ABSTRACT
A strand of textile-length fibers is drafted and attenuated by the effect of a vacuum applied at the entrance end of an aspirator nozzle, said strand being accelerated through the body of the aspirator and being further accelerated and attenuated by the action of a high velocity air stream concentric with said tube. The resultant high velocity fibrous stream may be decelerated and diffused in a plenum chamber and removed therefrom as a fibrous web.

4 Claims, 5 Drawing Figures
VACUUM DRAFTING OF FIBROUS STRANDS

This invention relates to a two-stage process for the pneumatic drafting of individual textile-length fibers from a strand comprising a multiplicity of such fibers, and to a process for depositing the resulting air-borne fibers in the form of a fleece or web. More particularly it relates to a process wherein fibers are drawn from a tip-draftable strand by vacuum into an open-end tube, accelerated in an attenuated stream along the length of said tube, and are subjected to a second stage of acceleration and attenuation by an air stream of high velocity upon emerging from the exit end of said tube.

In the formation of fibrous webs to be fashioned into nonwoven fabrics, batting, coir, and the like, it is customary to feed a supply of staple fibers to a card, garnet, air-lay machine, or the like, which separates discrete and small groups or clumps of fibers from the feed mass and assembles these discrete clumps in the form of a fibrous web.

There are at least two disadvantages in the production of such fibrous webs by conventional methods. First, man-made fibers are produced in the form of a bundle or tow of continuous filaments, which must be cut to staple length by a tow cutter, for formation into card webs. Second, and more importantly, the conventional web-forming devices mentioned above do not separate fibers completely from each other, but instead they pluck off small groups or clumps of fibers from the main fibrous mass, so that card webs and garnet webs have a blotchy appearance. Furthermore, a fibrous web composed of fibrous clumps or aggregates does not develop the tensile strength which it would possess if the fibrous elements were substantially completely separated from one another and then reassembled in web form.

In my copending application Ser. No. 159,229, filed July 2, 1971, there is described a process wherein a twist-free strand of staple fibers is fed through an open-end tube to the propulsive zone of a high-velocity fluid stream under such conditions that a few fibers at a time are tip-drafted from the sliver to form a high-velocity fibrous stream at or near the exit end of the tube. Apparatus for creating such a high-velocity jet stream, and means for decelerating and diffusing the attenuated fibrous stream in a plenum chamber, are also described.

It has now been found that a tip-draftable strand of textile-length fibers can be transformed into a fibrous stream by a two-stage process wherein the primary operating force serving to separate fibers from the strand is applied by exposing the end of the strand to a fiber-drafting vacuum developed at the entrance end of an open-end vacuum tube. The air in the vacuum tube is preferably at or near sonic velocity. The stream of fibers thus formed is then further accelerated to a higher velocity, in a second step, by means of a second high velocity air stream after leaving the exit end of the tube.

By this two-stage process, the fibers in the strand, whether twisted or twist-free, are more thoroughly separated and individualized than by the process set forth in Ser. No. 159,229 with a consequently greater uniformity of fiber dispersion when they are decelerated and diffused in a plenum chamber, and improved web uniformity when the diffused fiber cloud is collected in web form.

It is an object of this invention to provide a two-stage process for vacuum-drafting a tip-draftable fibrous strand into the entrance end of a vacuum tube, accelerating the attenuated fibrous stream through said tube, and further accelerating and attenuating said fibrous stream at the exit end of said tube by the impact of a second high-velocity air stream.

It is a further object of the invention to provide a process for decelerating and diffusing said fibrous stream into a plenum chamber and removing the fibers in the form of a web or fleece.

Other objects of the invention will appear more clearly from the following description and drawings, in which:

FIG. 1 is a cross-sectional view of an aspirator tube suitable for carrying out the process of the invention.

FIG. 2 is an enlarged cross-sectional view, partly broken away, of the entrance and exit portions of the strand-guide tube of the aspirator of FIG. 1.

FIG. 3 is a set of curves showing the variation of static vacuum measured in the entrance end of the tube, in inches of mercury, with air pressure applied at the jet section of the aspirator, in pound per square inch gage.

FIG. 4 is a cross-sectional side view of a plenum chamber suitable for the deceleration and diffusion of an air-borne stream of fibers.

FIG. 5 is a front elevation of the plenum chamber of FIG. 4.

