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(54) METHOD FOR LOCAL FORMING OF A HOLLOW WORKPIECE

VERFAHREN ZUM LOKALEN UMFORMEN EINES HOHLEN WERKSTÜCKS

PROCÉDÉ DE FAÇONNAGE LOCAL D'UNE PIÈCE CREUSE

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Description

[0001] The invention relates to a method for local forming of a hollow profile where a forming tool interacts with an induction coil.

[0002] It is well known to make local imprints in a work piece with uniform temperature. In conventional forming techniques the final shape of the work piece is defined by the geometry of a stamp and a die or backing tool.

[0003] Many conventional forming operations are often performed at ambient temperatures, where the formability is relatively low. Exceeding the critical plastic strain will lead to e.g. cracks, localised necking or formation of Luderbands or even failure of the work piece.

[0004] Cold forming will furthermore lead to work hardening in the material being formed. This leads to a lower ductility during the forming operation as well as in the final work piece.

[0005] The tool concept, consisting of a stamp and a backing tool, often demands a time consuming and expensive fabrication of necessary tools. The relatively complex tools may also lead to poor reliability in production or high maintenance costs.

[0006] Furthermore it is often difficult or even impossible to insert a backing tool inside a hollow work piece due to the limited accessibility. This is particularly the case for long closed profiles such as bumper beams or profiles having a complex geometry. This will add a limitation on the design of such profiles.

[0007] Work pieces such as extruded and formed aluminium profiles often exhibit unwanted deviations from the nominal geometry. Such geometric deviations may often disqualify the parts in applications where accurate and consistent geometry is required.

[0008] Such deviation may e.g. represent a problem in assembly or joining processes such as welding, brazing, bonding, riveting or other mechanical joining methods, which usually require a good fit up of the parts to be joined.

[0009] Such problems may require the use of calibration operations such as reshaping, milling, grinding, cutting or etching. This often represents time-consuming operations and thereby increased production costs.

[0010] Furthermore they also have limited applicability. In the case of milling, grinding, cutting or etching, the calibration operation generates waste material.

[0011] Calibration using cold forming is associated with a relatively high degree of elastic spring back of the work piece. Due to the elastic spring back, small geometrical corrections will be difficult to perform. Variations in the spring back e.g. due to inconsistent mechanical properties or geometrical dimensions, will cause deviations in the final geometry of the work piece.

[0012] The US 4,532,793 discloses a method for local forming of a sheet metal where a force is applied to a forming tool for forming a part of said sheet and where a predefined local area of the sheet is heated to a temperature where the yield stress of the material in the said area is substantially lower than the yield stress of the surrounding colder material by an induction coil and that this heated area is formed by pressing the forming tool into the heated area while the surrounding colder material of the sheet is maintained substantially unaffected of the forming operation.

[0013] The present invention as defined by claim 1 or 2 represents a flexible method for fabrication of e.g. local protrusions or imprints. The principles also enable a higher degree of forming of the work piece and can be performed preferably without any backing tool, thereby enabling processing in regions of the work piece where the access of a backing tool is limited. The method furthermore improves the flexibility of the geometry due to the ability of obtaining small bending radii or sharp edges on the protrusions or imprints.

[0014] The relative simple, low cost apparatus also decrease the possibility of failure during production, thereby reducing maintenance costs, increasing the up time of the production and reducing the scrap rate. The method furthermore enables the calibration of end sections without any cutting operations.

[0015] The present invention utilises the temperature dependency of the mechanical properties of the material. This spatial variation of mechanical properties across the work piece is utilised to allow forming within a locally heated region without distorting the surrounding material, which has a higher resistance to forming. The present invention may for some applications, utilise the thermal field as a virtual die for defining the regions of plastic flow and hence the final shape.

[0016] This is done by rapid local heating of selected regions of the profile, which renders the heated material into a soft and ductile state with improved formability. The localised heating can be manipulated to form a sufficiently sharp boundary between the soft and hot material that easily forms plastically and the adjacent material at lower temperature, which has a higher resistance to forming.

[0017] The rapid local heating is done. by an induction coil, which is situated in the neighbourhood or on the surface of the work piece. Material in close proximity of the coil will be heated until a temperature is reached where the yield stress of the material is substantially lower than the surrounding material. Thus, the forming operation takes place in material with an essentially non-uniform temperature distribution. As the surrounding material have higher strength, the difference in material strength will enable the surrounding material to maintain its original shape.

[0018] It is known from the publication "Adapted Mechanical Properties for Improved Formability of Aluminium Blanks by Local Induction Heating" by Michael Kerausch, Marion Merklein and Manfred Geiger (JSAE 20037024), presented at the International Body Engineering Conference October 2003 in Tokyo, to use induction coils to locally heat an aluminium alloy to modify the material properties of a limited area of the aluminium

sheet. The sheet is heated up to a predefined maximum temperature and thereafter cooled down to room temperature. The heating and cooling phase form part of a heat treatment aiming to modify the material properties of the treated sheet. After cooling down the sheet, a cylindrical cup was deep drawn into the material, thereby proving a better formability of the heat treated material.

[0019] However, this technique does not take advantage of the possibility of forming parts of the sheet in a heated mode. The heating procedure is used as a material property treatment aiming to change the room temperature properties within a localised area of the profile. Even though this method changes the room temperature formability of the material, the benefit of the process is substantially lower than for forming in a partially hot state.

