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Okzaki et al.

[54] **METHOD AND APPARATUS FOR PREPARING NON-WOVEN FIBROUS MATERIALS**

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[21] Appl. No.: **36,159**

[52] **U.S. Cl.** **28/1.4,** 28/72.12

[51] **Int. Cl.** **D02g 1/16**

[58] **Field of Search**.........19/65 T, 66 T; 28/1.4, 1 R, 28/72.12, 72.3, 76

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Primary Examiner—Dorsey Newton

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[57] **ABSTRACT**

A method and apparatus for preparing non-woven fibrous materials employing fluid jets is provided comprising feeding fiber strands to a contact zone defined by a pair of symmetrically arranged opposed plated, each plate containing a plurality of apertures therein and forcing a fluid under pressure through said apertures to impinge upon said fiber strands causing the fiber strands passing through said contact zone to open and interlock.

6 Claims, 13 Drawing Figures

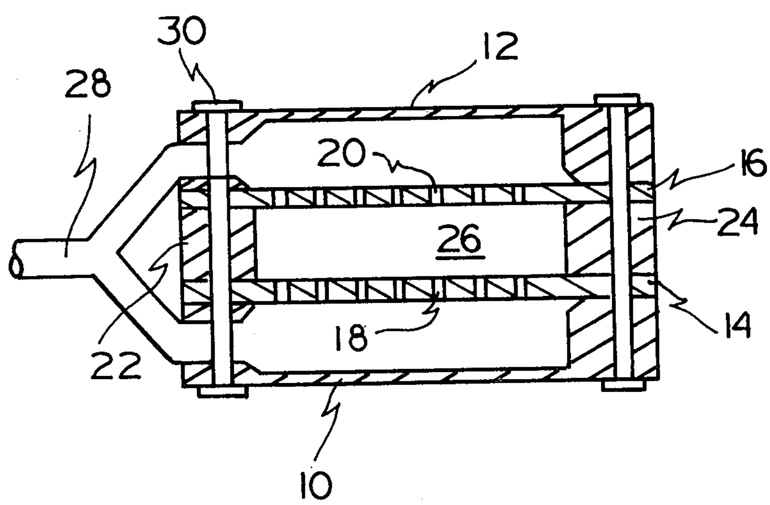

FIG. 1

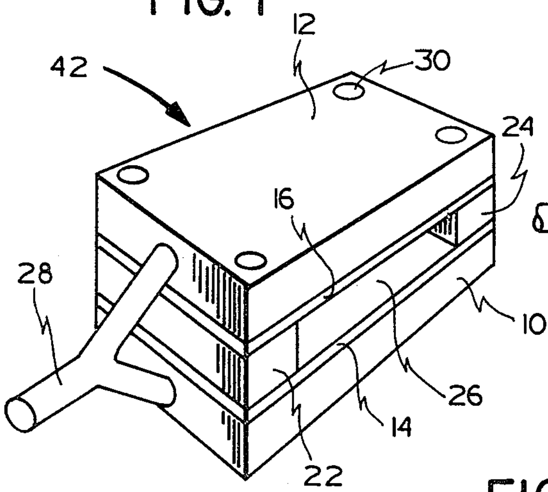

FIG. 2

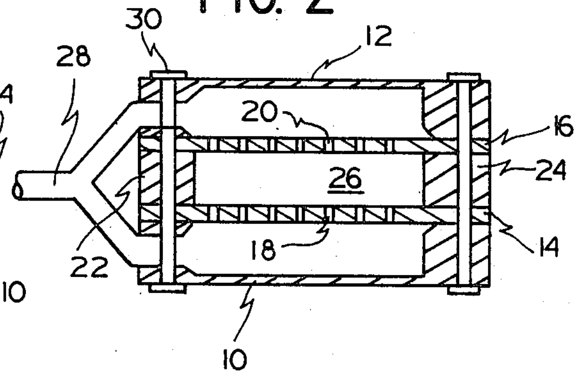

FIG. 3

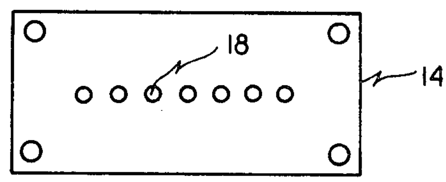

FIG. 5

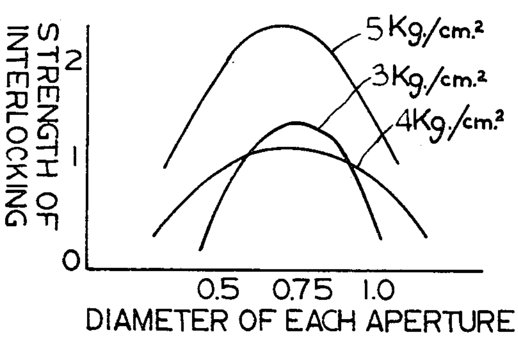

FIG. 4

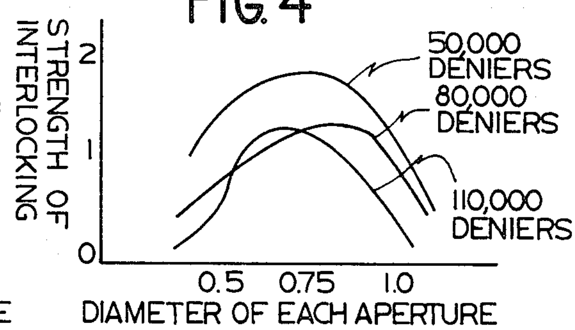

FIG. 6

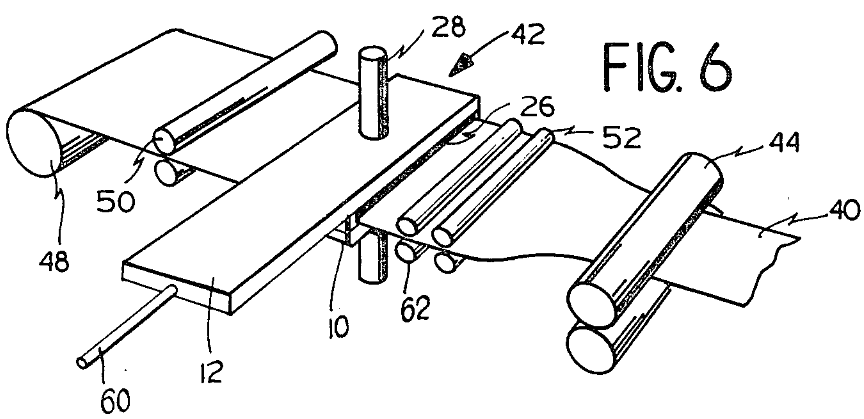

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FIG. 7A

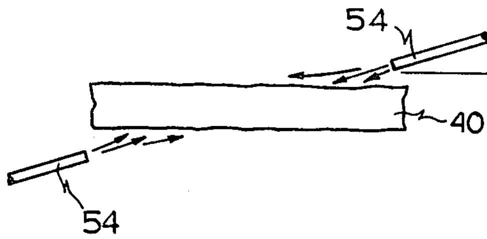


FIG. 7B

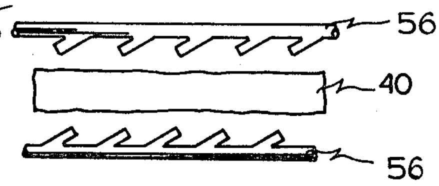


FIG. 8A

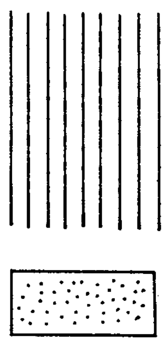


FIG. 8B

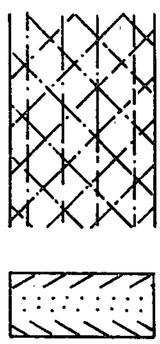


FIG. 9

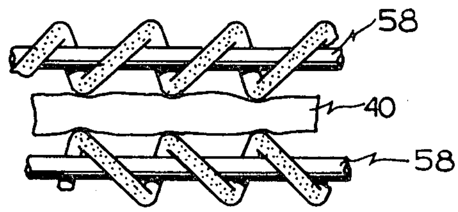


FIG. 10A

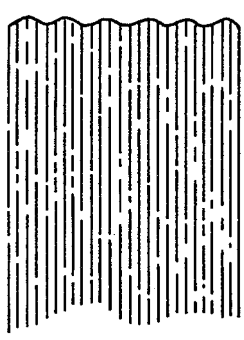
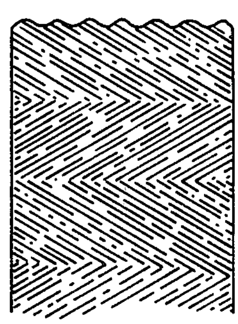


FIG. 10B



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METHOD AND APPARATUS FOR PREPARING NON-WOVEN FIBROUS MATERIALS

BACKGROUND OF THE INVENTION

This invention relates to a fluid jet method and apparatus for manufacturing non-woven fibrous materials.

