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(54) Methods for forming nonwoven fibrous webs.

(57) Relatively uniform air laid webs of paper making fiber are produced by dispersing fibers of the order of 6 mm long in air and conveying them as a stream in air obliquely to a moving web-forming surface (12), the rate of travel (V_o) of the forming surface (12) being not less than 2.54 m/sec. To achieve uniform webs, the stream of air and fibers is given a component of velocity (V_1) in the direction of travel of the forming surface, and a component of velocity (V_2) normal to the forming surface, related to one another and to V_o such that the difference between V_o and V_1 is less than 3 times V_2.

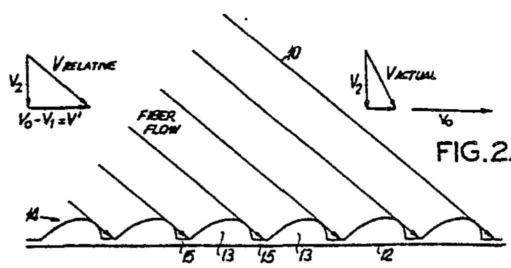

FIG.2A

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"METHODS FOR FORMING NONWOVEN FIBROUS WEBS"

This invention relates to methods for forming nonwoven fibrous webs, wherein a layer of fibers is deposited from a gaseous suspension of fibers onto a moving foraminous forming surface. More specifically, this invention provides improvements in methods of achieving high speed production of nonwoven fibrous webs.

In the production of nonwoven webs, the prior art has generally disclosed systems which form an air suspension of fibers and direct the suspended fibers toward a moving foraminous forming surface upon which the fibers from the suspension are condensed to form the nonwoven web. Various apparatuses exist for generating the air suspension of fibers. The fibers, for example, can be produced by a lickerin, a hammermill, or by other apparatus known in the art. The fibers can be dispersed in a gaseous medium by a variety of methods, and conveyed to a forming surface in an air stream operating generally as a pressure flow system, a vacuum system or a closed loop system. We have found that critical process limitations exist in the production of such air laid nonwoven webs, and that in a given system the uniformity of the formed web tends to decrease as the speed of the forming surface increases. It has been found that particularly at commercial speeds above about 550 feet per minute (2.79 meters per second), fiber lay-down on the moving forming surface tends to become uneven in the machine direction (i.e. the direction of travel of the forming surface). Thus the deposited webs exhibit an upper surface having an undulating, wave-like or ripple effect extending transverse to the machine direction, so that the webs exhibit corresponding variations in thickness and in weight. This rippling effect becomes more pronounced as the speed of the forming surface increases, with the spacing between the thicker portions of the web becoming greater and with the web becoming more varied along its surface as to basis weight. This rippling effect worsens with increased speed and eventually renders webs commercially unacceptable at some higher speed. This invention has sought to alleviate significantly the detrimental ripple effect. We have determined that there exists a critical relationship between the velocity of the fibers relative to the velocity of the moving forming surface as the fibers are being deposited onto the forming surface. We have found that the detrimental ripple effect can be controlled by controlling the ratio of the tangential velocity of the fibers relative to the moving forming surface, as compared to the velocity of the fibers normal to the moving surface.

Prior art concerned with obtaining higher production speeds in the production of air laid webs includes U.S. patent No. 4,004,323 wherein it is taught that speeds in excess of 200 feet per minute (1.01 m/sec) can be achieved by inclining a duct, which carries a stream of fibers, at an angle to a forming surface. The patent teaches a range of angles of incidence of the duct relative to the forming surface of from about 10° to about 30°. The patent fails, however, to report the high speed formation defect termed herein the rippling effect, and does not teach the criticality of the velocity ratios as between the fibers and the forming surface in alleviating the detrimental rippling effect. Indeed, the present invention teaches that there are combinations of fiber stream velocities and forming surface velocities for which ducts aligned as recommended in Gotchel will produce unacceptable webs with pronounced ripples.

This invention relates to methods for forming a nonwoven fibrous web on a foraminous forming surface moving at a speed in excess of about 500 feet per minute (2.54 m/sec). The methods include dispersing the fibers uniformly in a gaseous medium to form a gaseous suspension of fibers. The gaseous suspension of fibers is conveyed in a stream to the moving forming surface onto which the fibers from the gaseous suspension are deposited to form a nonwoven fibrous web. The detrimental high-speed forming phenomenon termed the rippling effect is alleviated by controlling the critical relationship between the velocity of the fibers being deposited onto the moving forming surface, relative to the velocity of the latter.

