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(54) Apparatus and method for stabilizing a moving web

(57) An apparatus for causing an air movement in a cross-machine direction and substantially parallel with a stabilizer surface (17) adjacent a moving web (4), the apparatus positioned adjacent the stabilizer (1) at or outside a sheet edge (16) of the stabilizer (1), the apparatus directing a fluid movement in a direction moving away from the side edges (5) of the moving web (4) to stabilize the edges of the web (5).

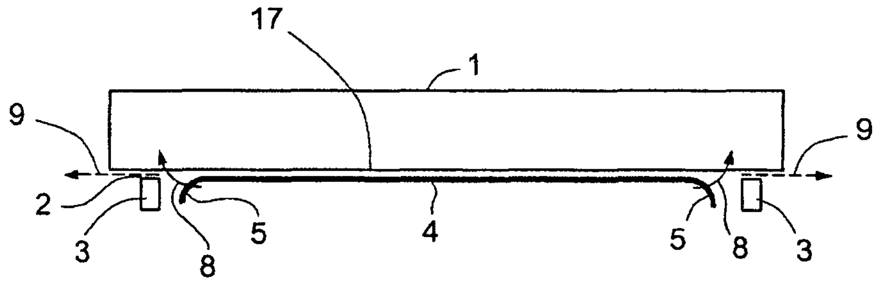

Figure 2

EP 2 223 877 A2

Description

BACKGROUND OF THE INVENTION

[0001] Webs of material (including but not limited to tissue, towel, paper, board, plastics, and polymers) are transported through spans that typically have web stabilizers, such as shown in U.S. Patent 4,321,107. The webs move at a relatively high speed through the spans and across the stabilizers.

[0002] As the web moves across the flat surface of the stabilizers, the side edges of the web tend to curl. Curling may increase the stresses applied to the web, especially at the web edges. Curling may result in non-uniform stretching of the web across the width of the web and increase the risk of web tearing. The side edges most commonly curl away from the stabilizers due to web tension, gravity, differences in material properties, outside influences such as air currents and that the material on the web ends is connected to other web material only on one side of the web. There is a need for devices and methods to reduce curling at the side edges of webs.

BRIEF DESCRIPTION OF THE INVENTION

[0003] To minimize web curling, a force is applied to the outside sheet edge region of the stabilizer to draw the side edges of the web to the stabilizer. By drawing the side edges of the web to the stabilizer, the edges of the web are kept in-line with other portions of the web moving across the stabilizer. Minimizing curling of the side edges assists in stabilizing the web, reduces stresses in the web material, reduces web breaks and may improve characteristics of the web material because the side ends are subjected to less stress and stretching.

[0004] The force applied to the web edge may be formed by air movement along and away from the outside sheet edge region of the surface of the stabilizer facing the web. For example, compressed air or a vacuum (collectively referred to as "pressurized" air) may be applied at or near the sheet edge region to draw air from between stabilizer surface and the edge of the web to create a suction force between the web and stabilizer pushing the edge of the web towards the stabilizer. To create the suction force, air may be forced or drawn through a gap adjacent the sheet edge and between the outside sheet edge region and an air movement direction device. The gap is generally parallel to and adjacent the side edge of the web. As the air flows through the gap, a pressure drop forms at the web side edge that draws the side edge towards the sheet edge region of the stabilizer.

[0005] To create the force applied to the side edge of the web, the air movement over the sheet edge region is preferably in a direction flowing away from the web, substantially perpendicular, e.g., 65 degrees to 125 degrees, to the web edge, and aligned, e.g., in a plane, with the intended elevation of the web. In addition or alternatively, air movement may be directed in other directions, including towards or away from the stabilizer. The air flow should create a low pressure between the web and the sheet edge of the stabilizer such that the low pressure pulls the side edges of the web towards the sheet edge.

[0006] The invention may be embodied as a web stabilizer comprising: a surface adjacent a moving web, wherein the surface includes a sheet edge region adjacent each side edge of the web, and a fluid moving device mounted to or near the sheet edge region, wherein the fluid moving device causes fluid to move adjacent the sheet edge region in a direction moving away from the side edge of the web aligned with the sheet region.

[0007] In another embodiment, the invention may be a web stabilizer comprising: a surface adjacent a moving web, wherein the surface includes a sheet edge region adjacent each side edge of the web; a gap forming device mounted to or near the sheet edge region; a gap adjacent the side edge of the web and formed between the gap forming device and the surface, and a source of pressurized fluid positioned to force a fluid through the gap in a direction away from the side edge of the web.

[0008] The invention may be embodied as a method to reduce curl in a side edge of a moving web comprising: moving the web along a surface of a stabilizer; moving air away from a side edge of the web as the web moves along the surface of the stabilizer; moving the edge of the web towards the surface of the stabilizer by a force formed by the movement of the air away from the side edge.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIGURE 1 is a schematic diagram showing in cross-section a web stabilizer and a web moving below the stabilizer in a direction perpendicular to the page of the figure. The figure shows a curl at the side edges of the web.

FIGURE 2 is a schematic diagram showing in cross-section a web stabilizer and a web moving below the stabilizer, wherein the side edges of the web have curled and air (shown by arrows with dotted lines) is flowing away from the sheet edge and through a gap.

