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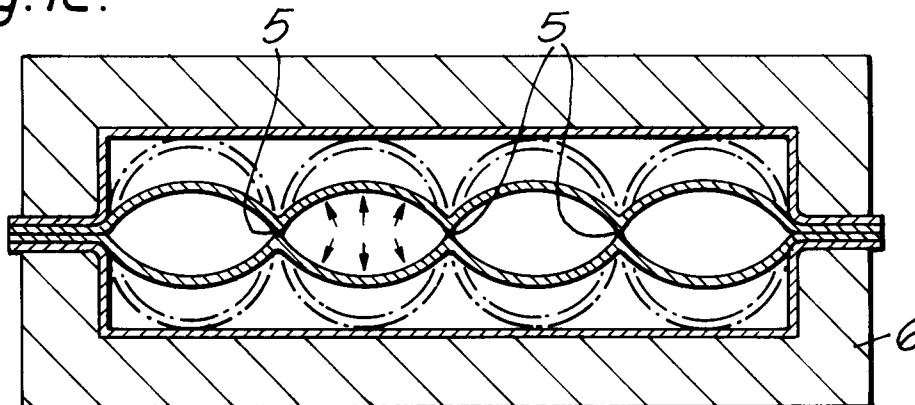
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(54) **Improvements relating to superplastically formed components.**

(57) An improvement to the method of manufacturing superplastically formed components is disclosed. The improvement consists of the overlaying of additional sheets (12,56,58,60) (doublers) of superplastically formable material on the main sheet(s) (7,54) of material, prior to superplastic forming, in regions where additional strength in the final component is required, or where excessive elongation is to occur during forming which, otherwise, would result in the region being locally thinned/weakened.

Fig.1C.



This invention relates to an improved method of forming components from materials having superplastic characteristics, and in particular to the use of additional sheets of material to improve the strength characteristics of formed components.

Metals having superplastic characteristics, such as titanium and many of its alloys, have a composition and microstructure such that, when heated to within an appropriate range of temperature and when deformed within an appropriate range of strain rate, they exhibit the flow characteristics of a viscous fluid. The condition in which these characteristics are attained is known as superplasticity, and, in this condition, the metals may be deformed so that they undergo elongations of several hundred percent without fracture or significant necking. This is due to the fine, uniform grain structures of superplastically formable metals which, when in the condition of superplasticity, allow grain boundary sliding by diffusion mechanisms so that the individual metal crystals slide relative to one another.

Diffusion bonding is often combined with superplastic forming to enable the manufacture of multi-sheet components of complex structure. The diffusion bonding process concerns the metallurgical joining of surfaces by applying heat and pressure which results in the co-mingling of atoms at the joint interface, the interface as a result becoming metallurgically undetectable. In order to achieve structures of a complex nature it is often a requirement that the multi-sheet metals are not bonded at all their contacting areas, and therefore bond inhibitors (commonly known as stop-off or stopping-off materials) are applied to selected areas by, for example, a silk screen printing process.

Titanium, in sheet form, has in its received state the characteristics needed for superplastic forming, and because it will absorb its own oxide layer at high temperature in an inert atmosphere to provide an oxide-free surface, it is also particularly amenable to diffusion bonding under pressure. The optimum temperature for this self-cleaning is 930°C which is also the optimum superplastic forming temperature. Thus, superplastic forming and diffusion bonding of titanium components can be carried out at the same time.

The ability to combine superplastic forming (SPF) and diffusion bonding (DB) has enabled our company to design multi-sheet components of complex structure that are essentially of one-piece construction. Such structures have a potential application in aircraft manufacture, for example the manufacture of wing leading and trailing edge control surfaces and canards which must have smooth, aerodynamic skin surfaces and be strong and light in weight.

Many aircraft components require structures of variable gauge. Attachment points on wing sections, for example, often require locally thickened regions,

for example.

