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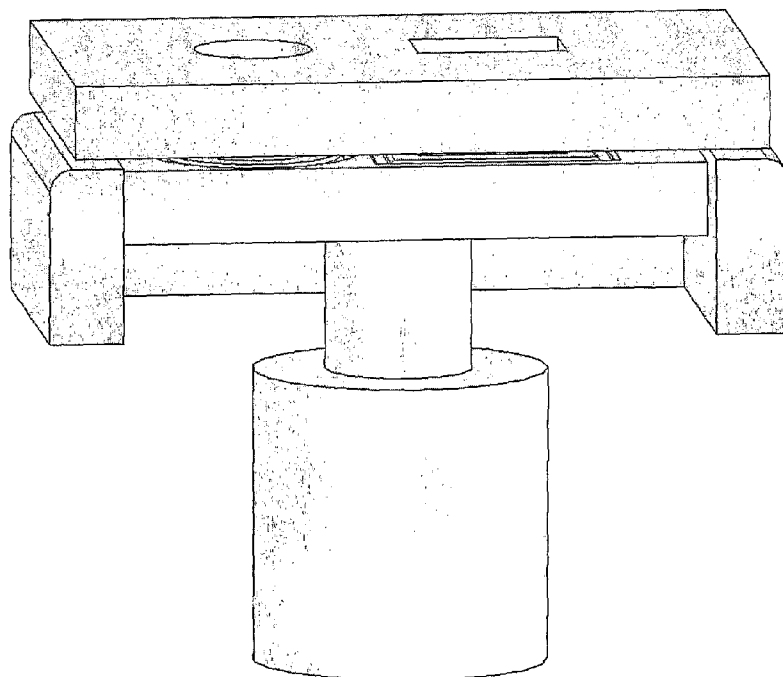
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(54) Title: A TOOL FOR CONTROLLING COOLING AND HARDENING EFFECTS IN HOT STAMPING OPERATIONS



(57) Abstract: It is a die type which reduces the heat transfer from hot sheet to dies, cutting/piercing tools, and blank holder in necessary zones in the way process conditions require and can increase it in die hardening by heat treatment effect, contrary to the approach used for stamping of hot workpieces between cold dies. This die type has the capability of forming the sheet and making forming process by heat transfer in necessary zones simultaneously according to the properties of workpiece.

A TOOL FOR CONTROLLING COOLING AND HARDENING EFFECTS IN HOT STAMPING OPERATIONS

The invention relates with a moulding system that will make processes of sheet-metal forming, hardening by a locally controlled heat treatment, cutting and piercing.

Hot sheet-metal stamping process is a production method that is getting gradually important especially in automotive industry. Along with the increasing demand of vehicle safety, structural parts are required to be made of materials that have strength as high as possible. Since these materials are required to have high elongation and forming characteristics while formed materials are asked to have high strength values, special processes are needed. On the other hand, vehicles have to be manufactured as light as possible, because of the increasing fuel costs. This requires using minimum amount of material to gain a particular strength, so it is a gradually rising tendency to use high-strength and hard-to-be-formed types of steel-aluminum alloyed sheets in vehicle production. Hot stamping and die quenching process has been developed to meet these demands. In summary this method is to stamp sheet in high temperature and then holding it in the die for a while to ensure cooling of the sheet by heat transfer from hot sheet to cold die. In this process hardening by heat treatment is done by rapid cooling in the part after forming using hardenable materials suitable to heat treatment and strength of the workpiece can be doubled. Common application of this method in industry consists of followings: Heating of the boron-alloyed, heat treatment suitable, 22 MnB 5 type steel sheet to 900° C, immediately after stamping and hardening by martensitic process called quenching through holding in the die for a while and rapid cooling of hot sheet. In this method, sheet, at starting conditions having yield stress of 350 MPA and elongation of 25%, is heated; passes to austenite phase at 900° C, and stamped at about 800° C. It is cooled by being hold stamped in the die about 10-20 sec. and contacting to die. At this step cooling rate of 20-30 C/sec. down to about 200° C must be ensured. When this heat treatment conditions come true, yield stress limit of sheet reaches to 1100 MPA and rupture limit reaches to 1500 MPA. New elongation rate is changeable between 50 – 80% according to applied process in stamping and forming capability dramatically increases compared to cold stamping. Similar process can be carried out for alloys of metals such as aluminum and magnesium that are suitable for heat treatment. For example, sheets made of aluminum 7075 type alloy can be processed like

that. Generally, at first, workpiece is heated to a necessary temperature for heat treatment, then stamped in a temperature suitable for forming capability, and then heat treatment conditions are ensured through a cooling in which a particular cooling rate is exceeded, so formed workpiece has been hardened.

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This process whose main features is summarized above, has important problems in industrial application. These problems are listed as follows:

- 10 - In hardening in moulding process, sufficient cooling rate can be achieved in the zones in which sufficient contact pressure between sheet and die exists. Because of the die structure sufficient contact pressure can not be obtained in many zones, so critical cooling rate can not be achieved in every zone. This causes non-homogenous hardening and many places of workpiece stay semi-hardened.
- 15 - Blank holder can not be used in application. Blank holder causes a sudden cooling and hardening in the surfaces of hot sheet and cold blank holder which contact surface to surface, when it press from surrounding. Material shifting from surrounding to forming zone is getting hard. Therefore, only workpieces that are simple shaped and can be formed by single-axis strain, can be hot stamped; many workpieces that will be formed by double-axis strain are cold formed and then heated and quenched in the die. This increases
20 the costs and causes that forming advantages of hot stamping can not be used.
- Zones of formed workpiece on which trimming and piercing will be applied are hardened too. Then, some expensive solutions such as laser cutting or cutting by special equipments will be required.
- 25 In summary, the structure which is used in cold sheet moulding and only for forming causes defects in many aspects and process problems in hot stamping.

