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(54) **Title**: PNEUMATICALLY ACTUATED REDIRECT SURFACE

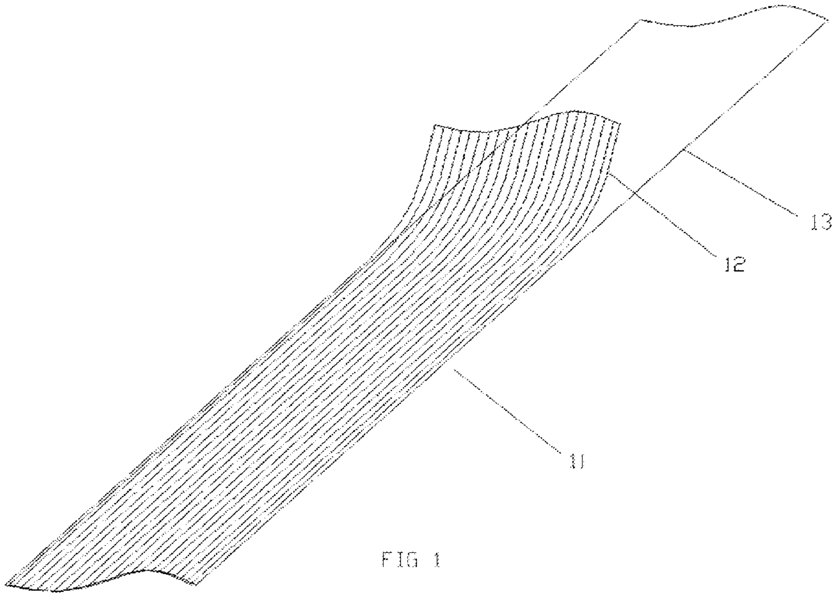

FIG 1

(57) **Abstract**: The present invention is directed to a pneumatically actuated redirection surface guide tool for use in tape laying systems. In the laying of unidirectional, pre-impregnated carbon fiber tapes, for instance, a tape can be directed between a tape supply reel and a tape laying head through use of one or more of the disclosed guide tools. The surface of the guide tool includes small holes that allow for positive and negative air pressure to be applied to the surface to increase or decrease the friction between the tape that is passing over and being redirected by the surface.

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PNEUMATICALLY ACTUATED REDIRECT SURFACE

This application claims the benefit of U.S. Provisional Application Serial Number 61/515,473, filed August 5, 2011, entitled "Pneumatically Actuated Redirect Surface (PARS)", which is incorporated by reference herein in its entirety.

The present invention relates to a method and apparatus to steer and direct a composite tape web as it travels from a supply roll or reel unto a work surface or work piece.

BACKGROUND

In an apparatus that lays composite tape, the tape redirection is normally accomplished by turning the tape around redirect rollers. This is well known in the field of composite manufacture such as utilized in the construction of laminated composite parts for aerospace products. Redirect rollers are commonly utilized within Automatic Tape Layers or ATLs such as disclosed in U.S. Patent No. 7,836,931 and U.S. Patent No. 5,431,749.

Figures 1 and 2 are examples of a tape and rollers used in existing ATLs. For instance, Figure 1 shows a unidirectional pre-impregnated carbon fiber tape 12, laminated to a silicone coated paper backer web 13. The lamination bond is due to the carbon fiber tape's impregnated adhesive. The laminated tape assembly 11 is referred to as the tape.

This type of tape is well known in the field of composite tape assembly where for example a tape would have a width of 1/2" to 12" and the paper backer would have a thickness of .001" to .005" and the carbon fiber tape would have a thickness between .0005" and .0070" and be 60% carbon fiber by volume and 40% epoxy adhesive by volume. An example tape is T800H manufactured by Toray USA.

Figure 2 shows a prior art redirect roller 21 that rotates on a shaft 22, where said shaft is concentric to the roller surface 23. A tape 11 is supported along its travel path by the roller surface and the roller rotates with a surface speed equal to the tape speed. The roller is rotated by the traction of the tape being pulled tangent around the roller or by a drive motor connected to the roller. The redirect roller effects a direction change to the tape while maintaining the tape edge tangent to a plane that in normal to the rotational axis of the roller. The tape 11 travels to the roller in a straight line, makes tangent contact with the roller, continues around the roller in tangent contact, then exits the roller to continue traveling in a straight line.

Notwithstanding the wide use of rollers for redirection, there are limitations in those roller systems relating to tape handling and machine system design.

SUMMARY

Accordingly, it is an object of the present invention to overcome the limitations of existing roller redirect systems. The surface described herein includes a surface that is perforated with small holes that are in fluid communication with a source of either positive or negative air pressure. This surface may be used in tape laying apparatuses and may solve some of the drawbacks and limitations of existing roller systems.

In one example, a pneumatically actuated redirect surface is used in steering and directing a tape web, the surface comprises a guide tool comprising a curved

substantially smooth surface, wherein the surface has perforations therein, and wherein the surface comprises a tangent contact portion. The guide tool further comprises a manifold therein, with the perforations in the surface in fluid communication with the manifold. A movable tool mount carries the guide tool and is adapted to be movable. The tool is movable and the entry and exit points of the tape web moving over the surface are able to be changed while a tape is in motion. The tangent contact portion of the tool surface maybe a straight line, or alternatively, not a straight line. The tool surface may be comprised of a flexible sheet which has the perforations therein, in wherein the tangent contact portion of the tool surface is not a straight line. The tool mount may be movable in a rotatable manner about an axis of rotation wherein the axis of rotation is substantially the center to the tangent contact portion of the surface. The tool surface may be curved in the shape of a part of a circle or in the shape of a semi-circle.

