AIR FLOTATION SYSTEM FOR CONVEYING WEB MATERIALS

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ABSTRACT OF THE DISCLOSURE

A coated or impregnated web of flexible material is conveyed or subjected to desired treatment, such as drying, during movement through a housing in which the web is supported and guided in floating condition by support means using a gaseous medium and is maintained out of contact with devices within the housing. The support means comprises a plurality of spaced, novel, support nozzles that are positioned adjacent and across one side of the web and that are so constructed as to utilize the Bernoulli theorem as applied to gases and the "Coanda Effect" during operation.

BACKGROUND OF THE INVENTION

This invention relates to the art of conveying web materials and, more particularly, to improved apparatus for supporting and guiding a moving web of a flexible material in floating or contact-free condition in the course of travel from one point to another.

It is known to the art to support a moving web of a flexible material, such as paper, plastic film, metal foil and the like, in floating condition in a gaseous atmosphere so it passes through a treating unit so as to prevent contact of the web with any parts within the treating unit. It is also known to support such a web in a treating unit by impinging streams of air, in the form of jets or blasts, on one or both sides of the web, the air streams being directed against the web by nozzles of various designs. One known prior art web support equipment includes the use of Venturi devices or a combination of a Venturi device and air jet nozzles.

Present day procedures and equipment of the types indicated above are not entirely satisfactory commercially for the reason that they have inherent operating difficulties. For one thing, it is very difficult to create and maintain a uniform air cushion under or over and under the web by employing known treating equipment. While uneven air pressure distribution can be tolerated to some extent in the handling of heavy webs in the category of heavy cardboard or flexible webs, such distribution is unacceptable in the treatment of lightweight and highly flexible webs of paper, plastic films and the like. Experience has demonstrated that it is extremely difficult to balance air flows to obtain a consistent pass line of the moving web. A change in the type of web material, web unit weight, weight of coating, web speed, etc. usually requires extensive and time-consuming rebalancing of air flows. Fluctuating at the edges of the web constitutes another difficulty and problem that is encountered by the use of conventional equipment. Such fluctuation is due to spilling of air at the web edges. Past attempts to overcome this problem by the employment of complex and expensive devices have not been wholly successful.

One of the inherent objections to known procedures for supporting and treating a moving web arises from the fact that they employ the same means for both supporting and treating the web. As a consequence, it is not possible to adjust conditions or parameters for one objective without adversely affecting another. For example, in a dryer in which the web is supported and dried by impinging air jets, it may be desirable and advantageous at a particular time to alter the drying rate while maintaining the same drying air temperature. This may be accomplished by increasing or decreasing the air jet velocity. Such air jet velocity increase or decrease will, however, correspondingly change the support afforded to the web by the same air jets and, therefore, will necessitate a rebalancing of the support conditions.

In many operations in the paper and film industries, it is often desirable or necessary to convey a web material from one location to another in floating or contact-free condition in the course of travel. This may be done to the web being coated on one or both sides with a wet or tacky coating or a desire to minimize scratching which occurs from idler rolls or bars on certain types of web materials.

SUMMARY OF THE INVENTION

As will be evident from the ensuing discussion and the detailed description appearing further along herein, apparatus constructed in accordance with this invention is adapted to properly support and guide a moving flexible web in floating condition. The apparatus includes an improved air support nozzle having superior operational characteristics whereby the apparatus is free of the above-mentioned objections and difficulties in use.

The air support nozzle constitutes an important feature of the invention. This nozzle is positioned adjacent and across one side of the web and is so constructed and arranged as to utilize the Bernoulli theorem as applied to gases in operation. The Bernoulli theorem states, in effect, that any increase or decrease in the velocity of a stream of gas results in a corresponding decrease or increase of the pressure of the gas. The air support nozzle also utilizes and takes advantage of the "Coanda Effect" which is described in H. Coanda Pat. No. 2,052,869 and is referred to in O. G. Haywood Pat. No. 3,316,657.

