FORAMINAL APPARATUS FOR SPLAYING
AND DEPOSITING NONWOVEN FILAMENTARY STRUCTURES

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6 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for augmenting dispersal and improving
deposition of a plurality of continuous filaments onto a
continuously moving surface whereby random distribution
of the filaments is provided for the production of uni-
formly distributed nonwoven webs. Such apparatus com-
prises a foraminal spaying device having two opposing
surfaces with holes extending through at least one of the
two opposing surfaces. Compressed gas, e.g., air, is dis-
charged through the holes in substantially parallel col-
umns so as to interpenetrate a filament bundle passing
between the two opposing surfaces. The two opposing
surfaces of the spaying device have continuous surfaces
curvature which surfaces exhibit a converging to
diverging pattern as the opposing surfaces extend from
the exit of the aspirator. The foraminal spaying device
is positioned near the exit of an aspirator so as to spread
the filaments in substantially all directions and thereby
to provide greater openness and greater random laydown
of filaments.

CROSS-REFERENCE TO RELATED APPLICATIONS

The invention herein set forth in related to the inven-
tions described in copending applications Ser. No. 184,420
entitled “Two-Planar Deflector for Dispersing and De-
positing Nonwoven Filamentary Structures,” filed on
Sept. 28, 1971 in the name of Walter P. Lipscomb and
Garland L. Turner and Ser. No. 184,421 entitled “Appa-
ratus for Splaying and Depositing Nonwoven Filamen-
tary Structures” filed on Sept. 28, 1971 in the name of
Walter P. Lipscomb and Eli B. Shelburne, Sr., wherein
different apparatus for improving the dispersal and deposi-
tion of a plurality of continuous filaments onto a continu-
ously moving surface are disclosed.

BACKGROUND OF THE INVENTION

This invention relates to an improved apparatus for
improving the dispersal and deposition of filaments. In
particular, it relates to an apparatus for augmenting the
dispersal of continuous filaments onto a receiving surface
so as to form a nonwoven web of randomly disposed
filaments.

Nonwoven webs formed from continuous filamentary
materials which have been laid on a receiving surface in
a random configuration are well known in the art. In the
formation of such webs, great care is frequently taken to
ensure that the filaments are maintained apart from each
other and that interfilamentary entanglement and the for-
mination of filament aggregates are avoided.

Nonwoven webs comprising multi-filaments are com-
monly formed by withdrawing the filaments from a source
of supply, such as a melt spinnerette, and then depositing
the filaments at high velocity onto a moving surface by
means of an aspirator. In the production of nonwoven
products having a substantial width, there must be pro-
vided either a plurality of aspiators for depositing a
plurality of filamentary bundles in a random manner
upon the moving surface or there must be provided a
means, normally unduly complicated and cumbersome,
to move the aspirator over the width of the product to
be produced.

When depositing filaments from a conventional aspira-
tor onto a collecting surface, the filaments may spread
out within the confines of the aspirator boundary. How-
ever, the filament distribution in the jet stream is not
always uniform and random and is often restricted to a
small laydown area; for example, a web width not ex-
ceeding eight inches when a fixed aspirator jet is situated
at a distance of one to three feet from the receiving
surface.

Some of these deficiencies have been overcome by
forwarding the filaments between surfaces patterned so as
to utilize the principle of aerodynamics known as the
Coanda effect before the filaments are massed in web
form. The principle, named for its discoverer, Henri
Coanda, was applied to a useful structure in U.S. Pat.
2,052,869. Such structure was used to control the dis-
charge into an elastic fluid atmosphere of a stream of
another elastic fluid moving at high velocity, wherein
means were provided to alter flow of the elastic fluid of
the atmosphere induced by the fluid stream issuing from
its high velocity source. In this manner, the fluid stream
was diverted in a direction generally contiguous to a
diverting contour of an extension to the outlet conduit of
the high velocity source. Such flow diversion commenced
generally at the area of substantial contact of the fluid
stream with the slower velocity elastic fluid of the atmos-
phere. Adaptation of such a Coanda structure to spread,
to a great degree, the filaments exiting from an aspirator
jet without sacrificing other desirable objects at the ex-
 pense of such greater spreading would be of great benefit
to many producers of nonwoven webs. Such greater
spreading of the filaments, if accompanied by no loss in
strength or in other desirable properties in the resultant
web, would improve yarn openness and thus broaden the
web width by providing greater filament coverage per
pass on a filament receiving surface. Utilization of such
a device would reduce manufacturing costs as well as
produce wider webs having greater randomness and
uniform filament distribution.