British Patent No. 1,122,313 describes a fluid jet method for manufacturing interlocking non-woven fibrous materials out of fiber strands. The non-woven fibrous materials obtained through use of such method are of limited practical use because of their lack of strength in the lateral direction although they exhibit high strength in the longitudinal direction.

In order to obviate the defects which have heretofore limited the use of the fluid jet method for manufacture of non-woven fibrous materials, the present invention provides a fluid jet method and apparatus capable of manufacturing interlocking non-woven fibrous materials exhibiting high strength both in the longitudinal and the lateral directions.

Generally, it is considered preferable for preparing non-woven fibrous materials by entangling and interlocking fibers under the pressure of fluid jets to employ methods such as those described in the above British patent wherein jets of fluid are charged into a contact zone through plates containing a plurality of apertures therein. The contact zone is adapted to permit passage of fiber strands therethrough and to spread the fluid jets over the fiber strands therein. In this method, the high fluid pressure and the high fluid flow rates provide a high degree of interlocking. However, the degree of interlocking depends largely upon the physical state and quantity of the supplied fiber strands. If the ratio of the fluid flow rate to the feed rate of the fiber strands is too low, the desired degree of interlocking cannot be obtained because of insufficient resistance to bending and the friction force between the fibers; whereas, if the ratio is too high, the fiber strands upon their passage through the contact zone are essentially torn apart by the large turbulent area created within the contact zone and simultaneously undesirable loops and entanglement are imparted to the fibers attributable to the turbulent influence of the fluid. Thus non-woven fibrous materials exhibiting a low degree of interlocking and little practical use are produced.

SUMMARY OF THE INVENTION

In accordance with the present invention a method for preparing non-woven fibrous materials exhibiting high strength both in the longitudinal and lateral directions is provided comprising feeding fiber strands to a contact zone adapted to receive said fiber strands and to permit passage of said strands therethrough, said fiber strands exhibiting from 8,000 to 25,000 deniers per centimeter of width of said contact zone, said contact zone containing opposed symmetrical plates each plate containing a plurality of apertures therein ranging from 0.5 to 1.0 mm in diameter, said apertures being disposed in at least one row with intervals between apertures of 0.5 to 2.0 mm; said plates defining a passage for the fiber strands through the contact zone, charging fluid through said apertures forming fluid jets which impinge upon said fiber strands causing said strands to interlock, and thereafter recovering the resulting non-woven fibrous materials.

In another embodiment, an improved interlocking nozzle is provided for preparing non-woven fibrous materials by the fluid jet method, said interlocking nozzle comprising a pair of fluid tanks, each tank terminating in a plate containing a plurality of apertures, said apertures ranging from 0.5 to 1.0 mm in diameter, said apertures being disposed in at least one row with intervals between apertures of 0.5 to 2 mm, said tanks being maintained in opposed space relation with said plates facing each other, spacing means for maintaining said tanks in said spaced relation, said spacing means and said plates defining a contact zone adapted to receive the fiber strands, said contact zone having a width of at least 3 mm, and means for charging fluid to said fluid tanks, whereby the charged fluid upon egress from the apertures impinges upon the fiber strands within the contact zone causing interlocking of said strands forming a non-woven fibrous material.