According to the present invention, there is provided a method for forming a nonwoven fibrous web on a moving foraminous forming surface from fibers of a papermaking length generally less than 1/4 inch (6.35 mm) characterised by the steps of

(a) moving the forming surface at a velocity V_o not less than 500 feet per minute (2.54 m/sec)

(b) distributing the fibers in a gaseous medium to form a gaseous suspension of fibers;

(c) conveying the gaseous fiber suspension in a stream to the moving forming surface, the gaseous stream having a velocity component V_1 in the direction of motion of the forming surface and a velocity component V_2 normal to the forming surface, the magnitude of the difference between velocity V_o and velocity component V_1 being less than 3 times the fiber velocity component V_2; and

(d) depositing the fibers from the gaseous suspension onto the forming surface to form a nonwoven fibrous web.

The forming surface onto which the fibers are deposited need not be planar, but could be curved, in which case it will have a tangential velocity V_o greater than 500 feet per minute (2.54 m/sec), the fiber velocity component V_1 being directed in the same direction as the motion of the curved forming surface.

When the velocities meet this ratio of 3:1 or less, the air-laid product is generally acceptable in terms of the ripple effect; outside this ratio the air-laid product generally is unacceptable as having excessive ripple characteristics.

In more complicated air/fiber flow patterns, wherein the gaseous stream containing the fibers has a further velocity component V_3 in the cross machine direction, the magnitude of the relative velocity component of the gaseous stream tangential to the forming surface, V', is equal to the square root of the quantity $(V_o-V_1)^2$ plus $(V_3)^2$. In this case also, the velocity V' should be less than about three (3) times the fiber velocity V_2.

Operation within the critical relationship between the fiber velocities relative to the forming surface velocity can be implemented in a variety of ways. For a given velocity V_o of the forming surface, the normal fiber velocity V_2 can be increased, for example by increasing the amount of suction pulling the gaseous stream through the moving surface. As a second example, the gaseous stream can be deflected to impinge upon the forming surface at an oblique angle, thereby increasing the velocity component V_1 of the gaseous stream in the direction of motion of the forming surface while maintaining velocity V_2 constant by increasing the amount of suction. In either approach the ratio of the velocity of the fibers relative to the velocity of the moving forming surface, compared to the component of the fiber velocities normal to the forming surface, can be varied to produce more acceptable products having more uniform web characteristics.

The invention will now be described in more detail by way of non-limiting example, with reference to the accompanying drawings, in which:

FIGURES 1A and 1B illustrate air laid webs produced at velocity ratios (as hereinbefore mentioned) of 2.5:1 and 3.5:1, respectively;

FIGURES 2A and 2B are diagrams illustrating the ripple effect at velocity ratios of 1.3:1 and 4:1, respectively;

FIGURE 3 is a graph illustrating ripple wavelength for velocity ratios of from 1:1 to 5:1; and

FIGURE 4 illustrates apparatus for use in practising this invention, with partial cutouts for clarity.

We have found that the high speed production of air laid webs is severely limited by a non-uniformity of web formation herein termed the ripple effect. This invention aims at alleviating the detrimental ripple effect by controlling certain critical relationships between the velocity of fibers in a gaseous stream being condensed on a moving foraminous forming surface, relative to the velocity of the moving surface.

Figures 2A and 2B illustrate two conditions of air laid web formation under two differing velocity conditions as viewed relative to the surface 12. In Figure 2A, typical fiber paths, 10, illustrate fibers approaching a forming surface 12 at an overall relative velocity V (relative), relative to the surface 12. As shown, this overall relative velocity V (relative) is how an oncoming fiber would be viewed from a stationary point riding on the moving surface 12. The relative velocity, therefore, is the vector sum of the actual fiber velocity, here shown as V (actual) which has vector components V_2 normal to the forming surface and V_1 parallel to the forming surface 12. When viewed relative to the forming surface 12 moving at a velocity V_o, the velocity V_1 component is subtracted from V_o to obtain the fiber velocity V' relative to the surface 12. The magnitude of V_o-V_1 therefore represents the relative velocity of the oncoming fiber in a direction along the forming surface, and V_2 represents the velocity of the oncoming fiber in the direction normal to the forming surface. We have determined that a critical parameter in the formation of a web as illustrated in Figure 1A is the ratio of V' to the fiber velocity V_2 normal to the surface. We have found that in forming a nonwoven fibrous web substantially comprising fibers of a papermaking length generally less than 1/4 inch (6.35 mm), this ratio must be maintained below about

3:1 to obtain acceptable product in terms of uniformity of the web, i.e. in terms of the inherent ripple effect.