FIGURE 3 is a schematic diagram showing in cross-section a web stabilizer and a web moving below the stabilizer, wherein the side edges of the web have been drawn to the sheet edge of the stabilizer by the air flowing through a gap.

FIGURE 4A is a bottom view of the stabilizer showing the web and air flowing in several possible directions away from the side edges of the web.

FIGURE 4B is a schematic diagram showing in cross-section a side of a web stabilizer and an apparatus for creating a force, e.g., an air movement, adjacent and away from the edges of the web.

FIGURE 5 is a schematic diagram showing in cross-section a web stabilizer and a web moving below the stabilizer, wherein recesses or projections are formed in the stabilizer surface adjacent the side edges of the web to supply and direct the air movement.

FIGURE 6A is a schematic diagram showing in cross-section a web stabilizer and a web moving below the stabilizer, wherein air nozzles are arranged in the stabilizer adjacent and outside of the side edges of the web.

FIGURE 6B is a schematic diagram showing in cross-section a web stabilizer and a web moving below the stabilizer, wherein air nozzles are arranged in the stabilizer adjacent and inside of the side edges of the web.

FIGURE 7A is a schematic diagram showing in cross-section a side of a web stabilizer and illustrating a Coanda effect as the air movement through the gap with the stabilizer.

FIGURE 7B is a schematic diagram showing in cross-section a side of a web stabilizer and air flowing through a gap where the air flows from the air source in or near the gap.

FIGURE 8 illustrates an installation of a device to form a gap near a side edge of the web and apply an air movement through the gap.

FIGURE 9 is a schematic diagram showing in cross section an air knife, as an air movement device, adjacent a stabilizer and a web, wherein only a portion of the stabilizer and the web are illustrated.

DETAILED DESCRIPTION OF THE INVENTION

[0010] FIGURES 1 and 2 are schematic cross-sectional diagrams of a web stabilizer 1 and a web or sheet 4 (collectively referred to as a web) moving below the stabilizer in a direction perpendicular to the page of the figure. A moving fluid, preferably a gas such as air, is introduced along a strip, e.g., sheet edge region 16 of a bottom surface 17 of the stabilizer, and just at or outside the edges 5 of the moving web 4. The moving fluid, e.g. air, 9 creates a force that stabilizes the web edges 5 and reduces or eliminates curling of the edges 5.

[0011] Figures 1 and 2 show curled edges of the web. Reducing curling should reduce sheet breaks and improve performance and the speed potential of the web machine, which may be a tissue, paper, board or other web processing machine.

[0012] The stationary web stabilizer 1 may be a generally rectangular device having a substantially flat bottom surface 17. The web 4 moves at a high velocity, e.g., such as 4,000 to 7,000 feet per minute (1,200 to 2,100 meters per minute). The movement of the web causes the air next to the web to move and particularly causes the air to move in a gap between the web and stabilizer. Because of the movement air, there the gap is at a lower static pressure as compared to the air on the opposite side of the web. This pressure difference across opposite sides of the web draws the web towards the bottom surface 17 of the stabilizer. The center portion of the web 4 may be adjacent the bottom of the stabilizer. The side edges 5 of the web may curl away from the sheet edge region 16 of the bottom 17 of the stabilizer. There is a desire to eliminate the curling and force the side edge 5 into the same plane as the center portion of the web 4.

[0013] Figure 3 illustrates a moving web 4 having side edges 5 that are uncurled due to moving fluid, e.g., air streams, 9 moving away from the side edges. To remove the curl of side edges 5 of the web 4, a moving fluid 9, e.g., air, is directed away from the side edges 5 to generate a force applied to the side edges. The force causes the side edges 5 of the web to move towards the sheet edge region 16, which is a strip of the flat bottom surface 17 of the stabilizer adjacent the desired location of the side edges 5 of the web. The force results from the movement of the fluid, e.g., an air flow 9, away from the web edges 5 and along or adjacent the sheet edge 16 of the bottom of the stabilizer. The term "air" is used to refer to a moving fluid that is preferably pressurized atmospheric air but may be other gases and liquids and includes using a vacuum or other devices to impart a positive or negative pressure as compared to atmospheric air pressure.

[0014] The air may flow through a gap 2 between an air movement or air direction device 3, e.g., a hollow beam that may have air nozzles, that is adjacent the sheet edge and slightly beyond the side edges of the web. There may be an air movement or direction device 3 attached to the bottom surface of the stabilizer such that an air gap 2 is formed between the beam and bottom surface 17 of the stabilizer.

[0015] The moving fluid 9 is directed away from the edges 5 of the web 4 in a direction that is preferably perpendicular to the web movement. The fluid may flow in other directions 11, such as shown in Figures 4A and 4B. The air flows generally directed away from the sheet edge region 16 and the side edges 5 of the web. The preferred method is directing the fluid in a direction that is perpendicular or substantially perpendicular to the path of web travel and away from the web. The fluid movement 9 creates a low pressure region between the web edges 5 and the sheet edge region 16 of the stabilizer. The low pressure region draws the edge 5 of the web towards the sheet.