BRIEF DESCRIPTION OF THE DRAWING

This invention will now be described in conjunction with the accompanying drawing wherein:

FIG. 1 is an isometric view illustrating one embodiment of the apparatus utilized in this invention for manufacturing non-woven fibrous materials by the fluid jet method;

FIG. 2 is a cross-sectional elevation view of the apparatus shown in **FIG. 1**;

FIG. 3 is a plan view of a plate containing a plurality of apertures in accordance with the present apparatus shown in **FIGS. 1** and **2**;

FIG. 4 graphically shows the relationship between the diameter of each aperture and the strength of interlocking corresponding to variations in the total denier of the supplied fiber strands when the fluid is jetted under fluid pressure of 4 kg/cm^2;

FIG. 5 graphically shows the relationship between the diameter of each aperture and the strength of interlocking corresponding to variations of the fluid pressure when the total denier of the supplied fiber strands is 8,000 deniers;

FIG. 6 is a schematic view of a process in accordance with the present invention for the manufacture of the interlocking non-woven fibrous materials;

FIGS. **7**(*a*) and **7**(*b*) illustrate schematically alternate embodiments of fiber-direction converting apparatus;

FIG. 8 shows the comparative interlocking degrees of the non-woven fibrous materials according to the use and non-use of the above apparatus in FIG. **7**(*a*);

FIG. 9 illustrates schematically an alternate embodiment of a fiber direction converting apparatus; and

FIG. 10 shows the comparative interlocking degrees of the non-woven fibrous material respectively according to the use and no-use of the above apparatus in FIG. **9**.

DETAILED DESCRIPTION OF THE DRAWING

Referring now to the drawing and more particularly to FIG. **1** thereof, there is illustrated one embodiment of an interlocking nozzle according to the present invention shown generally as **42**. FIG. **1** shows fluid tanks **10** and **12** each terminating in plates **14** and **16**, respectively, each containing a plurality of apertures therein **18** and **20**. The tanks are fixed in opposed spaced relation with the plates **14** and **16** facing each other. Interposed between the tanks are spacing bars **22** and **24** which together with plates **14** and **16** define a passage way for the fiber strands, said passage way being referred to herein as the "contact zone" **26**. Fluid feed tube **28** is adapted to supply fluid to the fluid tanks **10** and **12**. Clamping bolts **30** passing through the tanks, plates and spacing bars maintain the apertures in axial alignment and provide a unitized construction. The fiber strands are fed to the contact zone **26** wherein the fibers are caused to interlock with one another by the action of the fluid charged through the fluid tube **28** into the fluid tanks **10** and **12** and jetted through the apertures in plates **14** and **16**.

As shown in FIG. **6**, the fibrous strands are opened under the influence of fluid discharged from fiber direction converting apparatus **52** prior to being fed to the interlocking nozzle **42**. The opened fibers are imparted with interlocking properties within the contact zone **26** of the interlocking nozzle **42**. Preferably, the fiber strands are fed to the interlocking nozzle **42** by the feed roller **44** at a relatively faster rate than they are withdrawn by the delivery roller **50**. This overfeeding or stuffing of the fiber strands into the contact zone aids in opening the fibers for treatment within the contact zone. However, if the overfeeding is too small, it provides insufficient opening effects, thereby making it rather difficult to obtain non-woven fibrous materials with highly interlocking properties in the lateral direction. It is concluded, therefore, that the optimum overfeeding amount is obtained by maintaining a relative difference in speeds between the feed and delivery rollers whereby the feed roller rotates from 5 to 10 percent faster than the delivery roller in order to produce non-woven fibrous materials of high quality, e.g., having continuous entanglement in the lateral direction under the optimum fiber movement.

It is preferable to arrange the contact zone in such a way that the upper plate **12** is positioned symmetrically with respect to the lower plate **10**. The apertures in the corresponding upper and lower plates should be on identical axes and the two plates are respectively provided with the same shaped apertures and arrangements; otherwise, the jetted fluid forms eddy currents, instead of disturbing currents which cause interlocking of the fiber strands, thereby providing a deleterious influence on the interlocking properties.