Further, if large recesses or protrusion are required in a surface to be made by superplastic forming, the extreme, localised elongations required can result in the weakening (or necking) of the surface in these areas. Such surfaces are sometimes used in aerodynamic or hydrodynamic applications (see our European Patent Application No. 0 267 023, for example). The problem of weakening of the surface can be reduced by providing locally thickened areas of the sheet from which the surface is formed.

Previously such thickening or strengthening has been achieved by using uniformly thickened sheets in the multi-sheet SPF/DB process. However, it is then necessary to add an additional, onerous step to the production process of chemical-milling in order to reduce the thickness of the sheets in areas where strengthening is not required. This chemical milling step is time consuming, wasteful of material and produces hazardous waste products.

According to the present invention there is provided a method of manufacturing a component from a main sheet of superplastically formable material and at least one additional sheet of superplastically formable material having a face of smaller area than a face of said main sheet, the method including the steps of overlaying said face of the at least one additional sheet on said face of the main sheet prior to superplastically forming the component, and superplastically forming the component such that after forming said face of the at least one additional sheets is substantially in contact with said face of said main sheet.

Optionally said component is manufactured from a plurality of main sheets over at least one of which at least one additional sheet of material is laid; selected areas of said main and additional sheets are pre-treated with a bond inhibitor or to which a stop-off material has been applied;

and said main and additional sheets are laid over one another and diffusion bonded as required and superplastically formed in a mould to form a component with a cellular internal structure and having a thickened region where said additional sheet is present.

Optionally said at least one additional sheet of material is positioned on said main sheet in a region which when the main and additional sheets are positioned on a form tool will coincide with a region on the form tool which defines a recess or protrusion, the main and additional sheets being formed into said component by placing them in the form tool and applying heat and pressure.

Conveniently said face of the at least one additional sheet is spot welded to said face of the main sheet prior to superplastic forming.

Alternatively said face of the at least one additional sheet is line bonded to said face of the main sheet prior to superplastic forming.

Optionally said face of the at least one additional sheet is diffusion bonded to said face of the main sheet prior to superplastic forming.

Hereinafter the term "doubler" is used to refer to additional sheet(s) of material.

For a better understanding of the invention, embodiments of it will now be described by way of example only, and with particular reference to the accompanying drawings in which:-

Figs. 1A, 1B, 1C and 1D show the formation of a component by a conventional SFP/DB process, Figs. 2A, 2B, and 2C illustrate the application of a core-sheet reinforcing doubler,

Fig. 3 illustrates the application of a skin-sheet reinforcing doubler,

Fig. 4 shows an aircraft wing with a leading edge configuration which is manufactured in accordance with the invention,

Fig. 5 shows a main sheet onto which additional sheets (doublers) have been placed,

Fig. 6 shows a form tool for forming the wing leading edge of Fig. 4, and

Fig. 7 shows sheets positioned for forming in the form tool of Fig. 6.

Figs. 1A to 1D illustrate a known 4-sheet SPF/DB process for making a component having a cellular internal structure. 4 titanium alloy sheets, 1, 2, 3, and 4, are laid one on top of the other but the sheets 2 and 3 are separated by a pattern of stop-off material leaving a grid of untreated areas where line bonds 5 in the final structure are required. (See Fig. 1A). The two outer sheets 1 and 4 will after formation become the skin of the component and are hereinafter referred to as skin sheets, whereas the two inner sheets 2 and 3 will become the core or support walls of the component and are hereinafter referred to as core sheets.

Fig. 1B shows a cross-section through the assembly of skin and core sheets transverse to the line bonds 5. The core sheets 2 and 3 of this 4-sheet "pack" are pressed together at 930°C so that diffusion bonding between the core sheets 2 and 3 takes place at the line bonds but is inhibited elsewhere wherever the stop-off material is laid.

Fig. 1C shows how the bonded pack is clamped between the two halves of a nickel chromium steel mould 6, heated to 930°C and an inert gas introduced under pressure via suitable gas pipe connections to regions between the 4-sheets of the pack. As the inert gas is introduced initially to the regions between the skin and core sheets, and subsequently between the core sheets, the sheets deform superplastically and bow out towards the inner mould surfaces, as shown by the dotted lines. The core sheets 2 and 3 do not separate at the diffusion bonded line bonds 5. Eventually the structure superplastically deforms to correspond to the inner shape of the mould but, because

of the line bonding, vertical walls of titanium alloy are formed at regular intervals throughout the structure as shown in Fig. 1D.