[0020] In contrast to the above described method, the present invention is based on forming of a localised hot area of the work piece, thereby taking advantage of the extended softening of the heated material and the increased difference in material strength between the hot region and the surrounding cooler material. Furthermore the invention requires simpler and cheaper tooling compared to conventional forming. It also requires very low loads for forming, which reduce the investment cost as well as the complexity of the production equipment. In addition, the geometric accuracy of the components and parts fabricated by the method is high due to limited elastic strain as a consequence of the low yield stress at elevated temperature. Normally, the forming is done without use of any lubricants. Another benefit is obtained during the forming since most metallic materials exhibits reduced anisotropy at elevated temperatures, but this depends on the initial texture as obtained from the preceding thermo mechanical process route.

[0021] A further benefit of the invention is the possibility to control the mechanical properties in the protrusion or imprint. By the localised heating before and during forming, the work hardening is reduced, thereby ensuring an even better ductility in the formed regions. This is especially advantageous in regions with sharp forming radii which often experience large strains in e.g. impact absorbing members.

[0022] The invention will now be further explained by means of figures, where

Fig. 1 shows a first example of a tool set up, for making a local imprint,

Fig. 2 shows the cross section of a hollow profile and forming tool prior to a forming operation,

Fig. 3 shows the cross section of a hollow profile and tool during the forming operation,

Figs. 4a-b show a first example of a sequence diagram showing the heating power and the tool displacement, and a typical resulting thermal cycle for an arbitrary position in the forming area,

Figs. 5a-b show an example of a local imprint in an extruded profile,

Figs. 6a-b show an example of a local imprint in an extruded profile,

Figs. 7a-b show an example of a local imprint in a crash absorbing member,

Figs. 8a-b show an example of a tool set up with a rolling wheel tool,

Figs. 9a-b show an example of a tool set up with a sliding tool,

Fig. 10 shows an example of a tool set up.

Figure 1 shows a section of a work piece such as a hollow profile 1 prior to forming. An induction coil 2 is in the proximity of or directly at the profile surface 3. The induction coil 2 generates localised heat in the profile side wall 4. The affected region of the hollow profile 1 is heated until a favourable transient temperature distribution is reached. A stamp 5 is thereafter pressed onto the area 6.

Figure 2 shows the cross section of the hollow profile 1, an induction coil 2 and a stamp 5 prior to a forming operation. The induction coil is situated on the profile surface 3. As the induction coil is turned on, a localised hot area 6 will occur in the profile side wall 4. The stamp 5 will normally be placed above the hot area 6 inside the induction coil 2 prior to forming.

Figure 3 shows the cross section of the profile 1, the induction coil 2 and the stamp 5 during or after the forming operation. The area of the profile side wall 4 surrounding the induction coil 2 will remain mostly unaffected of the heating from the heat source. The profile 1 will be insignificantly heated by the electro magnetic field and as the induction heating process is highly localised, the surrounding structure of the profile 1 remains unaffected during forming. When the stamp 5 is pressed onto the profile 1, the softened hot area 6 will therefore deform while the adjacent unaffected area will resist deformation.

Figure 4a shows an example of the time history of the temperature in the heated area during a local forming operation. Figure 4b shows an example of a time-displacement curve for the stamp related to the temperature cycles in Figure 4a.

Figures 5a-b show an example of a section of a profile 12 provided with a local imprint 13. Figure 5a

shows a perspective view of the profile and figure 5b shows a cross sectional view of the profile 12 with an imprint 13. In long closed hollow profiles such as bumpers, there is often a need for local protrusions or imprints 13 where for example lights, sensors or other equipment can be mounted. Such imprints 13 can easily be made by the present method.
There can be as many protrusions or imprints as desired on a work piece, thereby enabling the design of a complicated shape. Even if there is only one imprint 13 in one of the side walls of the profile 12 described on Figure 7, it should be understood that it is possible to make protrusions or imprints on any of the side walls of a profile or other work piece.

Figures 6a-b show a section of a profile 12 provided with a local imprint 13. Figure 6a shows a perspective view of the section and Figure 6b shows a cross sectional view of the section with the protrusion 13. With an induction coil enabling the local heating of an edge of a hollow profile, it is possible to make imprints on edges, corners or the like.

Figures 7a-b show a hollow profile provided with local imprints. Figure 7a shows a perspective view of an impact absorbing member 14. In impact absorbing members 14, such as crash boxes, it is often desired to introduce protrusions or imprints 13 which work as triggers to ensure a controlled deformation of the impact absorbing member 14 in an impact situation. The impact absorbing member 14 of the present example is provided with a set of imprints 13 in at least one of the member side walls 15.

Figure 7b shows a cross sectional view of the impact absorbing member 14. On Figure 7 the imprints 13 are made in two opposing member side walls 15. It is also possible to make a set of imprints in two member walls facing directly onto each other. Furthermore, it is possible to make protrusions or imprints in more than two side walls of the member if this is found suitable.
It should also be noted that imprints or protrusions can be made in the member end plate 10 of the impact absorbing member 14. It is also possible to make one or more protrusions or imprints in the member flanges 17 of the impact absorbing member 14.

Figures 8a-b show a tool set up. A rotating tool 22 in combination with an induction coil 2 which moves relative to a work piece, can be used to make an imprint. The direction of the imprint on the work piece can be arbitrary and also curved. The shape of the imprint can change as a function of the shape of the rotating tool 22.

Figure 8a shows the rotating tool 22 in a perspective view. A forming wheel is situated in the area affected by an induction coil 2. As the induction coil 2 is moved along the profile side wall 4 (see Fig. 8b), at the same time as a force is acting on the axle an imprint will be made. Figure 8b shows the rotating tool 22 in a cross sectional view. The axis 25 situated in the center 23 of the forming wheel 24 (see Fig. 8a) can be mounted separately from or directly onto the induction coil 2.