In another example, a method of steering and directing a tape web in its path of travel from a supply reel to a work surface comprises the steps of providing a guide tool comprising a curved substantially smooth surface. The surface has perforations therein, and comprises a tangent contact portion. The guide tool further comprises a manifold therein, with the perforations in the surface in fluid communication with the manifold. An air pressure pump is in fluid communication with the manifold, wherein the pump is adapted to provide positive air pressure to the manifold. A tape web is provided and moved wherein the moving web is positioned over the surface of the guide tool. The direction of travel of the moving web changes between an approach path toward the guide tool surface and a departure path from the guide tool surface. The pump is activated to deliver positive air pressure to the manifold, whereby air provided into the manifold and forced out of the perforations provides a lifting pressure between the guide tool surface and the tape web that reduces the friction otherwise caused by movement of the web over the surface. Alternatively, the pump is also adapted to provide vacuum air pressure to the manifold. The guide tool may be rotatable about an axis of rotation. In this alternative, the guide tool may be moved simultaneously with moving the tape web across the surface of the guide tool. The tape web may have a substantially zero Gaussian curvature as it moves across the guide tool surface. The tangent contact portion of the tool surface is a straight line or alternatively not a straight line. The tape web may comprise a laminate of a pre-impregnated fiber tape on backer web. The fiber tape may be a carbon fiber tape, and the backer web may be silicone coated paper.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a unidirectional, pre-impregnated carbon fiber tape laminated to a backer web.

Figure 2 is a perspective view of the carbon fiber tape and backer web moving around a roller.

Figure 3 is a perspective view of a carbon fiber tape moving around a pneumatically actuated redirect surface.

Figures 4A and 4B illustrate side elevation views of alternative embodiments of a pneumatically actuated redirect surface. Figure 4C is a front elevation view of a pneumatically actuated redirect surface.

Figure 5A is a front elevation view of tape moving across a pneumatically actuated redirect surface. Figure 5B is a side elevation view of the tape moving across of the surface as shown in Figure 5A.

Figures 6A and 6B illustrate the rotation of a pneumatically actuated redirect surface to demonstrate a change of direction of the tape moving across the surface.

Figure 7 is a front elevation view of a tape moving across a pair of pneumatically actuated redirect surfaces mounted adjacent each other.

Figures 8A and 8B are side elevation views of a pneumatically actuated redirect surface having a flexible sheet as the surface of the tool

DETAILED DESCRIPTION

Figure 3 shows an example of a guide tool that is also referred to herein as the Pneumatically Actuated Redirect Surface (PARS) 31. The PARS guide tool 31 is comprised of an outer surface 33 that is perforated with small holes 36 that are in fluid communication with an inner manifold 34 that is in fluid communication with a source 35 of air with either positive pressure or negative pressure (vacuum).

A tape 11 approaches the PARS traveling in a straight line until it is in tangent contact with the PARS surface 33. The tape is oriented such that the paper backer side or face is adjacent to the PARS surface. When positive pressure air 35 is forced into the PARS manifold 34, the air creates a lifting pressure between the PARS surface 33 and the tape backer surface of tape 11. The tape experiences virtually no friction as it passes over the PARS surface, thus effecting a redirection of the tape without the need of a roller.

The surface perforations 36 are normally placed only at location under where the tape 11 is known to be in tangent contact with the PARS surface 33.

When a vacuum pressure is presented at the manifold port 35, the perforations 36 remove air from the space between the tape 11 and the PARS surface 33 causing the tape backer to adhere to the PARS surface. This effects an effective braking in the motion of the tape.

Figures 4A and 4B show a side view from a perspective that is normal to the plane of the tape travel. Figure 4A shows a 90 degree tape direction change while maintaining the tape in a constant plane. Figure 4 shows a 180 degree tape direction change while maintaining the tape in a constant plane. Figure 4C shows the rotated view of the two PARS examples of 4A and 4B. In Figure 4A and 4B, a tape 11 approaches the PARS 31 and makes tangent contact at 41, travels around the PARS surface 33 and exits the PARS surface at 42.

Figure 5A and 5B show a tape 11 that is being simultaneously redirected at two angles by a single PARS surface. The tape 11 approaches the PARS along an approach path 51 and is then redirected by the PARS surface to exit along a departure path 52.

Figures 6A and 6B show a movable PARS surface where the entire manifold 31 is rotated while the tape 11 is in motion across the PARS surface 33. Figure 6A shows a tape 11 approaching a PARS surface 31 with an approach path 51. The tape exits the PARS surface with a departure path 61. As the PARS manifold is rotated by 90 degrees 65 about pivot axis 64 (normal to the page) the departure path of the tape is rotated through 180 degrees until it exits at departure path 62. One-half way through the rotation at 45 degrees from figure 6A, the PARS and tape would appear as shown in Figure 4C.

All tapes referred to so for in this disclosure have zero Gaussian curvature and would lay flat upon a flat surface. And, accordingly all redirect means disclosed have a surface with zero Gaussian curvature. Such surfaces may be cylindrical, conical, and planar and may contain combinations or portions of such surfaces joined so that the combined surface is continuous and smooth with zero Gaussian curvature. All redirect means discussed here preserve the tape's zero Gaussian curvature.

One could also produce a PARS surface that is comprised of a flexible foil or sheet a section of which is shown in Fig 8A and Fig 8B where the said foil or sheet would comprise the outer surface 33 with perforations that are in fluid communication with a source of pressurized air where the foil or sheet could have its curvature adjusted for example between Fig 8A to Fig 8B while the tape is in motion while maintaining zero Gaussian curvature. The foil or sheet would have an integral network of flexible tubes 864 which supply pressurized air to manifold tubes 834 where each manifold tube supplies pressurized air to a row of surface perforations (disposed in a row normal to the plane of the page in Fig 8A and Fig 8B where the network of flexible tubes allow the flow of pressurized air 835 from the air pump to each of the surface perforations, said tubes would be flexible enough so as not to interfere with the bending of the foil or sheet. Such a foil or sheet would be positioned and deformed by the controlled displacement of its support attachment points.