As stated previously, although this conventional technique is satisfactory for many applications, sometimes locally thickened regions are required. For example, for high strength cellular structures it may be desired to have thickened vertical or horizontal walls. This can be achieved by the method described below.

In Fig. 2a is shown a plan view of a core sheet 7 of superplastically formable and diffusion bondable material having an inner area X bounded by a border 8 which is to be superplastically deformed and an outer area Y bounded by a border 9 which is to cooperate with the clamping surfaces of a forming tool, such as that shown at 6 in Fig. 1C, and via which inflating gas will be introduced to the inner surface 8 by means of breakthrough areas (not shown). A bond line 10 defines an area of the area X which during subsequent diffusion bonding bonds to an adjacent identical core sheet. A stop-off material, or bond inhibitor, is applied by any known method, for example silk screen printing, to all areas of the inner area X except the bond line and a rectangular area Z bounded by a border 11 (shown dotted) in the centre of the area X.

The area Z is that part of the finished cellular structure where thickening is required. A rectangular doubler 12 of identical superplastically deformable diffusion bondable material to that of the core sheet 7 and having chamfered edges and dimensions identical to the area Z is laid over the area Z. The bond line 10 is continued over the surface of the doubler 12 which is otherwise treated with stop-off.

The sheet 7 and its overlaid doubler will be assembled into a bond pack in the manner shown in Fig. 1B. The sheet and doubler will be positioned as one of the core sheets, say 2 in Fig. 1B. An identical combination of core sheet and doubler will form the other core sheet, in this case 3 in Fig. 1B, and so that the two doublers will be in contact. Prior to the skin sheets 1 and 4 being overlaid onto the core sheets 2 and 3, the core sheets 2 and 3 are subjected to diffusion bonding pressure at 930 degrees C. The doublers diffusion bond to their respective core sheets 7 in the regions Z. Each pair of core sheets and doublers also diffusion bond to each other along the bond line 10. The pack is then assembled as shown in Figure 1B.

After assembly the bond pack is placed in a steel mould tool, for example 6 in Fig. 1C, being clamped by the mould faces at the area Y. The temperature of the tool is raised to 930 degrees C in a suitable furnace and Argon gas is initially introduced to the regions between the skin and core sheets 1, 2 and 3, 4 to blow them under uniform pressure to the designed shape, for example as shown in Fig. 1D. When the skin sheets 1 and 4 are formed, the regions between the core sheets 2 and 3 are similarly blown under

pressure, and form the vertical walls of the component. In addition to shaping, the application of pressure may also result in the diffusion bonding of surfaces as they come into contact with one another. In this case, because of the existence of the doublers, the cross-section of the formed support wall will be thicker than the formed skin in those regions. Note that after the SPF operation the plan view of the doubler, originally area Z, will be reduced to an area Z' bounded by a border 11'. Fig. 2B is a view then on section A-A in Fig. 2A and shows the formed thickened support wall 13. In contrast, the thickness of the skin at 14 is thin and corresponds approximately to the thickness of the skins 1 and 4 in Fig. 1B before DB/SPF. Regions 15, where the support wall joins the outer skin 14 are also thickened due to the doubler and the dimensions of this region 15 are clearly determined by the width of the doubler in relation to the height of the SPF mould tool.

Fig. 2C is a section on B-B in Fig. 2A after SPF/DB and shows the formed structure in the region of a non-thickened support wall 16.

Where it is specifically desired to increase the thickness of the skin sheets 1 or 4 in Fig. 1B, suitable shaped doublers are located on those sheets prior to core sheet bonding. Fig. 3 shows a cross-section through a formed cellular structure in which doublers had been applied to both upper and lower skins (1 and 4 in Fig. 1B) in the region of a support wall formed by the core sheets (2 and 3 in Fig. 1B). The skin reinforcing doublers have resulted in thickened areas 17 which due to the constraints of the mould tool have resulted in uniformly flat outer skins but humped inner surfaces in the region of the support walls 18.