Invented system is a die type which will make the contact between hot sheet and cold die, cooling and hardening in required order, prevent the early cooling complicating the process
30 difficult and ensure the post-forming critical cooling conditions.

This hot stamping die type has the capability of forming the workpiece, including blank holder, in necessary shape; ensure the critical cooling rate in the required parts of

workpiece; making the blank holder slide in the required strain holding the sheet in control; preventing early hardening due to cooling from surrounding; cutting the parts to be cut during stamping or leaving unhardened to be cut easily later.

In this die structure, there are channels allowing flow of cooling fluid which contacts the hot sheet and ensures the critical cooling rate during die quenching process. While hot stamped sheet will be hold stamped ensuring size sensitivity and preventing the reverse bouncing, air or another fluid, which will pass through the channels which grooved on the workpiece viewing surface of die, will ensure the critical cooling rate and homogenous hardening by sweeping the workpiece surface.

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5 figures have been drawn to explain the invention on figures in details.

Figure 1 shows the structure of blank holder involved in this process.

Figure 2 show the trimming process, process in which needless extensions on the outer edge of workpiece are being cut during stamping.

15 Figure 3 shows the structure which will be able to leave some parts of the workpiece unhardened so that processes such as cutting, piercing and bending will be applied later. This figure shows also cooling air flow channels and additional cooling system on places where the die contact can not secure the sufficient cooling rate during die quenching process.

20 Figure 4 shows the structure which will secure piercing before contact and hardening during hot stamping.

Figure 5 shows another structure which will be able to be used for piercing that can be done with stamping.

25 In figure 1 a blank holder which will be used for hot stamping is shown. In this blank holder, parts (1) which will contact the sheet are placed on the channels/chamfers (6) caved on the body of blank holder (2) or die. Contact interfaces (4) of these parts (1) to sheet (3) are not planar but in sawtooth shape (4). End points (4) of these contact lines should be rounded so that sheet can slide. It is aimed that contact lines of these upper and lower parts don't contact the same points of the upper and lower planes of the sheet and pressure will be homogenously distributed along the contact lines through bouncing between lower (5) and upper (4) contact lines on the sheet. For this reason, locations of lower (5) and upper (4) contact lines are different. For example, such positioning that upper contact lines (4) will be

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facing the cavities between the lower contact lines (5) can be made. These lower (5) and upper (4) contact lines preferably should be parallel and should not intersect each other.

Existences of the string functioning hard strips (7) under the channels (6) on which these parts (1) are located have following benefits: supplying homogenous pressure over the sheet by pushing out the part (1); preventing the crack of parts by smoothing the stroke impact in the contact moment to the sheet (3) if the parts are made of rigid and breakable materials.

These contacting parts (1) can be made of heat-resistant and having low thermal conductivity glass or ceramic-based materials or hard metal type materials by powder metallurgy. Such materials are generally hard and have low thermal permeability. If channels (6) and contacting parts (1) are in standard structure replacement of new parts will be an easy solution in case of crack in these components. If they are to be made of metal, hard stainless steels will be good options because of their low thermal permeability.

Figure 2 shows the application of trimming process – cutting the needless extensions of workpiece in edges – in hot stamping. This structure is applicable especially in process in which sheet is heated by current passing through (Terziakin, US Pat. No. 6.463.779), flow cross section of current doesn't change (rectangular) so homogenous current density and heating is obtained. Sheet having rectangular cross section are reduced to required size by peripheral cutting. An important point in this subject is that, sheet is hold by a blank holder having reduced (linear) contact interfaces (4, 5) or a ceramic passing type contact parts indicated in previous figure, without being wrinkled, but doesn't get hardened through cooling by contacts. This type of blank holder can be placed between die and cutting edges as well, so sheet which has been peripheral cut can be ensured to be sliding to die blank with a controlled strain. This option is defined in description but not shown in figure to avoid having figure to be complicated. The upper, moveable die is indicated as female, lower stationary die is indicated as male in the figure. This is not related with subject, opposite of this is applicable.

No.8 and 9 cutting tools are mounted so that one will move with moveable die, other one will stay stationary. Cutting edges are shaped to scissor the sheet between them. Lower and

upper surfaces of cutting tools which will contact the sheet are intentionally roughed in order to reduce the heat transfer from sheet and cooling and hardening of sheet.

Cutting process in the figure is done as following: Upper cutting edges (8) which are mounted to outer side of upper die moves as connected with upper die (11). In figure 2A, sheet (13) is placed on hinged nails (10) in order to minimize cooling due to contact. These hinged nails (10) hold the sheet (13) by a spring or a mechanism not shown in the figure; they don't turn by the weight of sheet but if sheet is pushed from above they allow the sheet to move down by turning downward. They turn into previous positions when sheet is released from nails. Upper die (11) going down and cutting tools (8) release the sheet (13) from nails and drop it onto lower stationary cutting tool (9). Moveable cutting tool (8) keeping going down along the inner side of lower stationary cutting tool (9) scissors and cuts the sheet (13) staying between them. In figure 2B dropping of this cut out sheet onto lower die. In order to avoid shift of sheet, contact to preferably lower die or another stationary part should be ensured simultaneously with cutting. In figure 2B contact to lower die simultaneously with cutting is ensured. Upper die (11) and moveable cutting tool (8) keep going down and stamp the sheet between lower (12) and upper (11) dies. If die quenching will be done in order to harden with heat treatment effect, it will stay in this position for a while. If heat treatment with rapid cooling by spraying a cooling agent is to be done, upper die is lifted up after stamping and heat treatment with rapid cooling will be done through spraying air, pulverized water or a fluid in gas form over the sheet by nozzles which are not shown in the figure. Another important point in this subject is that slots or blanks which will allow the moveable cutting tool to go down should exist around the lower die.

