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(54) **APPARATUS FOR AND METHOD OF FORMING CURVED PANELS**

VORRICHTUNG UND VERFAHREN ZUM FORMEN VON GEKRÜMMTEN PLATTEN

DISPOSITIF ET MÉTHODE DE FORMAGE DE PANNEAUX INCURVÉS

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Description

[0001] This invention concerns the forming of curved panels from sheet material, for the construction of reflectors for antennas including satellite communications antennas, and other purposes such as lighting reflectors and solar collectors.

[0002] A satellite communications antenna, for instance one used for TV signals, typically comprises a reflective parabolic dish several metres across arranged to collect an incoming signal and focus it at the focal point of the dish. Such dishes are typically constructed from a number of curved panels, and for effective performance each panel must be extremely accurate in form - typically an average error of not more than 0.5mm over the panel. The panels are commonly made by means of a stretch forming machine in which a ductile aluminium sheet is stretched beyond its elastic limit (or "pulled") over a former. The "skin" so formed is relatively delicate and therefore before use it is usually stiffened by "stringers" secured to the skin.

[0003] Heretofore the manufacture of antenna panels by stretch forming has been difficult and expensive for three reasons as follows. First, conventional stretch forming machines are designed principally for large-scale applications such as the manufacture of aircraft wings and fuselage sections and such machines are therefore needlessly massive (and hence unnecessarily costly) for the manufacture of antenna panels. For example, many sections typically manufactured by the stretch form process require considerable curvature in the panel, and therefore the conventional machine drives the former into the ductile sheet by means of a massive ram. The cost problem is exacerbated by the need for conventional stretch forming machines to be versatile, and therefore relatively complex, in order to accommodate a large variety of jobs and sustain the investment in the machine. Second, the former for such a machine is conventionally made from a solid block of material accurately machined to the required shape. Formers of this kind are very expensive to make, and more so to modify, which in turn means that non-standard reflectors cannot generally be afforded. It will also be understood that these formers are awkward to store. Third, the stringers supporting the panel are themselves conventionally pre-formed and secured to the skin by means of a special assembly fixture, adding two more cost elements to the manufacture of the antenna.

[0004] It is an object of the present invention to reduce the cost of manufacturing curved panels for use in the construction of satellite communications antennas and the like.

[0005] Thus according to a first aspect of the invention there is provided apparatus for forming from ductile sheet material a panel curved in mutually orthogonal x, y and z dimensions, which apparatus comprises two side rails and an intermediate rail between the two side rails, all said rails extending generally in the x direction, and a

plurality of bars held by the side rails to extend generally in the y direction and be mutually spaced apart in the x direction, characterised in that the side rails and the intermediate rails are relatively configured and arranged so that the bars are flexed thereby to form a plurality of curves in yz planes and the apices of the curves in the yz planes form a curve in the xz plane.

[0006] There may be two or more said intermediate rails and there may also be two or more said side rails each side of these.

[0007] Each bar may be held at or adjacent its ends in openings formed in the side rails. The openings in the side rails may comprise holes for the respective bars each formed to extend along the curve in the yz plane of the bar it holds, the holes being mutually spaced apart in the y direction along a curve in the xz plane. Alternatively each opening may comprise a lengthwise slot holding a plurality of said bars.

[0008] Preferably each bar is flexed over a seat on the intermediate rail, and the seats mutually spaced apart in the y direction along a curve in the xz plane.

[0009] Those skilled in the art will appreciate that the use of multiple bars as a former is much cheaper to manufacture than the solid formers in general use heretofore, because instead of accurately machining a complete surface it is necessary only to provide accurate locations for the bars by means of the rails that hold them. Further, if a panel requires some modification, it is at most necessary to adjust the rails, which is much cheaper than reshaping a solid former. Also the assembly of rails and bars can be readily dismantled for convenient storage when not in use.

[0010] Preferably the apparatus comprises a former defining a surface curved in mutually orthogonal x, y and z dimensions and two clamps extending generally in the y direction and mutually spaced apart in the x direction to clamp sheet material at opposite ends of said former, and a jack operable to drive said clamps apart and stretch the clamped sheet material over said surface whereby each said clamp is carried on a frame pivoted about an axis extending generally in the y direction and rearward of said former (which is to say, in a direction opposite to the convexity of the former) whereby when the clamps are driven apart the sheet material is pulled rearwards onto said surface. The jack, which may be operable by fluid pressure, is preferably arranged between said clamps to bear on each thereof; or there may be two jacks, one on each clamp, bearing on each other.

[0011] This aspect of the invention takes advantage of the fact that items such as antenna panels have small curvatures in comparison with most stretch formed components such as aircraft parts. The action of the pivoting clamps draws the material down onto the former, as the material is strained, obviating the need for a massive ram to drive the former as heretofore. The pivoting arrangement of the clamps is a simple and therefore relatively inexpensive way of drawing the workpiece sheet onto the former. And by arranging one jack to act on both

clamps, or two jacks to act against each other, there is no need for a particularly massive frame to resist the jacking force.

[0012] Each clamp may comprise first and second members arranged to receive said sheet material therebetween and a source of pressurised fluid arranged to drive the second member towards the first member thereby to clamp the sheet material, and there may be a flexible membrane between the second member and the source of pressurised fluid.

[0013] According to a second aspect of the invention there is provided a method of forming from ductile sheet material a panel curved in mutually orthogonal x, y and z dimensions, characterised in that said method comprises arranging a plurality of bars to extend generally in the y direction and be mutually spaced apart in the x direction, flexing the bars to form a plurality of curves in the yz plane, locating the bars so that the apices of the curves in the yz planes form a curve in the xz plane and stretching said sheet material over said bars.

[0014] A panel formed as aforesaid may be reinforced by stringers applied to the convex face of the panel while its concave face is on said former, and the stringers may be made from lengths of box section made flexible by kerfing before application to the panel. This means that the stringers are cheaply and easily made and their application to the panel does not require a special assembly fixture.

[0015] Panels included within the invention may be formed from aluminium and may be used in the construction of a communications antenna, or another product such as a lighting reflector or a solar heating reflector.

[0016] Other features of the invention will be apparent from the following description, which is made by way of example only and with reference to the accompanying schematic drawings, in which -

Figures 1 to 3 show in third angle projection three corresponding views of an antenna panel of the kind made by means of the invention, Figure 1 being a front elevation, Figure 2 being a side elevation and Figure 3 being a plan view from below;

Figure 4 is an isometric view of a stretch forming machine embodying the invention;

Figures 5 and 6 illustrate the operation of the stretch forming machine of Figure 4;

Figure 7 is an isometric view of a former for the stretch forming machine of Figure 4;

Figure 8 is a cross-sectional view of a clamp of the machine of Figure 4;

Figure 9 illustrates a stringer for application to an antenna panel;

Figure 10 is a plan view of a former different from that shown in Figure 7; and

Figure 11 is a schematic section at A-A of Figure 10.