It will be appreciated that many modifications, variations and improvements to the method according to this embodiment may now be devised. For example, skin doublers may now be employed in structures made from any plurality of SPF sheets not just 4-sheet cellular structures. When used to reinforce outer skins in 4-sheet structures, the doublers need not reinforce regions adjacent inner support walls formed from core sheets, but may thicken any area of the outer skin. Many other variations will now suggest themselves to those skilled in the art.

Doublers may also be employed in the manufacture of surfaces which require large recesses or protrusions to avoid localised weakening in these areas due to the excessive localised elongation. Such a surface is shown in Figure 4 at 50 and forms part of the leading edge of a wing 52.

Figure 5 shows the main sheet 54 from which the surface is to be formed, and onto which three additional sheets (doublers) 56, 58 and 60 have been laid. The additional sheets 56, 58 and 60 are positioned in the region where the recess is required in the finished component. The sheets 56, 58 and 60 are attached to the main sheet and to one another by spot

welding, line bonding or diffusion bonding. The methods of spot welding and line bonding, for example at opposing sides of the mound formed by the additional sheets, allow all the sheets to move relative to one another where they are not bonded during subsequent superplastic forming. If the sheets are diffusion bonded in their contacting areas then this relative movement will not be possible.

The lower tool of a form tool for the manufacture of the surface 50 is shown at 62 in Figure 6. The region 64 will define the recess in the wing leading edge.

Figure 7 shows the assembly of Figure 5, positioned between the two members of a form tool 66. The assembly is heated to a temperature at which the sheets of material become superplastic (930°C for example). Gas pressure is applied to the sheets via a gas feed line (not shown). This forces the sheets into the cavity of the lower tool 62, and hence forms the leading edge for the wing 52 - as illustrated in Figure 4.

The doublers are positioned so that they coincide with the region 64 of the lower tool 62 (which forms the recess in the wing leading edge). It will be apparent that where the sheets 54 - 60 are forced against region 64, they undergo a greater degree of elongation than in other areas (which can result in localised thinning). The presence of the doublers compensates for this and result in the finished component having an approximately uniform thickness.

Claims

1. A method of manufacturing a component from a main sheet of superplastically formable material (7,54) and at least one additional sheet of superplastically formable material (12,56,58,60) having a face of smaller area than a face of said main sheet, the method including the steps of overlaying said face of the at least one additional sheet on said face of the main sheet prior to superplastically forming the component, and superplastically forming the component such that after forming said face of the at least one additional sheets is substantially in contact with said face of said main sheet.
2. A method according to claim 1 wherein said component is manufactured from a plurality of main sheets (1,2,3,4,) over at least one of which at least one additional sheet of material (12) is laid; selected areas of said main and additional sheets are pretreated with a bond inhibitor or to which a stop-off material has been applied; and said main and additional sheets are laid over one another and diffusion bonded as required and superplastically formed in a mould (6) to form a component with a cellular internal structure and having a

thickened region (15,17) where said additional sheet is present.

3. A method according to claim 1, wherein said at least one additional sheet of material is positioned on said main sheet in a region which when the main and additional sheets are positioned on a form tool will coincide with a region on the form tool (62) which defines a recess or protrusion (64), the main and additional sheets being formed into said component by placing them in the form tool and applying heat and pressure. 5
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4. A method according to claim 1 or claim 3, wherein said face of the at least one additional sheet is spot welded to said face of the main sheet prior to superplastic forming. 15
5. A method according to claim 1 or claim 3, wherein said face of the at least one additional sheet is line bonded to said face of the main sheet prior to superplastic forming. 20
6. A method according to claim 1 or claim 3, wherein said face of the at least one additional sheet is diffusion bonded to said face of the main sheet prior to superplastic forming. 25

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Fig.1A.