Another important feature of the invention is the provision of separate and independently adjustable means for furnishing air under pressure to air treating means and to the air support nozzles. This feature permits changes in operating conditions, such as an increase or decrease in drying rate, without appreciably affecting the operational efficacy of the air support nozzles. Moreover, the air treating means and the air support nozzles may each be designed for optimum functional efficiency in contrast to prior art constructions in which the design of the combined treating and support means necessitates undesirable functional compromise.

The primary object of this invention is to provide web conveying apparatus having improved features of design and construction.

Another object of the invention is to provide apparatus for simultaneously treating a moving web of flexible material and supporting the web in floating condition in a gaseous environment.

It is a further object of the invention to provide apparatus for effectively supporting and guiding a web for contact-free movement along a predetermined path.

A still further object of the invention is the provision of web treating apparatus of the character indicated that is relatively simple in design; that is rugged and durable in construction; that is reasonable in manufacturing, installation, maintenance and operating costs; that is adapted to properly handle a wide variety of materials which may differ in degree of flexibility, width and unit weight; and that is capable of performing its intended functions in an efficient and dependable manner.
The enumerated objects and features and additional objects and features, together with the advantages of the invention, will be readily understood by persons trained in the art from the following detailed description and the accompanying drawings which respectively describe and illustrate a preferred and recommended embodiment of the invention and three modifications thereof.

**BRIEF DESCRIPTION OF THE DRAWINGS**

In the drawings, wherein like reference characters denote corresponding parts throughout the several views:

- FIG. 1 is a view, partly diagramatic and partly in vertical longitudinal cross section, of a system of apparatus constructed in accordance with this invention;
- FIG. 2 is a view taken along line 2--2 of FIG. 1;
- FIG. 3 corresponds to a portion of FIG. 1 and illustrates a first modification thereof, certain parts which are the same as like parts in FIG. 1 being omitted;
- FIG. 4 also corresponds to a portion of FIG. 1 and illustrates a second modification thereof, certain parts which are the same as like parts in FIG. 1 being omitted;
- FIG. 5 is an enlarged side elevation view of a web support nozzle unit which is also shown in FIGS. 1 and 2;
- FIG. 6 is an enlarged view taken along line 6--6 of FIG. 5;
- FIG. 7 is a fragmentary view which is derived from FIG. 6 and which identifies critical dimensions of and between parts of illustrated elements; and
- FIG. 8 is a generally schematic representation of a third modification of the invention.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The term “air,” as used in this description and in the claims, is not limited to atmospheric air but encompasses, instead, any suitable gas or mixture of gases.

Referring initially to FIG. 1 of the drawings, the therein illustrated system of apparatus comprises a first mechanism 10, a second mechanism 11, which is spaced laterally from the first mechanism, and a web treating unit 12, which is positioned between these mechanisms. Mechanism 10 serves multiple functions which include supporting and dispensing a continuous flexible web W. Mechanism 11 also serves multiple functions which include receiving and supporting the web. As is indicated in FIG. 1, web W extends through treating unit 12 in the course of travel from mechanism 10 to mechanism 11.

Mechanism 10 comprises a supply reel 13 on which is wound the material of web W; a pan 14 containing a supply of a selected liquid treating composition 15; and a plurality of rolls, namely rolls 16, 17, 18, and 19. Reel 13 and rolls 16 through 19 are rotatable about corresponding parallel axes. As shown, roll 16 is positioned above and between reel 13 and roll 17; roll 17 is disposed in pan 14 and is submerged in composition 15; and rolls 18 and 19 are arranged above the pan and to the right of roll 17. Also, web W, on leaving reel 13, advances in the direction indicated by the arrows and passes over rolls 16, under roll 17, between the nip of rolls 18 and 19, and then over roll 19. Depending on the material of the web, the same is coated, impregnated or saturated with composition 15 as it moves through pan 14. Excess amounts of the composition on the web are squeezed out as the web passes between rolls 18 and 19 and returned by gravity to the pan.