Figure 2A further illustrates this ripple effect and our present belief of the reasons for the nonuniform web formation. Figure 2A illustrates a nonwoven web 14 formed of fibers deposited, as illustrated, along fiber paths 10. As the fibers are deposited on the forming surface 12, the fibers approach the surface at an oblique angle as viewed in a coordinate system moving with the forming surface. The ripple is believed to be primarily caused by a "shadowing" effect caused by the oblique approach of the fibers to the surface 12. This shadowing begins with the first fiber deposits, which occur randomly on the surface 12. These fiber deposites cause "shadows" directly downstream from their positions generally preventing oncoming fibers from falling in the areas of the shadows. Fiber continues to accumulate directly upstream from these initial deposites such as in thicker web portions 13 until the shadowing influence of a neighboring upstream deposit interferes. With further fiber deposition there is an apparent linking up of fiber deposits 13 in the cross machine direction to form the characteristic ripple effect. As is apparent from the Figure, this shadowing phenomenon produces the ripple effect with thicker web portions 13 alternating with thinner web portions 15. Further fiber deposition only increases the ripple characteristic of the web without changing the ripple wavelength. Except for some possible fiber bouncing or slipping during the initial deposition of fibers onto a surface, no fiber bouncing or slipping has been observed in the formation of webs below a velocity ratio of about 3:1. At ratios above about 3:1, fiber bouncing or slippage was observed to be a more significant forming phenomenon, with the resulting web exhibiting extremely non-uniform web characteristics.

Figures 2A and 2B illustrate the relation between the nonuniformity of web formation, i.e. the ripple effect, and the ratios between the fiber and forming surface velocities. In Figure 2A, V', the difference between velocity V_o of the moving surface 12 and velocity component V_1 of the fibers in the direction of motion of the surface, is about one and three tenths (1.3) times the velocity V_2 of the fibers normal to the moving surface, i.e. a velocity ratio of 1.3. The resulting web, 14, is relatively uniform with closely spaced thicker web portions 13. In Figure 2B, the difference V' between velocity V_o of the moving surface 12_B and velocity component V_1 of the fibers in the direction of motion of the surface, is about four times that of velocity V_2 of the fibers normal to the moving surface 12_B, (a velocity ratio of 4:1) and the resulting web 14_B is much less uniform than the web 14 of Figure 2A, with a more pronounced ripple effect, i.e. with the thicker portions 13_B of the web more widely spaced and of greater relative basis weight than in the web 14 of 2A.

Figures 2A and 2B illustrate fiber velocities only having components V_1 in the direction of motion of the forming surface and V_2 normal to the forming surface. No fiber velocity components in the cross-machine direction, i.e. perpendicular both to velocity component V_1 and to velocity component V_2, have been illustrated since such velocity components are generally undesirable in the manufacture of air laid webs. In instances where such cross-machine velocity components do in fact exist, such velocity components V_3 may affect the web formation since those cross-machine velocity components will increase the relative velocity V' by the following formula, V' is equal to the square root of $(V_o-V_1)^2 + (V_3)^2$, and thereby affect the velocity ratio $V':V_2$. Such cross machine velocities V_3 may deleteriously affect the web, requiring corresponding adjustments to reduce V' or increase V_2 in those affected web areas.

Figures 1A and 1B are plan views of webs formed at velocity ratios of 2.5:1 and 3.5:1, respectively. As seen in Figure 1A, at the lower 2.5:1 ratio, the web produced is relatively uniform, exhibiting the ripple effect to a minor, but acceptable degree. Some variation in fiber deposit is evident, with recurring heavier deposits at, for example, 17A, 17B, 17C. As seen in Figure 1A, the distances between these uniformly recurring heavier deposits 17A, 17B, 17C can be measured and are termed the "wavelength" of the "ripples". As seen in Figure 1B, web formed at a velocity ratio of 3.5:1 exhibits a ripple effect of far greater wavelength with thicker portions 19A, 19B, 19C, interspersed with thinner portions 19D and 19E. The web of Figure 1B is far less uniform in basis weight than the web of Figure 1A and is generally unacceptable.