PRIOR ART

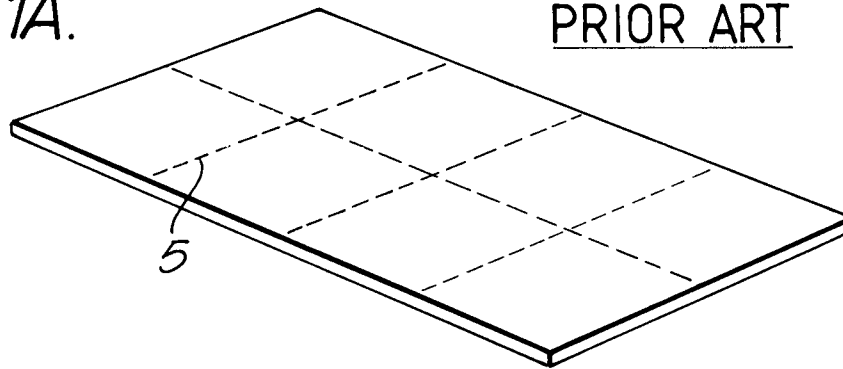


Fig.1B.

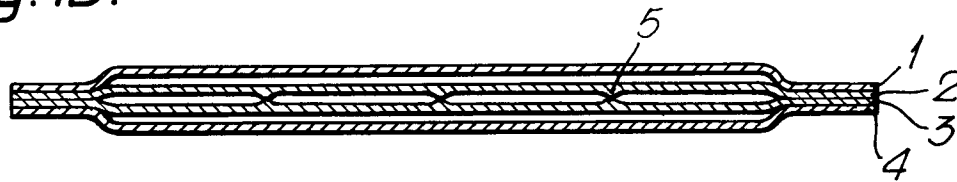


Fig.1C.

