A method and apparatus for making uniform non-woven webs. The apparatus comprises a tubular collector, on to which filaments are sprayed by two or more filament forwarding devices, with uniform relative angular motion between the forwarding devices and the collector surface. The filaments adhere to the collector and form a band of non-woven webs which is slowly advanced so that a tubular uniform non-woven web is produced. The web may be collected by flattening it to provide a double thickness or it may be slit along its length.
MANUFACTURE OF NON-WOVEN MATERIALS

The invention relates to methods of and apparatus for manufacture of non-woven fabrics comprising continuous synthetic filaments. More particularly, the invention relates to a method and apparatus for forming non-woven materials by deposition of continuous filaments on a collecting surface.

In the past, non-woven structures comprising continuous filaments have been made by the deposition of the filaments on to an advancing collector surface. Many variations on basic manufacturing technique have been disclosed, such as for example, depositing a curtain of filaments upon an advancing conveyor, forwarding filaments by means of stationary forwarding devices or by means of forwarding devices arranged to reciprocally traverse perpendicularly to the direction of advance of the collector surface. The collector surface has comprised a flat conveyor, a rotating drum or a flat rotating disc, and the purpose of the surface is to remove the filaments as they are laid into a non-woven structure from the lay-down zone.

A major criterion in the success of a particular method of forming the non-woven sheet is the uniformity, as measured for example by the weight per unit area, of the product. When a single stationary, forwarding or depositing means is employed this criterion is quite readily satisfied, but the provision of a plurality of forwarding or depositing means, and/or reciprocating motion of a single forwarding means, as has been frequently proposed, requires much more complicated arrangements in order to ensure a uniform product. A particular disadvantage of those methods of manufacture of continuous filament non-woven webs employing a multiplicity of forwarding means and/or reciprocating means known to us before the present invention was that the edges of the non-woven structure were of a different weight per unit area to the main body of the structure. In order to overcome this non-uniformity it proved necessary to trim away the edges of the product so that only the central, uniform portions remained. The cost of manufacturing the edge portions which were subsequently trimmed away and wasted is obviously undesirable and the need for a method, or apparatus, for manufacturing at high throughputs of a non-woven web of uniform weight per unit area even at its edges without trimming became apparent.

It is an object of the invention to provide an improved method of making webs comprising continuous filaments. Another object of the invention is to provide novel apparatus for the manufacture of non-woven webs. Yet another object of the invention is to provide a method and apparatus for the manufacture of a uniform continuous filament non-woven webs using a multiplicity of filament forwarding devices. Other objects of the invention will become apparent during the detailed description which follows.

Accordingly, the invention provides in one of its embodiments a method of making non-woven webs which comprises forwarding a plurality of synthetic polymeric continuous filaments to two or more forwarding means situated in the proximity of a hollow collecting tubular member, advancing thereby said continuous filaments at an angle to the axis of the said tubular member so that they impinge upon and lightly adhere to, the surface of said tubular member, causing relative angular motion between said forwarding means and said tubular member about the axis of said tubular member such that the distance between said forwarding means and the surface of said tubular member remains preferably substantially constant, thereby forming a band of continuous filamentary web on the surface of said tubular member, withdrawing said band of web at a preferably substantially constant rate from the end of the tubular member so as to form a tubular non-woven web and collecting said web by suitable means.

In another embodiment, the invention provides apparatus for making a non-woven web comprising filament supply means, two or more filament forwarding means, a collecting surface arranged in the form of a tube, the exit passage at least of said forwarding means being inclined at an angle to the axis of the tube and means causing preferably uniform relative angular motion between said forwarding means and said tube such that the mean distance between said forwarding means and the surface of said tube remains substantially constant, whilst ensuring that the overall relative angular motion between filament supply means and the inlets at least of the filament forwarding means is at least substantially zero.