SUMMARY OF THE INVENTION

In accordance with this invention, it has been found,
surprisingly, that even greater openness and greater ran-
domness of filament laydown can be obtained through the
use of a foraminal spaying means having opposing sur-
faces with compressed gas discharge holes extending
through at least one of the opposing surfaces, between
which surfaces a filament bundle passes.

The holes are arranged on such opposing surface in a
manner so as to release columns of compressed gas
through the holes, such columns intersecting the filament
bundle in order to spread substantially the filaments of
the bundle. The filaments are deposited onto a receiving
surface in a randomly dispersed manner to form a non-
woven web of randomly disposed filaments substantially
uniformly distributed throughout said web.

More specifically, the invention features an apparatus
for spreading while depositing filaments onto a receiving
surface which comprises, in combination, an aspirator to
forward filaments at a high velocity and a foraminal spay-
ning device having a plurality of compressed gas holes on
at least one of two opposing surfaces of such foraminal
spaying device for spreading the filaments substantially
in all directions from the foraminal spaying device onto
the receiving surface. Consequently, the area of filament
deposition on the receiving surface is effectively enlarged
in all directions. Preferably, the compressed gas holes have
diameters ranging from approximately 0.003 inch to ap-

3,738,894
Patented June 12, 1973
approximately 0.030 inch. Such holes are preferably spaced apart at a center-to-center distance ranging from 2.5 times to 10 times the hole diameters. The foraminol spaying device is preferably formed so as to make use of the principle of aerodynamics known as the Coanda effect. Accordingly, the two opposing surfaces of the spaying device are characterized by having continuously smooth surfaces of curvature, which opposing surfaces form a converging to diverging pattern as the surface of curvature develops from the exit of the aspirator.

In a preferred embodiment of this invention, the compressed gas holes are generally on a line extending across one of the two opposing surfaces in a direction substantially perpendicular to the direction of motion of the filaments. Such a line is generally coincident with the line of greatest convergence on this opposing surface of the spaying means. Each of such compressed gas holes has a diameter preferably ranging from approximately 0.010 inch to approximately 0.020 inch. Air is being discharged through such holes at a pressure of approximately from 3 p.s.i.g. to 100 p.s.i.g. More preferably, there are approximately from 5 to 15 discharge holes along this line of greatest convergence of the foraminal spaying means.

Advantageously, the combination of the foraminal spaying device with the aspirator may be reciprocated above a moving receiving surface in a direction substantially transverse to the forward motion of the receiving surface. Further advantageously, this combination may be made up to a part of a plurality of substantially similar combinations and then reciprocated at essentially the same rate and stroke in a pattern such that filaments from a given combination can overlap those of the next adjacent combination so as to further increase web width.

A feature of this invention is its capability to spread filaments exiting therefrom in substantially all directions due to the presence of the compressed gas holes, thereby providing a highly random and broad filament distribution in the filament product. Conventional Coanda spaying devices spread the filaments generally only in the direction of the diverging opposing surfaces of the Coanda spaying device.

Another feature of this invention is its quick and easy adaptability for use with many conventional aspirators in designing and depositing filamentary materials onto a moving receiving surface.

The method utilizing the apparatus of this invention comprises, in general, the utilization of the foraminal spaying device in combination with an aspirator whereby filaments, preferably forwarded from a spinnerette of a spinning mechanism and thereafter from a drawing mechanism, are forwarded through a high velocity fluid jet of the aspirator. Subsequent thereto, the aspirator jet stream propels the filaments through the foraminal spaying device whereby the filaments are separated and forwarded onto a continuously moving, preferably foraminous, surface in the form of a uniform nonwoven web comprising randomly disposed, substantially uniformly distributed filaments. Deposition of the filaments may be aided by a suction chamber located underneath the moving surface.

The described apparatus can be readily used for greater separation of filaments, or alternately, strands, yarns, slivers or other similar forms of materials, or mixtures thereof. Such materials include any fiber-forming thermoplastic polymer from which filaments can be obtained. These materials include: polyamides, for example, poly(ethylene adipamide) (hereinafter nylon 6) and poly(hexamethylene adipamide) (hereinafter nylon 66); linear polyesters, for example, poly(ethylene terephthalate); acrylonitrile polymers and copolymers; olefinic polymers; for example, polyethylene, propylene, and polyvinyl chloride; and cellulose acetates. Preferred materials include nylon 6, nylon 66 and poly(ethylene terephthalate).