[0016] The air movement and direction device 3 and the movement of the fluid 9 blocks air currents from outside the machine from entering the area near the side edges 5 of the web and the sheet edge region 16 of the bottom 17 of the stabilizer. As such, the air movement device 3 and air movement 9 prevent outside air flows from disturbing the side edges 5 of the web 4.

[0017] The air movement and direction device 3 may be a row of one or more air knives, pipes, beams or bars with internal air passages and air nozzles formed by drilled holes or slots along the length of the device 3. The air movement and direction devices 3 are preferably mounted on or in the vicinity of a bottom surface of the stabilizer 1 and, particularly, at or outside the sheet edge region 16 of the bottom surface 17. Alternatively, the stabilizer 1 may be positioned below the web and have an upper surface adjacent the web, where the air movement device is mounted on top of the upper surface. The bottom surface 17 of the stabilizer adjacent the web may be flat, arched, contoured or have other shape which faces the web.

[0018] A gap 2 may be formed between the region 16 of the substantially planar bottom surface 17 of the stabilizer and the air movement or direction device 3 to provide a gap 2 for the air movement that forces the side edges 5 of the web 4 towards the sheet edge region 16 of the planar surface. The gap 2 may be adjacent the air movement or direction device 3, integrated into the stabilizer 1, or integrated into both the air movement device 3 and the stabilizer 1.

[0019] The air movement or direction device(s) 3 may cause air movement across the side edges regions 16 of the stabilizer and through the gap 2 between the side edge regions 16 and the devices 3. The air movement is at a velocity sufficient to influence the position and orientation of the web edges 5 and cause a reduced pressure that moves the web edges into alignment, e.g., the same plane, as the center portion of the web 4.

[0020] The gap 2 may also be between a solid bar gap forming device 3a, which is a type of air direction device, and the sheet edge region 16 of the stabilizer. The gap is adjacent a source 20 of a vacuum that draws air through the gap. The source is next to the stabilizer, as shown in Figure 3. The gap forming device 3a may not be a fluid moving device and forms an obstruction directing air flow through the gap. The gap forming device 3a may be a solid bar having a cross-section shape of a rectangle, circle, oval, airfoil, wing or other shape. Preferably, the cross-sectional shape of the gap forming device 3a promotes the flow of air through the gap between the stabilizer and gap forming device. The source of air, such as vacuum source 20 moving through the gap may be pressurized air from the stabilizer, or a separate fluid moving device, e.g., a vacuum 20, that moves air through the gap.

[0021] The bottom surface 17 of the stabilizer 1 adjacent the web may be smooth or rough, a bottom (or top) surface and a planar surface. The sheet edge regions 16 of the bottom surface 17 of the stabilizer 1 are aligned with the web edges 5 and may extend past the web edges 5 (as shown in Figures 1, 2, 3, 4a, 5, 6a, 6b, 7a and 7b) or end at the web edges (as shown in Figure 4b).

[0022] The air movement or direction device(s) 3, 3a may be mounted near one or both of the sheet edge regions 16 of the stabilizer. The device(s) 3, 3a may cause air movement starting at or outside of the web edges 5 and cause the air movement to flow away from the web edges, such as shown in Figures 4a and 4b, 5 and 6a. The devices 3, 3a may also be located between the stabilizer and the web edges 5, such as shown in Figure 6b. In Figure 6B, the air movement devices include grooves or slots in the sheet edge region 16 of the stabilizer, wherein the grooves or slots have air apertures to inject air out of the stabilizer or draw air into the stabilizer. The air movement devices 3, 3a may extend part way or full length of the stabilizer 1 and be fixed to or moveable with respect to the stabilizer.

[0023] The air flowing from the air movement device 3 need not impinge directly on the edges 5 of the web, as shown in Figures 2 and 4. While the direct impingement of air on the edges 5 may force the edges towards the stabilizer, the direct impingement of air may create stresses and stretching of the web. Directing the air flow away from the web edges without direct impingement of the air on the edges can create a suction between the curled web edges 5 and the sheet edge region 16 of the stabilizer. This suction draws the web edges to the surface of the stabilizer. As shown in Figures 3, 4a, 4b, 5, 6a, 6b, 7a, and 7b, air can be directed through the gap 2 without impinging the air directly on the web edges 5.

[0024] The air (see arrows 9) may be introduced along an inside surface 6 (Fig. 1) of the air movement device 3 facing the edges 5 of the web. When introduced along the inside surface 6 of the device, a Coanda effect that results in the air 9 moving along to the upper surface 7 of the air movement device 3, which surface faces the gap 2, as illustrated in Figure 7a or up to the surface 16 of the stabilizer as shown in Figure 9.