The invention proposes relative angular motion between the forwarding means and the tubular member. Thus both forwarding means and collecting means may rotate or preferably either one or the other may be stationary. If the tubular member is rotated, it then becomes necessary to rotate the collecting means about the axis of the tubular member at the same angular velocity as the tubular member in order to avoid twisting of the web, and engineering, maintenance and doffing complications are thereby encountered. Therefore, in a highly preferred embodiment of the invention the tubular member is not rotated and so the collecting means need not be rotated about the axis of the tube; and the filament forwarding means is moved so that the direction of spraying proceeds at preferably constant angular velocity. However, in the latter case it is necessary, in order to prevent interference between and twisting of, the threadlines between the supply means and the forwarding devices that there is no accumulative relative rotational motion between the supply means and the inlet ends of the forwarding devices. The means in which this requirement may be met in practice are set forth in greater detail hereinafter.

The means for collecting the web will usually comprise means whereby the tubular web may be wound up on a roller in an orderly manner although alternative collecting means such as piddling the web into a collecting can are not excluded. Conventionally the collecting surface may be somewhat flattened towards the web outlet end so that the web may be collected as a "lay-flat" doubled web. Alternatively, if a web having a large width is desired, the tubular web produced by the process of the invention may be slit once along its length. Slitting may be performed by conventional means such as cutting, shearing or by thermal means.

The web may be subsequently treated in known manner to produce a non-woven product. For example the web may be impregnated with an adhesive and heated to bond the fibres together, or the web may contain composite filaments, having a component which may be rendered adhesive under conditions which leave the other component(s) substantially unaffected.

The production of a tubular non-woven web has valuable advantages over known techniques of producing
continuous filament webs in which continuous filaments are deposited on a flat collecting surface by means of a filament forwarding device which is traversed to and fro above the collecting surface. Amongst these advantages mention may be made of the compactness of the apparatus compared with conventional machinery for manufacturing a non-woven web of comparative width, which renders the apparatus extremely valuable in production where frequently floor space is at a premium. The production of tubular non-woven web by the process of the invention further provides a means of attaining higher productivity, since high traverse speeds are obtainable because there is no sudden change in velocity of the filament forwarding means and furthermore the web produced may be made completely uniform across its width whereas webs made by conventional traversing forwarding devices depositing filaments on a horizontal collecting surface have edges having a different weight per unit area to the remainder of the web, because of the finite time taken to effect reversal of direction of traverse of the forwarding devices.

The tubular or slit-tubular web produced may be readily bonded by methods available from the art. Thus the web may be impregnated with an adhesive binder which may be applied as a solid, a liquid or a solution with such further treatment as may be necessary so as to effect bonding. In a preferred embodiment the web comprises bicomponent filaments, one component of which occupies at least a proportion of the periphery of the filament and may be rendered adhesive under conditions which leave the other component substantially unaffected, thereby forming bonds between contiguous filaments.

The hollow tubular member may be composed of a plurality of vertically arranged continuous belts which abut or overlap at their edges. The belts may be driven in synchronous manner so that the internal wall formed thereby descends at a speed determined by the throughput of the filament advancing means and the desired weight of product. The belts or sheets may be impervious or foraminous, as desired. Alternatively, the tubular member may comprise a stationary sheet in which case the web is progressed down the cylinder by tension supplied by haul-off rolls. We have found that such a simple tube arrangement works perfectly satisfactorily when the continuous filaments are polyamides. We believe that the polyamide filaments become charged with static electricity during their passage through the forwarding devices and as a consequence adhere to the surface of the collector. As the charge on the filaments disperses (due to atmospheric humidity or steam injected into the collector) the adherence of the web to the collector surface decreases sufficiently to enable the web to advance under the haul-off tension without becoming unduly damaged. The tubular member may again alternatively be parallel rods, some of which are arranged to move inwardly and downwardly then outwardly and upwardly in a predetermined cycle and the remainder of the rods are stationary, so that the tubular web is passed down the collecting surface in a predetermined fashion. The tubular member may be formed from any material, although metal is preferred.

The exhausts of the forwarding means are inclined at an angle to the axis so that filaments are caused to impinge upon the hollow collecting cylinder.