Figures 9a-b show a tool set up. A sliding tool 26 in combination with an induction coil 2 which moves relative to a work piece can be used to make an imprint. The direction of the imprint in the work piece can be freely chosen. Elevating or lowering the sliding tool 26 relative to the surface of the profile side wall 4 can continuously change the depth of the imprint (see Fig. 9b).

Figure 9a shows a perspective view of such sliding tool 26 and Figure 9b shows a cross sectional view of the sliding tool. The sliding tool 26 is situated in an induction coil 2 and slides over the surface of a profile side wall 4 while it is pressed down onto the profile side wall 4. The sliding tool 26 will function as described above for the rotating tool.

Figure 10 shows another example of a tool set up. Depending on the shape of the rotating tool 22, it is possible to vary the geometry of the imprint during forming.

[0023] The method can be used to any local reshaping of a hollow profile and is especially suitable for local forming in thin walled open or closed profiles such as extruded or rolled hollow profiles. Typical applications include automotive structures such as bumpers, crash boxes, engine cradles and other frame structures.

[0024] It should also be noted that the method can be used on any material being affected by a heat treatment, such as aluminium alloys, other metals such as steel, magnesium and alloys of these, polymers and the like.

[0025] The method can also be used to make imprints or protrusions on already formed imprints or protrusions.

Claims

1. Method for local forming of a hollow profile (1,12) preferably an impact absorbing member (14), where a force is applied to a forming tool for forming a part of said profile (1,12) and where a predefined local area (6) of the profile (1,12) is heated rapidly to a temperature where the yield stress of the material in the said area (6) is substantially lower than the yield stress of the surrounding colder material by an induction coil (2) and that this heated area (6) is formed by pressing the forming tool into the heated area (6)

while the surrounding colder material of the profile (1,12) is maintained substantially unaffected of the forming operation,
whereby the induction coil (2) is placed in the immediate neighbourhood of or on the surface (3) of the profile side wall (4,15) for heating the area (6) and whereby the forming tool is a stamp (5), which is placed inside the induction coil (2) for performing the forming operation.

2. Method for local forming of a hollow profile (1,12) preferably an impact absorbing member (14), where a force is applied to a forming tool for forming a part of said profile (1,12) and where a predefined local area (6) of the profile (1,12) is heated rapidly to a temperature where the yield stress of the material in the said area (6) is substantially lower than the yield stress of the surrounding colder material by an induction coil (2) and that this heated area (6) is formed by pressing the forming tool into the heated area (6) while the surrounding colder material of the profile (1,12) is maintained substantially unaffected of the forming operation,
whereby the induction coil (2) is placed in the immediate neighbourhood of or on the surface (3) of the profile side wall (4,15) for heating the area (6) and whereby the forming tool is a rotating tool (22) or a sliding tool (26), which is placed inside the induction coil (2) and the forming tool in combination with the induction coil (2) is moved relative to the hollow profile (1,12) for performing the forming operation.

3. Method according to claim 1 or 2, whereby the forming operation is performed without a backing device.

Patentansprüche

1. Verfahren zum lokalen Umformen eines Hohlprofils (1, 12), vorzugsweise eines stoßabsorbierenden Glieds (14), bei dem ein Umformwerkzeug zur Umformung eines Teils des Profils (1, 12) mit einer Kraft beaufschlagt wird und bei dem ein vordefinierter lokaler Bereich (6) des Profils (1, 12) durch eine Induktionsspule (2) zügig auf eine Temperatur, bei der die Fließspannung des Materials in dem Bereich (6) im Wesentlichen unter der Fließspannung des umgebenden kälteren Materials liegt, erhitzt wird und dieser erhitzte Bereich (6) umgeformt wird, indem man das Umformwerkzeug in den erhitzten Bereich (6) drückt, während das umgebende kältere Material des Profils (1, 12) im Wesentlichen von dem Umformvorgang unbeeinflusst bleibt,
wobei man zur Erhitzung des Bereichs (6) die Induktionsspule (2) in die unmittelbare Nachbarschaft der Oberfläche (3) oder auf die Oberfläche (3) der Profilseitenwand (4, 15) platziert und wobei es sich bei dem Umformwerkzeug um einen Stempel (5) handelt, der zur Durchführung des Umformvorgangs in die Induktionsspule (2) platziert wird.

2. Verfahren zum lokalen Umformen eines Hohlprofils (1, 12), vorzugsweise eines stoßabsorbierenden Glieds (14), bei dem ein Umformwerkzeug zur Umformung eines Teils des Profils (1, 12) mit einer Kraft beaufschlagt wird und bei dem ein vordefinierter lokaler Bereich (6) des Profils (1, 12) durch eine Induktionsspule (2) zügig auf eine Temperatur, bei der die Fließspannung des Materials in dem Bereich (6) im Wesentlichen unter der Fließspannung des umgebenden kälteren Materials liegt, erhitzt wird und dieser erhitzte Bereich (6) umgeformt wird, indem man das Umformwerkzeug in den erhitzten Bereich (6) drückt, während das umgebende kältere Material des Profils (1, 12) im Wesentlichen von dem Umformvorgang unbeeinflusst bleibt,
wobei man zur Erhitzung des Bereichs (6) die Induktionsspule (2) in die unmittelbare Nachbarschaft der Oberfläche (3) oder auf die Oberfläche (3) der Profilseitenwand (4, 15) platziert und wobei es sich bei dem Umformwerkzeug um ein rotierendes Werkzeug (22) oder ein gleitendes Werkzeug (26) handelt, wobei das Umformwerkzeug zur Durchführung des Umformvorgangs in die Induktionsspule (2) platziert und in Kombination mit der Induktionsspule (2) relativ zum Hohlprofil (1, 12) bewegt wird.