[0017] Referring first to *Figures 1 to 3*, it should first be noted that the curvature of the antenna panel indicated

at **10** therein is shown exaggerated for clarity of illustration. The panel **10** has a top **12** and a bottom **14** and two sides **16** and **18** and is curved so as to have a concave face **20** and a convex face **22**.

5 [0018] The panel **10** is formed from aluminium alloy **1050A**, which is ductile, and its concave face **20** acts as a focussing reflector for electromagnetic signals. Thus in use the panel **10** is put together with others (as indicated in broken lines at **24**, **26** and **28**) to construct a satellite communications antenna. The antenna is of parabolic form, but the details of its construction are not germane to the present invention, save that the concave face of each panel must have an average error of not more than 0.5 mm or possibly even less across its surface.

10 [0019] As can be seen (exaggerated) in *Figures 1 to 3*, and as will be understood by those skilled in the art, the panel **10** is curved in three mutually orthogonal dimensions, identified in *Figures 1 to 3* and elsewhere herein as x, y and z.

15 [0020] *Figure 4* shows indicated generally at **30** a stretch forming machine according to the present invention.

[0021] A sheet **32** of aluminium is placed on a former **34** of the machine **30**. The former **34**, which will be described in more detail hereinafter, is configured and arranged to present a generally convex forward face (ie the upper face as seen in *Figure 4*). This face is curved in mutually orthogonal x, y and z dimensions.

25 [0022] The sheet **32** is gripped at each end by a clamp **36** secured to a swinging frame **38** mounted on pivots **40** on the main frame **42** of the machine **30**. The swinging frames **38** are each thus rotatable about an axis through their pivots **40**, which are rearward of the convex face of the former **34** (ie below the former **34**, as seen in *Figure 4*). In use the swinging frames are driven by a hydraulic jack **50** (not shown in *Figure 4*) as will now be described with reference to the diagrammatic *Figures 5 and 6*.

30 [0023] The hydraulic jack **50** is connected to each of the swinging frames **38**. Before use, as shown in *Figure 5*, the swinging frames **38** are positioned close up to the ends of the main frame **42** of the machine **30**. In this position the aluminium sheet **32**, held at each end by the clamps **36**, rests on the convex face of the former **34**. Pressurised fluid (from a source not shown) is admitted to the jack **50** which then drives the frames **38** apart, each rotating about its pivots **40**. Thus the clamps **36** move arcuately and the sheet **50** is stretched and simultaneously pulled down onto the former **34**, as shown in *Figure 6*.

35 [0024] It should be noted that rotation of the swinging frames **38** and hence the stretching of the sheet **32** is exaggerated in *Figures 5 and 6*, for clarity of illustration, but in practice it is sufficient for the sheet **32** to be stretched beyond its elastic limit. In this way the sheet **32** is conformed to the shape of the convex face of the former **34**. It should also be noted that each swinging frame **38** is cranked adjacent its pivots **40**, as indicated at **38a**, which has the effect reducing the amount of ro-

tation required to draw the sheet **32** onto the former **34**.

[0025] Referring now to *Figure 7*, the former **34** comprises a plurality of steel bars **60** extending in the y direction and mutually spaced apart in the x direction. The bars **60** are held in side rails **62** and **64**, which are formed with holes **66** to receive the bars **60**, and flexed over an intermediate rail **68**. Thus each bar **60** is curved in a yz plane. Each hole **66** is bored to align with the flexure of the bar **60** it holds.

[0026] As can be seen from *Figure 7*, the holes **66** lie on a curve in an xz plane. Similarly the seats (not detailed) for the bars on the intermediate rail **68** lie on a curve in an xz plane.

[0027] By these means the bars **60** combine to define an envelope which is curved in mutually orthogonal x, y and z dimensions. Therefore, when an aluminium sheet **32** is stretched over the former **34** as aforescribed, it takes up the shape of this envelope. More particularly, the sheet **32** is given a convex face closely conforming to the envelope defined by the bars **60**. It can then be released from the clamps **36** and trimmed (by means of a plasma cutter) along top, bottom and sides to provide an antenna panel as shown in *Figures 1 to 3*.

[0028] This arrangement is substantially cheaper than the conventional use of a solid former, even with a large number of bars **60**. Further cost reductions can be effected by using fewer bars **60**, but some consequent reduction in accuracy may limit the application of panels so made.

[0029] The accuracy of the panel (for any given application) is checked by means of a measurement system comprising commercial off-the-shelf (COTS) units that it is considered unnecessary to illustrate or describe. If the resulting shape is not exactly as required, the bars **60** can be removed and relocated, or the rails may be adjusted or new rails made.

[0030] After use the former **34** may be stored as an assembly, or alternatively dismantled for more compact storage. If it is dismantled the bars are removed and, being only elastically flexed, may then be used to make other formers. The rails **62**, **64** and **68** may be retained for reuse in the event that a panel to the same design is required again.

[0031] *Figure 8* illustrates the construction of a clamp **36**. An edge of the sheet **32** is located between a first member **70** and a second member **72**. The first member is a fixed part of the clamp **36** and the second member **72** is a movable part thereof. The second member **74** is backed by a flexible membrane **74**. Pressurised fluid **76** (from a source not shown, but which may be the same as that for the jack **50**) is delivered behind the membrane **74** and thus the movable second member **72** is driven towards the edge of the sheet **32** which is then firmly held against the fixed first member **70**.

[0032] The formed and trimmed panel **10** is reinforced by a stringer **80**. The panel **10** is conveniently supported on the former **34** (or a separate similarly constructed assembly tool) during this process. The stringer **80** is man-

ufactured from a length of straight box section material with a plurality of kerfs **82** cut through three sides thereof so as to be flexible. The side of the stringer **80** opposite the uncut side of the box section is placed on the panel **10** and conformed thereto by the application of weights or other means such as by air pressure. The stringer **80** is then secured to the panel **10** by any appropriate mean such as glue, rivets, bolts, screws or welding, or a combination of these means.

[0033] *Figures 10 and 11* show a former **90** different from that described above with particular reference to *Figure 7*. The former **90** has two side rails **92** and **94** and an intermediate rail **96** spaced apart in the y direction and extending generally (but not parallel) in the x direction. A plurality of steel bars **98** mutually spaced apart in the x direction extend between the side rails **92** and **94** and over the intermediate rail **96**. Each of the bars **98** is flexed and held in place by pins **100** in the rails **92**, **94** and **96**. (For simplicity of illustration, only a few of the pins **100** are referenced in *Figures 10 and 11*. And for improved stability there may be pins **100** each side of each bar **98**, at least in the side rails **92** and **94**, although this is also not illustrated).