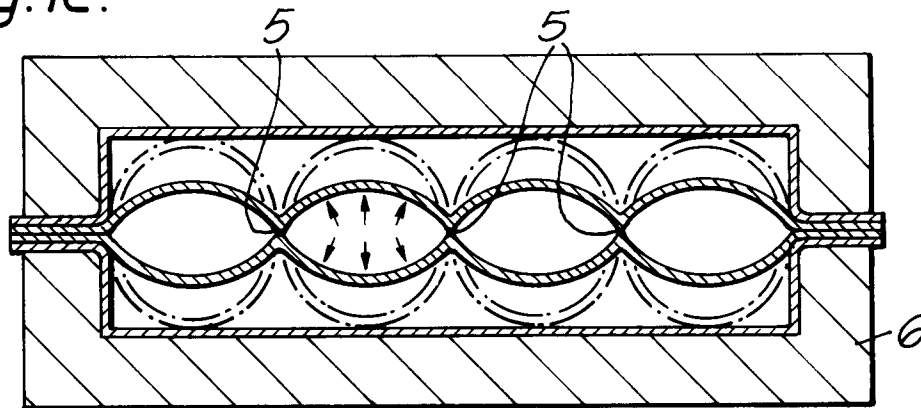
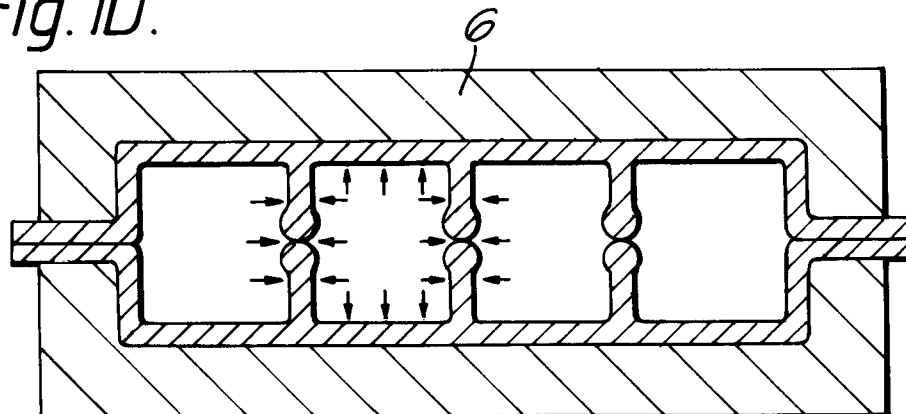
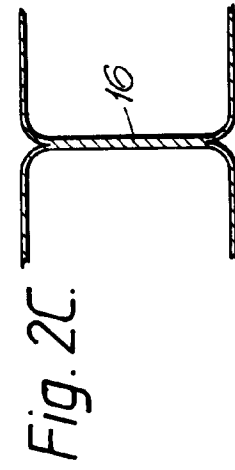
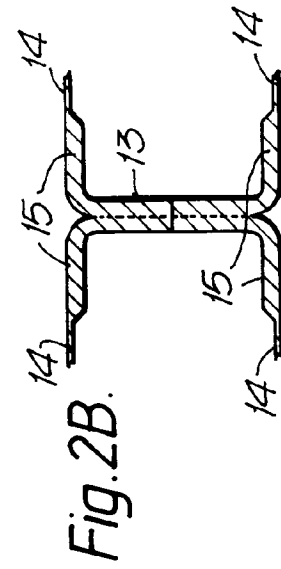
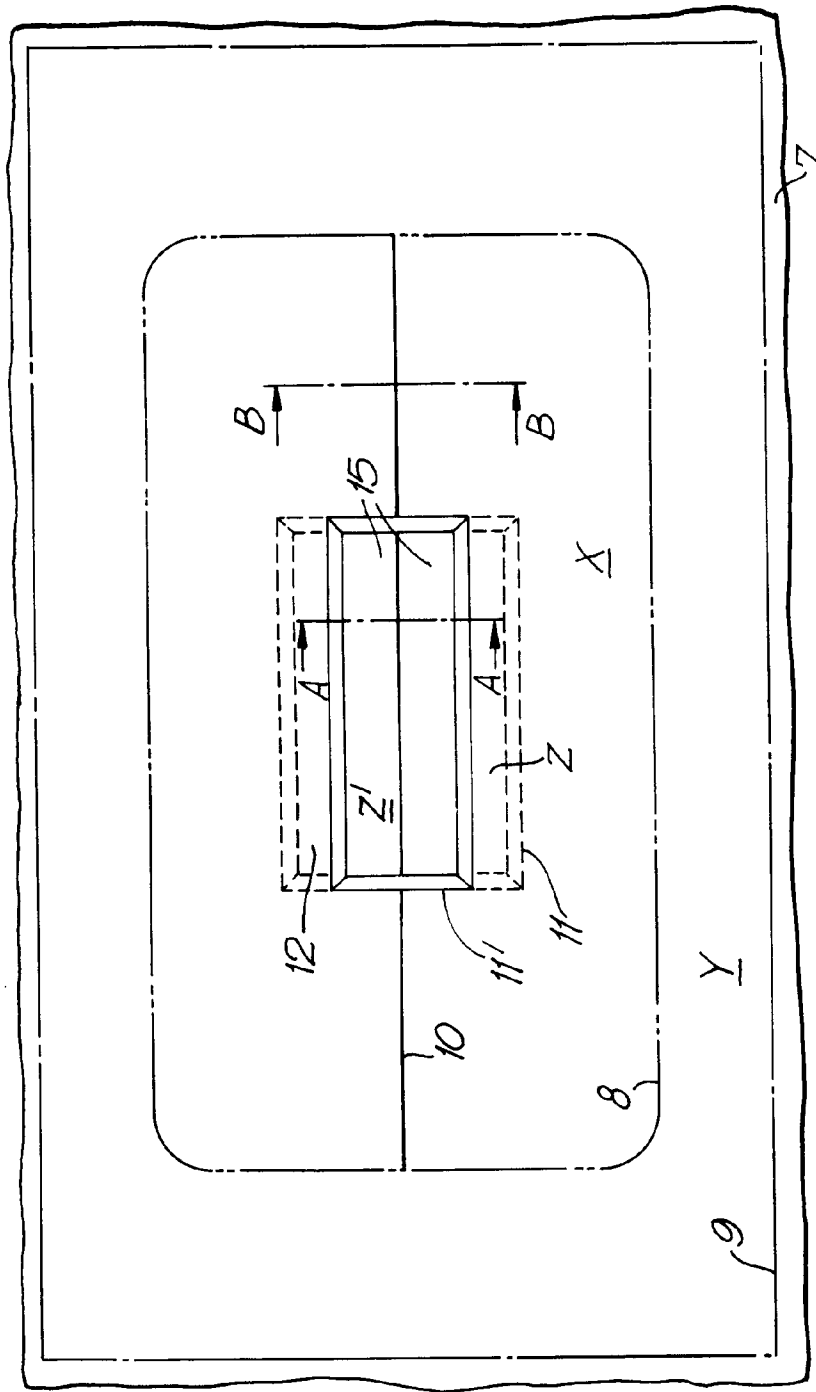