It is required that the normal vector of the tape surface be parallel to the normal vector of the PARS surface at the point of the tape's tangent point of contact. The tape exit surface normal vector will be parallel to the normal vector of the PARS surface at the point of tape exit point of contact.

PARS surfaces may be fixed in a static position with respect to a tape entry path, or the PARS surface may be able to dynamically rotate such that the tape entry or exit or both be able to be changed while the tape is in motion - see Figure 6A and 6B. In one example, a tape laying machine may be engineered to lay a single type of tape onto a single, uniform surface. In this example, the PARS may be fixed in a single position along the tape path, and because of its single purpose, it will never move. However, in many tape laying machines, the surface onto which a tape is laid, and even the tape itself, will change. For this purpose, the PARS guide tool will be attached to and carried by a mount that is adapted to be moveable. This movement may be in a rotating fashion as exemplified in Figures 6A and 6B where the PARS 31 rotates around the point 64. In another example, the point of rotation may be at a different position along the PARS 31 tool. Still further alternatively, and in order to achieve substantial versatility, the tool mount on which the PARS guide tool 31 is mounted may be moveable multidirectionally in two or three dimensions in order to most favorably change the tape path for a given tape and a particular surface onto which the tape is laid. This moveable tool mount may be manually adjustable to change positions of the mount and the tool on the mount. Alternatively, this mount is guided through the use of various motors and by a computer so that the movement of the PARS tool 31 can be accurately monitored and managed.

The PARS surface 31 is positioned on a tool mount (not shown). The tool mount is movable so that the PARS surface may be moved to accommodate a moving tape. The tool mount is simple hardware that supports the PARS surface. The tool mount may be a component of a tape laying machine generally. The tool mount may be on a tape supply reel system or on a tape laying system or independently in between. One or more PARS surfaces may be used in one or several locations in the larger apparatus.

As PARS surfaces are essentially replacing one or more rollers to redirect a moving tape, their placement can be analyzed by inspecting the desired tape path and the required redirect points. To analyze the placement of a moveable (steerable) PARS surface then the point along two alternative tape paths where the tape path diverges between the two alternative tape paths is where a moveable PARS would be located.

The two extreme alternate tape paths determine the extremes of movement of the PARS such that the PARS placement in all orientations between and including the extreme PARS orientations follow the geometric constraints relating to the tape-PARS entry and exit stated above.

The pump that supplies positive and/or negative air pressure to the manifold need only supply a nominal pressure for the example application below. The pressure in imperial units would be on the order of 10 inches of H2O and 200 CFM. Such a pump would be a centrifugal fan with less than 1 horsepower.

EXAMPLE

An example configuration as shown in Fig 5A and Fig 5B would have the following quantities in imperial units:

Outside diameter - 8.0 inches
Inside diameter - 6.5 inches
Holes spacing - 0.5 inches
Hole diameter - 1/16 inches
Tape width - 5.0 inches

Tape Entry Angle in Fig 5A - 135 degrees (East equals 0 degrees)
Tape Exit Angle in Fig 5A - 225 degrees (East equals 0 degrees)

PARS length required to support the tape - apron 19.64 inches.
(length of the perforation matrix)

Fig 7 shows a typical use for a PARS surface. It is desired to reverse the direction of a moving composite prepreg tape on a backer, but maintain the direction in which the composite tape is facing. Two PARS surfaces are inserted at appropriate positions and angles as shown in Fig 7.

Methods and Benefits of Use

A PARS surface can have a variety of non-cylindrical shaped surfaces that effect a significant change in tape travel direction and tape plane of travel. During use, and especially in a machine design, the combination of multiple PARS surfaces and the movability of those surfaces means that a tape can be moved dynamically during the tape laying process while moving across the strategically deployed PARS surfaces.

Additionally, when the size and speed of tape are known, then the proper amount of positive air pressure that is applied to the manifold in the PARS surface can mean that there is effectively zero friction as a result of the movement of a tape over the surface. In the alternative example, when it is important in the tape laying process that the tape be braked or stopped all together, then the pump can be modified to instead draw varying degrees of vacuum on the surface of the PARS tools to facilitate and better manage the slowing down of a tape moving over the PARS surfaces. Accordingly, with proper positive and negative air pressure control, the tape redirection and management can be achieved while adding essentially zero mass to the tape's motion. This facilitates instant stopping and starting without exerting destructive or degrading sheer forces to, for instance, a carbon fiber tape with a paper backer web.

Additionally, the PARS surface provides a large radius redirection in smaller space than a redirect roller. Only the surface of tape contact needs to be present. A large radius roller takes up substantial space in an apparatus. In the situation of a large radius, it is important to reduce the delaminating of the fibers and the backer prior to the fibers being deposited onto a work surface.

While unidirectional pre-impregnated carbon fiber tape with a silicone tape or backing web is disclosed herein in substantial detail, other types of tapes and webs can also be redirected by the PARS apparatus without deviating from the scope of the invention.

Other embodiments of the present invention will be apparent to those skilled in the art from consideration of the specification. It is intended that the specification and Figures be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

What is claimed is:

1. A pneumatically actuated redirect surface for use in steering and directing a tape web, the surface comprising:

a guide tool comprising a curved substantially smooth surface, wherein the surface has perforations therein, and wherein the surface comprises a tangent contact portion;

the guide tool further comprising a manifold therein, with the perforations in the surface in fluid communication with the manifold; and

a moveable tool mount, wherein the mount carries the guide tool and is adapted to be movable,

whereby the tool is movable and the entry and exit points of a tape web moving over the surface is able to be changed while a tape is in motion.

2. A pneumatically actuated redirect surface as described in claim 1, wherein the tangent contact portion of the tool surface is a straight line.

3. A pneumatically actuated redirect surface as described in claim 1, wherein the tangent contact portion of the tool surface is not a straight line.