Mechanism 11 comprises a pair of cooling rolls 20 and 21 and a winding reel 22, all of which are supported for rotation about axes parallel to the web. Web W passes from roll 19, through unit 12, over and under roll 20, over and under roll 21 and thence onto reel 22 in the order named. Mechanisms 10 and 11 are driven in timed relation by suitable means (not shown). The several reels and rolls may be of any desired appropriate form and construction known to the art.

In the course of its travel from roll 19 to roll 20, web W is subjected to handling and treatment in unit 12 which will now be described, having reference at this time to FIGS. 1 and 2. Unit 12 includes a housing H having a top wall 24, a bottom wall 25, a front end wall 26, a rear end wall 27 and a pair of side walls 28 and 29. Rear end wall 26 has a horizontal inlet slot 30 for entry of the web into the housing while front end wall 27 has a like discharge slot 31 for exit of the web from the housing. Positioned within housing H in the vicinity of the upper air drying means 32, each having a discharge tube or nozzle 33, and another plurality of banks of lower air drying means 34, each having a discharge tube or nozzle 35. Air drying means 32 and 34 are located to opposite sides of web W and are relatively inverted whereby to direct high velocity streams or jets of air against corresponding faces of the web. Means 32 and 34 may be of any suitable type known to the art, such as that disclosed in U.S. Patent No. 3,134,654 to which reference may be had for details of construction and operation.

Drying means 32 are connected to a plenum chamber 36. A blower 37 supplies air, at desired temperature and under predetermined pressure, to plenum chamber 36 by way of a conduit 38 that is equipped with a damper 39 for controlling air flow. In like manner, drying means 34 are connected to a plenum chamber 40 and air, at desired temperature and under predetermined pressure, is supplied to this plenum chamber by a blower 41 and a conduit 42 having a damper 43. Air is exhausted from the interior of the housing by an arrangement of devices including an upper exhaust header 44 that is positioned in the upper region of the housing and a lower exhaust header 45 that is positioned in the lower region of the housing. The headers communicate with an exhaust blower 46, that is mounted above the housing, by means of corresponding conduits 47 and 48 and a common conduit 49.

Treating unit 12 also comprises a plurality of air support nozzles 50 which will be described in detail further along herein. These nozzles are positioned in housing H and above web W and are so constructed and arranged as to cooperate with other parts to create an air cushion whereby the web is supported for movement along a substantially horizontal path, approximately midway between corresponding air discharge nozzles 32 and 33, as it passes through the housing and is maintained out of contact with devices within the housing. Air support nozzles 50 are spaced within the housing, one being located adjacent inlet slot 30, another adjacent outlet slot 31 and at least still another between banks of upper air drying means 32. Proper spacing of the nozzles is dependent on a number of factors including the unit weight of the web, the tension developed in the web between rolls 19 and 20, the velocity and volume of drying air supplied by air drying means 32 and 34. It has been determined that a spacing of from 2 feet to 10 feet, or more, between successive air support nozzles 50 results in satisfactory performance in the treating and handling of usual webs by a system of apparatus according to this invention.

A blower 51, which is mounted on housing top wall 24, furnishes air to support nozzles 50 by way of a conduit 52, a manifold 53 and branch conduits 54 and 55 which are named (FIG. 1). Conduit 52 is equipped with a damper 55 for controlling the flow of air therethrough. It will be observed from examination of FIGS. 1 and 2 that the air supply for the support nozzles 50 is independent of the drying air supply for each of air drying means 32 and 34 and that such support air means 50 is separately and independently controlled by respective dampers 55, 39 and 43. If desired, the air supplied to the support nozzles may be heated by conventional means (not shown) to the end that the air upon discharge from these nozzles assists in drying the web and thereby increases the overall drying capacity of unit 12.
The detailed description of the illustrated complete embodiment of the invention is being interrupted at this point in order to briefly describe and comment upon the modifications of the invention shown in FIGS. 3 and 4. In each of the modifications the web passes through housing H in a bowed or arch configuration instead of in a substantially straight or rectilinear pass (FIG. 1).