The invention will be more clearly understood and ad-
is most preferably approximately 2 times the diameter of the diffuser passageway 54. The cross-sectional area of diffuser passageway 54 is designed such that the cross-sectional area of filament bundle 12 passing therein ranges preferably from 0.5 percent to 5 percent, most preferably from 0.2 percent to 1.5 percent, of the diffuser passageway cross-sectional area. The respective lengths and diameters of air nozzle entrance chamber 50 and of collar chamber 52 are not critical. However, such lengths and diameters should be used as are practical, i.e. compatible with the overall design of the process herein described.

Although the foraminar spaying device 22 works especially with the preferred aspirating jet 19 as described in FIG. 2 and as described in greater detail in patent application Ser. No. 184,542 entitled "Process and Apparatus for Production of a Nonwoven Web," filed on Sept. 28, 1971 in the name of Walter P. Lipscomb and Garland L. Turner, it has been designed to work compatibly with many conventional aspirators. In general, such conventional aspirators are especially suitable for use with the apparatus of this invention if these aspirators forward the filament bundle at a high velocity, generate sufficient pull through the filaments under minimum tension, open and separate the filament bundle during the exiting of the filaments from the aspirators, and prevent filaments from undergoing any substantial twisting, knotting or entanglement therein.

Referring now to FIG. 3, as well as to FIG. 2, extension 18 of the foraminar spaying device 22 is attached securely to the bottom portion of diffuser 11 by a suitable means, such as welding or bolting. Foraminar spaying device 22 is patterned so as to make use of the principle of aerodynamics known as the Coanda effect. Spaying device 22 involves a modification and utilization of this principle. Spaying devices suitable for use in this invention include any device having continuously smooth, preferably symmetrical, opposing surfaces of curvature in accordance with Coanda's aerodynamical principle. Such opposing surfaces form a converging to diverging pattern as the surfaces extend in distance from the aspirator passageway exit 17. Preferred is a spaying device similar to that shown in FIG. 2 wherein there are two such opposing surfaces, each of which develops from a line (shown as point 40 in FIG. 2) which is above exit 17 to a line (shown as point 42) of maximum convergence and thereafter to a line (shown as point 41) of maximum divergence. The lines of maximum convergence and the lines of maximum divergence are preferably perpendicular in reference to the center-line aspirator passageway 54, so as to enhance symmetrical spaying patterns. Experience has shown that the minimum distance between the lines 42 of maximum convergence for effective filament spreading is at least as great as the diameter of aspirator exit passageway 54.

The essential feature of this invention is the use of compressed gas holes on the opposing surfaces of the suitable spaying device 22. The degree of filament spreading and randomness, and consequently of web width, is greatly increased without appreciably affecting the other properties of the nonwoven web 23 by providing at least two holes 37 through at least one of the opposing surfaces of the foraminar spaying device 22 for the release of a compressed gas through these holes. Although the compressed gas holes may be provided successfully on more than one surface, each hole is from 0.1 to 0.2 inches in diameter, and the degree of filament spreading is especially enhanced in an efficient manner when compressed gas holes are positioned on only one opposing surface of the foraminar spaying devices such that the number of such holes on such opposing surface is greater on or in close proximity to the line of maximum divergence, and the line of such holes on the number of holes on the surface area between the line of maximum convergence and the line of minimum convergence of such opposing surface. More preferably, a superior degree of filament spreading as well as efficient conservation of compressed air requirements and of the number of holes necessary to attain such superior spreading has been realized by placing all holes in close proximity to, and most preferably on, the line of maximum convergence. It is preferred that the holes are placed on or near this line of greatest convergence because of the tendency at that lowest flow area to form compressed gas columns easily and to resist interplay by adverse aerodynamical phenomenon, i.e. turbulence. It is believed that compressed gas exits these holes in the form of parallel comb teeth so as to impart a tension, and possibly a small degree of pulsation, on the filament bundle which travels generally perpendicular to these parallel columns of compressed gas. Consequently, the filaments are spread generally into smaller bundles under this tension between the compressed gas columns. Subsequent to passing these compressed gas columns, the filaments in each smaller bundle spread extensively in generally all directions in resistance to such tension. Thereafter, the separated filaments are deposited in a highly random manner on a receiving surface. Because of the diverging surface of curvature of the Coanda spaying means, this spreading is not restricted due to spatial limitation and is probably augmented.