[0034] As shown in *Figure 11*, the surface of the side rail **94** is curved in the xz plane and the other side rail **92** and the intermediate rail **96** are each similarly formed. By this means the bars **98**, which are all similar and of rectangular cross section, are so located as to define an envelope (indicated in broken lines at **102** in *Figure 11*) which is curved in the mutually orthogonal x, y and z dimensions. Thus, as aforescribed in relation to the former **34**, an aluminium sheet may be similarly stretched over the former **90**, thereby to take up the shape of this envelope.

[0035] Various modifications and adaptations of the apparatus may be made. For instance, in the former **34** of *Figure 7*, in place of the individual holes **66**, the plurality of bars **60** may be held in lengthwise slots milled in the rails **62** and **64**. In the former **90** of *Figures 10 and 11*, as an alternative to the arrangement described, the rails **92**, **94** and **96** may each have a flat upper surface and the bars **98** be arcuately formed to define an appropriate envelope. The invention may use bars of any appropriate shape, not necessarily the circular cross section of the bars **60** or the rectangular cross section of the bars **98**. Some material other than aluminium may be used for the panels. The single jack **50** shown in the drawings may be replaced by two jacks carried respectively by the two clamps and bearing upon each other. Further, panels may be made for applications other than satellite communications antennas, eg radar and microwave antennas, reflectors for high power lighting units of the kind used in sports stadiums and solar heating reflectors. Other possible modifications and adaptations will be apparent to those skilled in the art.

[0036] It will also be apparent that the tool described herein is of general utility, and can be used for methods other than stretch forming, for example in processes

where the material is kept within its elastic limit and held in shape by strong stringers, or in the manufacture of items made from composite material.

[0037] Finally it should be noted that the x, y and z dimensions referred to herein and so annotated in the drawings are not intended to designate any specific orientation with respect to any forming machine or any former for such a machine or any panel made by such a machine. Thus, for instance, whilst *Figure 7* is described as showing a former with its bars 60 extending in the y direction (ie widthwise) and mutually spaced apart in the x direction (ie lengthwise), this is done purely for clarity of illustration. It should be understood that the invention does not call for an x dimension to be defined with reference to the length of any former or a y dimension to be defined with reference to its width. Similarly, with regard to *Figure 4*, neither the lengthwise axis nor the widthwise axis of the machine shown therein defines a specific x or y dimension. And with regard to *Figures 1* to *3*, whilst the distance from head 12 to tail 14 of the panel 10 is shown aligned with the x dimension, this does not mean that the x dimension is defined with reference to the head and tail of any panel 9 (and nor is the y dimension defined with reference to the sides of a panel). Rather, the x, y and z dimensions are simply conventional designations of three mutually orthogonal dimensions, and the panel 10, the former 34 and the machine 30 may be orientated in any way relative to those dimensions. It follows that the bars 60 may extend generally in the x direction as well as or instead of the y direction as described hereinbefore, and the bars may be flexed in an xz plane as well as or instead of a yz plane as described. Whilst the z dimension herein accords with the conventional reference to up-down dimensions, no such constraint is to be inferred. The x, y and z dimensions hereof can refer to any three mutually orthogonal dimensions.

Claims

1. Apparatus for forming from sheet material a panel (10) curved in mutually orthogonal x, y and z dimensions, which apparatus comprises two side rails (62, 64) and an intermediate rail (68) between the two side rails (62, 64), all said rails (62, 64, 68) extending generally in the x direction, and a plurality of bars (60) held by the side rails (62, 64) to extend generally in the y direction and be mutually spaced apart in the x direction, **characterised in that** the side rails (62, 64) and the intermediate rail (68) are relatively configured and arranged so that the bars (60) are flexed thereby to form a plurality of curves in yz planes and the apices of the curves in the yz planes form a curve in the xz plane.
2. Apparatus for forming a panel (10) as claimed in claim 1 **characterised in that** the bars (60) each have substantially the same cross section.
3. Apparatus for forming a panel (10) as claimed in claim 1 **characterised in that** each bar (60) is held at or adjacent its ends in openings formed in the side rails (62, 64).
4. Apparatus for forming a panel (10) as claimed in claim 3 **characterised in that** the openings in the side rails (62, 64) comprise holes (66) for the respective bars (60) each formed to extend along the curve in the yz plane of the bar (60) it holds.
5. Apparatus for forming a panel (10) as claimed in claim 4 **characterised in that** said holes (66) are mutually spaced apart in the y direction along a curve in the xz plane.
6. Apparatus for forming a panel (10) as claimed in claim 4 **characterised in that** each said opening comprises a lengthwise slot holding a plurality of said bars (60).
7. Apparatus for forming a panel (10) as claimed in any preceding claim **characterised in that** each bar (60) is flexed over a seat on the intermediate rail (68), said seats being mutually spaced apart in the y direction along a curve in the xz plane.
8. Apparatus for forming a panel (10) as claimed in any preceding claim **characterised in that** there is more than one said intermediate rail (68).
9. Apparatus for forming a panel (10) as claimed in any preceding claim **characterised in that** there is more than one said side rail (62, 64) each side of the intermediate rail or rails (68).
10. Apparatus for forming a panel (10) as claimed in any preceding claim, which apparatus comprises a former (34) defining a surface curved in mutually orthogonal x, y and z dimensions, two clamps (36) extending generally in the y direction and mutually spaced apart in the x direction to clamp sheet material (32) at opposite ends of said former (34), and a jack (50) operable to drive said clamps (36) apart and stretch the clamped sheet material (32) over said surface, whereby one or each said clamp (36) is carried on a frame (38) pivoted about an axis extending generally in the y direction and rearward of said former (34), whereby when the clamps (36) are driven apart the sheet material (32) is pulled rearwards onto said surface.
11. Apparatus for forming a panel (10) as claimed in claim 10 **characterised in that** said jack (50) is arranged between said clamps (36) to bear on each thereof.
12. Apparatus for forming a panel (10) as claimed in

claim 10 or claim 11 wherein each said clamp (36) comprises first and second members (70, 72) arranged to receive said sheet material (32) therebetween and a source of pressurised fluid (76) arranged to drive the second member (72) towards the first member (70) thereby to clamp the sheet material (32), **characterised in that** each said clamp (36) includes a flexible membrane (74) between the second member (72) and the source of pressurised fluid (76).

13. A method of forming from sheet material (32) a panel (10) curved in mutually orthogonal x, y and z dimensions, **characterised in that** said method comprises arranging a plurality of bars (60) to extend generally in the y direction and be mutually spaced apart in the x direction, flexing the bars (60) to form a plurality of curves in the yz plane, locating the bars (60) so that the apices of the curves in the yz planes form a curve in the xz plane and stretching said sheet material (32) over said bars (60).
14. A method of forming a panel (10) as claimed in claim 13 wherein the sheet material (32) is clamped along edges extending in the y direction at opposite ends of said former (34) and the clamped edges are driven apart to stretch the clamped sheet material (32) over said bars (60), **characterised in that** one or each said clamped edge is driven arcuately about an axis extending generally in the y direction and rearward of said former (34), whereby the clamped sheet material (32) is pulled rearwards onto said bars (60).
15. A method of forming a panel (10) as claimed in claim 14 **characterised in that** the panel (10) is reinforced by stringers (80) applied to the convex face of the panel (10) while its concave face is on said former (34).
16. A method of forming a panel as claimed in claim 15 **characterised in that** each said stringer (80) is made from a length of box section made flexible by kerfing before application to the panel (10).