[0025] FIGURE 5 shows a stabilizer 1 having a recess (or protruding) strip(s) 13 (or slots, gaps or grooves) in the sheet edge region 16 of the bottom surface 17 of the stabilizer. The recess strip 13 provides a passage for the air movement away from the web edge 5. The movement of air 9 along the strip 13 of the stabilizer 1 forms a low pressure region between the web edge 5 and the sheet edge region 16 to cause the web edges 5 to move towards sheet edge region of the stabilizer 1. The surface 13 may be parallel with, recessed into or slightly protruding from the bottom surface of the stabilizer

[0026] FIGURES 6A and 6B show a stabilizer 1 in which the air movement device 3 is an array of air openings, nozzles, air pipes, air slots or air channels (collectively air directors 14) that directs an air flow 12 along the bottom surface of the stabilizer and away from the web edges 5. The array of air directors 14 may be arranged continuously or at regular or irregular intervals, preferably short intervals, along the sheet edge region 16 of the bottom surface 17 of the stabilizer. The air directors 14 may inject air into the sheet edge region 16 from either just outside of the web edges 5 (as shown in

Figure 6A) or inward of the web edges 5 (as shown in Figure 6B). The air directors 14 may receive pressurized air (27 in Fig. 8) through conduits internal to the stabilizer or may be connected to suction devices that draw air through the directors. The air directors 14 may be embedded in the stabilizer 1, or in an air movement device 3 to provide an actual or effective gap 2 for air movement. The movement of air 9 through gap 2 causes the web edges 5 to move 8 towards the stabilizer 1 and thereby eliminates or reduces curl in the web edges 5.

[0027] FIGURE 8 is a schematic diagram showing the location of an air movement device, an air knife 19, being positioned adjacent to the sheet edge region 16 of the bottom planar surface 17 of a stabilizer. The gap 10 between the air movement device 3, e.g., a conduit for air, and the web edge 5 is preferably in a range of zero (e.g. 0.001 inch) to four inches, but may be as much as two feet. A gap 2 is formed between the air movement device 3 and the sheet edge region. The gap is preferably less than one inch (e.g., 25 millimeters) and may be less than one-quarter inch (e.g., 6 millimeters) in a vertical direction.

[0028] The air knife 19 and the air movement device 3 may be hollow and coupled end to end to other knives or devices. The assembly of knives or devices is connected to a source of pressurized air 27. The pressurized air flows through the assembly of air knives (or devices 3) and flows out air slots in the air knife arranged on an inside wall 6. As the air flows from a slot in the air knife 19 follows the surface of the knife and the air flows through the gap 2.

[0029] FIGURE 9 shows in cross-section an air knife 19, as an air movement device 3, adjacent a sheet edge region 16 of a stabilizer 1 and a web 4. Air 23, e.g., pressurized air, is discharged from an air slot 22 in the air knife. The air slot 22 is arranged on an inside surface 6 of the knife that generally faces the web 4. The air slot 22 may be near a corner 24 on the knife between the inside surface 6 and a surface 25 of the knife facing the gap 2.

[0030] Pressurized air 23 is discharged from the slot 22 at a higher velocity than the moving air near the sheet edge region and web edge 5. The air discharged by the air knife flows from a conduit 28 in the air knife that is supplied by a source of pressurized air external to the knife. From the conduit 28, air flows into the slot 22 that is formed by the main body 19 of the knife and a plate 30.

[0031] As air 23 is discharged from the slot 22, the air flows along the surfaces 6, 24 and 25 of the air knife and through the gap 2. The air flows along the surfaces due to the coanda effect in which fluid flows tend to attach to a curved surface, such as corner 24.

[0032] The movement of high velocity air 23 passing through the gap 2 creates a reduced pressure area in the gap 2 that sucks air 26 from near the web edge 5 and sheet edge region 16. The suction of air 26 also applies a force 31 to the web edge 5 that tends to uncurl the edge and maintain the web edge 5 in the same plane as the remainder of the web.

[0033] The apparatus and method disclosed herein may be used to uncurl a web edge 5 or prevent curl by moving a fluid away from the edge to create a force that draws the edge towards the surface of a stabilizer. The apparatus may be an air movement device 3 incorporated in the stabilizer (see Fig. 6a and 6b) or an air movement device 3 adjacent the stabilizer and spaced a horizontal distance from the web edge of preferably no more than four inches. The air movement device 3 may inject air from a source of pressurized air, such as a compressor or blower, or a source of sub-atmospheric air such as a vacuum. The air movement or direction device 3 may comprise a first device, e.g., a bar, which forms a gap 2 through with air is drawn and a second device providing a source of air, such as a vacuum or compressed air. These devices may be separate, such as shown in Figures 3, 7A and 7B or integrated such as shown in Figures 4B, 6A and 6B. The air may be applied at an elevation between the web and the stabilizer (Fig. 6A), recessed within the stabilizer (Figs. 5 and 6B), at the same elevation as the web (Fig. 6A) or at an elevation below both the web and stabilizer (Figs. 3, 4B, 7A and 7B).

[0034] Further, the air from the air movement device may be introduced beyond the edge 5 in a horizontal dimension, such in a range of zero to four inches from the web edge. The air may be introduced such that the air flows 15 along the surface of the stabilizer or air movement device 3 pursuant to the coanda effect. The air flows away from edge 5 of the web in a direction substantially parallel to the surface of the stabilizer. The apparatus may use the coanda effect to cause air to move away from web through a gap 2.

[0035] In addition, a controller 21 (Fig. 4B), e.g., computer or manual controls, may have an ability to adjust the air pressure or vacuum level from the air movement device 3, the rate of air flow through the gap 2, and the distance of the width of the gap and the horizontal distance between the gap and edge of the web. For example, the air pressure, vacuum level, air flow rate through the gap and dimensions gap may be adjusted manually based on: observed curl in the web or by a curl sensor, e.g., a light beam and light sensor, detecting excessive curl; web speed, web tension or web crepe; and pressure sensors in the gap or in the sheet edge region 16 of the stabilizer.