A substantially constant weight per unit area along the web will be obtained if the distance the web is withdrawn per revolution of the forwarding means is small compared with the width of the band deposited by the forwarding means. For example, it is frequently found that the spray distribution is substantially Gaussian in which case the maximum advance of the web per revolution of the forwarding means, in order to ensure a substantially uniform product, is equal to the half peak width of the distribution. A substantially uniform web will be produced if the ejectors are symmetrically disposed around the vertical axis of the collecting cylinder, and the condition discussed above is complied with. Quality of the web may be improved if, for a given throughput of filaments through the forwarding means and given product weight, a high relative velocity between forwarding means and collecting surface together with a low web withdrawal speed are employed.

The filamentary material forming the web will generally be found to adhere to the walls of the collecting member by means of static charge as in the case of polyamide continuous filaments discussed above, but if necessary suction may be applied from the remote side of the collecting surface in order to increase adherence. Should the static charge be so great as to cause such adherence between filaments and the tubular member that the web is damaged by the haul-off tension, the charge, and consequently the adherence, may conveniently be reduced by injecting steam or moisture. Injection may be performed by a nozzle associated with the forwarding means.

It is of course necessary to avoid any twisting together and interference between the individual threadlines feeding the several forwarding means. This can be achieved by keeping the forwarding means and filament supply stationary and arranging for the collecting surface and winding means to rotate in tandem. However, as stated above, we prefer where possible that collecting surface and winding means do not rotate in tandem. Another possibility is that filament supply means and forwarding means are both rotated with the same angular velocity. The third, highly preferred alternative is to maintain filament supply means and collecting surface stationary, and to cause the direction in which the exit of the forwarding means points to proceed at uniform angular velocity whilst ensuring little relative movement, and no accumulated relative movement between supply means and the inlet end of the forwarding means. In order to avoid interference between threadline paths after forwarding, all ejectors should point in substantially the same direction.

This may be achieved by mounting the plurality of ejectors on a tilted non-rotateable plate and arranging for the plane of tilt to proceed at uniform angular velocity, which is a modification of the so-called "Swash Plate" member. The motion of the tilted plate is analogous to the precession of the axis of a spinning body around an axis of rotation and for convenience the motion will be referred to as a precession. Alternatively, several ejectors may be mounted on a fixed horizontal plate symmetrically above the axis of the tubular member and having exit orifices inclined at an angle to that axis.

When the diameter of the collecting cylinder is large it may not prove possible to arrange the threadline forwarding means to be centrally aligned above the collecting cylinder, since the distance that the filaments
must travel from forwarding means to impinge upon the collector cylinder is undesirably large. In such cases, one rotatable swash plate carrying a plurality of ejectors may be mounted conveniently near to the collector surface on an arm, extending from a centrally mounted rotatable shaft.

In a modified embodiment of the invention similar apparatus may be employed for spraying a fluid or fluidised material from a fluid reservoir onto the wall of a tubular construction. The modification requires additional relative motion between the tubular construction and the spraying means in a direction parallel to the axis of the tubular member. This modification may be used for sundry spraying purposes for which the following are chosen by way of example only: coating of internal and/or external surfaces of tubular constructions with protective substances such as paints, powders, metals, polyvinyl chloride, poly(tetrafluoroethylene), anti-corrosive agents and for scouring and cleaning by means of spraying abrasive powders, which may or may not be suspended in liquids. Other uses of the invention will be apparent to the skilled reader. The tubular constructions which may be so treated may be pipes, tanks, boilers, pressure vessels and so on.

The invention will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a schematic representation of one form of the apparatus of the invention.

FIG. 1A is a schematic plan view, on a reduced scale, of a collector having an oval cross-section near its base.

FIG. 2 is a section through a preferred yarn forwarding device comprising two air ejectors mounted on a rotatable swash plate.

FIGS. 3, 4, 5 and 6 show perspective views of a swash plate device similar to that illustrated in FIG. 2 but having four ejectors, in various attitudes.

FIG. 7 is a section through an alternative forwarding device comprising two filament forwarding means which may be used.