Figure 3 is a graph illustrating experimental results of studies as to the ripple effect, for velocity ratios (V_0-V_1:V_2) ranging from 1:1 to 5:1. These studies were conducted using softwood Kraft and included studies of other variables in the air laid forming process in order to verify the criticality of this velocity ratio parameter.

The tests verified that the ratio results as illustrated by Figure 3 are independent of the absolute speeds involved, from about 250 feet per minute (1.27 m /sec) up to a forming surface speed of about 2250 feet per minute (11.43 m/sec). It is believed that the ratio results are independent of speed at speeds lower than 250 feet per minute (1.27 m/sec) and greater than 2250 feet per minute (11.43 m/sec). Other tests verified that the ratio results as illustrated by Figure 3 are generally independent of the foraminous forming surface used for web formation at ratios of below 3:1. Most of the tests were conducted using a 59 (MD) x 42 (CD) brass forming wire, 0.0095 inch (MD) (0.241 mm) and 0.0115 inch (CD) (0.292 mm) in diameter. Other tests verifying these ratio results were conducted on wires: 40 (MD) x 32 (CD), bronze, 0.0112 inch (MD) (0.284 mm) x 0.0125 inch (CD) (0.317 mm); 78 (MD) x 64 (CD), bronze, 0.0067 inch (MD) (0.170 mm) x 0.00725 inch

(CD) (0.0184 mm), 108 (MD) x 64 (CD) double-weave polyester 0.00866 inch (MD) (0.220 mm) x 0.00866 (CD), top, and 0.0118 (CD) (0.300 mm) bottom; and 84 (MD) x 32 (CD) two-layer polyester, 0.0157 inch (MD) (0.399 mm) x 0.0157 inch (CD) (0.399 mm). In the foregoing, the numbers preceding "(MD)" and "(CD)" refer to the number of mesh openings ~~wires~~ per inch (25.4 mm), considered in the direction of motion of the forming surface and transverse to this direction, respectively.

As shown in Figure 3, up to the critical velocity ratio of approximately 3:1, the ripple wavelength, as defined above, increases to a minor degree with an increase in the velocity ratio. Air laid fibrous product produced under conditions of a velocity ratio of 3:1 or less, was generally considered to be acceptable in terms of uniformity of web density. Product produced at conditions of greater than a 3:1 velocity ratio was judged unacceptable in that the variances in web basis weight and thickness, the ripple effect, were too great. As seen in the graph of Figure 3, above the 3:1 ratio the variation in web characteristics becomes extremely disproportionate to a variation in velocity ratio, thereby establishing the criticality of the 3:1 limit.

Most of the studies establishing the criticality of the velocity ratio of 3:1 were conducted using softwood Kraft fibers which are relatively long cellulosic natural fibers. Use of fibers of other sizes would vary the ripple effect in terms of the wavelength but would not affect the criticality of the 3:1 ratio. For example, use of a shorter natural fiber such as a hardwood fiber, will cause less of the shadowing problem and will tend to shorten the wavelength in the web for a given velocity ratio.

Since lowering the velocity ratio will lower the ripple wavelength for a given length of fibers, the actual ratio at which the fibrous product is produced for commercial application can be varied to obtain a desired product. For example, it may be desired to produce fibrous product comprised substantially of softwood Kraft fibers at a velocity ratio of 2.5:1 for commercial purposes since that product would exhibit more uniform web characteristics than if produced at a 3:1 velocity ratio. Similarly, the fibrous product could be varied as to its composition, varying the fiber sizes to vary the ripple effect at a given velocity ratio. For example, a mixture of hardwood and softwood fibers might constitute commercially acceptable fibrous product at a higher velocity ratio than for a product produced primarily of softwood fibers.

As stated above, the wavelength of the ripple effect is independent of the overall basis weight of the deposited web. As the web is being deposited onto the forming surface, the spacing between the thicker portions of the web (the ripple wavelength) is established early during the deposition of the fibers, and further fiber deposition only increases the web thickness without affecting this ripple wavelength. For commercial purposes, a lower weight web, such as a tissue product, might be produced at a lower velocity ratio to shorten the ripple wavelength, obtaining a more satisfactory commercial product in terms of minimizing the effect of the thinner web portions 15. It is believed that this invention can be used to produce air laid webs at least in the range of from about 7 to about 75 pounds (3.17 to 34.01 kg) per 3000 square feet of web (278.7 sq. meters). The weight of fibers distributed over this area can be in the range 25 to 70 pounds (11.3 to 31.7 kg), for instance 30 to 45 pounds (13.6 to 20.4 kg).