FIG. **2** is a cross-sectional view of the apparatus shown in FIG. **1** and FIG. **3** is a plan view of plate **14** showing the positioning of the apertures **18**. In FIG. **3**, **18** denotes the fluid jet apertures, the size of which preferably range from 0.5 to 1.0 millimeters in diameter, as is apparent from FIGS. **4** and **5**. FIGS. **4** and **5** show the results obtained in making use of an apparatus wherein plates were employed, respectively, with a row of fluid jet apertures of 0.5, 0.75 and 1.0 millimeters, at an interval of 5 holes per centimeter perpendicularly to the direction of travel of the fiber strands. Bolts, such as **30** in FIG. **1**, were employed to maintain the upper and lower apertures in axial registration. FIG. **4** shows the relationship between the aperture diameter and the interlocking strength corresponding to variations of total denier of the supplied fiber strands when the fluid is jetted through said plates under fluid pressure of 4 kg/cm^2. FIG. **5** shows the relationship between the diameter of the aperture and the interlocking strength corresponding to variations of fluid pressure when fiber strands of 8,000 deniers are fed thereto. The optimum aperture diameter ranges from 0.5 to 1.0 millimeters, as is clear from the fact that variation of the total deniers of the supplied fiber strands and the fluid pressure have little influence on the relation between interlocking strength and aperture diameters. In the experiment shown in FIG. **4**, the plates employed were provided with apertures having intervals between apertures of 1.5 millimeters, 1.25 millimeters, and 1.0 millimeter respectively. However, similar results with regard to the relation between the aperture diameters and the interlocking strength can be obtained as those of FIGS. **4** and **5**, when apertures of the identical diameter are arranged at intervals between apertures ranging from 0.5 to 2.0 millimeters. It can be seen from FIGS. **4** and **5** that sufficient interlocking properties cannot be imparted if the interval between apertures is either more or less than the above limitation. As used herein, the phrase "interval between apertures" means the distance between one end of an aperture and the opposite end of an adjacent aperture, namely, the shortest distance between neighboring apertures.

If the interval between apertures exceeds 2.0 millimeters, the interlocking points (lines) are not sufficient enough to connect all the fiber strands; whereas, if it is less than the 0.5 millimeters, the individual fluid jets will be mixed to diminish the effects of the disturbing currents, thus deteriorating interlocking properties. Interlocking properties, as used herein, means strength of interlocking non-woven fibrous materials in the lateral direction and the unit thereof is kg/3.8 cms in FIGS. **4** and **5**. The interlocking properties do not depend on the number of rows of apertures and one or more rows can be employed if desired.

In the above experiments, the fluid jet apparatus comprises an interlocking nozzle having a contact zone therein, said contact zone having a width of more than 3 centimeters. The plates forming the contact zone are spaced at a distance from each other of 3 to 5 millimeters. If the width of the contact zone is less than 3 centimeters, undesirable twisting of the fiber strands results and impedes the manufacture of strong, non-woven fibrous materials because of insufficient fiber movement. The distance or the height between the plates preferably should be approximately 5 millimeters, though subject to the total deniers of the fiber strands, fluid pressure and fluid amount.

It is to be particularly noted, in a preferred embodiment of this invention, that there is a specific range of total deniers of the fiber strands, ranging from 8,000 to 25,000 deniers to be fed to the contact zone per 1 centimeter width of said contact zone. A number of cracks result in non-woven fibrous materials manufactured by an apparatus having a contact zone more than 3 cms wide, if fiber strands of less than 8,000 deniers per 1 cm width of the contact zone are used, thereby deteriorating its strength in the lateral direction. On the other hand, fiber strands exceeding 25,000 deniers per cm. of contact zone width cause insufficient movement of each fiber, thereby deteriorating interlocking properties of the fibers.

Employing the present invention, non-woven fibrous materials are obtained exhibiting superior strength in both longitudinal and lateral directions. Accordingly, the noniwoven fibrous materials thus obtained are superior to the conventional interlocking non-woven fibrous materials and provide a wide range of uses, including applications requiring strength in the lateral direction.

PREFERRED EMBODIMENT OF THE INVENTION

The preferred embodiment of this invention will now be discussed with reference to the drawings.

In manufacturing the interlocking non-woven fibrous materials of high strength, especially in the lateral direction, according to the present fluid jet method, it is preferable that the fiber strands to treated on both the lower and upper sides thereof with a fiber direction converting apparatus wherein fluid is jetted through a pair of different directioned fluid jet tubes **52** as shown in FIG. **6** prior to undergoing treatment in the interlocking nozzle **42**.