4. A pneumatically actuated redirect surface as described in claim 1, wherein the tool surface is comprised of a flexible sheet which has the perforations therein, and wherein the tangent contact portion of the tool surface is not a straight line.

5. A pneumatically actuated redirect surface as described in claim 1, wherein the tool mount is movable in a rotatable manner about an axis of rotation, and wherein the axis of rotation is substantially the center of the tangent contact portion of the surface.

6. A pneumatically actuated redirect surface as described in claim 1, wherein the tool surface is curved in the shape of a part of a circle.

7. A pneumatically actuated redirect surface as described in claim 6, wherein the tool surface is curved in the shaped of a semi-circle.

8. A method of steering and directing a tape web in its path of travel from a supply roll to a work surface comprising the steps of:

providing a guide tool comprising a curved, substantially smooth surface, wherein the surface has perforations therein, and wherein the surface comprises a tangent contact portion; the guide tool further comprising a manifold therein, with the perforations in the surface in fluid communication with the manifold; providing an air pressure pump in fluid communication with the manifold, wherein the pump is adapted to provide positive air pressure to the manifold;

providing a tape web;

moving the tape web, and positioning the moving web over the surface of the guide tool;

wherein the direction of travel of the moving web changes between an approach path toward the guide tool surface and a departure path from the guide tool surface; and

activating the pump to deliver positive air pressure to the manifold,

whereby air provided into the manifold and forced out of the perforations provides a lifting pressure between the guide tool surface and the tape web that reduces the friction otherwise caused by movement of the web over the surface.

9. A method as described in claim 8, wherein the pump is also adapted to provide vacuum air pressure to the manifold.

10. A method as described in claim 8, wherein the guide tool is rotatable about an axis of rotation,

and the method further comprising the step of moving the guide tool simultaneously with moving the tape web across the surface of the guide tool;

wherein the tape web has a substantially zero Gaussian curvature as it moves across the guide tool surface.

11. A method as described in claim 8, wherein the tangent contact portion of the tool surface is a straight line.

12. A method as described in claim 8, wherein the tangent contact portion of the tool surface is not a straight line.

13. A method as described in claim 8, wherein the tool surface is comprised of a flexible sheet which has the perforations therein, and wherein the tangent contact portion of the tool surface is not a straight line.

14. A method as described in claim 8, wherein the tool surface is curved in the shape of a part of a circle.

15. A method as described in claim 8, wherein the tool surface is curved in the shaped of a semi-circle.

16. A method as described in claim 8, wherein the tape web comprises a laminate of a pre-impregnated fiber tape on a backer web.

17. A method as described in claim 16, wherein the fiber tape is a carbon fiber tape and the backer web is silicone coated paper.