Fig.1D.





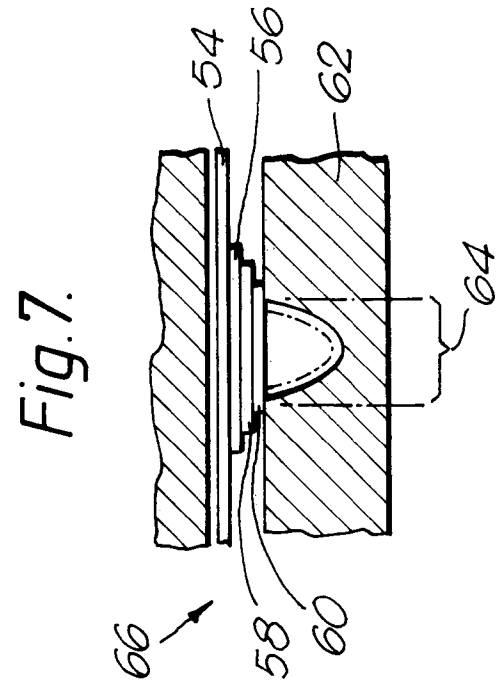
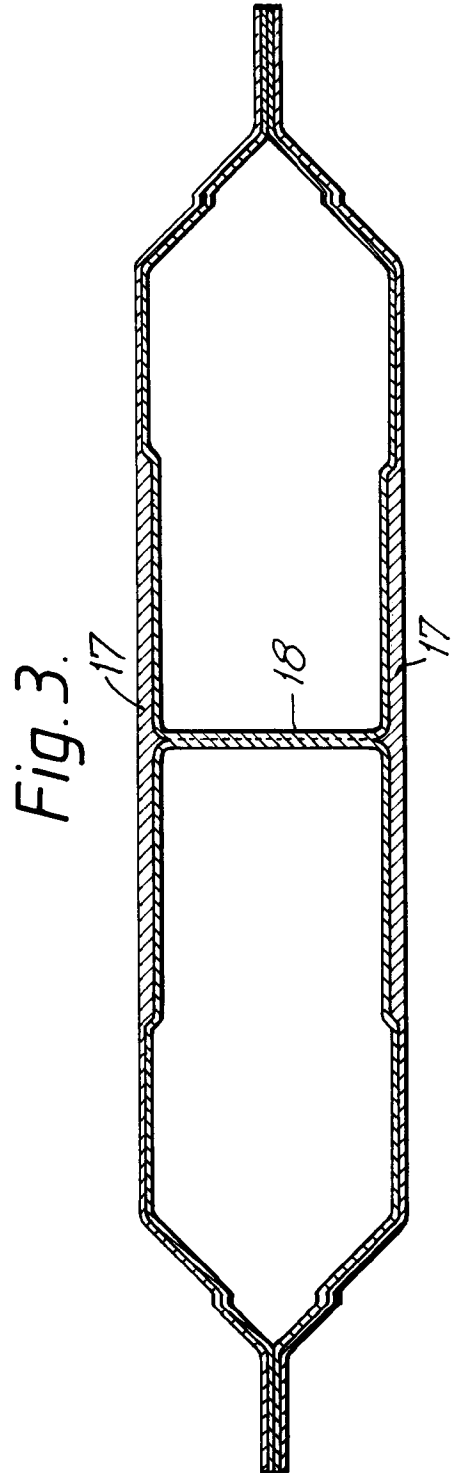


Fig.4.