Each of the compressed gas holes on the opposing surface of the foraminar spaying device should have effective diameters which favor the formation of discrete compressed gas columns having sufficient integrity to penetrate the filament bundle during passage through the foraminar spaying device. The effective diameter ranges preferably from approximately 0.003 inch to approximately 0.030 inch, more preferably from approximately 0.010 inch to approximately 0.020 inch. With values of effective hole diameter less than 0.003 inch, the compressed gas column tends to ripple turbulently and to become indistinct. With effective hole diameter values greater than 0.030 inch, the compressed gas column tends to exhibit boundary turbulence, to be too large in relation to the filament bundle which the column is designed to separate, and to project a volume of compressed gas which is too large in relation to the compressed gas volume used for forwarding the filament bundle.

Preferably, the center-to-center distance between the compressed gas holes ranges from approximately 2.5 times to approximately 10 times the hole diameter. With center-to-center hole spacing less than 2.5 times the hole diameter, the compressed gas columns tend to impact the filament bundle rather than progress further away from the bundle. With center-to-center spacing greater than 10 times the hole diameter, the compressed gas columns are too far apart to effectively interpenetrate the filament bundle. Still further, the holes along the most preferred location on the line of greatest convergence are preferably of a number which is capable of effectively and efficiently interpenetrating the filament bundle. A suitable range of the number of holes on such line of greatest convergence is from 5 to 15. Also, the greater the ratio of hole depth or length to hole diameter is, then the greater the likelihood of reducing turbulence in the flow of compressed gas exhausting each hole and of increasing the coherence and straight-line penetrating power of the compressed gas after exiting the hole and forming a column; both of these latter effects are desirable for purposes of this invention. A practical and preferred range of length-to-diameter ratios for the preferred holes is from 10 to 1. In general, the depth of gas, such as air, is discharged through each hole via entry port 39 and chamber 38 which is sealed by plug 36. The compressed gas is discharged preferably at a pressure of from 3 p.s.i.g. to a pressure which is less than approximately 90 percent of the aspirating medium pressure, preferably from 0.3 p.s.i.g. to 0.9 p.s.i.g. and preferably for the gas hole diameter. Gas pressure through each hole should be sufficient to form a compressed gas column that has adequate integrity to support itself and yet not so high as to consume compressed gas inefficiently.
In operation, the aspirating medium, which may be a pressurized fluid such as air, is introduced from a supply source, not shown, into chamber 50, at a pressure preferably less than 120 p.s.i.g. Such media enters and flows through nozzle passageway 51 and exits therefrom as a high velocity fluid stream exiting nozzle passageway 51 engages filaments 12 entering the aperture 57 with sufficient energy to propel the filaments through collar chamber 52 into diffuser 11, which is characterized by an initially diverging entrance chamber 53. Subsequently, the propelled filaments are splayed in a wide and random manner, via passage between the compressed gas columns emanating from holes 37 on spraying means 22. Then the filaments are deposited on a receiving surface which normally takes the form of a conveyor belt moving at a predetermined constant speed and at a predetermined distance from the foraminal spraying device 41. The receiving surface should be placed below the foraminal spraying device of this invention at a distance such that effectiveness and efficiency of random dispersal of filaments therein in a uniform manner is achieved. The pressurized state of such aspirating media and of the compressed gas used in the holes 37 of the foraminal spraying device 41 is shown in Figure 4. Various factors which influence operating pressures are the aspirating jet design, aspirating media pressure, consumed, type and nature of filament-forming polymer, degree of orientation to which filaments have been subjected, and the resulting properties of the nonwoven product. For convenience and economics, both the aspirating medium and the compressed gas may be air.

We have found that it is especially advantageous in the process utilizing this invention to fix the combination of the foraminal spraying device with the aspirating means, or a plurality of such combinations in parallel, on a reciprocating bar or similar mechanism and to reciprocate such combination or plurality of combinations in a direction substantially transverse to the direction of forward motion of said moving receiving surface. Preferably, a plurality of filaments are reciprocated at a rate and stroke in such a pattern that the filaments from a given combination overlap those from adjacent combinations. A suitable means of reciprocation is described in greater detail in the aforementioned patent application. Ser. No. 184,542 entitled "Process and Apparatus for Production of a Nonwoven Web," filed on Sept. 28, 1971.

The following example is provided as further illustrative of the present invention. The enumeration of details therein, however, should not be considered as restrictive of the scope of this invention.