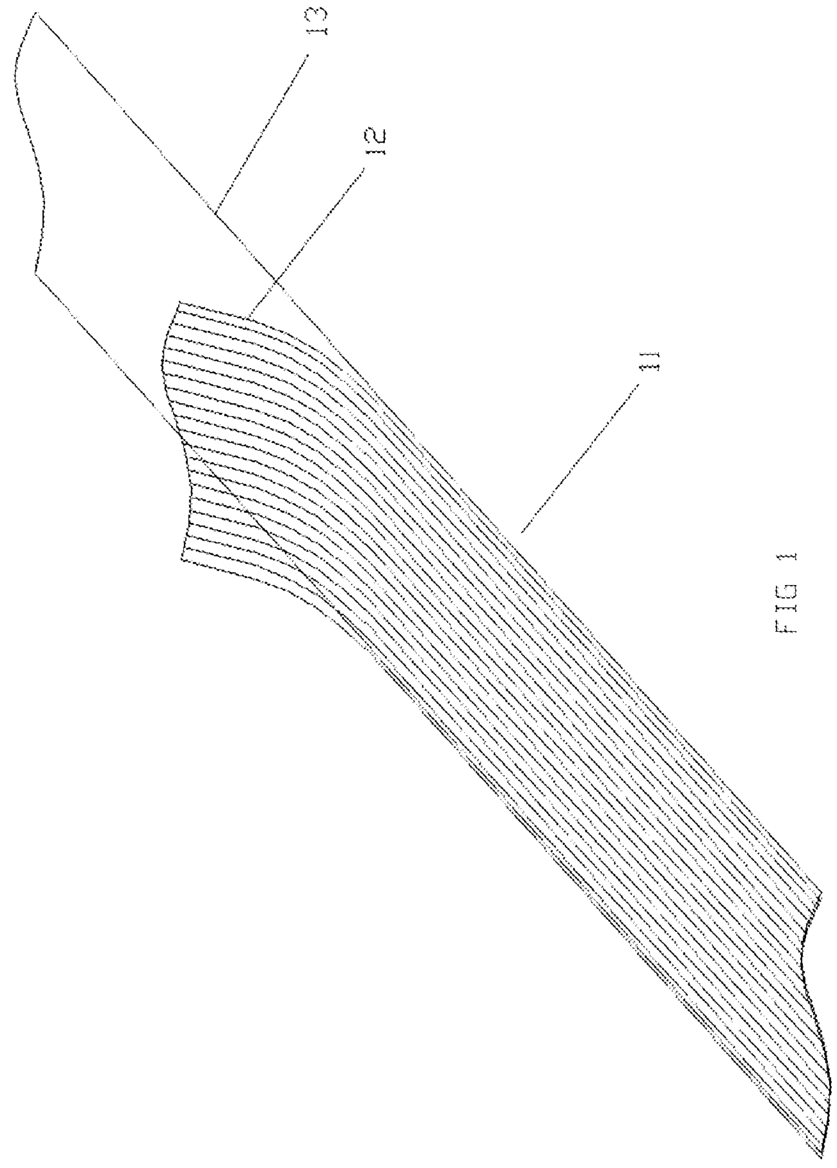


FIG 1

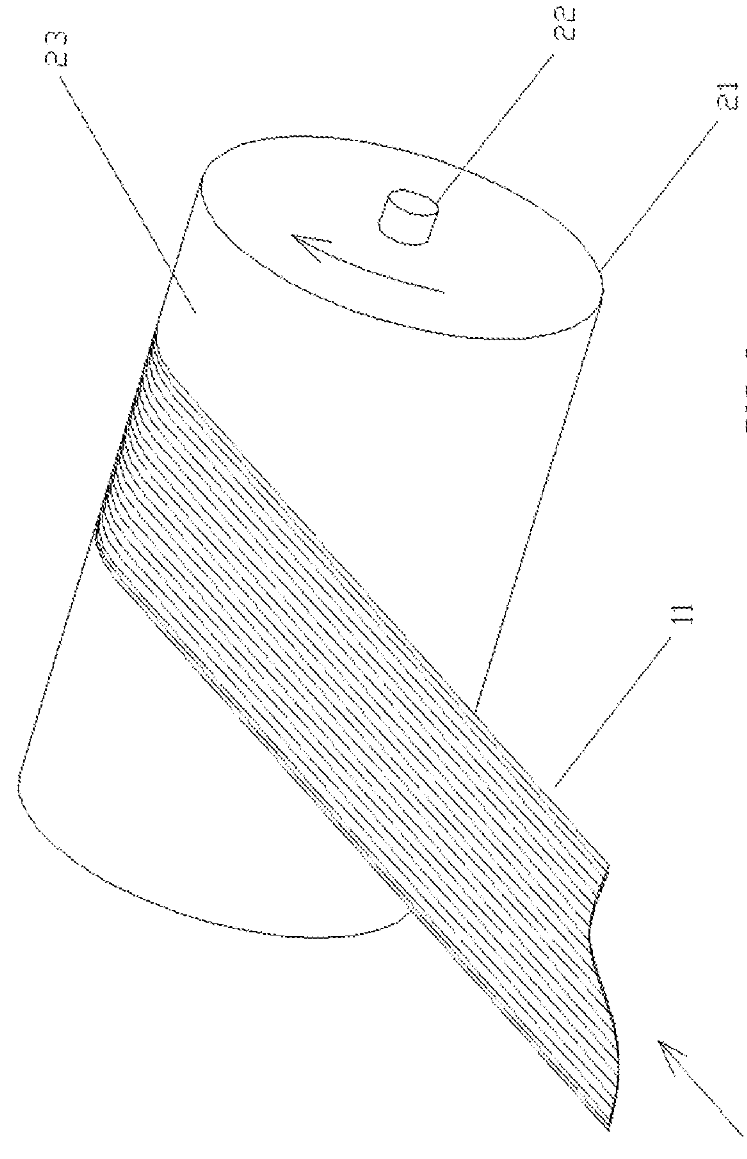


FIG 2

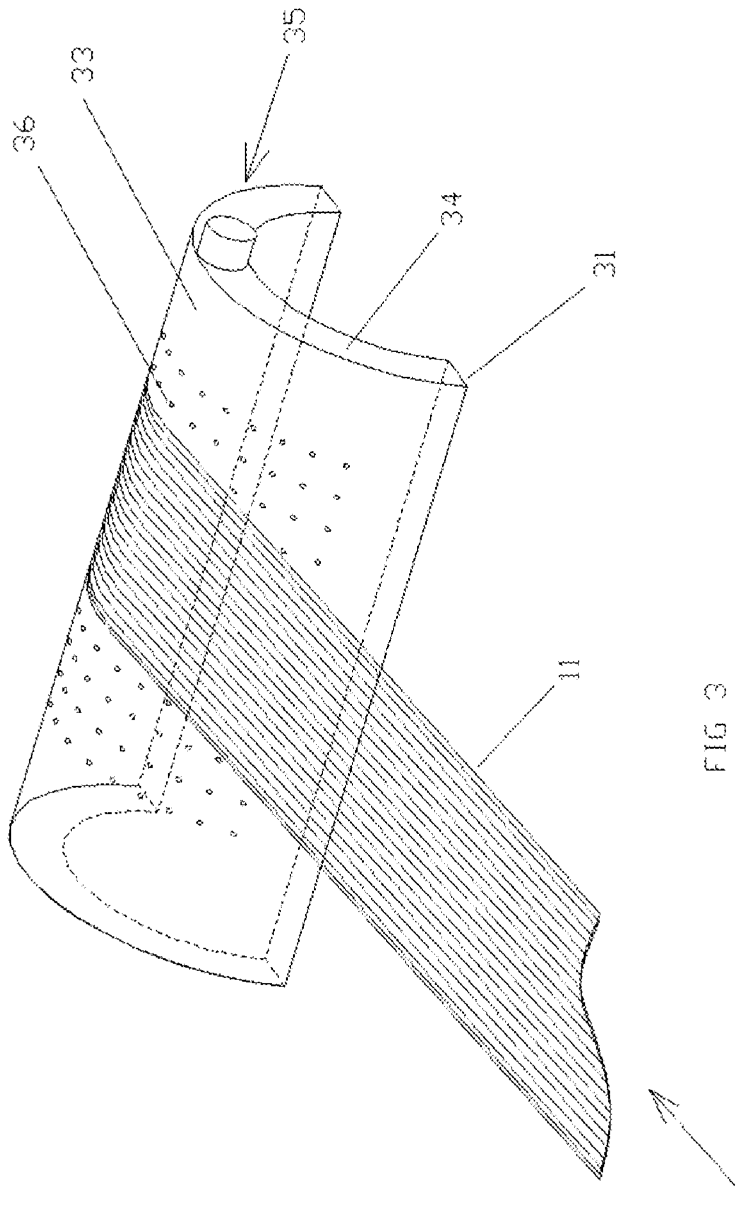