Patentansprüche

1. Vorrichtung zum Formen eines Paneels (10), das in zueinander orthogonalen x-, y- und z-Richtungen gekrümmt ist, aus einem Plattenmaterial, wobei die Vorrichtung zwei Seitenschienen (62, 64) und eine Zwischenschiene (68) zwischen den beiden Seitenschienen (62, 64) aufweist, sich alle genannten Schienen (62, 64, 68) im Wesentlichen in der x-Richtung erstrecken, und wobei von den Seitenschienen (62, 64) mehrere Stangen (60) gehalten sind, die sich im Wesentlichen in der y-Richtung zu erstrecken und in der x-Richtung einen Abstand voneinander

haben, **dadurch gekennzeichnet, dass** die Seitenschienen (62, 64) und die Zwischenschiene (68) relativ zueinander so angeordnet und ausgebildet sind, dass die Stäbe (60) **dadurch** gebeugt werden, um eine Vielzahl von Kurven in yz-Ebenen zu bilden und die Apizes der Kurven in den yz-Ebenen eine Kurve in der xz-Ebene bilden.

2. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Stäbe (60) jeweils im Wesentlichen denselben Querschnitt haben.
3. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** jeder Stab (60) an oder neben seinen Enden in Öffnungen gehalten ist, die in den Seitenschienen (62, 64) ausgebildet sind.
4. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 3, **dadurch gekennzeichnet, dass** die Öffnungen in den Seitenschienen (62, 64) Löcher (66) für die jeweiligen Stangen (60) bilden, die jeweils so geformt sind, dass sie sich entlang der Kurve in der yz-Ebene der von ihnen gehaltenen Stange (60) erstrecken.
5. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 4, **dadurch gekennzeichnet, dass** die Löcher (66) in einem Abstand voneinander in der y-Richtung entlang einer Kurve in der xz-Ebene angeordnet sind.
6. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 4, **dadurch gekennzeichnet, dass** jede der Öffnungen einen längs verlaufenden Schlitz bildet, der mehrere von den Stangen (60) hält.
7. Vorrichtung zum Formen eines Paneels (10) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** jede Stange (60) über einem Sitz auf der Zwischenschiene (68) gebogen ist, wobei die Sitze jeweils in einem Abstand voneinander in der y-Richtung entlang einer Kurve in der xz-Ebene angeordnet sind.
8. Vorrichtung zum Formen eines Paneels (10) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** mehr als eine Zwischenschiene (68) vorhanden ist.
9. Vorrichtung zum Formen eines Paneels (10) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** jeweils seitlich von der Zwischenschiene oder den Zwischenschienen (68) mehr als eine Seitenschiene (62, 64) vorhanden ist.
10. Vorrichtung zum Formen eines Paneels (10) nach

einem der vorstehenden Ansprüche, wobei die Vorrichtung einen Former (34), der eine Fläche definiert, die in zueinander senkrechten x-, y- und z-Richtungen gekrümmt ist, zwei Klemmen (36), die sich im Wesentlichen in der y-Richtung erstrecken und in der x-Richtung voneinander beabstandet angeordnet sind, um ein Plattenmaterial (32) an entgegengesetzten Enden des Formers (34) zu klemmen, und einen Strecker (50), mit dem sich die beiden Klemmen (36) auseinanderdrücken lassen und das geklemmte Plattenmaterial (32) über der Fläche strecken lässt, aufweist, wobei eine oder jede der Klemmen (36) von einem Rahmen (38) getragen werden, der um eine Achse, die sich im Wesentlichen in y-Richtung und hinter dem Former (34) erstreckt, drehbar ist, wobei beim Auseinanderbewegen der Klemmen (36) das Plattenmaterial (32) nach hinten auf die Fläche gezogen wird.

11. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 10, **dadurch gekennzeichnet, dass** der Strecker (50) zwischen den Klemmen (36) angeordnet ist, um gegen beide zu drücken.

12. Vorrichtung zum Formen eines Paneels (10) nach Anspruch 10 oder 11, wobei jede der Klemmen (36) erste und zweite Glieder (70, 72), die dafür vorgesehen sind, das Plattenmaterial (32) zwischen sich aufzunehmen, und eine Quelle eines unter Druck stehenden Fluids (76), um das zweite Glied (72) gegen das erste Glied (70) zu bewegen und **dadurch das Plattenmaterial (32) zu klemmen, aufweist, dadurch gekennzeichnet, dass** jede der Klemmen (36) eine flexible Membran (74) zwischen dem zweiten Glied (72) und der Quelle des unter Druck stehenden Fluids (76) aufweist.

13. Verfahren zum Formen eines Paneels (10), das in zueinander orthogonalen x-, y- und z-Richtungen gekrümmt ist, aus einem Plattenmaterial (32), **dadurch gekennzeichnet, dass** bei dem Verfahren mehrere Stangen (60) so angeordnet werden, dass sie sich im Wesentlichen in der y-Richtung erstrecken und in der x-Richtung einen Abstand voneinander haben, die Stangen (60) gebogen werden, um mehrere Kurven in der yz-Ebene zu bilden, die Stangen (60) arretiert werden, so dass die Apizes der Kurven in den yz-Ebenen eine Kurve in der xz-Ebene bilden, und das Plattenmaterial (32) über den Stangen (60) gestreckt wird.

14. Verfahren zum Formen eines Paneels (10) nach Anspruch 13, wobei das Plattenmaterial (32) an Rändern, die sich in der y-Richtung an gegenüberliegenden Enden des Formers (34) erstrecken, geklemmt wird und die geklemmten Ränder auseinander getrieben werden, um das geklemmte Plattenmaterial (32) über den Stangen (60) zu strecken, **dadurch**

gekennzeichnet, dass einer oder jeder der geklemmten Ränder bogenförmig um eine Achse bewegt werden, die sich im Wesentlichen in der y-Richtung und hinter dem Former (34) erstreckt, wobei das geklemmte Plattenmaterial (32) nach hinten auf die Stangen (60) gezogen wird.

15. Verfahren zum Formen eines Paneels (10) nach Anspruch 14, **dadurch gekennzeichnet, dass** das Paneel (10) mit Versteifungen (80) verstärkt wird, die auf der konvexen Seite des Paneels (10) angebracht werden, während seine konkave Seite auf dem Former (34) liegt.