Figure 3 shows how to leave desired parts unhardened during the die quenching process. Structure of the blank holder in the figure is the same as in previous figures. Open state and closed state of die are shown in figure 3A and 3B respectively. In this figure, heat loss of sheet surface which contacts the blank holder is reduced as in other two figures. Hot sheet is placed on the nails having little contact surfaces to avoid of contacting with blank holder and die and cooling. First of the basic subjects explained here is that some parts of die surface which will face the parts of the sheet which are to be cut or bended later (19, 20) have notches (21, 26) to ensure slow cooling without contact with die in order to ease

cutting process to be done later. In the figure, this type noncontacting zones are made in trimming (19) and piercing (20) zones. This type noncontacting notches are grooved on the lower (24) and upper (16) die surfaces corresponding trimming zone (19). In the lower part of male die, this type noncontacting notches are made on the die surface which corresponds the sheet parts which are to be pierced later. Notches and sheet don't contact each other in these zones. Cooling in these zones of sheet (19, 20) occurs by heat transfer to air, which is relatively cold, and to other neighboring parts of sheet. Since required cooling rate for hardening can only be ensured by contact between hot sheet and cold die, these zones will be left unhardened. For example, critical cooling rate of 25-30 C/sec. is required for hardening of 22 MnB 5 sheet gaining martensitic structure. Martensitic hardening can be ensured in case of cooling of sheet to about 200 – 250 C with this critical cooling rate. For 7075 aluminum alloy cooling rate of 75 C/sec. is required. There will be passing strips between the hard and soft zones in the sheet after treatment. These should be analyzed experimentally for each material. For example, if a hole with diameter of 20 mm. is to be made later by piercing diameter of notch circles (17) may be required to be 30 mm. Hot stamped sheet released from this die will be cut from relatively soft trimming zone (19) and pierced from soft piercing zone (20) in a cutting die later. Since outer part is hold by blank holder structure (28, 29) having reduced contact surface, hardening from outer parts will not occur and material shift to inward with controlled strain will be ensured. That will be beneficial especially for process in which double-axis strain occurs and stamping and hardening operations of complex shaped workpieces perform in the same die and the same step.

In Figure 3 another important feature is that cooling channels which will be used together with the contact between hot sheet and cold die which will not usually be sufficient for hardening in a workpiece that is to be hot stamped and die quenched. Uncompleted hardening resulted from this insufficient contact is encountered on the side edges of the sheet. Space between lower and upper dies which allows sheet to slide, prevent the solid contact pressure between sheet and die surfaces even when dies are completely closed. Air channels (25) which will be grooved on the parts of die surface, which correspond these zones, will form an air flow channel which will be bounded by sheet surface from one side and channel notch on the die surface from other side. There are air pipes (22, 23) placed in the die which deliver air flow from an air pressure system. Entrance (22) and exit (23)

should be designed by considering the channel structures (25) and feeding pressure should be determined by considering the air flow speed required for cooling. These channels (25) are formed when sheet is compressed between lower (24) and upper (16) dies during hot stamping, and pumped air or another cooling agent will increase the cooling rate by quickly sweeping the sheet surface. By this way critical, cooling conditions will be able to be ensured easily. Sheet can be secured to stay horizontally flowing in balance by making spaces on the other die surface which faces the channels of one die. Those can be appropriately designed for each workpiece according to die shape and material properties.

Same function can be done by other ways. For example; holes are opened on the female die surface so that sheet can be seen from outside through these holes; nozzles which can be placed to see the stamped sheet blows the cooling agent from this holes and this flow sweeps the hot sheet. Since this is another application of same principle, it is not shown on the figure. Important point in this subject is that sheet will be hold between two dies so that it won't make spring back or another form deviation and this form will be fixed and permanent by cooling.

It can also be seen from the figure that at the end of forming stage sheet is controlled and hold by blank holder and edges which will be cut are in flat form. These edges will be relatively soft since there is no any metallic surface contact to these zones and they will be able to be cut easily in a cutting die after forming.

Figure 3 shows also a feature which performs trimming operation between hot stamping and die quenching stages. In Figure 3A and Figure 3B a blank holder type with reduced contact interface is situated outside of the die. Inner edges of these blank holders and outer edges of the die surface are designed as cutting tools to be used for trimming extensions of the stamped sheet. Spacing between these inner and outer cutting edges and their sharpness rate are determined properly for cutting at the end of the stamping stage. These cutting edges are preferably made as separate and replaceable parts fixed to die and blank holder.

