicate, variation in thread guide spacing $d$ above 40 mm. or below 20 mm. at 4 atmospheres pressure produces unfavorable results, with the most desired characteristics being obtained at the 30 to 55 mm. spacings of runs 8 and 9. Likewise, most favorable results were obtained during the 5 atmosphere runs at a higher spacing $d$ of 30 to 55 mm., and particularly about 40 or 45 mm. Runs 17 to 20 were made while maintaining constant all features of the entrance passageway except diameter $b$ of the entrance passageway 22 leading into resonance chamber 21. Very poor results were obtained in run 17 with diameter $b$ smaller than the dimensions of $a$ of the jet orifice exit. Similarly, with diameter $b$ at about 2.5 times the dimension $a$, the results are poor. Preferred results shown at runs 18 and 19 occur when the opening or entrance passageway 22 is only slightly larger or equal to the dimension $a$.

The depth of resonance chamber 21 and likewise the volume or capacity thereof was changed in varying degree during runs 21 to 25. It will be seen that satisfactory results were obtained only at capacities ranging in the neighborhood of from 53 to 90 cubic millimeters at 5 atmospheres gauge pressure and 6 grams tension shown. In runs 26 to 28 the capacity of chamber 21 was maintained constant at 65 cubic millimeters while varying the diameter and depth progressively. It will be seen by comparing these runs that more satisfactory results are obtained with a disc-like or thin chamber having a large diameter and smaller depth.

In runs 29 to 38 both the pressure and air supplied through the jet orifice and the capacity of the resonance chamber were varied. It will be seen that better entangling results from increase in gauge pressure throughout the range of values. It also appears that capacity of the resonance chamber can be varied satisfactorily only within relatively narrow limits. For example, at capacities of 82 to 143 cubic millimeters, the entanglement dropped off considerably below the desired level obtained at lower chamber capacities.

In the remaining runs 39 through 43, all critical features of this invention were maintained constant except yarn tension, which was varied from 3.5 to 14 grams. It will be eminently obvious that the desired entanglement varied inversely with tension. In other words, increased yarn tension produces a lower entanglement evidenced by a reduced coherency factor $x$.

To permit duplication of the experiments recorded herein by those skilled in this art, it is deemed advisable to explain in some detail the manner in which the filament interwinding, referred to in the table as coherency factor, was determined. The method to be described admits of an arbitrary standard or index, but one which clearly records improvements of one run relative to other runs.

To obtain the coherency factor index, a yarn or thread at least 60 centimeters in length is clamped and suspended alongside a vertical scale graduated in centimeters. A steel needle measuring 0.4 mm. in thickness and bent through an angle of 120° into hook shape is inserted into the bundle of filaments at a point immediately below the suspension clamp. The needle should be inserted centrally of the filament entanglements or at least with 25% and preferably 33%, on one side of the hooked needle.

After insertion, the needle is carefully lowered manually, without damage to the filaments, at a rate of about 2 cm. per second. Normally, the needle may be lowered initially while unrolling slight entanglements, but eventually a point will be reached where the filaments are heavily intertwined or entangled. Needle lowering should be interrupted at a point where further movement obviously would result in filament breakage. Hook drop distances are read at this point with all distances of more than 50 cm. being recorded as 100 cm. To compensate for inaccurate needle insertion, it has been found that 0.5 cm. should be subtracted from the distance recorded.

The hook drop determination mentioned above should be repeated at least 10 times with additional yarn samples, after which an average hook drop distance $x$ is calculated. The coherency factor used herein may be defined as:

$$x = \frac{100}{d}$$

It has been found that a coherency factor of at least 1.5, preferably higher, is required for use of multi-filament untwisted yarn on textile machines, for example, weaving looms. Higher coherency factors, however, produce better results since yarn having such characteristics may be woven more satisfactorily without separation of filaments and snarling with processing apparatus.