FIG. **6** shows a general process for producing interlocking non-woven fibrous materials wherein fiber strands **40** are fed to the interlocking nozzle **42** by the feed rollers **44** to be provided with interlocking properties in contact zone **26** under high pressure of the fluid supplied through the fluid tube **28**. The resulting non-woven fibrous material is then taken up by the take-up roller **48** by way of the delivery roller **50**. At this stage, the overfeeding amount has to be controlled by regulation of the relative speeds of the rollers **44** and **50**. Otherwise excessive overfeeding can result in waviness of the fiber strands, and in uneven non-woven fibrous materials as well as deteriorated interlocking properties. The overfeeding amount suitable for interlocking properties provides only a small increase in the meandering or effective volume of the fiber strands, thus not appreciable contributing to the strength of the non-woven material in the lateral direction. Therefore, a fiber direction converting apparatus shown generally as **52**, is provided after the feed roller **44** and just in front of the interlocking nozzle **42** in order to interlock fibers with minimum waviness and to maximize forcibly the meandering or effective volume of the fiber strands in the manufacturing method for non-woven fibrous materials shown in FIG. **6**.

The fluid jet tubes **54** which form the fiber direction converting apparatus **52** are preferably employed as shown in FIG. 7(*a*) and they are arranged above and below the supplied fiber strands at a depression angle (θ) with the jets in opposed directions so as to obliquely move the upper and lower layers of the fiber strands. Said fiber strands are composed of three layers, i.e. the upper and the lower layers obliquely moving in opposite directions respectively and an intermediate layer with regular fiber directions. After treatment by the fiber direction converting apparatus the fibers are fed to the interlocking nozzle **42**.

The correlative overfeeding amount of the intermediate fiber layer increases proportionally with the amount of oblique movement of the upper and lower fiber layers. However, the amount is generally of no practical consequence. It is possible to control the overfeeding amount, if necessary, by supplying the upper, the intermediate and the lower fiber layers through respective feed rollers.

Either a pair of fluid jet tubes **54** as shown in FIG. **7**(*a*) or a pair of upper and lower fluid jet tubes **56** each provided with a plurality of fluid jet apertures as shown in FIG. 7(*b*) is suitable for use in the fiber direction converting apparatus. The former is advantageous for manufacturing non-woven fibrous materials of rather narrow width and the latter is advantageous for manufacturing those with a large width. The shapes, the size and the angle of the fluid jet apertures can be determined depending upon the contemplated use of the non-woven fibrous materials. The oblique angles of the upper and lower fibrous layers can be controlled with ease by adjusting the angle of the fluid jet tubes **54** or **56** with respect to the direction of travel of the supplied fiber strands, the fluid pressure (air pressure or steam pressure, for example) and the distances respectively between the interlocking nozzle **42** and the fluid jet tubes **54** or **56** and further between the former and the feed roller **44**. The fiber direction converting apparatus is preferably positioned as closely as possible to the interlocking nozzle, because all the fiber layers tend to change direction toward the direction of travel just before the interlocking nozzle due to the action of the discharged fluid, if the apparatus is positioned far from the interlocking nozzle.

Non-woven fibrous materials of zig-zag fiber arrangements can be manufactured if another pair of the fluid jet tubes **62**, as shown in FIG. **6**, is positioned above and below the fiber strands and the jet directions are properly converted in the reverse direction.

In the manufacturing method for non-woven fibrous materials as shown in FIG. **6**, the fiber direction converting apparatus **52** is employed to forcibly convert the fiber directions of the upper, the intermediate and the lower fiber strand layers and to feed said fiber strands to the interlocking nozzle **42** thereby obtaining the non-woven fibrous materials shown in FIG. **8**(*b*). As is clear from FIG. 8(*b*), the respective fiber layers of the non-woven fibrous materials are arranged in such a way that the upper fiber layer is in the right upward direction and the lower fiber layer is in the right downward direction and the intermediate fiber layer is in the same direction as the longitudinal direction of the fibrous materials. Consequently, the above three layers are interlocked with one another in upward, downward, lateral and longitudinal directions. On the other hand, FIG. **8**(*a*) shows the structure of non-woven fibrous materials obtained otherwise than through the use of the fiber direction converting apparatus indicating that all the fibers are in the same direction parallel to the direction of travel of the fibers. The comparative structure of the non-woven fibrous materials obtained through the respective methods shown in FIGS. **8**(*a*) and **8**(*b*) establish that the non-woven fibrous materials manufactured with the combined use of the fiber direction converting apparatus and the interlocking nozzle possess twice as much strength in the lateral direction as those manufactured otherwise.