3. Verfahren nach Anspruch 1 oder 2, wobei man den Umformvorgang ohne Unterlageeinrichtung durchführt.

Revendications

1. Procédé de façonnage localisé d'un profilé creux (1, 12), de préférence une pièce (14) absorbant les impacts, une force étant appliquée à un outil de formage en vue de façonner une partie dudit profilé (1, 12), une zone localisée prédéfinie (6) dudit profilé (1, 12) étant chauffée rapidement, par une bobine à induction (2), jusqu'à une température à laquelle la limite de contrainte du matériau, dans ladite zone (6), est substantiellement inférieure à la limite de contrainte du matériau environnant plus froid, et cette zone chauffée (6) étant formée en pressant l'outil de formage dans ladite zone chauffée (6), tandis que le matériau environnant du profilé (1, 12), plus froid, est maintenu substantiellement non affecté par l'opération de formage,
dans lequel la bobine à induction (2) est placée au voisinage direct, ou au contact de la surface (3) de la paroi latérale (4, 15) du profilé, en vue de chauffer la zone (6), et dans lequel l'outil de formage est un poinçon (5) qui est logé à l'intérieur de ladite bobine à induction (2), afin d'exécuter l'opération de formage.

2. Procédé de façonnage localisé d'un profilé creux (1, 12), de préférence une pièce (14) absorbant les impacts, une force étant appliquée à un outil de formage en vue de façonner une partie dudit profilé (1, 12), une zone localisée prédéfinie (6) dudit profilé (1, 12) étant chauffée rapidement, par une bobine à induction (2), jusqu'à une température à laquelle la limite de contrainte du matériau, dans ladite zone (6), est substantiellement inférieure à la limite de contrainte du matériau environnant plus froid, et cette zone chauffée (6) étant formée en pressant l'outil de formage dans ladite zone chauffée (6), tandis que le matériau environnant du profilé (1, 12), plus froid, est maintenu substantiellement non affecté par l'opération de formage,
dans lequel la bobine à induction (2) est placée au voisinage direct, ou au contact de la surface (3) de la paroi latérale (4, 15) du profilé, en vue de chauffer la zone (6), et dans lequel l'outil de formage est un outil rotatif (22) ou un outil coulissant (26) qui est logé à l'intérieur de ladite bobine à induction (2), ledit outil de formage étant mis en mouvement conjointement à ladite bobine à induction (2), vis-à-vis du profilé creux (1, 12), afin d'exécuter l'opération de formage.

3. Procédé selon la revendication 1 ou 2, dans lequel l'opération de formage est exécutée sans dispositif de contre-appui.