Referring specifically to FIG. 3, the therein illustrated construction is recommended for the treatment of a web W1 which has been coated only on its under or bottom surface. Banks of earlier described lower air drying means 34 are arranged in the form of an arch and are disposed beneath the web so that drying air impinges on the wet bottom surface coating. Air support nozzles 50 are arranged above the web, as shown, and maintain the web in arch configuration during operation. Depending on the velocity and volume of drying air impinging on the web, the support nozzles effectively support the web against the force of gravity and tension in the web; and, if the drying air volume and velocity are high, the support nozzles restrain the web from being blown upwardly.

The arrangement of banks of earlier described air drying means 32 and air support nozzles 50 shown in FIG. 4 is recommended for the treatment of a web W2 which has been coated only on its top surface. In this modification of the invention, the air drying means 32 are disposed about the web and the air support nozzles are disposed below the web, as shown. It is within the purview of this invention to utilize various arrangements of air drying means and air support nozzles other than those shown in FIGS. 1, 2, 3 and 4. In this case nozzles 50 may be located above, below or opposite sides of the web regardless of whether only one surface or both surfaces of a web are coated or the location of the air drying means.

Reference is now had to FIGS. 5, 6 and 7 for an understanding of the details of construction of air support nozzles. Each of these nozzles includes a hollow body which is comprised of a top wall 56, a pair of elongated parallel side walls 57 and 58 and a pair of end walls 59. The hollow body defines a plenum space 60 which communicates with conduit 54. A generally L-shaped nozzle member 61 is secured to the lower end portion of body side wall 57 by screws 62. The nozzle member includes a lower flange which terminates in a planar end part 63 that projects toward side wall 58. An angle bracket 64 bears against the outer surface of the lower portion of side wall 58 and is affixed thereto by screws 65. Welded to the lower face of the bracket is a Venturi plate 66. Nozzle member 61 and Venturi plate 66 extend the full width of the tubular body.

The Venturi plate is configured to obtain an inner end part 67 which projects upwardly and inwardly in plenum space 60, a concave, arcuate outer end part 68 and an intermediate planar part 69. Venturi plate part 69 and nozzle member part 63 are spaced apart and substantially parallel and define a throat 70. As is shown in FIG. 6, web W is located below and adjacent to nozzle 59. As is also indicated by the arrows in this view, air supplied to plenum space 60 by blower 51, during operation, is discharged through high velocity high velocity through throat 70 into a plenum space 71 which is bounded by Venturi plate 66 and web W where part of the air velocity is converted to a static head. Air flow continues through a restricted second passage 72, then through an enlarged second passage 73, which are defined by Venturi plate part 68 and web W, and into the region of housing H above the web. Due to the Coanda Effect, the air flowing through passage 72 follows the under surface of Venturi plate part 68; and, since this passage is relatively narrow, the air attains a very high velocity in this passage. As a consequence and in accordance with Bernoulli's theorem, this high velocity results in a corresponding low air pressure. Since the air pressure on the under side of the web is then greater than that in passage 72, the web is forced upward toward the Venturi plate. This causes passage 72 to become progressively more restricted. At the same time, the air pressure in passage 72 increases progressively to a value at which a state of pressure equilibrium is reached whereby the web remains stable a short distance below the air support nozzle.

FIG. 6 indicates not only the relative position of the portion of web W of FIG. 1 adjacent to an air support nozzle 50 but also the corresponding passage 72 of web W1 of FIG. 3 and web W2 of FIG. 4. It will be recognized from an examination of FIG. 6 that a web will be properly supported in a stable manner in any of the following conditions or combinations of such conditions:

Condition 1

The web approaches and moves past the air support nozzles in a substantially straight line that is substantially parallel to throat 70 and passage 72 and there is no force other than its own weight tending to make the web move toward or away from the air support nozzles. This condition is exemplified by web W and treating unit 12 of FIG. 1.

Condition 2

The web approaches and moves past the air support nozzles at an angle of less than 180°, which angle is on the air support nozzle side of the web, and the web tension force tends to move the web toward the air support nozzles. This condition is exemplified by web W2 and the treating unit modification shown in FIG. 4.