In an example, nylon 6 is melt spun into a 70-filament bundle 12 of 1100 denier. The filament bundle 12 is forwarded through aperture 57 into aspirating jet 19 at a rate of 1500 feet per minute. In collar chamber 52, the filament bundle 12 is subjected to air aspirating medium at a pressure of 40 p.s.i.g. The diameter of air nozzle passageway 51 is 0.040 inch. Bundle 12 is forwarded to and through diffuser passageway 54 by the aspirator jet stream. The diameter of diffuser passageway 54 is 0.072 inch. Thereafter, filament bundle 12 exits from jet 19 into foraminal spraying device 22. The jet 19 with spraying device 22 is reciprocated at a stroke of 10 inches with a frequency of 70 cycles per minute. The foraminal spraying device is constructed of stainless steel and is similar in physical profile to the spraying device shown in FIGS. 2 and 3. The spraying device 22 has the following physical characteristics: distance along the aspirator exit axis from aspirator exit to lines of greatest convergence is 0.375 inch; distance along the aspirator exit axis from lines of greatest convergence to lines of greatest divergence is 0.5 inch; distance between lines of maximum convergence is 0.078 inch; distance between lines of maximum divergence is 0.5 inch. Ten (10) compressed gas holes 37, each having a 0.015 inch diameter, are interspaced at a center-to-center distance of 0.050 inch substantially on the line of maximum convergence of one of the two opposing surfaces of the foraminal spraying device 22. The length-to-diameter ratio of each hole is 4:1. Air pressure at each hole is 20 p.s.i.g. Upon passage from foraminal spraying device 22, filaments of bundle 12 open up considerably and are deposited on a continuously moving foraminous horizontal conveyor 20 which is moving at a speed of 8 feet per minute and at a distance of 12 inches from the closest portion of foraminal spraying device 22.

Nonwoven webs produced in a process using the foraminal spraying device of this invention are characterized by a random filament distribution throughout. The appearance of webs is uniform, and it is essentially free of filament aggregates. Through the use of the spraying device of this invention, uniform web coverage per pass may exceed that using the aspirator alone by values of 33 percent and greater.

The nonwoven web or other useful construction processed from a coherent filament bundle prepared in accordance with this invention may serve a variety of useful purposes, particularly in the manufacture of nonwoven products, such as carpet backing, wall covering, insulation, interfacing, filters, and the like.

Various modifications and other advantages will be apparent to one skilled in the art, and it is not intended that this invention be limited to details presented by way of illustration except as required by express limitations in the appended claims.

What is claimed is:

1. In an apparatus for depositing a bundle of filaments onto a moving receiving surface in a randomly dispersed manner to form a nonwoven web of randomly dispersed filaments substantially uniformly distributed throughout said web, said apparatus comprising an aspirating means for forwardly the bundle of filaments at high velocity to the moving receiving surface, the improvement comprising a foraminal spraying device for augmenting spreading of the filaments while advancing said filaments from said aspirating means to said moving surface, said foraminal spraying device having two opposing surfaces with a plurality of compressed gas discharge holes on at least one of the opposing surfaces, said holes arranged on said opposing surface so as to release columns of compressed gas through said holes, said compressed gas columns intersecting said bundle of filaments passing between said opposing surfaces from said aspirating means in order to spread substantially said filaments of said bundle, said two opposing surfaces being characterized by continuously smooth surfaces of curvature and by forming a converting to diverging pattern as said surface of curvature develops and extends from the exit of said aspirating means.

2. The apparatus of claim 1 wherein said compressed gas holes are generally on a line extending across only one of the two opposing surfaces in a direction substantially transverse to the direction of motion of the axis of said filament bundle, said line being generally coincident with the line of greatest convergence on one of said opposing surfaces, said compressed gas being air and being forced through said holes in substantially parallel columns in said substantially transverse direction.

3. The apparatus of claim 2 wherein the diameter of said compressed gas holes ranges from approximately 0.003 inch to approximately 0.030 inch at said opposing surface of said spraying means and said air is discharged through each of said holes at a pressure of at least 3 p.s.i.g.

4. The apparatus of claim 3 wherein the center-to-center distance between said compressed gas holes ranges from 2.5 times to 10 times the diameter of each of said compressed gas holes.

5. The apparatus of claim 4 wherein the length of each of said compressed gas holes ranges from 4 to 10 times the diameter of each hole.
6. The apparatus of claim 5 wherein the diameter of said compressed gas holes ranges from 0.010 inch to 0.020 inch at said opposing surface and said air is discharged through each of said holes at a pressure ranging from 6 p.s.i.g. to 30 p.s.i.g.

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