In this way they can be sharpened or replaced in the case of wear or damage without changing other tools. There are spacings between edges of the dies and hot sheet at the trimming (26) and piercing zones (21) for avoiding early contact and hardening before cutting of the sheet (19, 20). In the figure there are noncontacting zones at the trimming

zone (19) and piercing zone (20) for facilitating following cutting operations by means of preventing early hardening. Cutting edges (26) of the dies are avoided to be in contact with the hot sheet during stamping stage. As soon as die pair completely compress the hot sheet, outer cutting tool is moved up or down by an external force and extensions of the sheet (19) is cut between outer and inner cutting edges. Then hot stamped and trimmed part is hardened by die quenching operation. During stamping stage blank holder provides controlled strain in material flow. At the end of the forming stage inner cutting edges of the same tool is used for trimming operation by being acted by an external force. In double action hydraulic presses, (secondary) hydraulic system used for blank holder action can be used for acting of cutting tools. Or separate hydraulic pistons (not shown in figure) can be used for acting part (29) upward for cutting sheet between cutting edges of part 26 and 29.

In Figure 4 cutting tool which will be placed into hot stamping die. Figure 4A show the system structure when piercing tool is in its slot (unpushed state) and ledge strip which encloses the piercing zone is out. This state is the beginning of stamping. Figure 4B shows the state in which sheet has been formed and piercing has been done at the end of stamping. Application of the structure which is used in cold cutting dies, to the hot cutting dies results in some problems such as trying to cut of hardened workpiece and form defects. For this reason, the structure shown in Figure 4 should be used. Basic principle of this subject is to prevent the contact of zones to be cut-pierced to die surfaces and cooling-hardening resulted from this contact before cutting operation. When suitable conditions are achieved, that is workpiece has been formed, piercing zones which have been prevented from contacting to cold die surfaces and from cooling and hardening will be pierced by piercing tool.

There is a group of piercing edges (34) connected to a hydraulic piston (30) here. On the other die there are spacings (35) in place where corresponds these edges. The ledge (33) around the zone where these piercing edges are placed encloses this zone on the die and prevents the sheet in this zone (36) from contacting die surface and from early cooling-hardening. This enclosing operation which suppresses contact and cooling can be done in two ways:

In first option, there is a zone with ledges (33) which encloses the piercing zone in the die. The sheet which will be pushed by these ledges (33) will be prevented from contacting to

piercing zone and hardening by this way. There are two basic options about this ledge structure. First, these ledges (33) are of springy structure which can enter into die, prevent parts of sheet in piercing zone from contacting during forming stage and then enter into slot (32) on the die by being pushed by other die during complete closing of two dies. The spring which pushes the ledges is so strong that it can push the sheet during forming stage but can be closed during closing of dies. These ledges are in such a form that it can be on the same level of surrounding after entering into die. By the use of this system, there will no bulging strip etc. around the holes in produced workpiece. System is pushed from back by a springy mechanism or hydraulic piston. It is situated a little (several mm.) out of its surrounding and prevents the die contacting sheet in piercing zone during stamping. In stamping moment it is pushed back by contact to other die and getting on the same level of surface of die which it is mounted. In figure 4B, it is shown that this ledge (33) enters its slot (32) on the die. At this moment piercing edges enter into spaces of other die and pierces the compressed sheet. In figure 4B, for being clear, the space between two dies is shown wide and sheet is shown away from upper die. This has been done to show details, actually in piercing stage two dies close, sheet is compressed between them and ledge (33) enters its slot (32). Various options based on this principle can be improvable.

Another option of piercing subject based on the same principle is shown in figure 5. In Figure 5, there are one male die and connected piercing tool and a female die on which piercing holes are placed. Although they normally stand facing each other, they are drawn next to each other in order to show the structure of both. In figure 5, hydraulic piercing tool (38, 39, 40) is placed inner side (43) of one of dies (44). On the other die, there are piercing holes (45) in the corresponding place which is opposite of the location of this tool. According to the basic principle of invention, during sheet forming, piercing zones are prevented from contacting to die surface (46) and hole zone (45) by ledge strip (42). On the die (44) on which piercing tool is placed, since piercing set is located inner side (40) piercing zone of sheet is prevented from early cooling and hardening.

During stamping, when two facing dies (44, 46) are completely closed hydraulic piercing piston (39) is pushed out and piercing edges (40) pierce the compressed sheet by entering into piercing holes (45). Parts which have been cut are released from other side of piercing holes (45). For this reason, placement of piercing tool on upper die, downward piercing and

dropping down of parts will be beneficial. Base (38) below the piercing edges (40) is pushed away until it seats on the opposite surface (46). Meanwhile, notches (41) and ledges (42) around male (40) and female (45) piercing zones seat on each other so that sheet is compressed between them. At this moment, circles enclosing piercing zones appear in the sheet. For this reason, a little material shift from piercing zone to out is ensured. This situation will prevent the sheet drilled by piercing edges (40) from standing back and cooling and shriveling sheet from squeezing the piercing edges from surrounding. If cooling and quenching with heat treatment effect will be done in the die workpiece is hold in the die for a while and then released. Piercing edges, independent from die, may be immediately pushed and pulled or pushed for a while and then pulled, according to the process conditions.

Notch (41) and ledge (42) pairs, which are placed around piercing edges and corresponding piercing holes respectively and shown as connected to moveable hydraulic piston in Figure 5, may be directly placed around male and female piercing sets. In this situation, when two dies are completely closed piercing and being pulled away of sheet from piercing tools by this notch and ledge pairs will be done. This option will be cheaper and easier to apply.

Since this type hot stamped workpieces are generally used in inner structural parts in automotive industry, formation of circles and similar figures around pierced places should be considered in design stage. Such little changes in the shape of such workpieces will not generally cause a problem.