FIG 3

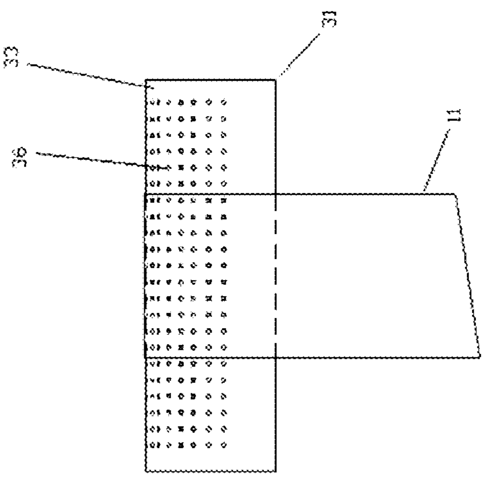


FIG 4C

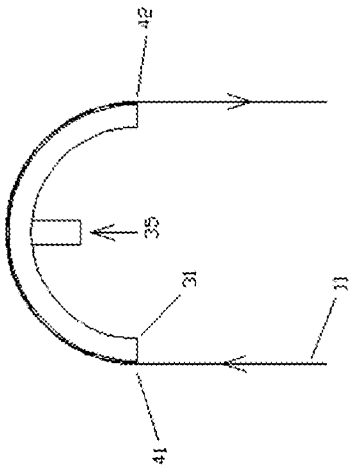


FIG 4B

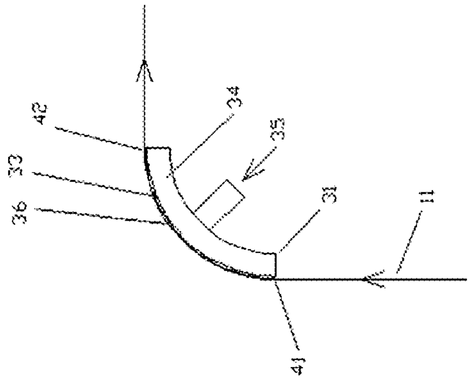