The apparatus of Figure 4 illustrates an application of this invention to enable the production of acceptable air-laid web at a higher speed of production than previously possible.

In Figure 4, apparatus 18 comprises a conventional fiber distributor 20 positioned above a moving foraminous forming surface 22 moving from left to right in the drawing in the direction shown, with cellulosic fibers being impelled from the bottom 24 of the distributor 20 to form an air suspension of fibers directed toward the forming surface 22. A suction box 26 is positioned below the forming surface 22, offset somewhat in the downstream direction relative to the distributor 18, the suction box 26 in use creating a moving air stream downwardly through the forming surface 22 and out via an exhaust pipe 28 to a fan (not shown).

The air stream fibers flow from the bottom 24 of the distributor box to the portion of the moving surface 22 above the suction box 26 where the fibers are deposited in the form of an air laid web 29. In this stream of fibers, the individual fibers are brought onto the moving surface 22 at an oblique angle by means of both the action of the offset position of the suction box 26 as well as by air turning foils 30. The turning foils 30 are positioned adjacent the upstream end of the distributor 20 and generally serve to introduce a horizontal air stream into the stream of fibers flowing from the distributor 20 to the forming web 22. Sealing roll 32 is positioned along the downstream end of distributor 20 substantially to seal the space between the distributor 20 and the forming surface 22. Side seals, not shown, seal the sides of the apparatus. These seals reduce air loss and minimize air turbulence within the apparatus.

The horizontal air stream introduced by the turning foils 30 coacts with the offset suction box 26 to impart a horizontal component of velocity to the fibers within the airstream. The dashed lines L in Fig. 4 indicate typical probable paths of fibers and illustrate that the fibers approach the moving surface 22 at an oblique angle having a velocity component in the direction of movement of the moving wire 22, thereby enabling the production of an acceptable air laid web at a higher speed of the forming surface 22 in accordance with this invention.

Claims:

1. A method for forming a nonwoven fibrous web on a moving foraminous forming surface from fibers of a papermaking length generally less than 1/4 inch (6.35 mm) characterised by the steps of

(a) moving the forming surface at a velocity V_o not less than 500 feet per minute (2.54 m/sec)

(b) distributing the fibers in a gaseous medium to form a gaseous suspension of fibers;

(c) conveying the gaseous fiber suspension in a stream to the moving forming surface, the gaseous stream having a velocity component V_1 in the direction of motion of the forming surface and a velocity component V_2 normal to the forming surface, the magnitude of the difference between velocity V_o and velocity component V_1 being less than 3 times the fiber velocity component V_2; and

(d) depositing the fibers from the gaseous suspension onto the forming surface to form a nonwoven fibrous web.

2. The method according to claim 1, characterised by the magnitude of the relative difference between velocity V_o and velocity component V_1 being less than 2.5 times the fiber velocity component V_2.

3. The method according to claim 1 or claim 2,

characterised in that the fibers are laid on a forming surface which is a screen comprised of 40 brass wires, each 0.0125 inch (0.317 mm) transverse to the direction of movement of the screen, and 60 brass wires, each 0.0112 inch (0.284 mm) in the said direction.

4. The method according to claim 1, 2 or 3, characterised in that the said stream is directed at a finite angle relative to the forming surface to impart a finite velocity component V_1 parallel to the forming surface and in the same direction as the velocity V_0 of the forming surface, and to impart a finite velocity component V_2 normal to the forming surface.

5. The method according to claim 1, 2, 3 or 4, characterised in that the fibers are deposited onto the forming surface to form a nonwoven fibrous web having a basis weight in the range of from 7 to 75 pounds (3.17 to 34.01 kg) per three thousand square feet (287.7 sq. m) of web.

6. The method according to claim 5, characterised in that the fibers are deposited to form a nonwoven fibrous web having a basis weight in the range of 25 to 70 pounds (11.3 to 31.7 kg) over the said web area.

7. The method according to claim 5, characterised in that the fibers are deposited to form a nonwoven fibrous web having a basis weight in the range of 30 to 45 pounds (13.6 to 20.4 kg) over the said web area.

8. The method according to any of claims 1 to 7, characterised by the relative difference between velocity V_o and velocity component V_1 being less than about 2.5 times the normal fiber velocity component, V_2, and the fibers being comprised substantially of softwood Kraft fibers.

9. The method according to any of claims 1 to 8, characterised by the relative difference between velocity V_o and velocity component V_1 being less than twice the normal fiber velocity component V_2.