16. Verfahren zum Formen eines Paneels (10) nach Anspruch 15, **dadurch gekennzeichnet, dass** jede der Versteifungen (80) aus einem Abschnitt eines Kastenprofils gemacht ist, das durch Einschneiden flexibel gemacht wurde, bevor es an dem Paneel (10) angebracht wurde.

Revendications

1. Appareil pour former à partir d'une tôle un panneau (10) courbé dans des dimensions x, y et z mutuellement orthogonales, ledit appareil comprend deux rails latéraux (62, 64) et un rail intermédiaire (68) entre les deux rails latéraux (62, 64), l'ensemble desdits rails (62, 64, 68) s'étendant généralement dans la direction x, et plusieurs barres (60) retenues par les rails latéraux (62, 64) pour s'étendre généralement dans la direction y et pour être espacés mutuellement dans la direction x, **caractérisé en ce que** les rails latéraux (62, 64) et le rail intermédiaire (68) sont relativement configurés et agencés de façon que les barres (60) soient fléchies en formant ainsi plusieurs courbes dans des plans yz, et les sommets des courbes dans les plans yz forment une courbe dans le plan xz.

2. Appareil pour former un panneau (10) selon la revendication 1, **caractérisé en ce que** les barres (60) ont chacune sensiblement la même section transversale.

3. Appareil pour former un panneau (10) selon la revendication 1, **caractérisé en ce que** chaque barre (60) est maintenue à ou d'une manière adjacente à ses extrémités dans des ouvertures formées dans les rails latéraux (62, 64).

4. Appareil pour former un panneau (10) selon la revendication 3, **caractérisé en ce que** les ouvertures dans les rails latéraux (62, 64) comprennent des trous (66) pour les barres respectives (60), chacun formé pour s'étendre le long de la courbe dans le plan yz de la barre (60) qu'il retient.

5. Appareil pour former un panneau (10) selon la revendication 4, **caractérisé en ce que** lesdits trous (66) sont mutuellement espacés dans la direction y le long d'une courbe dans le plan xz. 5
6. Appareil pour former un panneau (10) selon la revendication 4, **caractérisé en ce que** chaque ouverture précitée comprend une fente longitudinale retenant une pluralité desdites barres (60). 10
7. Appareil pour former un panneau (10) selon l'une quelconque des revendications précédentes, **caractérisé en ce que** chaque barre (60) est fléchée sur un siège sur le rail intermédiaire (68), lesdits sièges étant mutuellement espacés dans la direction y le long d'une courbe dans le plan xz. 15
8. Appareil pour former un panneau (10) selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'il y a plus d'un rail intermédiaire** précité (68). 20
9. Appareil pour former un panneau (10) selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'il y a plus d'un rail latéral** précité (62, 64) de chaque côté du ou des rails intermédiaires (68). 25
10. Appareil pour former un panneau (10) selon l'une quelconque des revendications précédentes, ledit appareil comprenant un formeur (34) définissant une surface courbée dans les dimensions x, y et z mutuellement orthogonales, deux pinces (36) s'étendant généralement dans la direction y et mutuellement espacés dans la direction x pour serrer la tôle (32) aux extrémités opposées dudit formeur (34), et un vérin (50) actionnable pour écarter lesdites pinces (36) et étirer le matériau de tôle serré (32) sur ladite surface, par quoi une ou chaque pince précitée (36) est portée sur un châssis (38) amené à pivoter autour d'un axe s'étendant généralement dans la direction y et vers l'arrière dudit formeur (34), par quoi, lorsque les pinces (36) sont écartées, le matériau de tôle (32) est tiré vers l'arrière sur ladite surface. 30 35 40 45
11. Appareil pour former un panneau (10) selon la revendication 10, **caractérisé en ce que** ledit vérin (50) est agencé entre lesdites pinces (36) pour porter sur chacune de celles-ci. 50
12. Appareil pour former un panneau (10) selon la revendication 10 ou la revendication 11, dans lequel chaque pince précitée (36) comprend des premier et second éléments (70, 72) agencés pour recevoir ledit matériau de tôle (32) entre eux ainsi qu'une source de fluide sous pression (76) agencée pour entraîner le second élément (72) vers le premier élément (70) en serrant ainsi le matériau de tôle (32), **caractérisé en ce que** chaque pince précitée (36) comporte une membrane flexible (74) entre le second élément (72) et la source de fluide sous pression (76). 55
13. Procédé pour former à partir d'un matériau de tôle (32) un panneau (10) courbé dans des dimensions x, y et z mutuellement orthogonales, **caractérisé en ce que** ledit procédé comprend l'agencement d'une pluralité de barres (60) pour s'étendre généralement dans la direction y et pour être espacées mutuellement dans la direction x, la flexion des barres (60) pour former une pluralité de courbes dans le plan yz, la localisation des barres (60) de façon que les sommets des courbes dans les plans yz forment une courbe dans le plan xz et l'étirage dudit matériau de tôle (32) sur lesdites barres (60).
14. Procédé pour former un panneau (10) selon la revendication 13, dans lequel le matériau de tôle (32) est serré le long de bords s'étendant dans la direction y aux extrémités opposées dudit formeur (34), et les bords serrés sont écartés pour étirer le matériau de tôle serré (32) sur lesdites barres (60), **caractérisé en ce que** le ou chaque bord serré précité est entraîné d'une manière arquée autour d'un axe s'étendant généralement dans la direction y et vers l'arrière dudit formeur (34), par quoi le matériau de feuille serré (32) est tiré vers l'arrière sur lesdites barres (60).
15. Procédé pour former un panneau (10) selon la revendication 14, **caractérisé en ce que** le panneau (10) est renforcé par des raidisseurs (80) appliqués à la face convexe du panneau (10) pendant que sa face convexe se trouve sur ledit formeur (34).
16. Procédé pour former un panneau selon la revendication 15, **caractérisé en ce que** chaque raidisseur précité (80) est réalisé en une longueur de section de boîte rendue flexible par des saignées avant l'application au panneau (10).