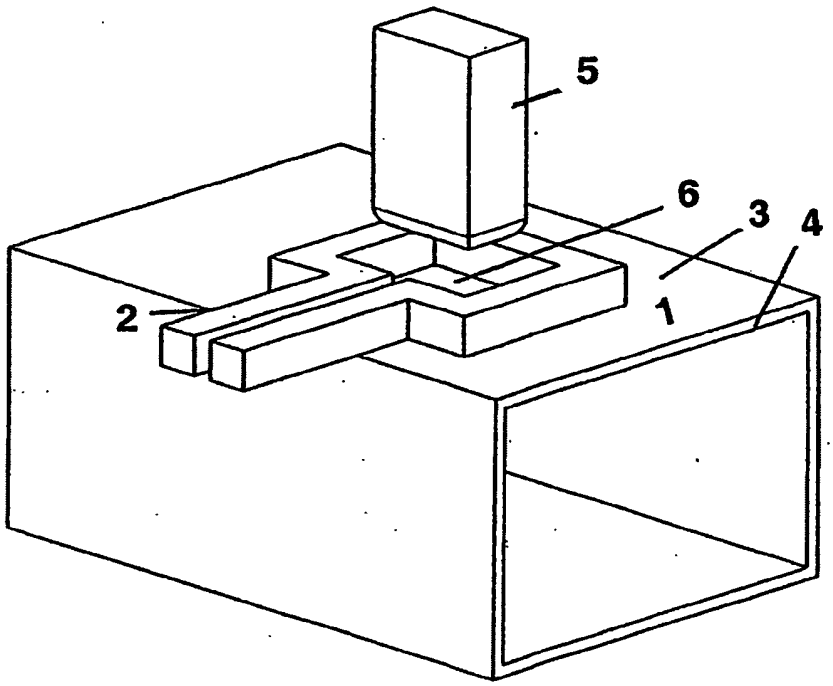


Fig. 1

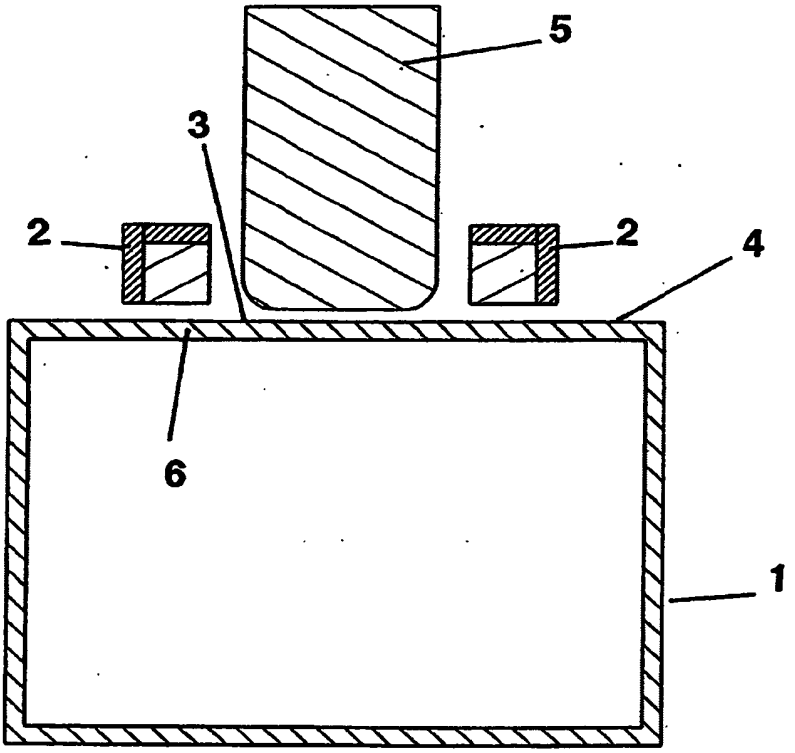


Fig. 2

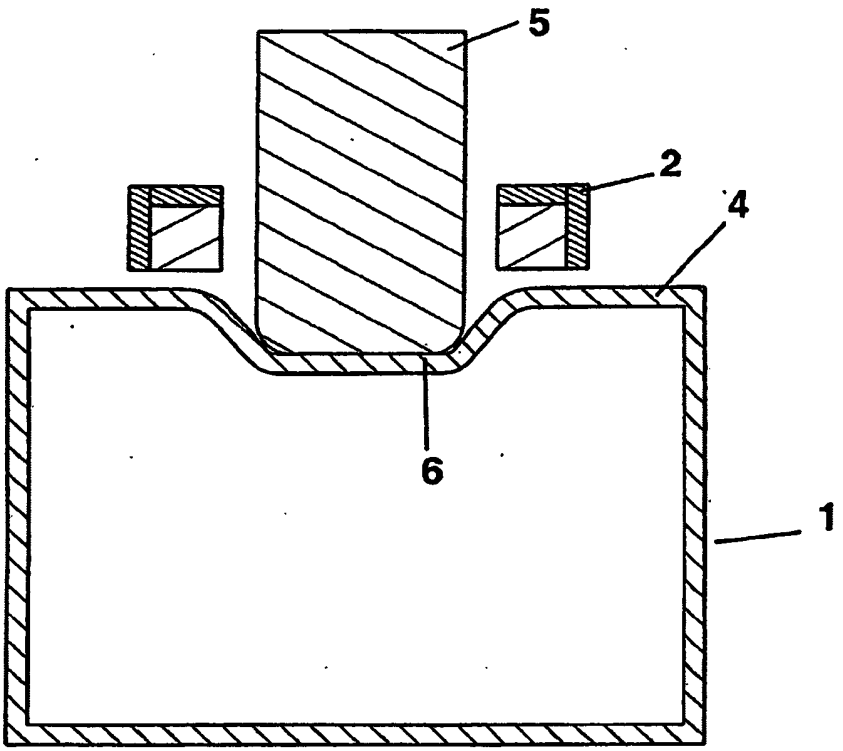


Fig. 3

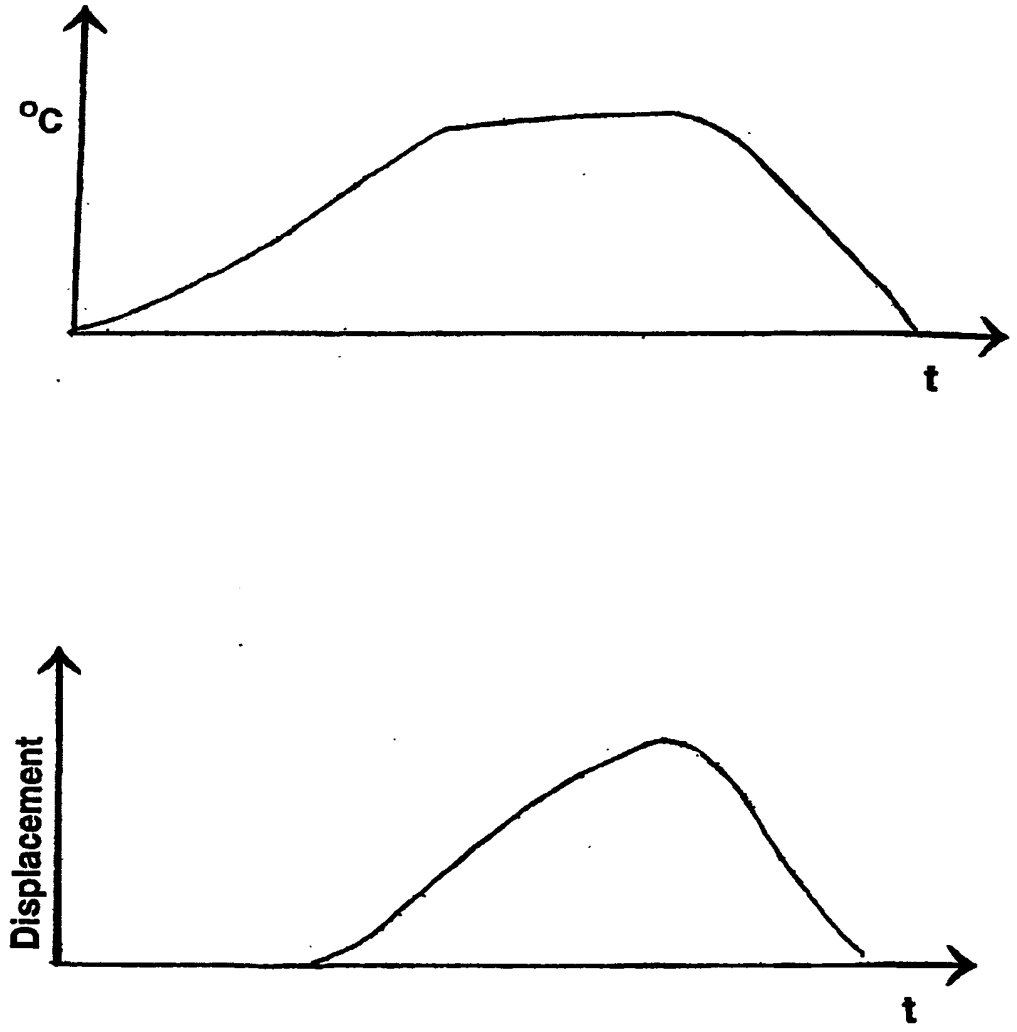