10. The method according to any preceding claim, characterised by the gaseous stream having a further velocity component V_3 in a direction perpendicular both to velocity component V_1 and to velocity component V_2; the magnitude of the square root of $(V_o - V_1)^2 + (V_3)^2$, being less than 3 times the normal fiber velocity component V_2.

11. The method according to any of the preceding claims, characterised in that the fibers

are deposited on a curved forming surface which has a tangential velocity component V_o greater than 500 feet per minute (2.54 m/sec), the fiber velocity component V_1 being directed in the same direction as the motion of the curved forming surface.

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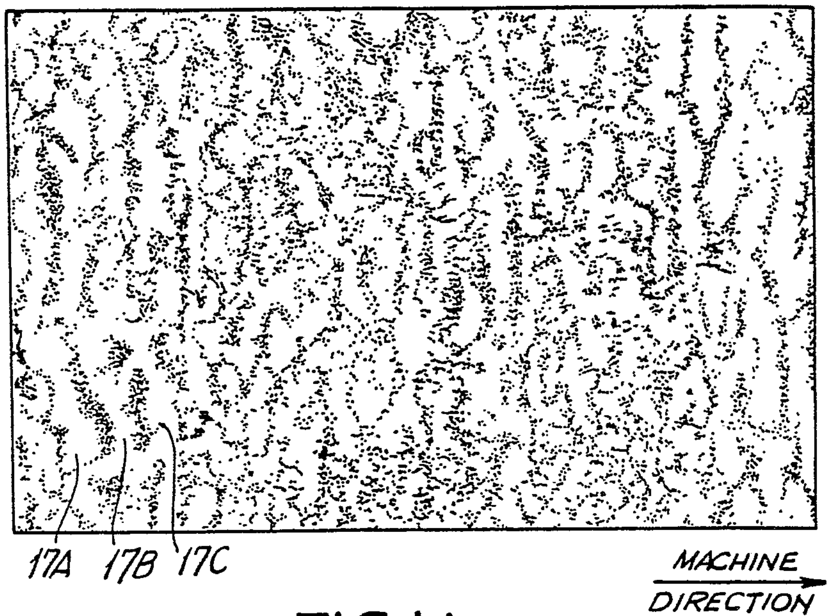