CLAIMS:

- 1) Delaying of cooling and hardening which will occur in the sheet resulting from the contact of cold die to hot sheet, in the structure of die and blank holder in the hot sheet stamping process which will be done between cold dies, reducing the heat transfer in the desired zones of sheet and reducing the contact surface to hot sheet in these zones in order to ease forming.
- 2) A method according to claim 1, characterized in that in the contact interface between blank holder and sheet; grooving channels on the contact surface of blank holder (1) to sheet (3) so contacting to sheet by reduced contact interfaces (4, 5) between channels and reducing the heat loss and hardening in the forming zone of sheet.
- 3) A method according to claim 1 and 2, characterized in that making contact interfaces (4, 5) in the lower and upper parts of blank holder not to intersect each other at the same point of the sheet (3) so avoiding of pressure to the sheet from above and below in any point.
- 4) A method according to claim 1 and 2, characterized in that, contacting of contact interfaces (4, 5) in the lower and upper blank holder to the sheet in different positions, so ensuring the sheet in between (3) to touch to contact lines of lower and upper blank holder homogenously by stretching.
- 5) A method according to claim 1, characterized in that, manufacturing of blank holder contact parts in such a way that these parts will be mountable in the channels (6) on a main body (2) and replaceable.
- 6) A method according to claim 1, characterized in that, in stamping process of hot sheet by cold dies, placing the cutting edges (8, 9) on outer side of lower (12) and upper (11) dies to cut the sheet (13); making peripheral cutting simultaneously with hot stamping by moving one of the cutting edges (8) in the direction of other cutting edge (9) to cut the part of the sheet apart from forming zone.

7) A method according to claim 1 and 6, characterized in that, reducing the contact interfaces of hot sheet cutting edges (8, 9), on the surface which will touch the hot sheet (13).

5 8) A method according to claim 1, characterized in that, reducing the cooling rate in particular zones (19, 20) during hardening by rapid cooling in the die after the hot stamping and forming noncontacting zones (21, 26) on the die surfaces which corresponds these particular zones of sheet in order to keep hardness of these zones low.

10 9) A method according to claim 1, characterized in that, making cooling channels (25) on the die surfaces in the process of hardening by die heat treatment which will made after hot sheet stamping, sweeping of sheet surface by the cooling agent which passes through these channels (25) one side of which is sheet surface and other side of which is notch surface grooved on the die; increasing the cooling rate of sheet in the die.

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10) A method according to claim 1, characterized in that, forming a ledge strip around piercing zones on the die surface in order to prevent piercing zones from contacting to die surface and from hardening during piercing process which is carried out during stamping so preventing the inner part of sheet from contacting to die surface until cutting tool contact
20 through stretching the sheet by this ledge strip.

11) A method according to claim 1, characterized in that, in order to prevent piercing zone from early contacting to die surface and from hardening by cooling during the hot stamping; moveable ledge parts around the piercing zones which can go in and out of die (31) and will
25 keep the hot sheet a little away (33) from die surface during sheet forming and will enter the slot (35) on the die which it is connected.

12) A method according to claim 1, characterized in that , existence of notch (41) and ledge (42) structures around piercing edges (40) which will be placed in the die (44) and female
30 piercing holes (45) over the opposite die (46); during piercing process by entering of the piercing edges (40) into piercing holes (45), being taking back of some parts of sheet from piercing hole surrounding by the notches (41) and ledge (42) structures around the piercing zone through standing on each other with compressed sheet between them; preventing the

cooling and shriveling sheet enclosing piercing edges (40) from squeezing the piercing tool (40) by sending cut parts of the sheet away from surrounding of the piercing edges (40) and ensuring the piercing tool (40) to exit easily.

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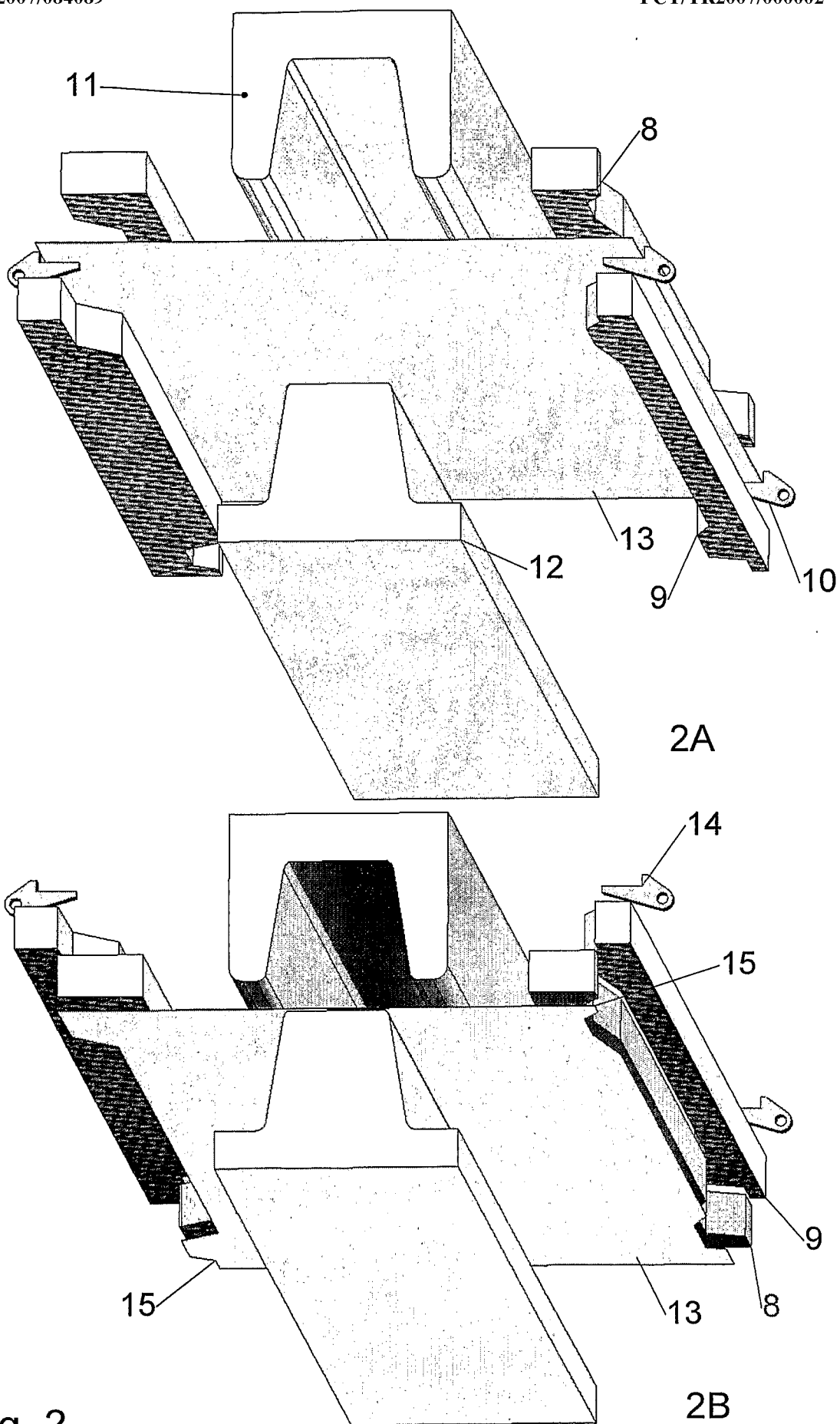