Fig. 4

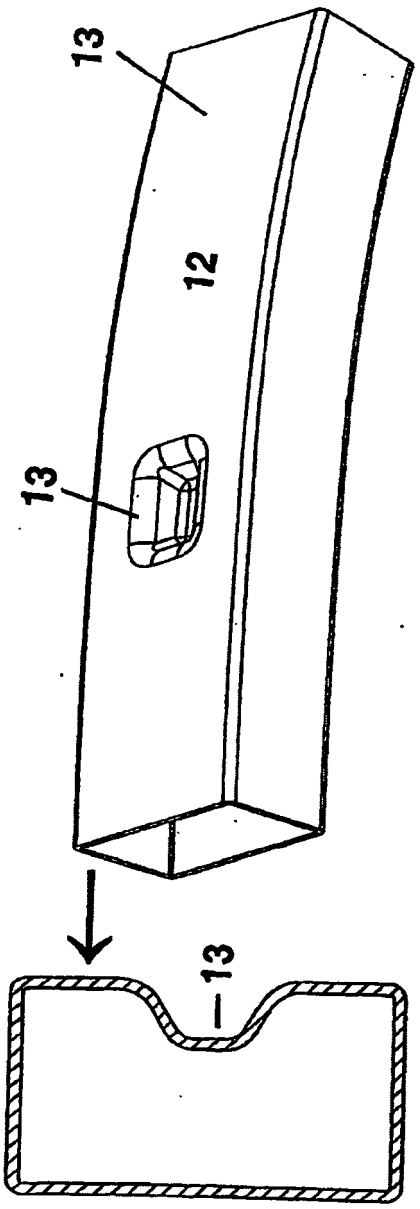


Fig. 5b

Fig. 5a

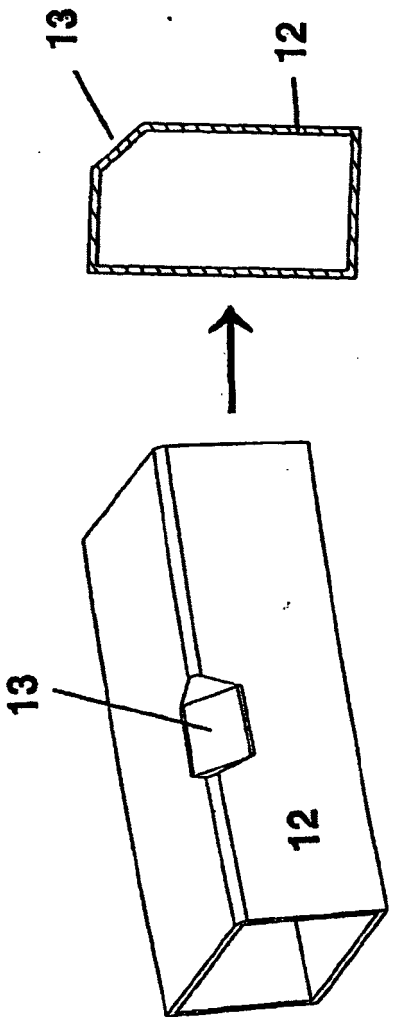


Fig. 6b

Fig. 6a

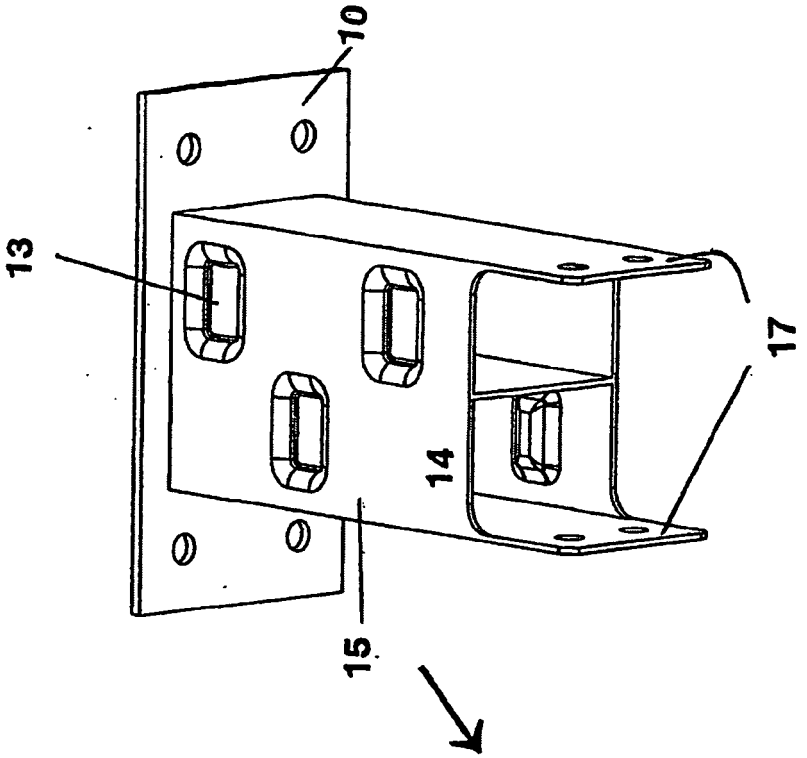


Fig. 7a