[0036] Preferably the gap is within twelve inches of the web edge along a horizontal direction.

[0037] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

[0038] Exemplary descriptions of reference numbers used in the drawings:

1. Web Stabilizer
2. gap (gap to be greater than zero up to four inches, with the preferred embodiment 0.001 inch to one inch)
3. Air movement or direction device 3 creating the gap 2 with stabilizer 1, which device 3 may be, for example:

- An air knife or hollow channel with one or more apertures to pass air;
- A separate component can be used to create a gap, such as a solid bar or plate 3a. A source of pressurized air or vacuum may be used to cause air movement through the gap 2 with the same or air movement device 3 used to form the gap.
- The gap 2 creating apparatus may be an integral part of the stabilizer 1
- The gap created by the device may be in the gap creating air movement device 3 (making the bar or plate with a slot, series of openings and so on) so the device 3 contacts the stabilizer 1, but the gap 2 exists as an integral part of the air movement device 3.
- The air movement device 3 may comprise one or more pieces assembled to create the gap 2

3a. Gap forming device (also referred to as an air direction device)
4. Web
5. Web Side Edge (also called Web End)
6. Inside surface of air movement or direction device facing web edge.
7. surface of air movement or direction device facing stabilizer
8. direction of uncurling of web edge
9. Air or fluid movement direction
10. gap between web edge and air movement or direction device in the direction of air movement
11. range of air movement directions
12. recessed or protruding area of stabilizer
13. air discharge opening(s) on, in or near stabilizer serving an air movement device (Figures 6a, 6b)
14. air directors
15. coanda air flow
16. Sheet edge region at bottom surface of stabilizer
17. bottom surface of stabilizer
18. compressed air outlets and nozzles
19. Air knife
20. vacuum source
21. controller
22. slot in air knife to discharge air
23. air discharged by knife
24. corner on air knife
25. surface on air knife facing stabilizer
27. Pressurized air source
28. Air conduit in knife
30. Plate of knife.
31. Force applied to web edge

Claims

1. A web stabilizer (1) comprising a surface (17) adjacent to a moving web (4), wherein the surface (17) includes a sheet edge region(16) adjacent to each side edge (5) of the web (4), **characterized by** the web stabilizer (1) comprising a fluid moving or direction device (3) mounted to or near the sheet edge region (16), wherein the fluid moving device (3) causes fluid to move adjacent to the sheet edge region (16) in a direction moving away from the side edge (5) of the web (4) aligned with the sheet region.

2. The web stabilizer (1) according to Claim 1, **characterized by** a gap (2) arranged between the fluid moving or direction device (3) and the planar surface (17), and the fluid moves through the gap (2).

3. The web stabilizer (1) according to Claim 1, **characterized by** the fluid moving or direction device (3) having a passage for positively or negatively pressurized air, e.g., compressed air or a vacuum, and the moving device (3) has at least one orifice arranged along the sheet region to move the fluid.

4. The web stabilizer (1) according to one of Claims 1 to 3, **characterized by** the fluid moving or direction device (3) is arranged along at least one of the sheet edge regions (16).

5. A web stabilizer (1) comprising a surface (17) adjacent to a moving web (4), wherein the surface (17) includes a sheet edge region (16) adjacent to each side edge (5) of the web (4), **characterized by** the web stabilizer (1) comprising

- a gap forming device (3a) mounted to or near the sheet edge region (16);
- a gap (2) adjacent to the side edge (5) of the web (4) and formed between the gap forming device (3a) and the surface (17), and
- a source of pressurized fluid (27) positioned to force a fluid through the gap (2) in a direction away from the side edge (5) of the web (4).

6. The web stabilizer (1) according to Claim 5, **characterized by** the source of pressurized fluid (27) being a vacuum drawing air out of the gap (2).

7. The web stabilizer (1) according to Claim 5 or 6, **characterized by** the gap forming device (3a) being a bar extending along the side edge of the web (5).

8. A method to reduce curl in a side edge (5) of a moving web (4) comprising:

- moving the web (4) along a surface (17) of a stabilizer (1);

- moving air away from a side edge (5) of the web (4) as the web (4) moves along the surface (17) of the stabilizer (1), and
- moving the edge (5) of the web (4) towards the surface (17) of the stabilizer (1) by a force formed by the movement of the air away from the side edge (5).

9. The method according to Claim 8, **characterized by** the movement of the air including passing the air between a gap (2) generally parallel to the side edge (5) of the web (4).

10. The method according to Claim 9, **characterized by** the air passing through the gap (2) flowing along the surface of the stabilizer (17) or an air discharge device in accordance with a Coanda Effect.

11. The method according to Claim 9, **characterized by** the air moving through the gap (2) by a pressure difference generated across the gap (2) by a source of compressed air (27) or a vacuum source (20).

12. The method according to Claim 11, **characterized by** the air source (27) comprising at least one air outlet, hole, slot, or nozzle.

13. The method according to Claim 9, **characterized by** the gap (2) being continuous along a length of the stabilizer (1).