Fig 1

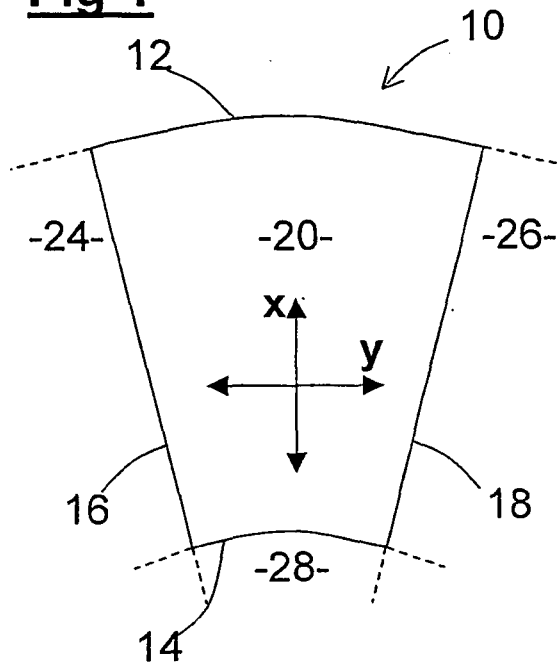


Fig 2

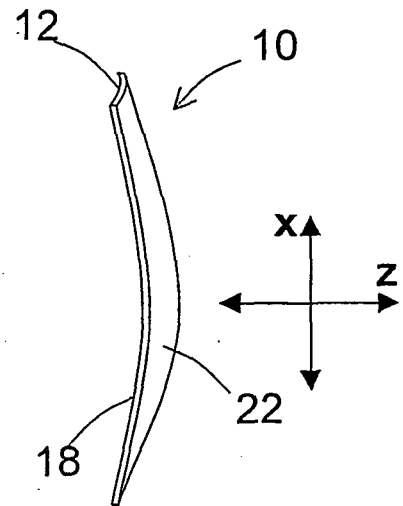


Fig 3

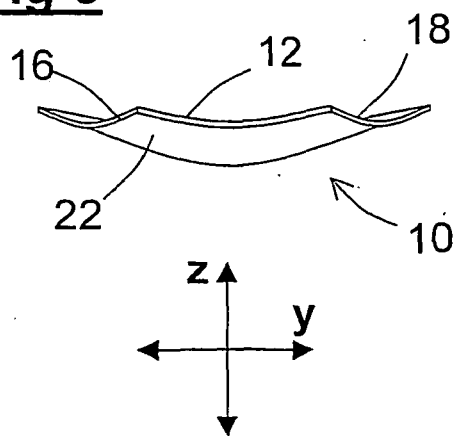


Fig 4