FIG 4A

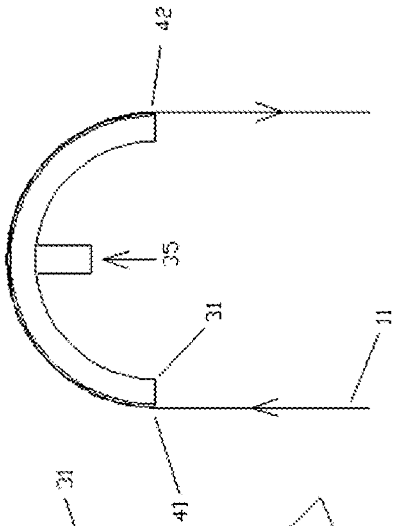


FIG 5B

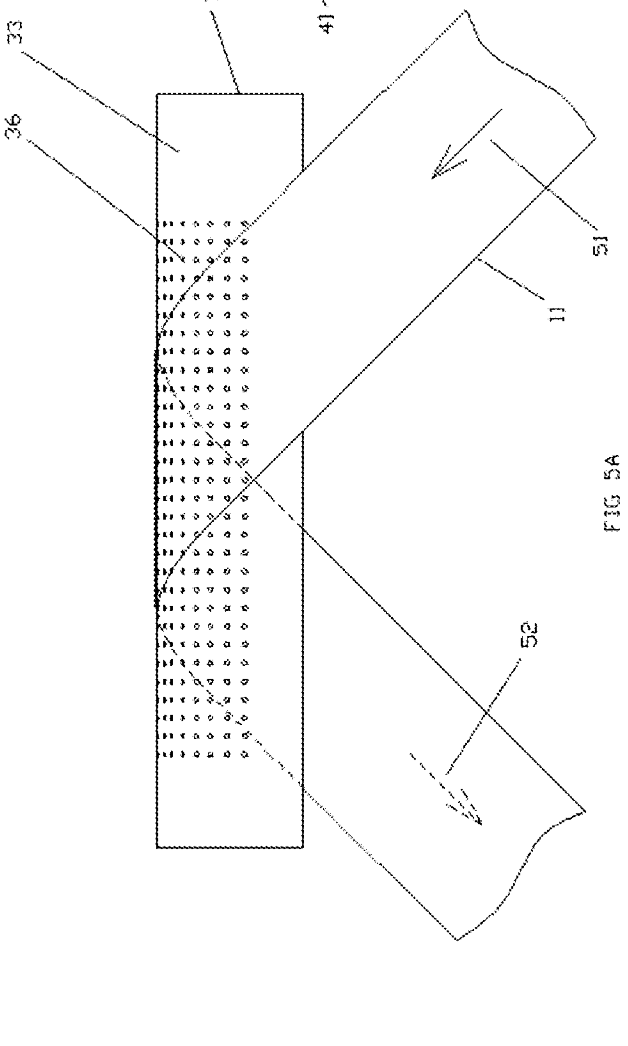
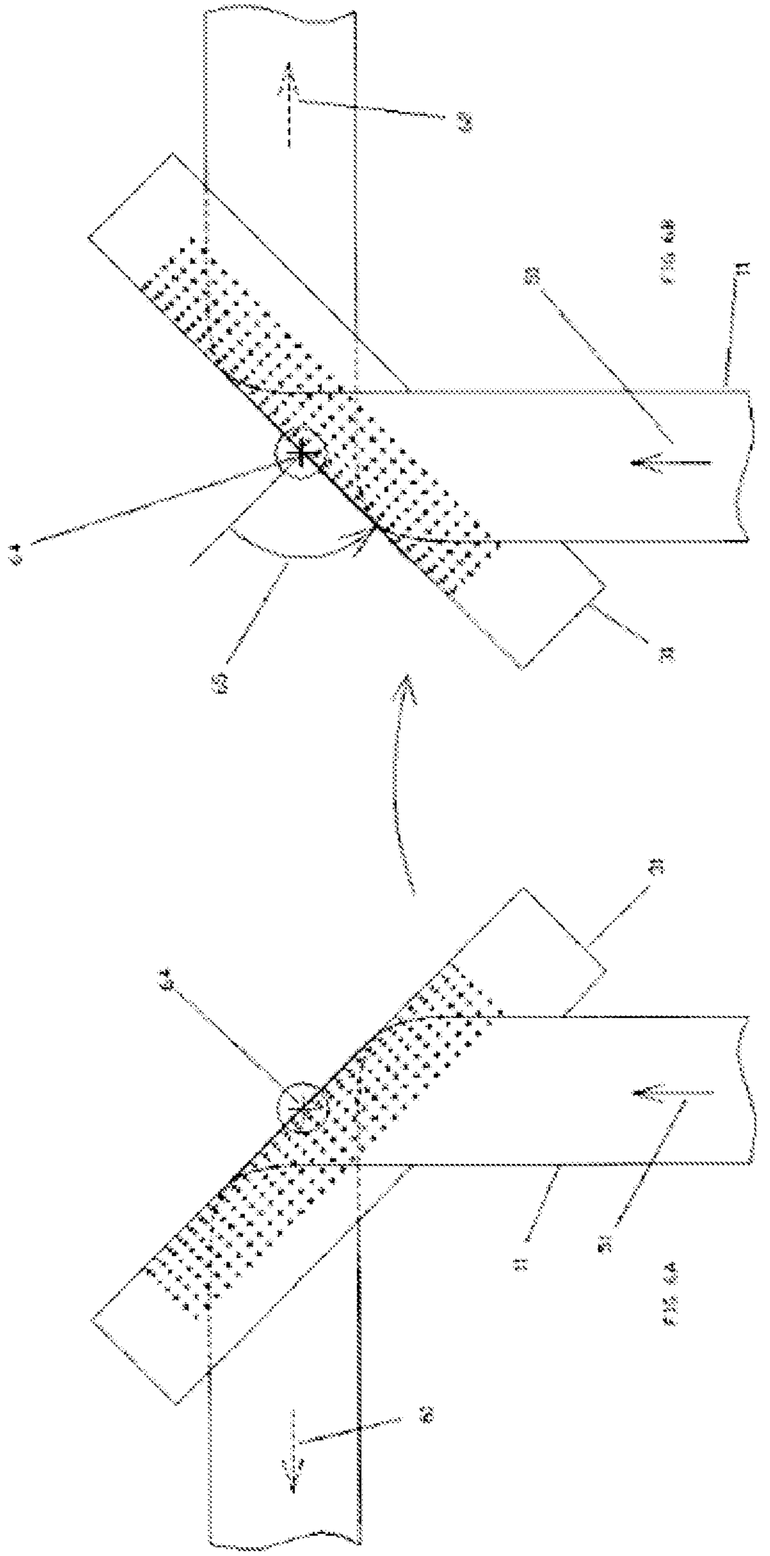