The serial steps involved in creating an accelerated stream of air-borne fibers according to this invention comprise:

1. Exposing a strand of tip-draftable textile-length fibers to the action of a strong vacuum at the entrance end of a vacuum tube while the strand as a whole is restrained, as by a pair of revolving nip rolls.

2. Drafting the fibers, a few at a time, from the tip of the strand into the vacuum tube.

3. Accelerating and attenuating the fiber stream thus formed along the length of the vacuum tube by means of the propulsive force of the vacuum.

4. Further accelerating and attenuating the fiber stream as it leaves the vacuum tube by means of a second high-velocity air stream concentric with said tube.

A tip-draftable strand in this application is taken to mean a sliver or top of textile-length fibers, commonly 1 inch to 6 or 8 inches in length, assembled together into a coil or strand wherein the fibers are generally parallelized, and wherein the internal inter-fiber frictional forces of twist, crimp, or finish are insufficient to completely restrain the fibers when the leading end of said strand is subjected to a high-velocity air stream. The impingement of such a high-velocity air stream on the end of said strand, by aerodynamic drafting, draws off individual fibers or small groups of parallel fibers rather than tangled segments of the strand.

Referring to FIG. 2, a strand 13 comprising a multiplicity of substantially parallelized fibers, restrained at A by passing through the revolving feed rolls 17, 17, is exposed at point B to the action of a strong vacuum, preferably 15 to 25 inches of mercury, established at the entrance end 18 of the vacuum tube or nozzle 10. The action of the vacuum at point B is one of strand at...
The fibrous stream is thus free to be further accelerated as at C in the guide tube 16, and upon emerging from this guide tube is again subjected as at D to a high velocity air stream established in the divergent section 25 of the tube.

In general, vacuum tubes suitable for the practice of this invention may be the same as the jet nozzles described in my copending application Ser. No. 159,229, the differences in process lying in the parameters of air pressure. In Ser. No. 159,229, a strand comprising a multiplicity of fibers is fed through the inlet tube of a jet nozzle, remaining substantially constant in cross-sectional population until it is tip-drafted at or near the exit end of the guide tube. In the instant invention, as stated above, tip drafting and strand attenuation occur in two stages, the first stage being exterior to the entrance end of the guide tube which is under vacuum.

As seen in FIG. 1, in its basic form the vacuum tube 10 comprises a cylindrical chamber 15, with wall section 12, capped at one end by an inlet cap 20 containing a tapered inlet 18 for the introduction of a tip-drafted stream of fibers, through guide tube 16 which is attached to the cap 20. The other end of the chamber 15 is capped by an exit cap 24, which restrains the straight exit section 22 and the convergent-divergent nozzle section 23 of the device. For convenience in machining, sections 22 and 23 are separated pieces, fitting in sliding relationship in the chamber 15. In operation they are held against lateral displacement toward the inlet tube by the air pressure in the chamber 15.

Air under pressure is fed to the chamber 15 by means of the air connection 14. The distance to which the guide tube 16 projects past the nozzle portion 23 of the device is adjustable by means of the threaded cap 20. The air, under pressure, is so adjusted as to create a propagated vacuum which extends back through the guide tube 16 and establish a substantial vacuum at the entrance 18 thereof. The air stream, converted to a convergent form in the convergent section 21 of the nozzle, diverges in section 25 and further accelerates and attenuates the fibrous stream. In this manner a doubly-attenuated fibrous stream is expelled through the nozzle orifice 26 in the cap 24.

The dimensions and relative proportions of a suitable tube will of course vary with the denier of the tip-draftable strand used as a source of fibers, and with the output poundage at which it is desired to operate the process. The device of FIG. 1 may, for example, be formed from a 10 inch length of brass pipe 2 inches I.D., with a similar piece of pipe 14 silver-soldered thereto.

The employment of tip draftable strands of heavy denier, for high poundage output, will necessitate larger filament input tubes and larger vacuum tubes; however, the scaling-up of the apparatus is a matter of engineering detail.

In calculating the net throat area of a vacuum tube, it will be obvious that the gross throat area must be reduced by the area occupied by the strand feed tube.