The system described hereinabove of course may be used as a separate stage in the trenting of yarn or may be coupled to conventional yarn treating means such as draw twisters, draw winders, etc. For obvious economic reasons, it is preferred that the apparatus described be mounted directly onto existing equipment to eliminate the necessity of additional yarn handling. The apparatus is quite versatile and may be used on a variety of known apparatus operating at yarn speeds within the capabilities of available air pressure, it being understood that a high traveling speed of yarn enabling insufficient exposure to the gas jet assembly would not produce the desired results.

The resonance chamber described herein and considered to be a critical feature of the present invention collects gas emerging through the jet orifice after passage of this gas through the traveling yarn bundle. Inasmuch as the chamber has been provided with no gas exits, the same operates as a cushion and also provides a back pressure vibrating at a resonant frequency to assist in interlinking of filaments within the yarn bundle. This chamber, therefore, is believed to operate as a flexible baffle and the same produces considerably improved results over the rigid baffles heretofore used or unbuffled thrusts of air.

As indicated earlier, it is important that yarn traveling through the interwinding apparatus be substantially restrained from all but longitudinal movement. With such an arrangement, any vibration produced by the jet blast will be limited to wave length or nodes defined by the spacing $d$ between the thread guides. Accordingly, more orderly entanglement and less air bulking of yarn occurs which in turn contributes to maintenance of initial yarn denier after passage through the apparatus.

Inasmuch as various modifications will become apparent to those skilled in this art, it is intended that the present invention be limited as set forth in the following claims.

What is claimed is:

1. A method of interwinding a substantially untwisted thermoplastic synthetic high polymer multi-filament yarn which comprises drawing said yarn under a tension be-
breen 0.05 gm./den. and 0.3 gm./den. along a rectilinear path in which the yarn at the points of entering and leaving the path is held against substantial lateral vibration, directing a jet of gas across the yarn path and into a confined resonance zone under sufficient pressure to create a greater loudness in that area than can normally be borne by the human ear, and correlating the pressure with the tension on the yarn.

2. A method of intertwining a substantially untwisted thermoplastic synthetic high polymer multi-filament yarn which comprises drawing said yarn under a low tension along a rectilinear path in which the yarn at the points of entering and leaving the path is held against substantial lateral vibration, directing a jet of gas across the yarn path and into a confined resonance zone under a pressure of 3 to 5 atmospheres to create a loudness which could not normally be borne by the human ear and inhibiting the noise in the resonance zone to thereby permit such pressure, and correlating the pressure with the tension on the yarn.

3. A method of intertwining a substantially untwisted thermoplastic synthetic high polymer multi-filament yarn which comprises drawing said yarn under a low tension along a rectilinear path in which the yarn at the points of entering and leaving the path is held against substantial lateral vibration, directing a jet of gas across the yarn path and into a confined resonance zone under sufficient pressure to create a maximum loudness which could not normally be borne by the human ear and inhibiting the noise in the resonance zone to thereby permit such pressure, and correlating the pressure with the tension on the yarn to obtain a yarn coherency factor of at least 1.5.

4. An apparatus for intertwining a substantially untwisted thermoplastic synthetic high polymer multi-filament yarn which comprises a nozzle having a fine orifice for supplying gas under pressure, a cylindrical resonance chamber having an opening disposed opposite the nozzle orifice at a distance from 1 to 3 mm., said opening having a diameter between 1.0 and 1.8 times the exit diameter of said orifice sound damping means surrounding said chamber, yarn guides located above and below the nozzle and chamber to position the yarn between the nozzle and the opening to the chamber, said guides embodying means to dampen the vibration of the yarn passing therebetween and to localize the nodes at those points, said guides being spaced from 20–55 mm. apart.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,115,704</td>
<td>Manes</td>
<td>Nov. 3, 1914</td>
</tr>
<tr>
<td>2,629,544</td>
<td>Ohmart</td>
<td>Feb. 24, 1953</td>
</tr>
<tr>
<td>2,928,589</td>
<td>Davey</td>
<td>Mar. 15, 1960</td>
</tr>
<tr>
<td>3,110,151</td>
<td>Bunting et al.</td>
<td>Nov. 12, 1963</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Country</th>
<th>Date</th>
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<tbody>
<tr>
<td>554,150</td>
<td>Canada</td>
<td>Mar. 11, 1958</td>
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</table>