Condition 3

The web approaches and moves past the air support nozzles at an angle greater than 180°, which angle is again on the air support nozzle side of the web, and the web tension force tends to move the web away from the air support nozzles. This condition is exemplified by web W1 and the treating unit modification shown in FIG. 3.

It has been ascertained that the apparatus of this invention operates satisfactorily and with good results regardless of the direction of movement of the web, i.e., whether the web moves in the same direction as the air flow through throats 70 of air support nozzles 50 or in a direction opposite to that of such air flow. Movement of the web in the same direction as the air flow through the nozzle throats is preferred whereas the web is lightweight and/or is under relatively low tension.

Reference is next had to FIG. 7 which illustrates the configuration and relative position of nozzle member 61 and Venturi plate 66 and which identifies the following critical dimensions:

A—Rise, which is the distance between the under surfaces of nozzle member part 63 and Venturi plate part 68;
B—Throat gap, which is the height of throat 70 (FIG. 6);
C—Venturi radius, which is the radius of Venturi plate part 68;
D—Advance, which is the distance between the free ends of part 63 and the vertical radius of part 68;
E—Throat length, which is the length of throat 70; and
F—Overhang, which is the distance between the vertical radius of part 68 and the outer or free end of part 68.

A typical air support nozzle 58 constructed in accordance with this invention has the following specific dimensions: rise A 0.175"; throat gap B 0.125"; Venturi radius C 5.000"; advance D 2.500"; throat length E 0.750" and overhang F 2.000". Air support nozzles of this design and having a length of 60 inches were utilized in a system of the character illustrated in FIGS. 1 and 2 and operated satisfactorily to effectively support from above an impregnated web of 100 pound kraft paper.
that was 54 inches wide. The air support nozzles were spaced on 5 to 6 foot centers and were operated with a static air pressure of 4 inch water column measured within the nozzle tubular body. It has been calculated that, at this pressure, the air velocity through nozzle throat 70 was approximately 8,000 feet per minute and that the air flow through each nozzle was approximately 415 cubic feet per minute.

The maximum and preferred ranges of the dimensions appearing in FIG. 7 and described above are as follows:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Maximum range</th>
<th>Preferred range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.50&quot;-1.50&quot;</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.50&quot;-1.50&quot;</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2.00&quot;-4.00&quot;</td>
<td>2.00&quot;-4.00&quot;</td>
</tr>
<tr>
<td>D</td>
<td>0.50&quot;-6.00&quot;</td>
<td>1.50&quot;-3.00&quot;</td>
</tr>
<tr>
<td>E</td>
<td>0.50&quot;-2.00&quot;</td>
<td>0.50&quot;-1.00&quot;</td>
</tr>
<tr>
<td>F</td>
<td>6.00&quot;-16.00&quot;</td>
<td>6.00&quot;-16.00&quot;</td>
</tr>
</tbody>
</table>

In order to attain proper and uniform air flow through nozzle throat 70 it is desirable and important that air support nozzle 50 have a suitable aspect ratio, i.e. the ratio of the cross sectional area of the air support nozzle, as shown in FIG. 6, to the area of the nozzle throat which is determined by multiplying throat gap B by the length of the air support nozzle. The aspect ratio should be at least 6 to 1 and preferably 10 to 1 or greater. The air pressure within the air support nozzles should be adjusted to the minimum necessary for satisfactory web support. Such adjustment may be readily and conveniently accomplished by means of damper 55. Heavy webs usually require a higher air pressure within the support nozzles than lighter webs.

In many known web coating procedures, it is necessary to provide means to prevent edge curling of the coated web in the drying equipment. Such curling is believed to be caused, at least in part, by shrinking of the coating material as it dries. Straight pass dryers of the general type shown in FIG. 1, by employing conventional web support means within the dryer housing, have been found to be unsuitable. It has therefore been necessary in the past to use arch type dryers which employ rolls to support the web from underneath. The break of the web over each such roll holds the web flat and prevents curling up of the edges. Arch type dryers of this type are considerably more expensive than straight pass dryers in both design and construction costs and, additionally, require much greater head room in a plant. By the use and practice of the present invention, the air support nozzles 50 maintain the web flat across its width, thereby preventing curling and permitting efficient use of a straight pass type dryer.