14. The method according to Claim 9, **characterized by** the gap (2) comprising a series of openings along a length of the stabilizer (1).

15. The method according to one of Claims 8 to 14, **characterized by** adjusting a rate or direction of the moving air based on at least one of a velocity of the web (4), an amount of curl in the side edge (5) of the web (4) and a composition of the web (4).

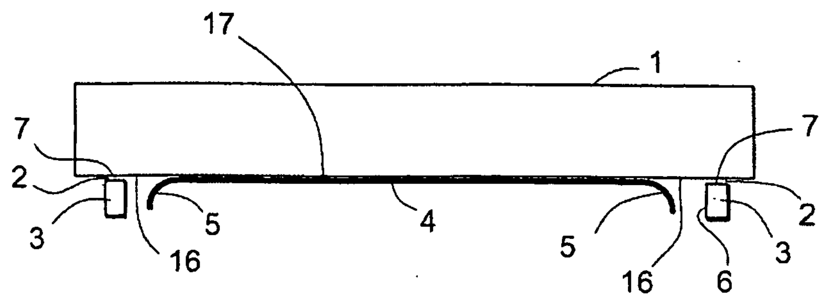

Figure 1

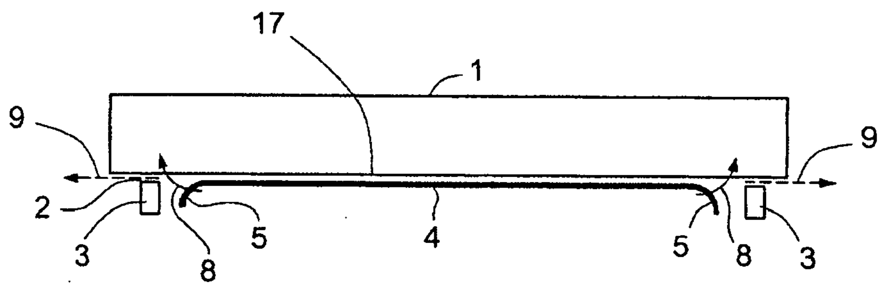

Figure 2

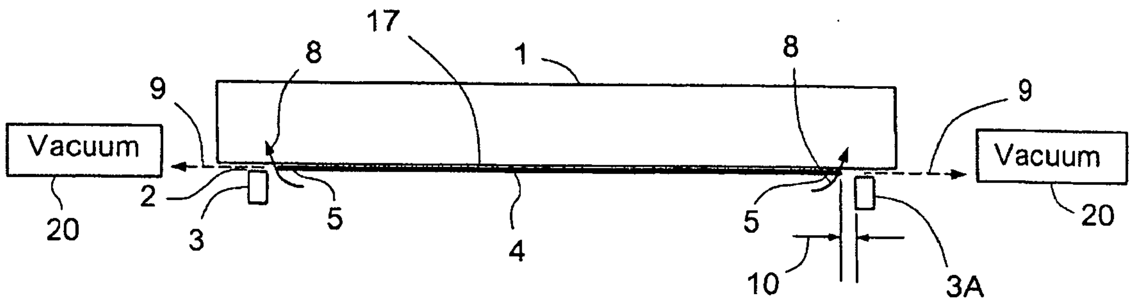

Figure 3

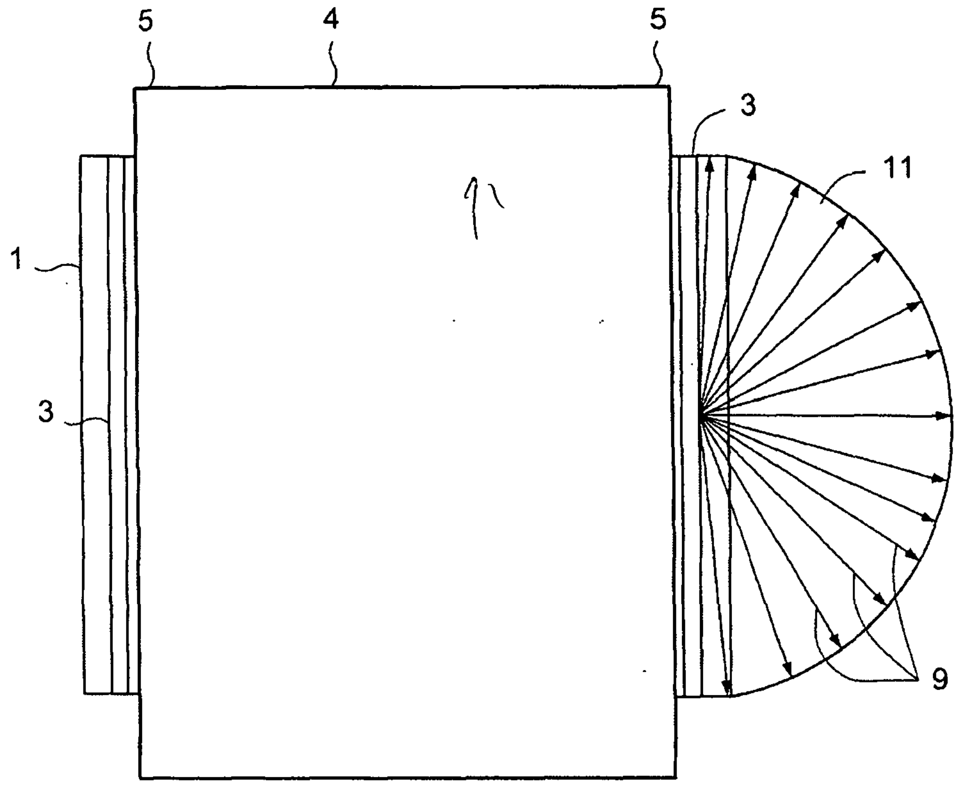

Figure 4A

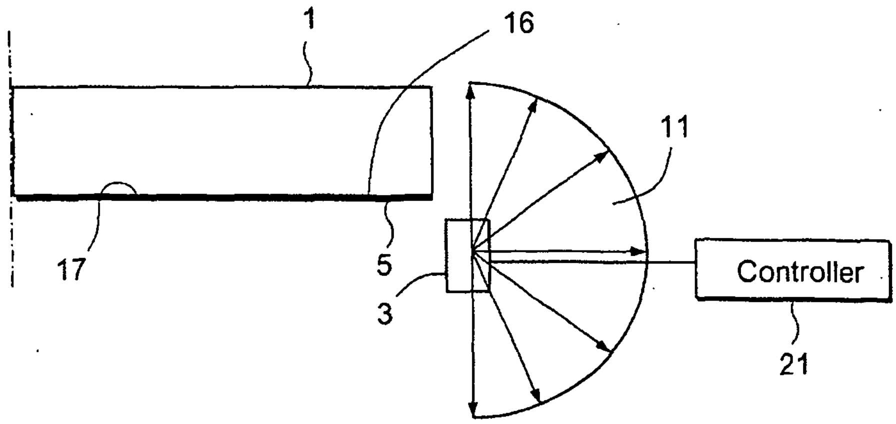

Figure 4B

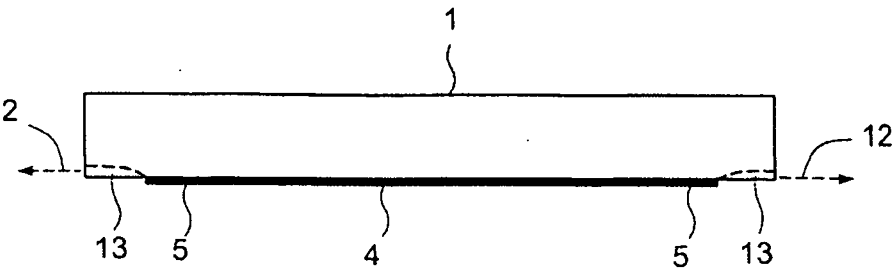

Figure 5

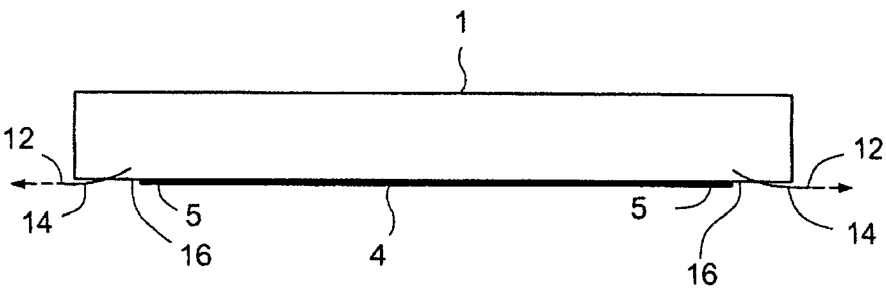