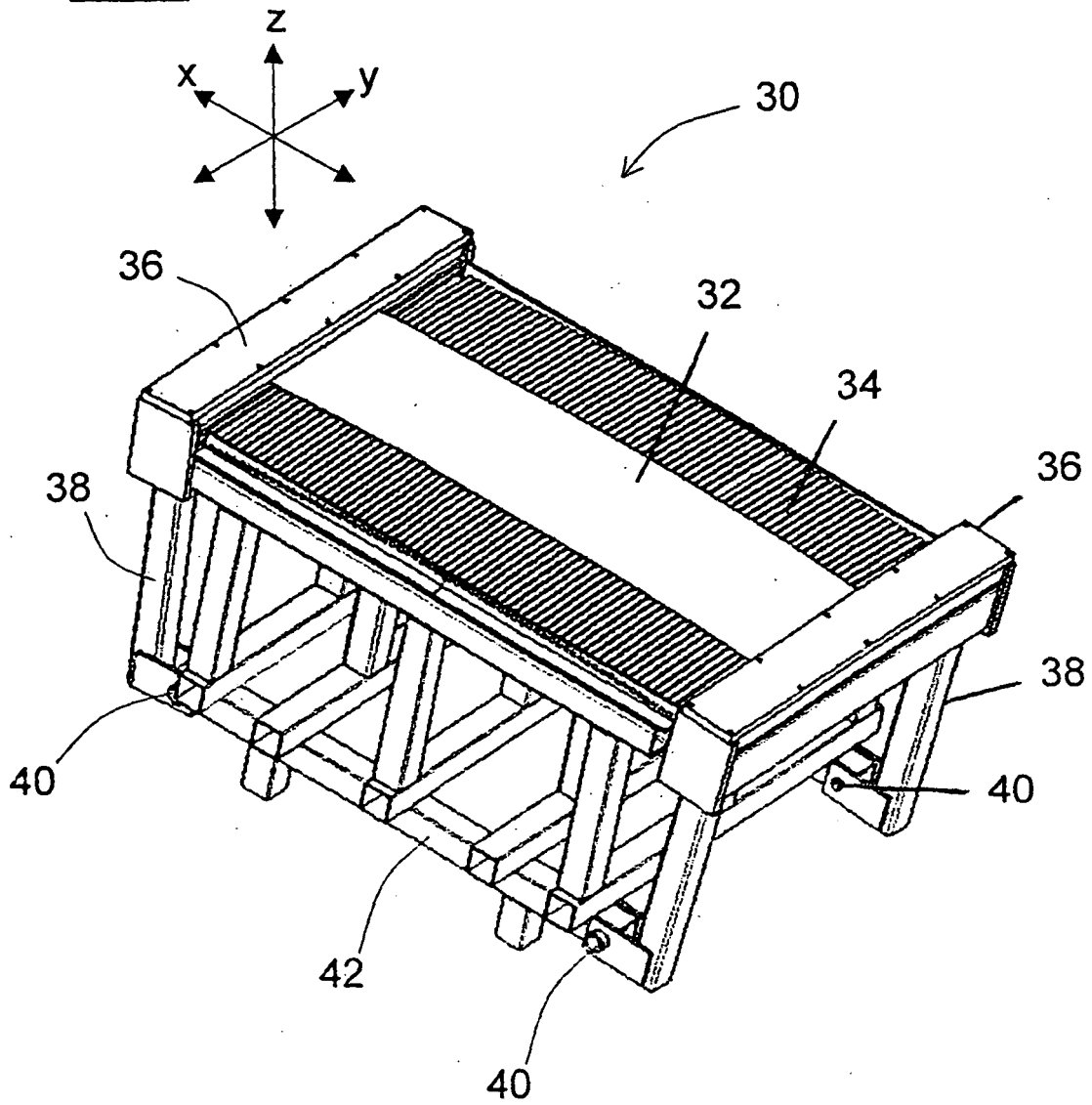


Fig 5

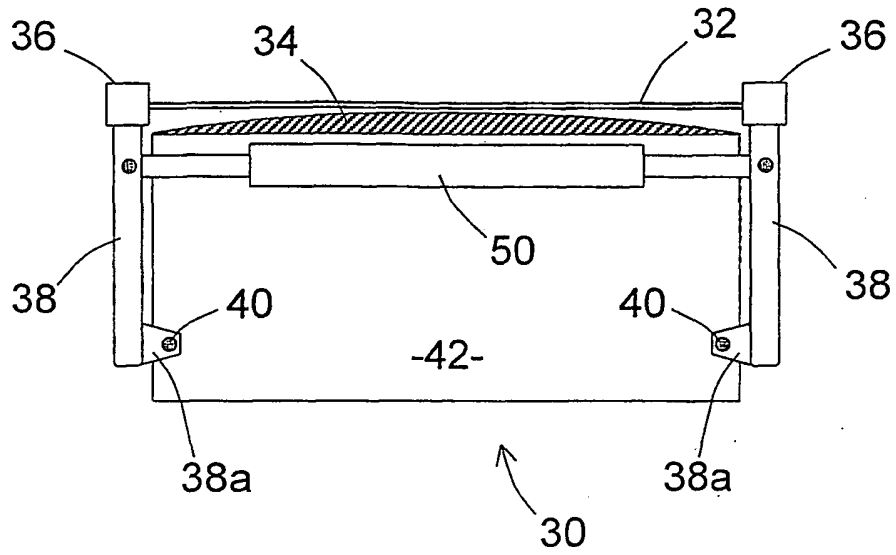


Fig 6

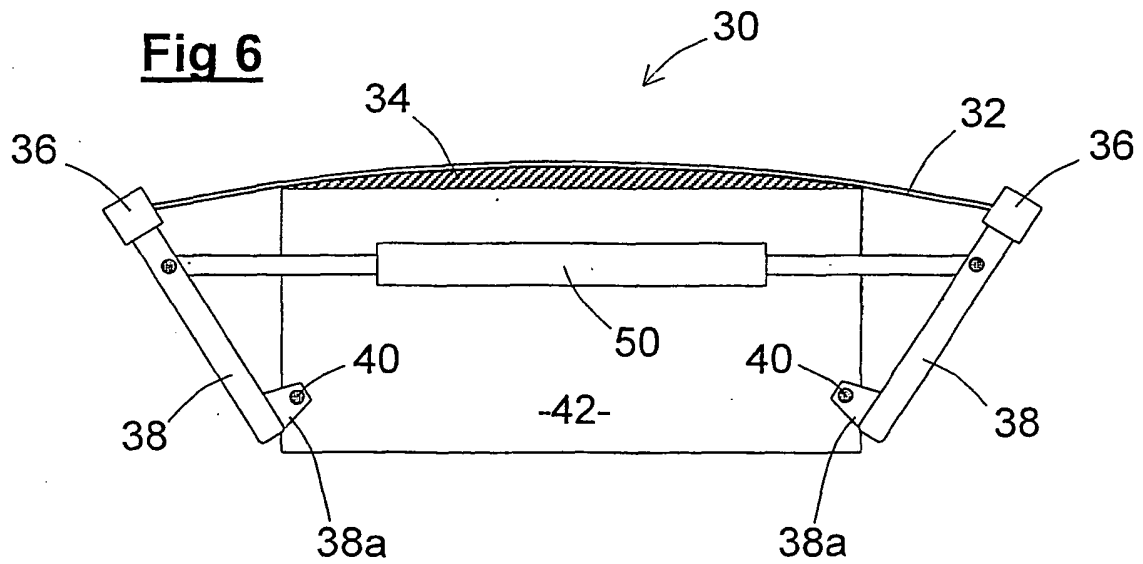


Fig 7

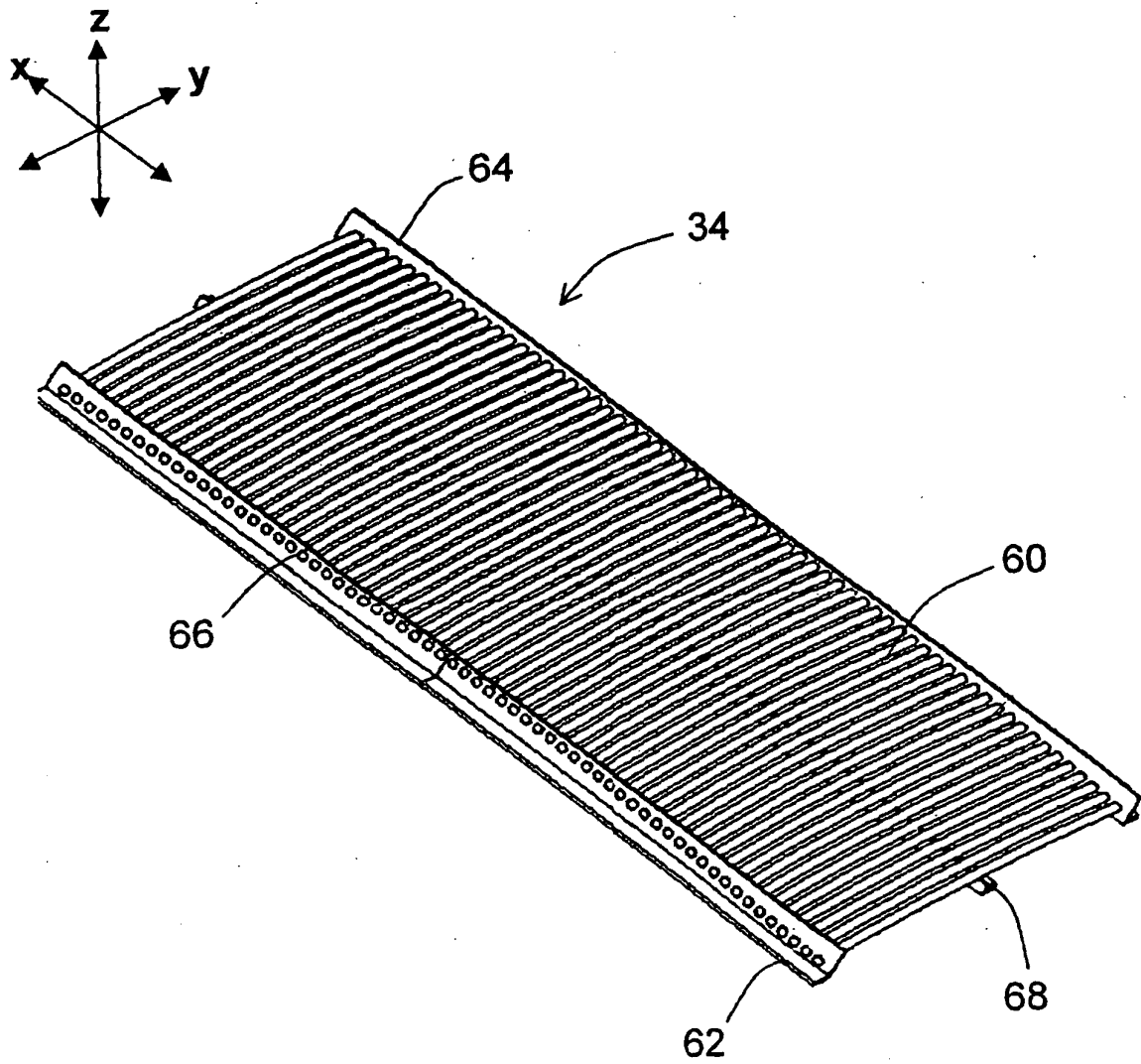