FIG 5A



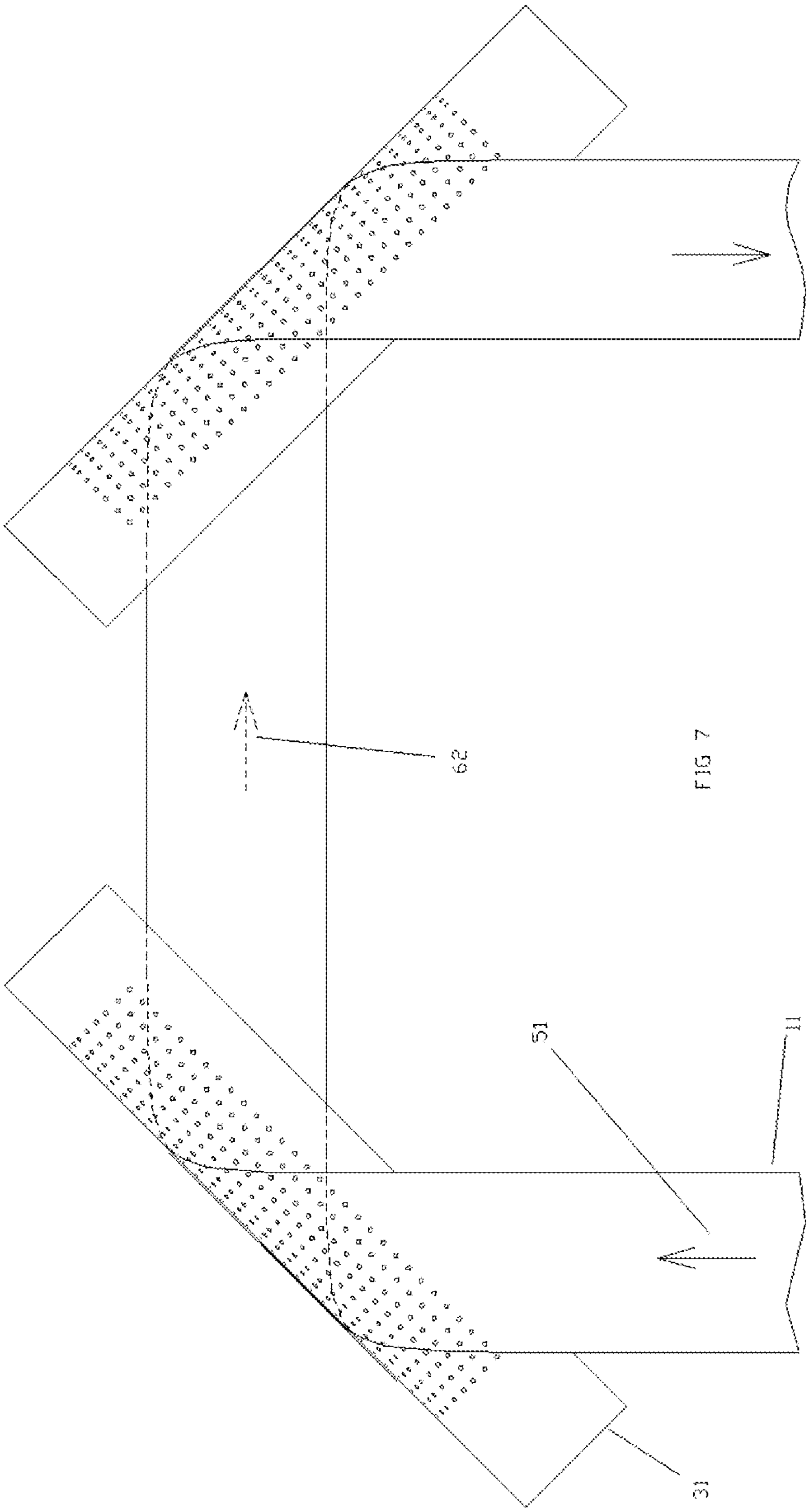


FIG 7

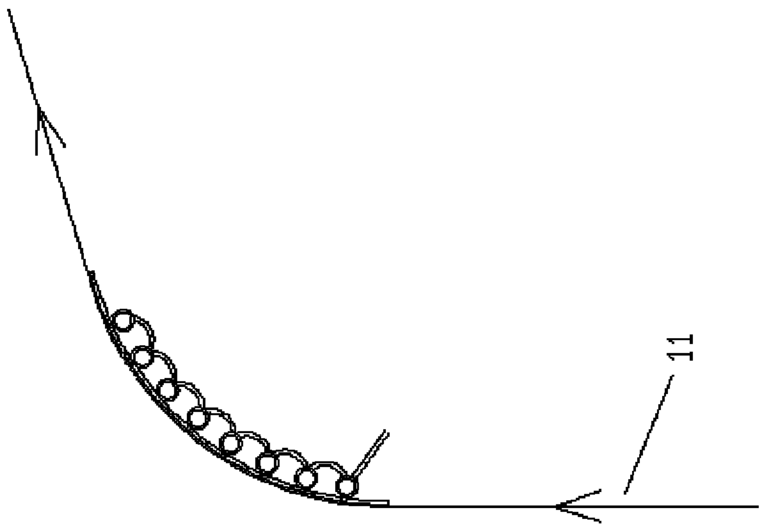


FIG 8B

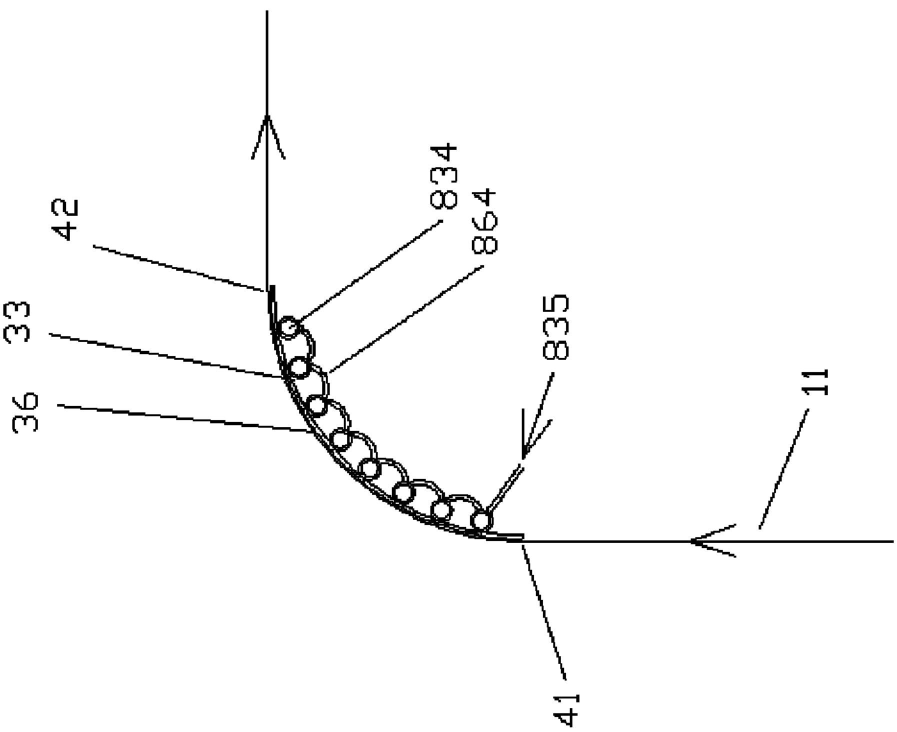


FIG 8A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/49125

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B29C 65/00 (2012.01)
USPC - 156/538
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B29C 65/00 (2012.01)
USPC - 156/538

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 156/425, 350, 523, 574, 577 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(USPT,PGPB,EPAB,JPAB); Google Scholar; Google Patents
Search Terms: tape, web, redirect, guide, pneumatic, gas, air, surface, holes, perforations, angle, offset, tangent, vacuum, pump, move, adjust,... etc.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,316,235 A (East et al.) 31 May 1994 (31.05.1994), fig 12 and 13, col 8, ln 8-59, col 10, ln 55-65	8, 11 and 14-15 ------------------------ 1-7, 9-10, 12-13 and 16-17
Y	US 2007/0119543 A1 (Ametani) 31 May 2007 (31.05.2007), fig 2, para [0053]-[0054]	1-7 and 10
Y	US 2011/0168041 A1 (Engelmann) 14 July 2011 (14.07.2011), para [0022] and [0026]	3-4, 9 and 12-13
Y	US 5,260,121 A (Gardner et al.) 09 November 1993 (09.11.1993), col 6, ln 30-33	16 and 17

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 September 2012 (29.09.2012)	15 OCT 2012

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774