The following types of vacuum tubes have been found suitable for the vacuum-drafting of tip-draftable strands into a stream of individual fibers:

<table>
<thead>
<tr>
<th>Type</th>
<th>Throat Diameter</th>
<th>Angle of Divergent Taper</th>
<th>Exit Section Diameter</th>
<th>Exit Section Length</th>
<th>O.D. of Guide Tube</th>
<th>I.D. of Guide Tube</th>
<th>Net Throat Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.624 in.</td>
<td>5.77°</td>
<td>1.120 in.</td>
<td>0.562 in.</td>
<td>0.704 in.</td>
<td>1.200 in.</td>
<td>0.600 in.</td>
</tr>
<tr>
<td>B</td>
<td>1.120 in.</td>
<td>5.77°</td>
<td>0.562 in.</td>
<td>0.704 in.</td>
<td>1.200 in.</td>
<td>0.562 in.</td>
<td>0.562 in.</td>
</tr>
<tr>
<td>C</td>
<td>1.200 in.</td>
<td>2.7°</td>
<td>0.562 in.</td>
<td>0.704 in.</td>
<td>1.200 in.</td>
<td>0.562 in.</td>
<td>0.562 in.</td>
</tr>
</tbody>
</table>

Type B, with guide tube interior diameter of 0.75 inch, is suitable for processing heavy fibrous strands of up to 500,000 denier.

Although frequent reference has been made above to air streams and air-powered aspirators, it will be obvious that the aspirator may be powered by steam or other gaseous fluids.

The parameters given above for suitable vacuum tubes or aspirators are exemplary and not restrictive. In general, the following considerations may be used as basic guides for the selection of an aspirator capable of developing a substantial vacuum at its entrance or feed end, suitable for the double-drafting of a textile strand.

1. Either low pressure or high pressure tubes may be used, the former requiring proportionately larger quantities of air to power a given size of tube.
2. The larger the ratio of the vacuum tube cross-sectional area to the cross-sectional area of the jet powering the tube, the higher the air pressure required to produce a given vacuum.
3. A tube designed to produce a maximum vacuum at a given air pressure will produce a lower vacuum at either higher or lower air pressure, as seen by the shape of the curves of FIG. 3.
4. The energy required to power a tube at a given vacuum will be determined primarily by the cross-sectional area of the tube. This area in turn will depend primarily on the size of the strand or strands to be dispersed.
5. The vacuum which drafts the strand into the tube is best measured in a static condition, since Pitot tube measurements of dynamic or operating vacuum are not reliable when the air velocity is above about 0.7 Mach number. For this reason, the preferred vacuum of 15 to 25 inches of mercury is measured by completely blocking the entrance area of the tube with a manometer and adjusting the air pressure accordingly.

Referring to FIG. 3, there is shown the static vacuum vs. air pressure dependency for the three tubes A, B, and C described above. For these, one skilled in the art can determine the air pressure to use for maximum vacuum development, as well as the air pressures above or below this optimum pressure which may be employed while still remaining in the preferred static vacuum range of 15 to 25 inches of mercury at the entrance end of the tube.

DECELERATION AND DIFFUSION

In order to decelerate the high-speed stream of fibers to a manageable velocity, it has been found convenient to employ a plenum chamber, into which the stream of individualized fibers is exhausted. Such a device is shown in FIGS. 4 and 5, in side and front elevation, respectively.
3,727,270

Referring to FIG. 4, there is shown a suitable plenum chamber with the side panel removed. A tip draftable strand of fibers 13, metered by the nip rolls 17, 17, is vacuum drafted into the aspirator tube 10 in a fine stream of fibers, accelerated and further attenuated by the impact of a second high velocity air stream in the divergent section of the tube, as set forth above. The resulting double-drafted high speed fibrous stream as it issues from the aspirator tube 10, diffuses a stream of individually separated fibers into the upper chamber 30. Although various types of plenum chamber may be used, for convenience and economy of space the device as shown is divided into an upper, middle, and lower chamber 30, 32, and 34 respectively, separated by the plates 42, 44, and 46 which extend the full width of the chamber. Plates 42 and 44 do not extend the full length of the chamber, however, so that the path of the decelerating fibers is a serpentine one, as shown by the dotted line. The rear and front partitions, 36 and 38, act as baffles, deflecting the air stream, so that a constant and substantially uniform flow of fibers, at a manageable velocity, emerges from the plenum chamber exit 48 to impinge on the upper surface of the screen conveyor belt 50. If desired, a conventional vacuum box 52 may be mounted on the under side of the porous conveyor to bleed off the last traces of air and assure proper deposition of the fibrous web 54 on the conveyor.