Fig. 2

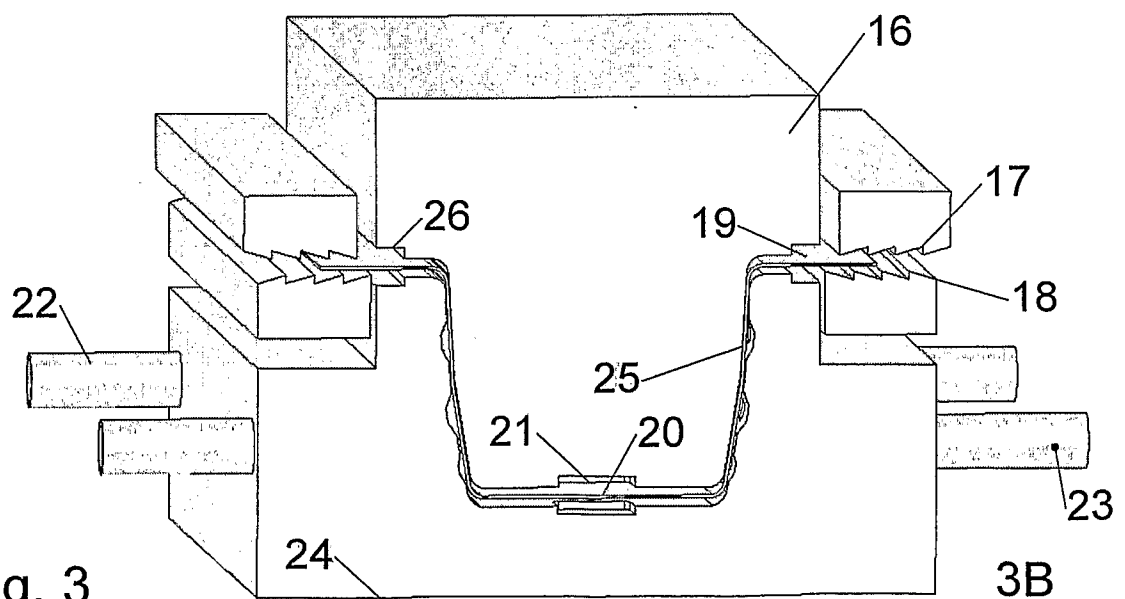
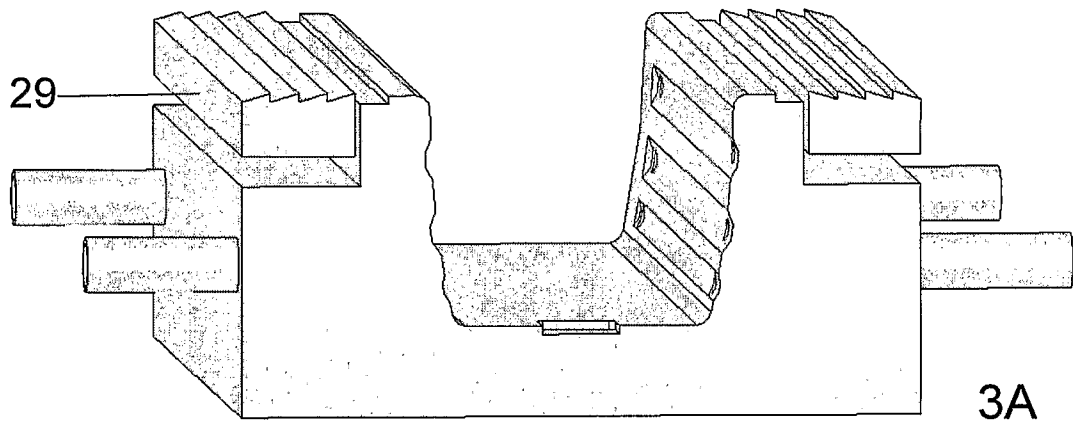
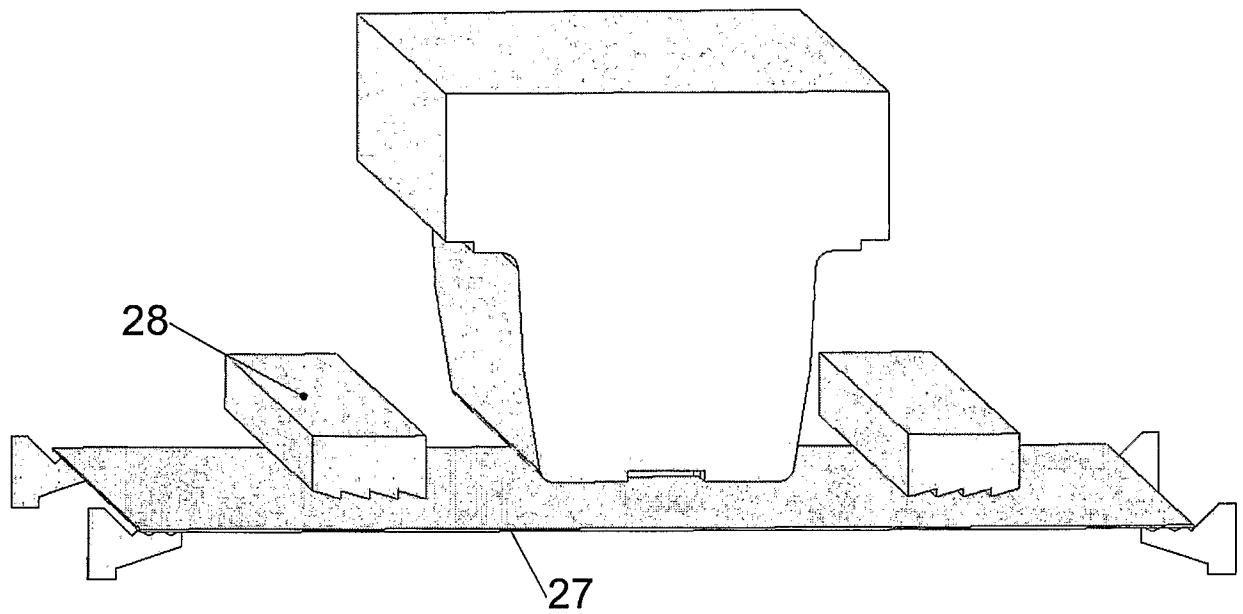