FIG.1A

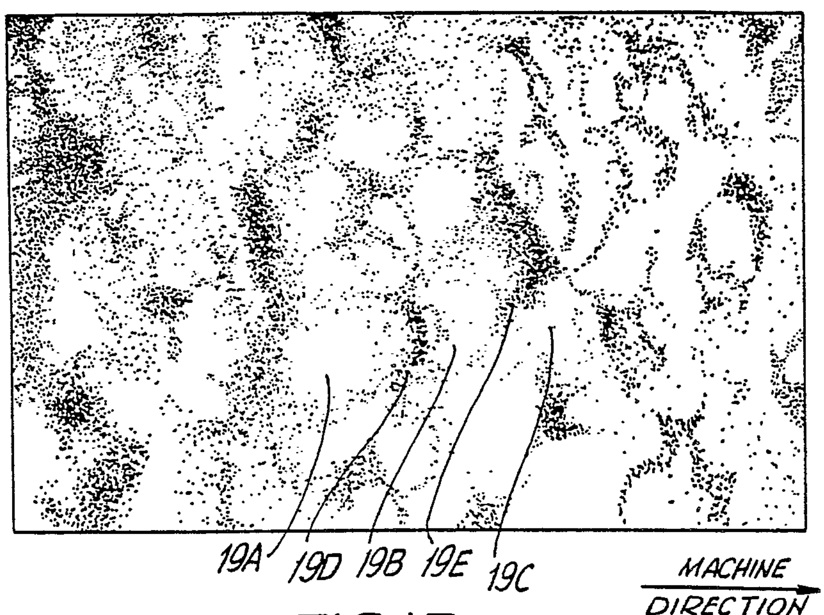

FIG.1B

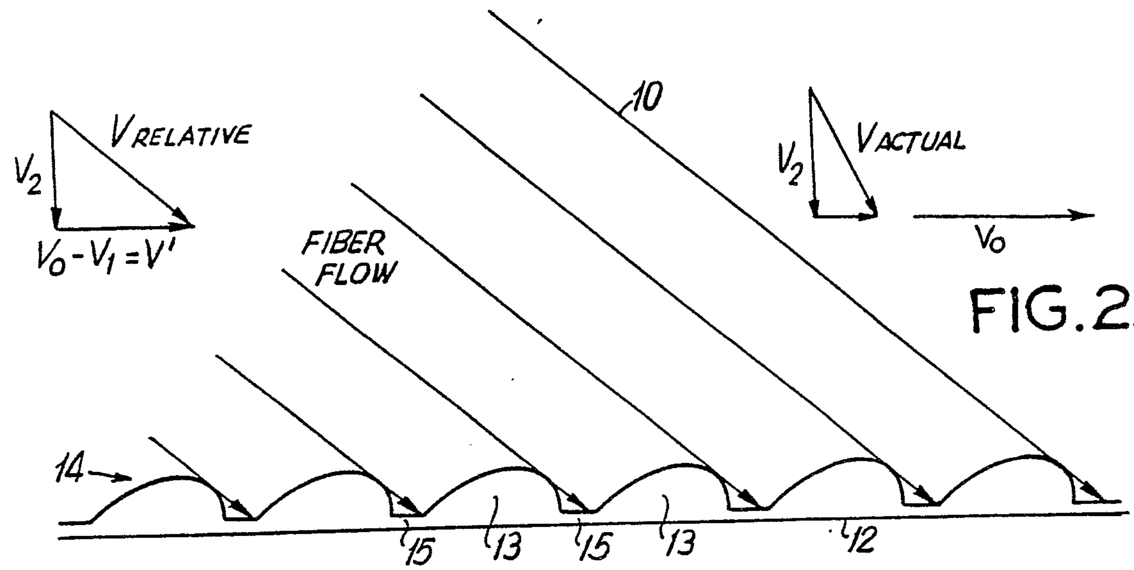

FIG.2A

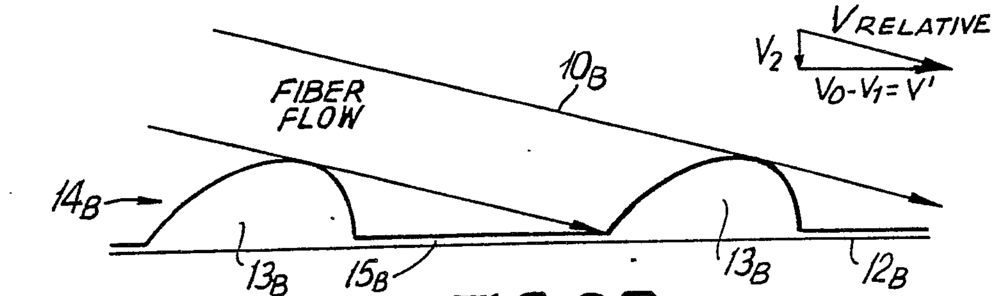

FIG.2B

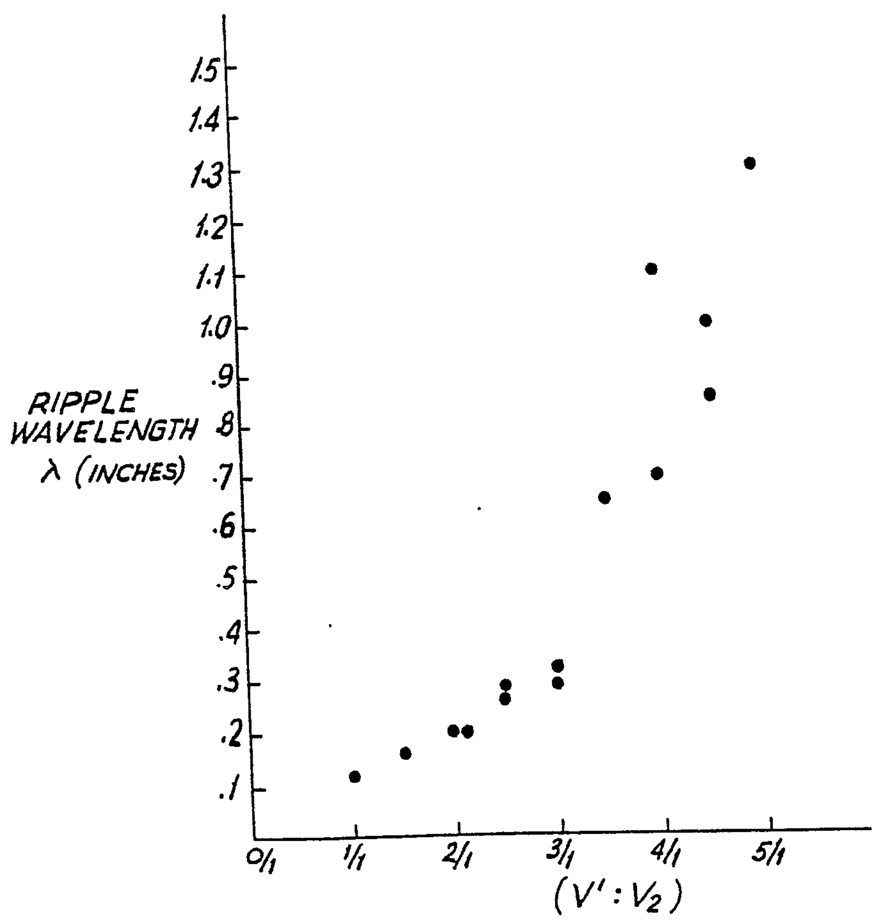

FIG.3

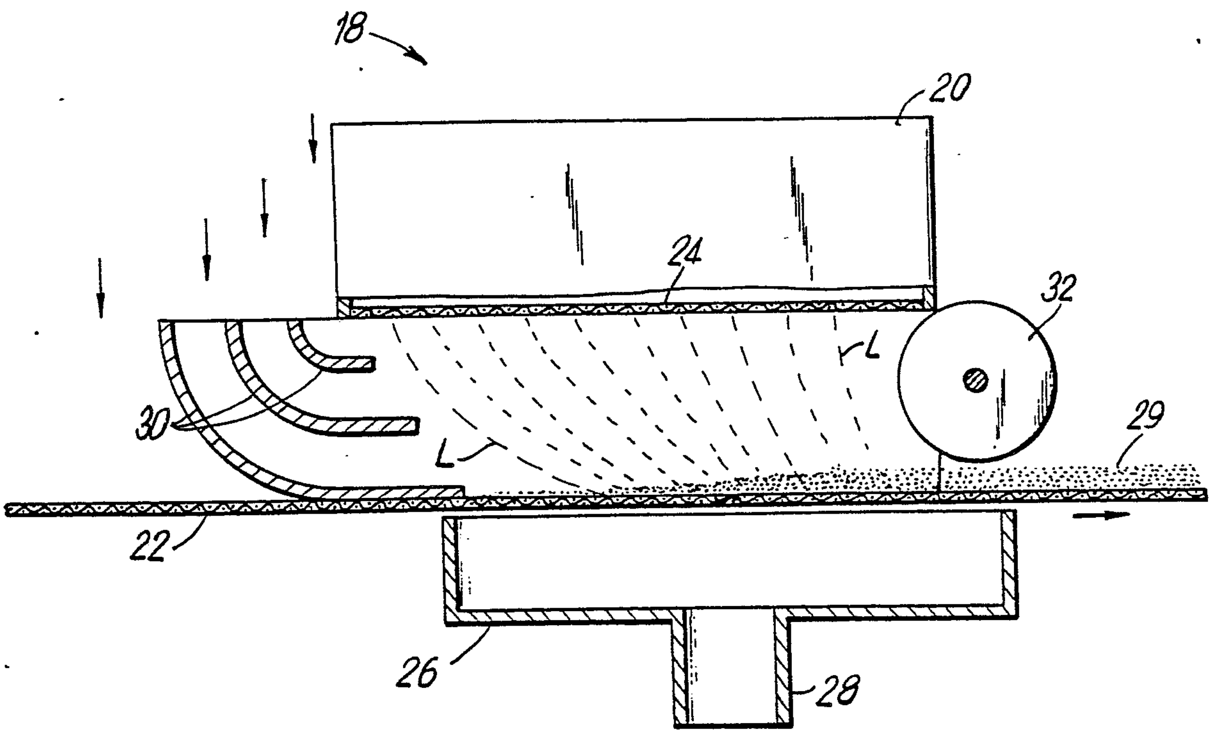

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

0060948

Application number

EP 81 30 1272

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	US - A - 3 755 856 (C.T. BANKS) * Figure 4; column 1, lines 37-62; column 2, lines 55-62; claims 1-7 * --	1	D 21 H 5/26 D 04 H 1/72
A	FR - A - 2 338 912 (TIITOLA) * Page 3, lines 3-11, 24-32; claim 2; figure 5 * ----	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.3)

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CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	29-09-1981	ELSEN-DROUOT

EPO Form 1503.1 06.78