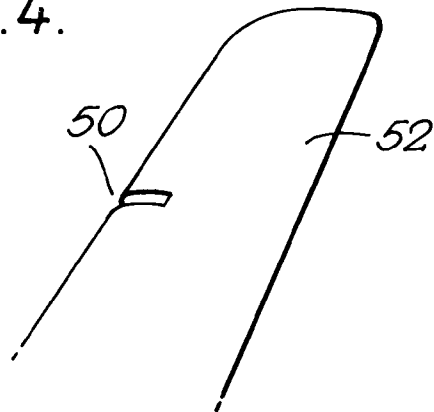


Fig.5.

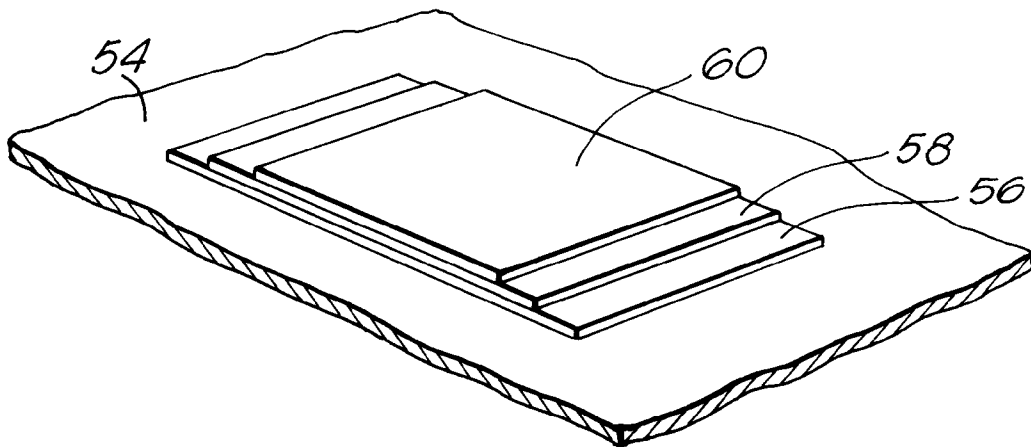
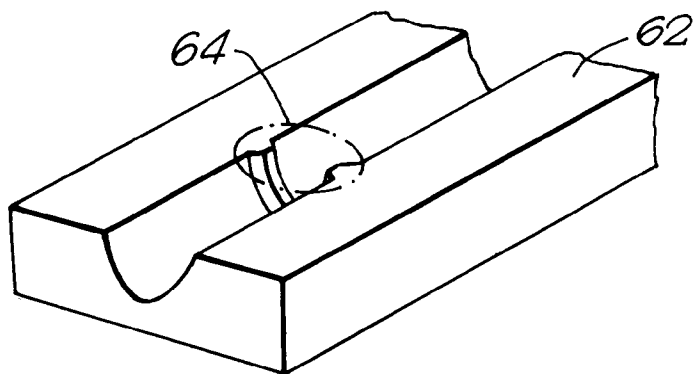


Fig.6.





European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 92 30 1205

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-2 109 711 (GRUMMAN AEROSPACE CORPORATION) * page 1, line 86 - page 1, line 91 * * page 3, line 27 - page 3, line 57 * * page 4, line 23 - page 4, line 30; figures 1-13 *	1-6	B21D26/02
X	US-A-4 361 262 (ISRAELI) * column 4, line 5 - column 4, line 48; figures 1-5 *	1,2	
A	US-A-4 304 821 (MASASHI)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B21D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05 JUNE 1992	Examiner GERARD O.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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