In addition to the fiber direction converting apparatus shown in FIGS. **7**(*a*) and **7**(*b*), a screw-brush apparatus **58** as shown in FIG. **9** can also be used for fiber direction conversion. Screw brushes having different spiral directions are rotated above and below the supplied fiber strands thereby obliquely moving the upper and lower fiber layers respectively. Screw brushes having identical spiral directions should not be used, however, since strength in the lateral direction will not thereby be improved. The size and the angle of the screw are determined according to the contemplated end use of the non-woven fibrous materials. It is preferable that the screw brushes be positioned as closely as possible to the interlocking nozzle **42** because the fiber layers already converted in their respective directions tend to return to the direction of travel upon action of the fluid discharged from the interlocking nozzle.

If at least one plate, in this instance shown as upper plate **12** in FIG. **6**, of at least twice the width of the normal maximum width of the contact zone within the interlocking nozzle is connected through a transverse lever **60** to a reciprocating motor or the like, (not shown) in a manner adapted to impart a reciprocating movement to the plate in a direction perpendicular to the direction of travel of the fiber strands, non-woven fibrous materials of higher strength can be manufactured exhibiting the interlocking conditions shown in FIG. **10**(*b*). On the other hand, FIG. **10**(*a*) shows the interlocking conditions of materials manufactured without using a movable reciprocating plate.

Furthermore, in a preferred embodiment of the present invention, non-woven fibrous materials of exceedingly high strength can be produced with the combined use of conventional binding agents. Although both filament tow and staple webs are applicable for use as the fiber strands in this invention, filament tow has been found to provide better results when employed herein and therefore is considered preferable.

What is claimed is:

1. A method for preparing non-woven materials exhibiting high strength both in the longitudinal and lateral directions comprising: feeding fiber strands having an upper layer, an intermediate layer, and a lower layer, through feed rollers to a fiber direction converting zone; forcing the fiber strands to open and causing the upper and lower layers of said fiber strands to obliquely move in opposite directions by impinging fluid jets upon said fiber strands from above and below said fiber strands, the direction of impingement from above being opposite of impingement from below; feeding the resulting opened fiber strands to a contact zone comprising upper and lower opposed symmetrical plates, each plate containing a plurality of apertures therein ranging from 0.5 to 1.0 millimeter in diameter, said apertures being disposed in each plate in at least one row with intervals between apertures of 0.5 to 2 millimeters; charging fluid through said apertures under pressure, forming fluid jets which impinge upon said open fiber strands in a direction perpendicular to the direction of travel of said fiber strands causing said strands to interlock; withdrawing the resulting non-woven fibrous material through take-up rollers; and passing said non-woven material to a final delivery roller.

2. Method as defined in claim **1** wherein a plurality of fluid jets are impinged on the upper surface of the fiber strands while a plurality of opposed fluid jets are impinged on the lower surface of the fiber strands.

3. Method as defined in claim **1** which further includes imparting a zig-zag pattern to the resulting non-woven material by impinging an additional pair of opposed fluid jets from above and below the fiber strands, said impingement upon said fiber strands being in directions opposite to that of the original fluid jets.

4. Method as defined in claim **5** wherein the feed rollers rotate at a speed of from 5 to 10 percent faster than the take-up rollers causing overfeeding of the fiber strands to the contact zone.

5. An apparatus for preparing non-woven fibrous material by the fluid jet method comprising a pair of tanks adapted to receive and transmit fluid under pressure, each tank terminating in a plate containing a plurality of apertures, the plurality of apertures in each plate ranging in diameter from 0.5 to 1.0 millimeter and being disposed in at least one row at intervals between 0.5 to 2 millimeters with corresponding apertures in each plate being on identical axes, said tanks being maintained in opposed spaced relation with said plates facing each other, spacing means situated between said tanks and being adapted to maintain said tanks in spaced relation, said spacing means and said plates defining a contact zone adapted to receive and permit passage therethrough of fiber strands, said contact zone having a width greater than 3 centimeters and a height of from 3 to 5 millimeters, means for passing said fiber strands through said contact zone, and means for charging fluid to said tanks, whereby the charged fluid upon egress from the apertures impinges upon the fiber strands in a direction perpendicular to the direction of travel of said fiber strands within the contact zone causing interlocking of said strands forming a non-woven fibrous material.

6. Apparatus as defined in claim **5** which further includes a lever connected to at least one of said plates, said lever being adapted to impart a reciprocating movement to said plate in a direction perpendicular to the direction of travel of the fiber strands, and wherein said plate connected to said lever is at least twice the width of said contact zone.

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