Fig. 3

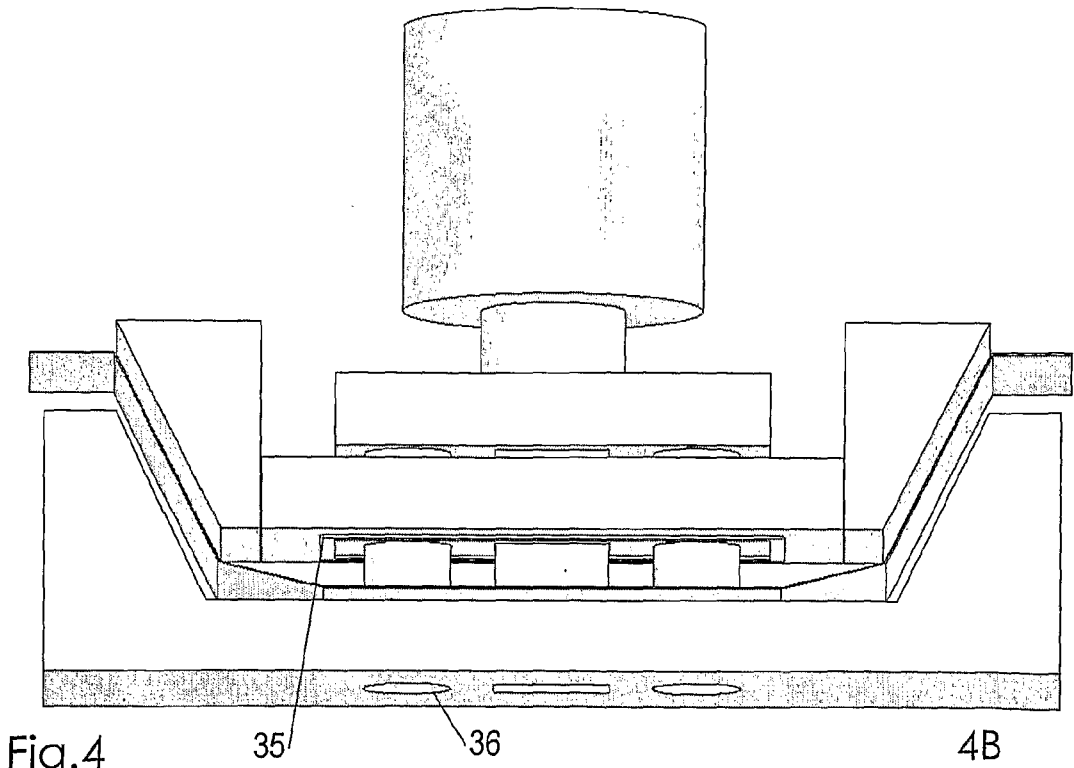
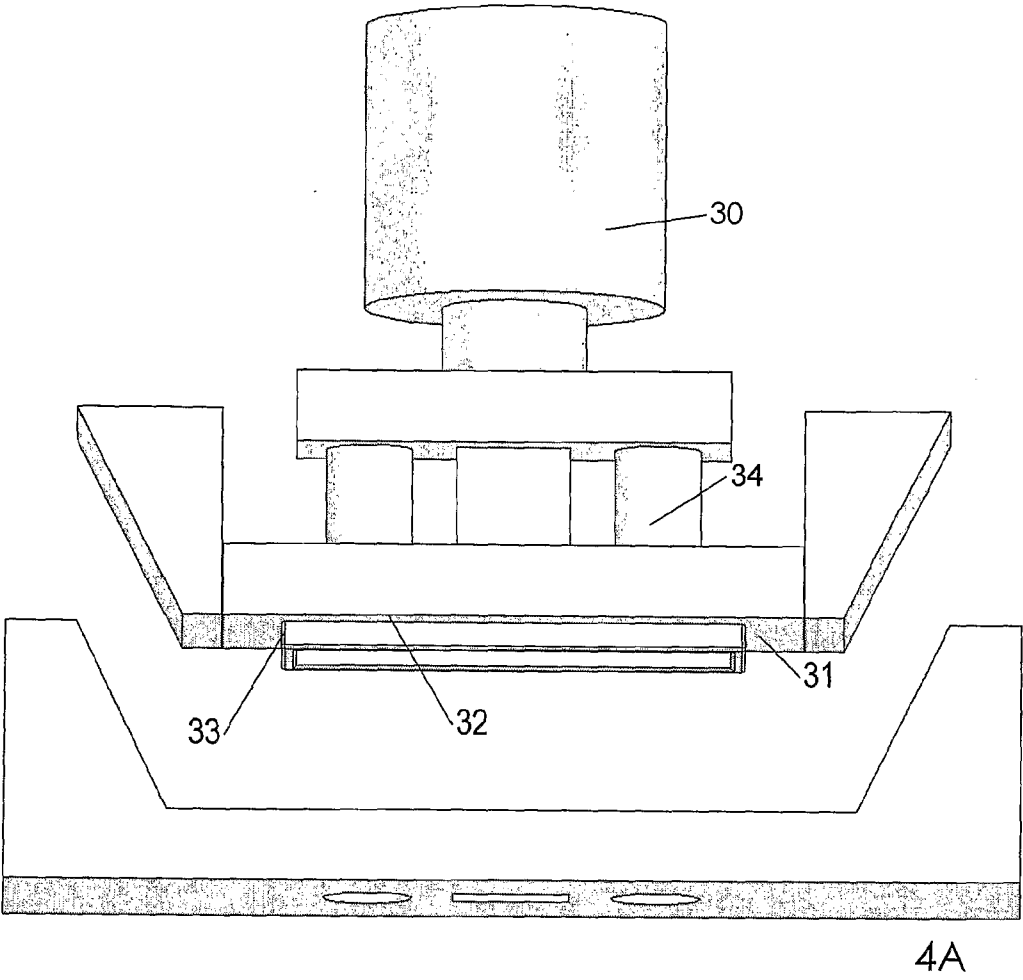