Referring to FIG. 1, continuous filaments 10 of a synthetic polymer are passed from spinnerets 12 integrally connected to spinning units 14, to pneumatic forwarding devices 16. The exit nozzles 18 of forwarding devices 16 are parallel at all times and inclined so as to project continuous filaments 10 without interference between the two masses of projected filaments 10 onto the internal wall 20 of a continuous collecting surface 22, shown as a cylinder. Forwarding devices 16 are situated on opposite sides of, and close to the axis of collector 22 and are arranged to rotate at constant angular velocity. A web 24 of continuous filaments is built up on the internal surface 20 of collector 22. Cylindrical web 25 is passed on exiting from collector 22 around curved roll 26 which serves to lay-flat the web 25 to form a doubled web 28. As seen in FIG. 1C the laying flat of web may be facilitated by designing the collector 22C so that it has an elliptical cross-section at least towards its base 20, and the ratio of the ellipse's major and minor axes becomes progressively greater towards the base. If desired web 25 may be slit along a length by slitting means (not shown) and opened by guide rolls (not shown) to form a single web 28 which would then proceed via roll 26 to occupy the position of web 28. Reference numeral 30 indicates schematically further treatment of web 28 whereby the filaments thereof are bonded together and web 28 is finally collected on roll 32 and may be interleaved by tissue paper 34 supplied from roll 36 if desired.

FIG. 2 illustrates a convenient form of pneumatic forwarding device 16, by which a plurality of individual bundles of continuous filaments 10 can be supplied to a forwarding device to increase throughput. For convenience, two threadlines are illustrated, and their relative positions are indicated by the suceses N, S, being two cardinal points of a compass. Thus, threadlines 10N, 10S, are passed to the pneumatic forwarding device which comprises air ejectors 38N, 38S, mounted perpendicularly to inclined swash plate 40.

Swash plate 40 is supported by vertical rigid hollow shaft 42 bent at its lower end and fixed thereat to ball race 44 embedded in plate 40. The vertical portion of shaft 42 is aligned with the axis of the collector (not shown in FIG. 2) and is rotatably driven by means of a chain or belt (not shown) running in contact with pulley or sprocket 43. Internally situated of shaft 42 is pneumatic supply tube 46 whereby ejectors 38N, 38S, are powered. Tube 46 is rigidly mounted to frame 48 and contains flexible portion 50.

In operation, shaft 42 is rotated, thereby causing the plane of tilt of plate 40 to precess whilst stationary flexible supply tube 46 prevents plate 40 from rotating. By this means, ejectors 38N, 38S, are held substantially in the same position relative to threadlines 10N, 10S, whilst the direction in which threadlines 10N, 10S, are propelled by ejectors 38N, 38S, precess.

FIGS. 3, 4, 5, 6 illustrate in perspective four successive attitudes of swash plate 40 carrying four ejectors 38N, 38S, 38E, 38W, in the course of one revolution.

FIG. 7 shows a second yarn forwarding device. Stationary plate 54 supports a number of air ejectors (two only shown). The ejectors comprise a non-rotating portion 56 and a rotatable portion 58, the two portions being linked at bearing 60. Rotatable portions 58 comprise a first section 59 coaxial with fixed portion 56 and a second portion 61 set at an angle to portion 59. First sections 59 of rotatable portions 58 are adapted to engage with a driving belt or chain (not shown); the portion engaging the driving means is indicated by reference numeral 65. The axes of second portions 61 preferably remain parallel and for this reason positive engagement between driving means and rotatable portions 58 is preferred, such as that afforded by a toothed wheel and a chain or ribbed belt.

The invention is further illustrated by the following example, which is provided as an illustration only and should not be construed as limiting the invention in any manner.

**EXAMPLE**

40 conjugate filaments, the components of which were arranged in a core-sheath configuration, were extruded from a spinneret assembly as described in our British Patent Ser. No. 1,100,430. The core was nylon 66 and the sheath was acopolymer composed of 70 percent nylon 66 and 30 percent nylon 6. The mean core: sheath volume ratio was 2:1 and the total spinneret throughput was 3.4 Kg/hr.

The filaments were divided into four bundles, each containing 10 filaments, and the bundles passed downwards through a cooling chimney to a spray head comprising four pneumatic forwarding devices equipped around a 17.8 cm pitch circle on a rotating swash plate assembly substantially as illustrated in FIG. 2 but with
four forwarding devices. The centre of the swash plate was 270 cm below the spinneret face and the plate was inclined at an angle of 60° to the horizontal. The forwarding devices caused the filaments to diverge and produced a circular spray pattern. The swash plate assembly precessed at 110 revolutions per minute.