There is shown in FIG. 8 a third modification of the invention by which a flexible web W4 is conveyed through the air in a free-floating condition with the aid of air support nozzles 50 which are not located in a confined zone, such as earlier-described treating unit 12. This modification comprises, by way of illustration, a coating unit, generally denoted by numeral 75, which is utilized to cost the undersurface of the web with a suitable composition having adhesive properties. The coating on the web may, if desired, be partially dried in unit 75. In any case, the exposed coated surface of the web remains in sticky or tacky condition between the time it exits from unit 75 and is bonded to a second flexible web W5 by means of a laminating unit 76 which comprises a pair of parallel rolls 77 and 78.

A first idler roll 80 is positioned adjacent unit 75 while a second idler roll 81 is positioned adjacent unit 76. These rolls are spaced apart a substantial distance, for example, 45 feet or more, and are mounted for rotation about parallel horizontal axes.

Coating unit 75 and idler roll 80 correspond in a broad sense to mechanism 10 (FIG. 1) in that they serve multiple functions including supporting and dispensing a web.
the flow of air through the air support nozzle and through the web treating means; and
(b) means for continuously withdrawing air that is discharged by the air support nozzle and the web treating means from the housing.

7. Apparatus according to claim 4 also comprising:
(a) means for continuously withdrawing air that is discharged by the air support nozzle and the web treating means from the housing.
(b) means for continuously withdrawing air that is discharged by the air support nozzle and the web treating means from the housing.

8. Apparatus according to claim 3 wherein said means also includes:
(a) web treating means positioned adjacent each side of the web for directing streams of air thereagainst;
(b) supply means for furnishing air under pressure to the air support nozzle and to the web treating means;
(c) adjustable means for controlling independently the flow of air through the air support nozzle and through the web treating means; and
(d) means for continuously withdrawing air that is discharged by the air support nozzle and the web treating means from the housing.

9. Apparatus according to claim 1 wherein the air support nozzle comprises:
(a) a hollow body having an inlet and including:
1. a pair of side walls and
2. a pair of spaced end walls;
(b) air discharge means extending along the lower portion of the hollow body and between the end walls and including:
1. a nozzle member carried by one of the side walls and
2. a Venturi member carried by the other side wall, the nozzle member and the Venturi member being spaced apart and defining a nozzle throat which establishes communication between the interior and the exterior of the hollow body.

10. Apparatus according to claim 9 wherein the air support nozzle has an aspect ratio of at least 6 to 1.

11. Apparatus according to claim 9 wherein:
(a) a part of the nozzle member projects toward the other side wall and has a substantially planar upper surface;
(b) one part of the Venturi member is spaced above said part of the nozzle member and has a substantially planar lower surface; and
(c) another part of the Venturi member has a convex lower surface which merges with said planar lower surface.

12. Apparatus according to claim 11 wherein said planar upper surface of the nozzle member is substantially parallel to said planar lower surface of the Venturi member.

13. Apparatus according to claim 12 wherein the air support nozzle has a rise (A) within the range of from 0.100" to 1.500", a throat gap (B) within the range of from 0.050" to 0.300", a Venturi radius (C) within the range of from 2.00" to 10.00", an advance (D) within the range of from 0.50" to 5.00", a throat length (E) within the range of from 0.20" to 2.00" and an overhang (F) within the range of from 0.50" to 4.00".

14. Apparatus according to claim 12 wherein the air support nozzle has a rise (A) within the range of from 0.250" to 1.000", a throat gap (B) within the range of from 0.105" to 0.156", a Venturi radius (C) within the range of from 4.00" to 6.00", an advance (D) within the range of from 1.25" to 3.00", a throat length (E) within the range of from 0.50" to 1.00" and an overhang (F) within the range of from 1.50" to 3.00".

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