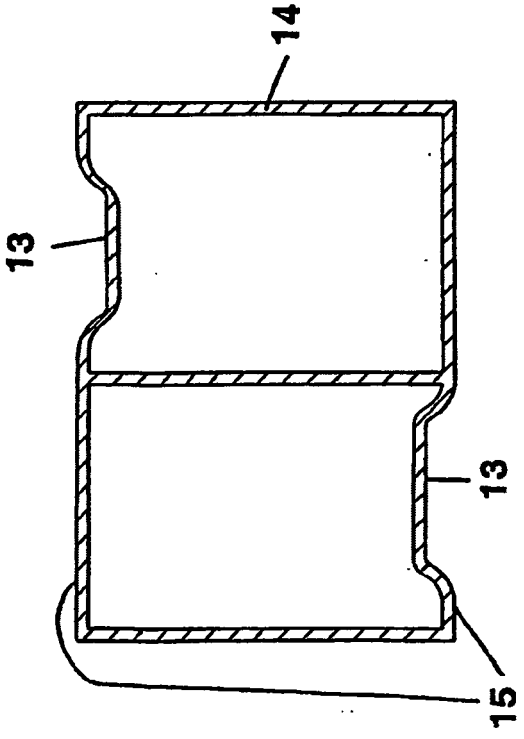


Fig. 7b

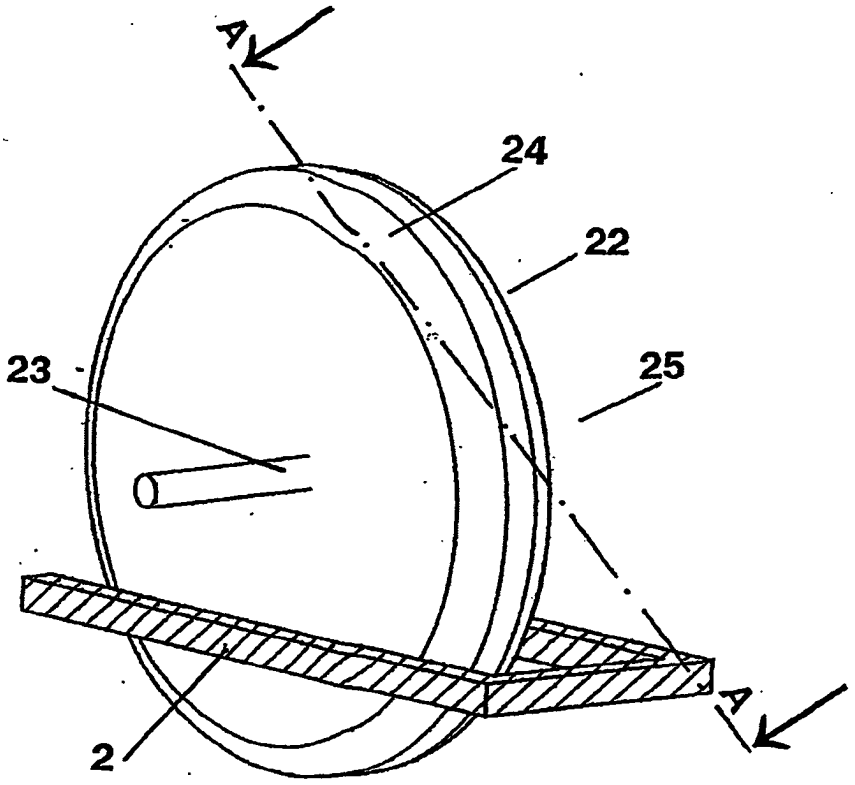


Fig. 8a

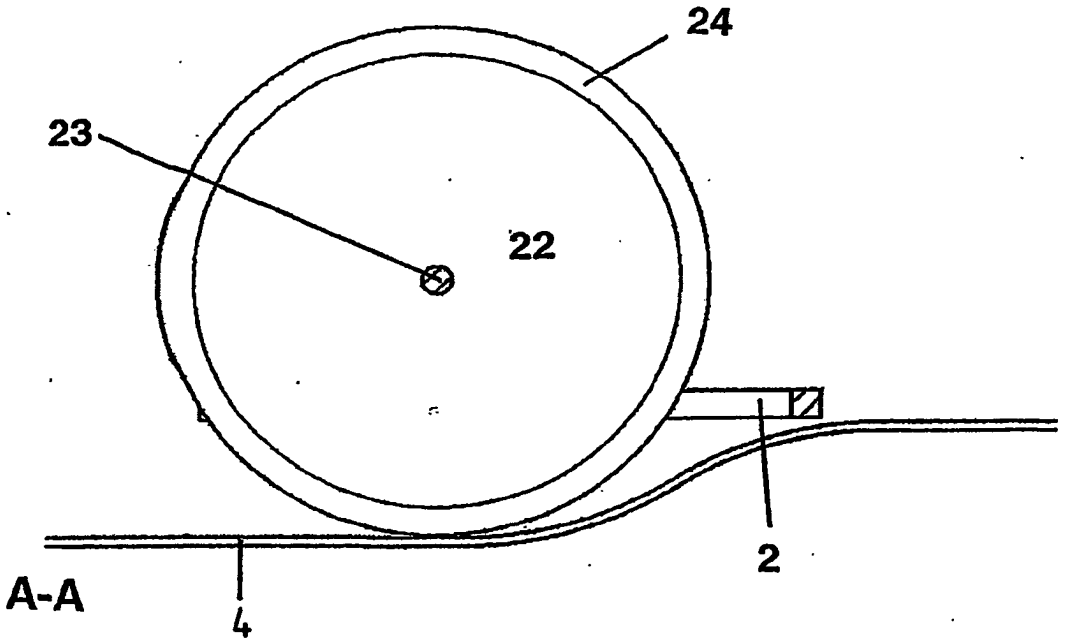


Fig. 8b

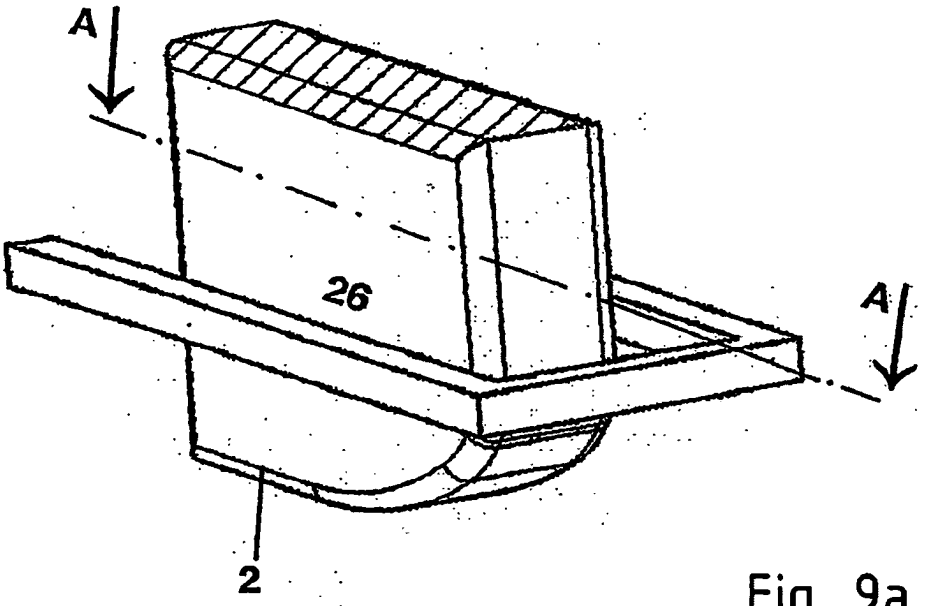


Fig. 9a