Filaments were forwarded from the forwarding devices and impinged on and adhered to a vertical receiver of perforated aluminium sheet, symmetrically arranged about the spray head, having a circumference of 305 cm. The horizontal cross section of the receiver was circular at the region corresponding to the centre line of the band of web produced by the rotating spray head. Below this region, the cross section of the receiver progressively changed to one of increasing ovality, and the depth of the receiver below the centre line of the band of web was about 50 cm.

A driven bowed roll was set under the collector with its axis (i.e., the line joining the ends of the bowed roll) parallel to the major axis of the oval cross-section of the base of the receiver. The roll had a radius of curvature of 355 cm and was arranged so as to be convex downwards and convex towards the wind-up described hereinafter, and its plane of curvature made an angle of 20° with the vertical. The centre of the roll was about 130 cm below the base of the receiver and was offset by about 18 cm from the axis of the receiver towards the wind up.

A conventional wind-up apparatus consisting of a driven roll was situated some 3 metres from the bowed roll.

The deposited band of filaments was slowly pulled down the receiver, initially with the assistance of tapes until the web built up and could be passed around the driven bowed roll to the wind-up. The wind-up speed was 180 cm.min⁻¹. The cross-section of the web changed gradually during its passage down the collector, from circular at the spray level, to flat at the bowed roll. The laid-flat web was wound up, interleaved with tissue paper. Steam was sprayed on to the web from a nozzle at the centre of the swash plate assembly disc, the steam flow being adjusted to obtain easy web movement down the receiver with a neat, reasonably taut sleeve between the receiver base and the bowed roll. The width of the web at wind up was about 140 cm and the web weight was 22 g.cm⁻².

The wound-up roll was transferred to a bonding oven comprising a steam cabinet containing saturated steam at a pressure of 2.45 Kg.cm⁻² gauge. The bonded web was found to be satisfactorily resistant to delaminating and samples measuring 10 cm × 10 cm portions cut at random from the bonded web had substantially constant weight.

We claim:
1. Apparatus for making a non-woven web comprising filament supply means, two or more filament forwarding means, a collecting surface arranged in the form of a tube, the exit passage at least of said forwarding means being inclined at an angle to the axis of the tube, and means causing preferably uniform relative angular motion between said forwarding means and said tube such that the mean distance between said forwarding means and the surface of said tube remains substantially constant while ensuring that the overall relative angular motion between filament supply means and the inlets at least of the filament forwarding means is at least substantially zero, said forwarding means including a plurality of air injectors mounted upon a tilted non-rotatable plate and means for causing the plane of the tilt of said plate to precess at a uniform angular velocity.
2. Apparatus as claimed in claim 1 wherein the tube comprises a vertically mounted tube having a substantially circular cross-section at its top and towards its base an oval cross-section, the ratio of major to minor axes of the said oval cross-section increasing as the plane of cross-section approaches the base of the tube.
3. Apparatus as claimed in claim 1 wherein the tube comprises a stationary foraminous basket.
4. Apparatus for making a non-woven web comprising filament supply means, two or more filament forwarding means, a collecting surface arranged in the form of a tube, the exit passage at least of said forwarding means being inclined at an angle to the axis of the tube, and means causing preferably uniform relative angular motion between said forwarding means and said tube such that the mean distance between said forwarding means and the surface of said tube remains substantially constant while ensuring that the overall relative angular motion between filament supply means and the inlets at least of the filament forwarding means is at least substantially zero, said forwarding means comprising a plurality of air injectors mounted on a stationary plate which is substantially co-axial with the tubular member, said air injectors comprising a stationary inlet means and a rotatable outlet means, said outlet means being inclined at an angle to the axes of the tubular member and the axes of all of said outlet means being substantially parallel.
5. Apparatus as claimed in claim 4 wherein the tube comprises a vertically mounted tube having a substantially circular cross-section at its top and towards its base an oval cross-section, the ratio of major to minor axes of the said oval cross-section increasing as the plane of cross-section approaches the base of the tube.
6. Apparatus as claimed in claim 4 wherein the tube comprises a stationary foraminous basket.