Fig. 6A

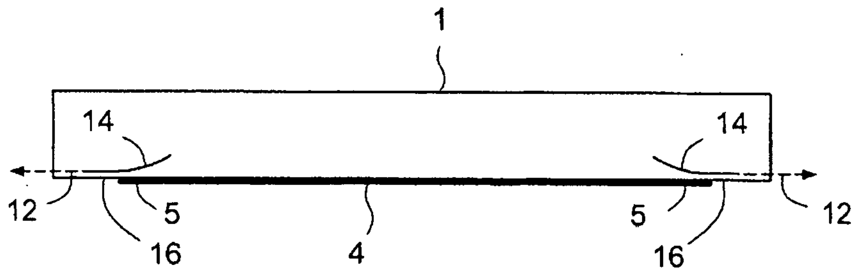

Fig. 6B

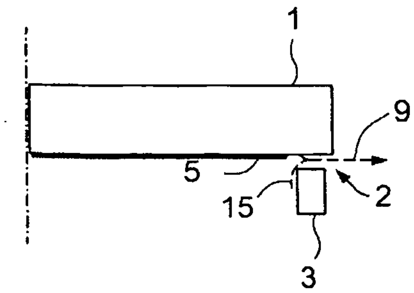

Fig. 7A

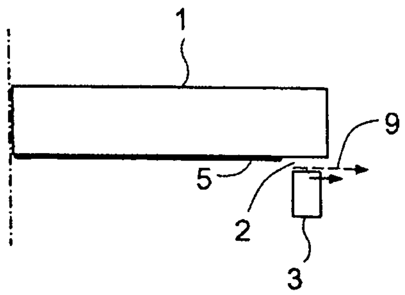

Fig. 7B

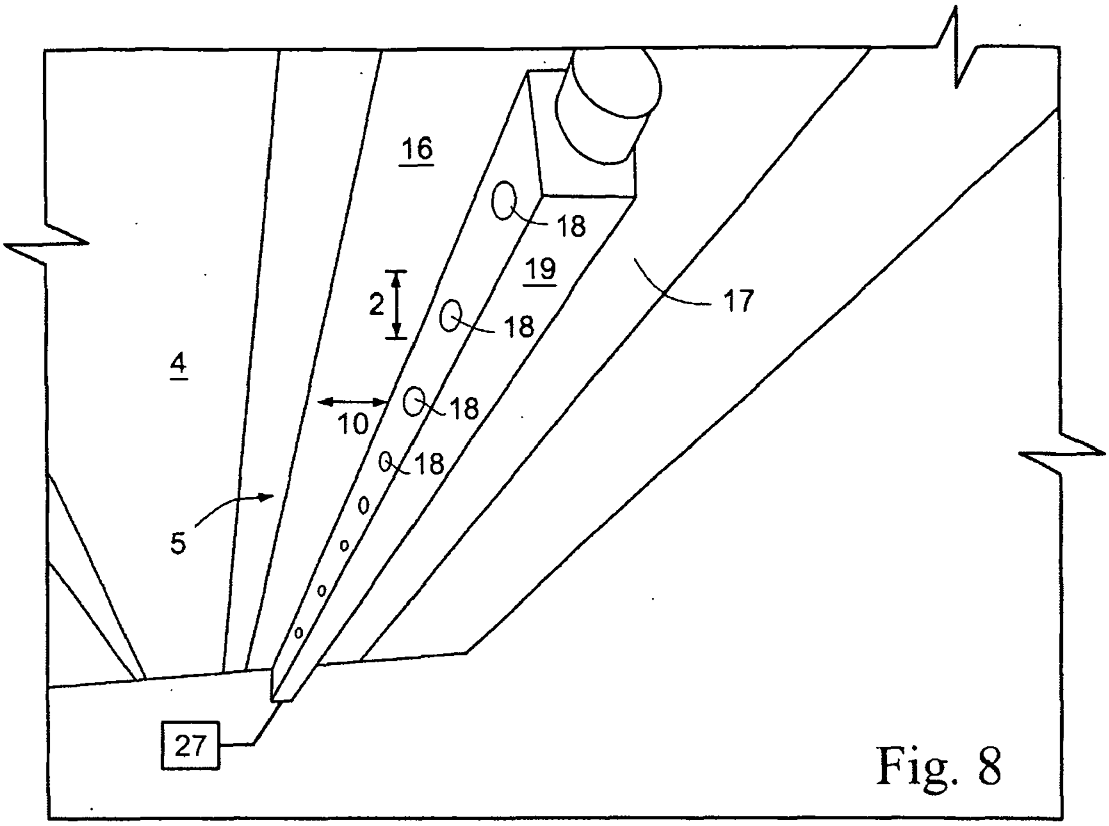

Fig. 8

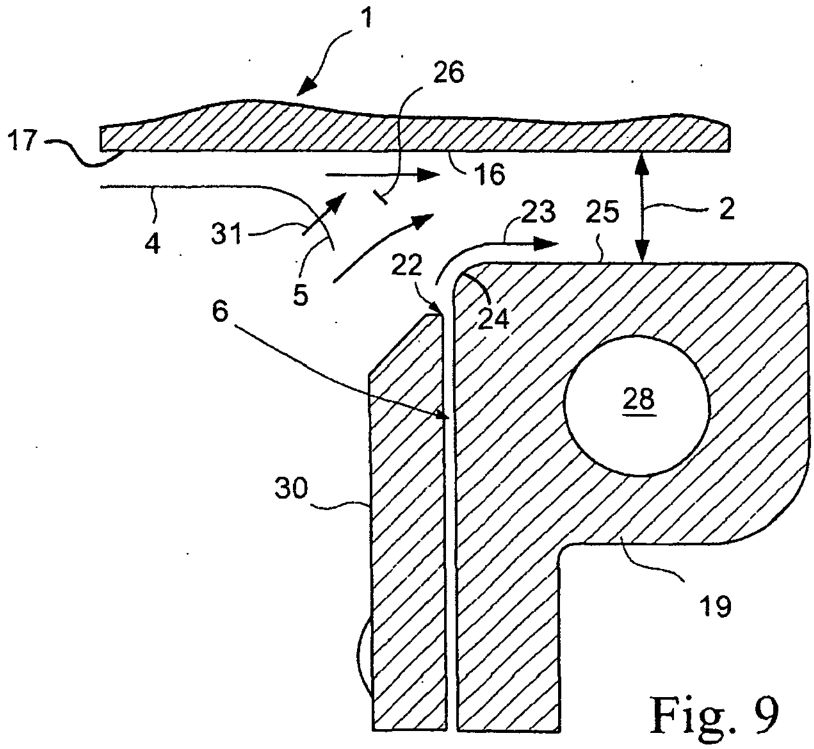

Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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