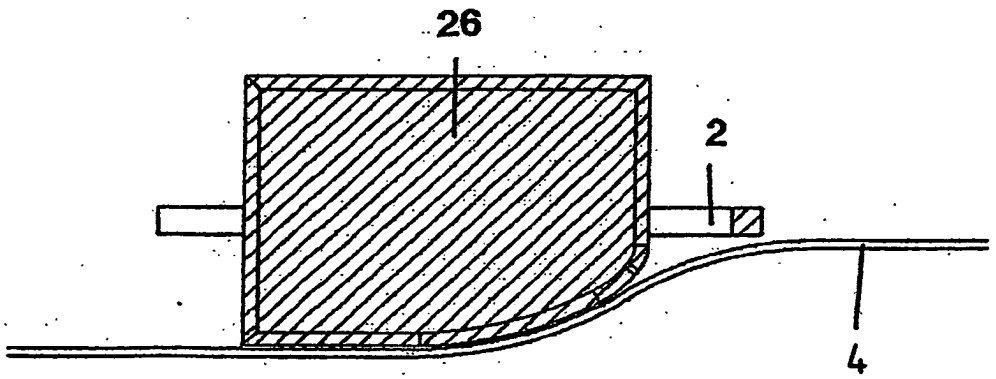


Fig. 9b

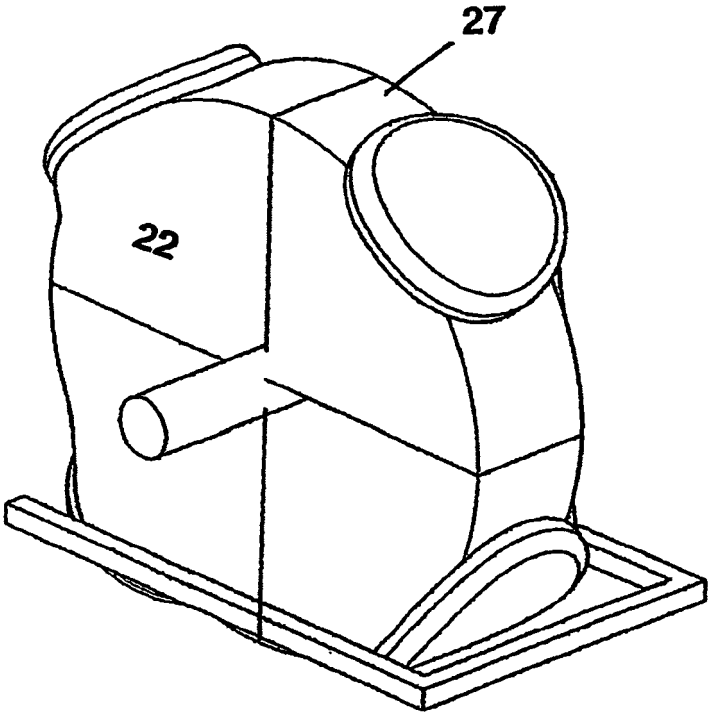


Fig. 10

REFERENCES CITED IN THE DESCRIPTION

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