Fig 8

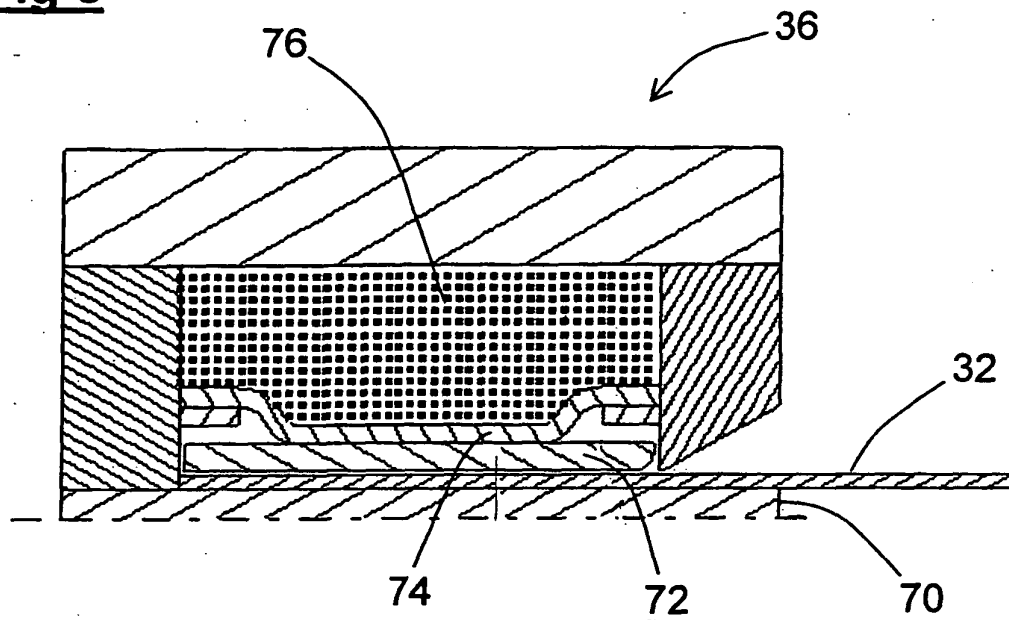


Fig 9

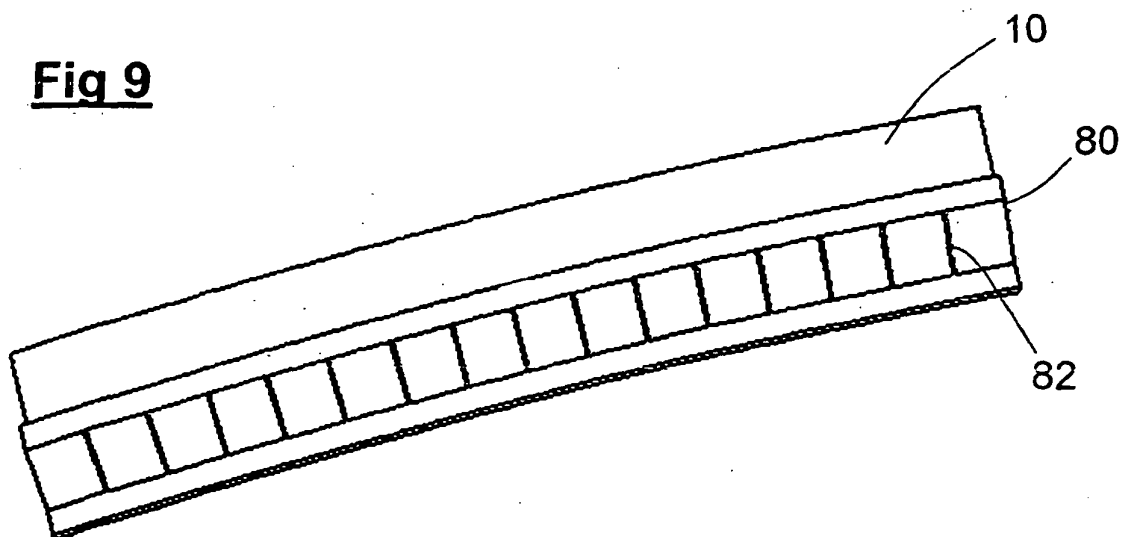


Fig 10

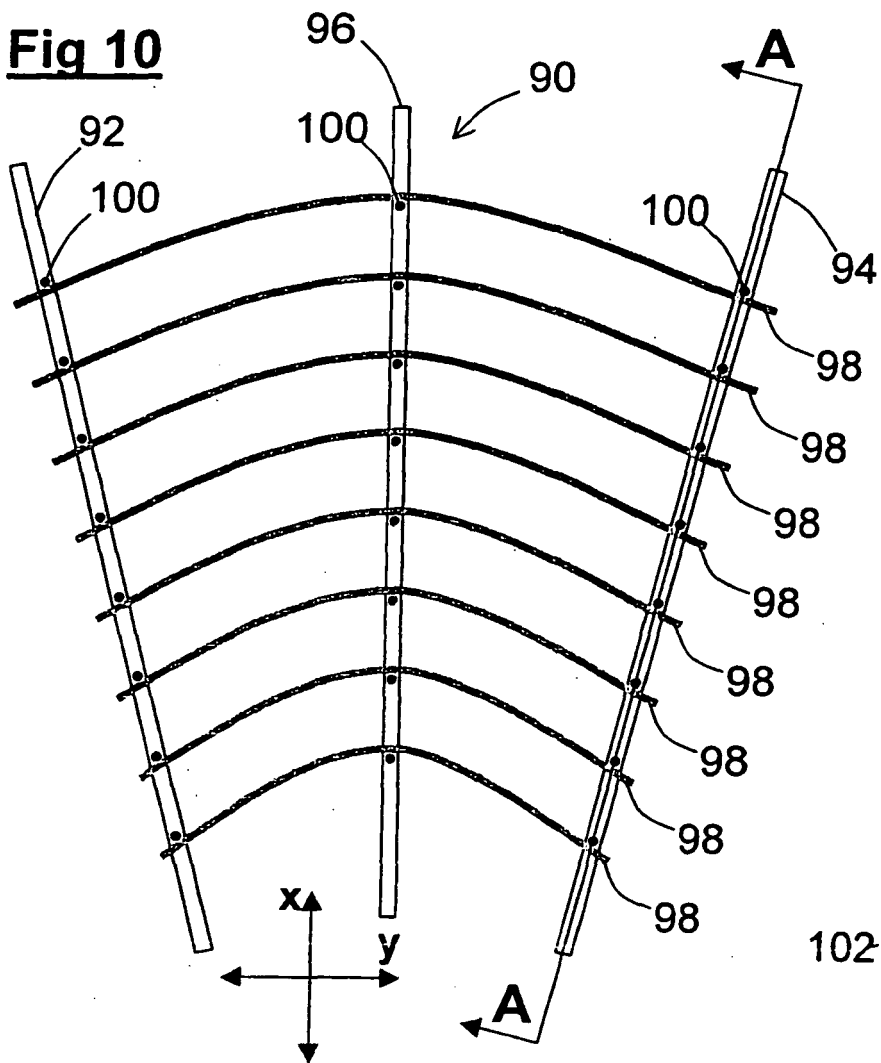


Fig 11