In some case, where the web is to be subjected to subsequent treatment such as lamination with another substrate, it is convenient to interpose between the conveyor screen and the fibrous stream a layer of permeable supportive material such as gauze, cellulose tissue, porous nonwoven fabric, or the like. Such expedients are well-known in the art, and are not shown.

The term “manageable velocity” as employed above means a stream velocity at which the fibers can be deposited continuously onto a moving porous belt with substantial absence of fiber clumping or deflection of the stream. The purpose of the plenum chamber or diffusor, therefore, is to spread the high speed jet stream over a large cross section, so that the kinetic energy of the stream is transferred to pressure, by diffusion. This pressure forces the air through the porous conveyor, which filters out the fibers in web or fleece form. A Convenient range of exit velocity that is, the air velocity at which the decelerated fibrous stream impinges on the porous conveyor belt has been found to be 3 to 30 feet per second.

Throttling the velocity of the fibrous stream issuing from the aspirator down to a manageable exit velocity is a function of the parameters of the plenum chamber, which can be calculated from a consideration of the volume of air be handled.

The invention will be illustrated by the following examples. In each case the draftable strand was fed to the tube at a rate controlled by the feed rolls 17, 17, and a three-section plenum chamber was used as in FIGS. 4 and 5. The upper chamber 30 was 20 inches square in cross-section, with a circular opening 40 of 16 inch diameter. The middle chamber 32 was 30 inches wide and 6 inches deep, while the bottom chamber was 40 inches wide and 4.5 inches deep. The length of the plenum chamber was 40 inches.

EXAMPLE 1

A 191.317 denier rayon top, consisting of 34,785 fibers in cross-section, each fiber being 5.5 denier and approximately 6 inches long, was prepared from a continuous filament rayon tow cut by a Pacific Converter and then pin-drafted. It was passed between restraining rolls to a jet of Type B in the table above operating at an air pressure of 125 PSIG at a rate of 21.6 feet per minute or 18.6 pounds per hour. The distance between the rolls 27, 17 and the entrance end of the aspirator tube device was approximately 7 inches.

The high velocity air stream of fibers was fed directly from the exit section of the tube 10 to the plenum chamber of FIG. 4, whence it was collected on the conveyor screen as a light, uniform web 40 inches wide, of 6-inch fibers weighing 65.3 grams per square yard, at a rate of 5.78 feet per minute.

EXAMPLE 2

Four ends of the strand of Example 1, totaling 765,268 denier, were fed simultaneously through 4 separate tubes of Type A, above, at a rate of 11.7 feet per minute, with the same distance between feed rolls and tubes as in Example 1. The air pressure in the tubes was 45 PSIG, developing a static vacuum of about 23 inches of mercury at the tube inlets.

The stream of fibers was exhausted into the plenum chamber of Example 1, forming a web 40 inches wide, weighing 18 grams per square yard, at a rate of 45.56 feet per minute.

EXAMPLE 3

Using the same multiple strand feed and the same plenum chamber as in Example 2, four Type C aspirator tubes were used at an air pressure of 75 PSIG, developing a static vacuum of nearly 24 inches of mercury at the entrance end of the tubes. The resultant 40 inch-wide web weighed 14.4 grams per square yard and was produced at a rate of 170 feet per minute.

Web weights of from 6 to over 400 grams per square yard can be produced by varying the feed weight, rate, and other parameters. The pounds per hour output of Examples 1, 2, and 3 were respectively 18.56, 40.3, and 120.5.

Having thus described my invention, I claim:
1. The method of forming a high-velocity air stream of discretely separated textile-length fibers which comprises
subjecting the leading end of a strand comprising a multiplicity of substantially parallel overlapping textile-length fibers to the drafting effect of a vacuum established at the entrance end of a vacuum tube, attenuating the strand and reducing the cross-sectional fiber population of said strand by the drafting effect of said vacuum prior to the entrance of the strand into the vacuum tube, accelerating and attenuating the resultant stream of air-borne fibers through the body of said tube, and further accelerating and attenuating said strand by the action of a second high-velocity air stream concentric with said tube.
2. The method according to claim 1 in which the strand comprises viscose rayon fibers.
3. The method according to claim 1 in which the strand is between 30,000 and 500,000 denier.

4. The method of forming a fibrous web of staple textile-length fibers which comprises forming a high-velocity air stream of discretely separated fibers according to the method of claim

1. decelerating and diffusing said fibrous stream by expansion of said stream into a plenum chamber, and collecting the fibers from said stream from said plenum chamber in the form of a fibrous web.

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