Fig.4

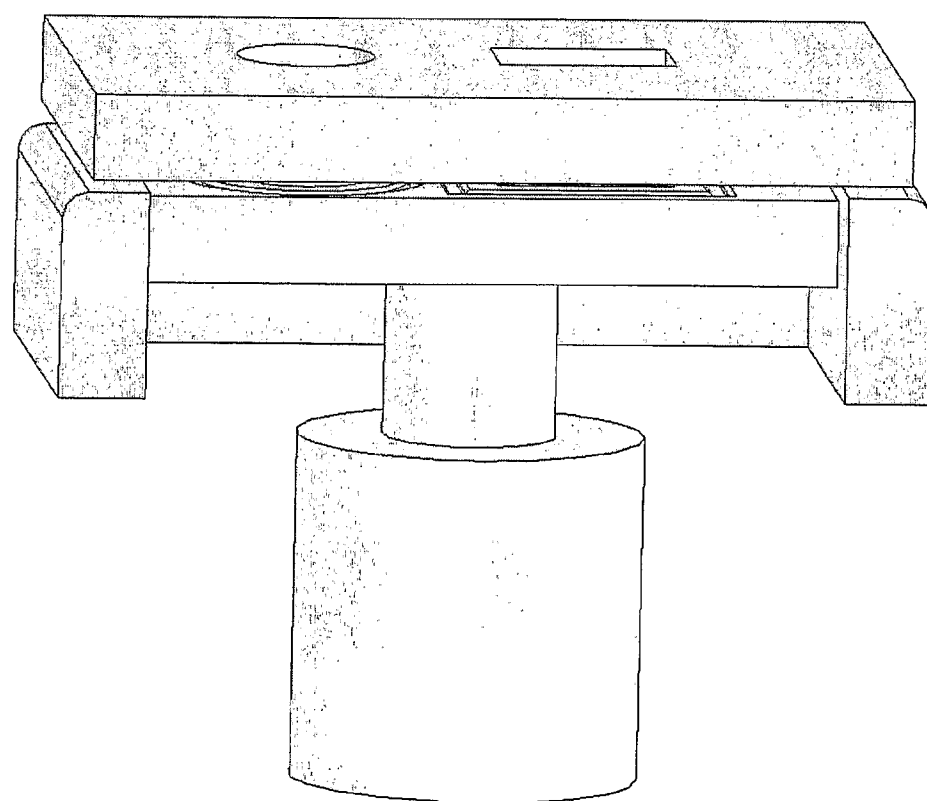
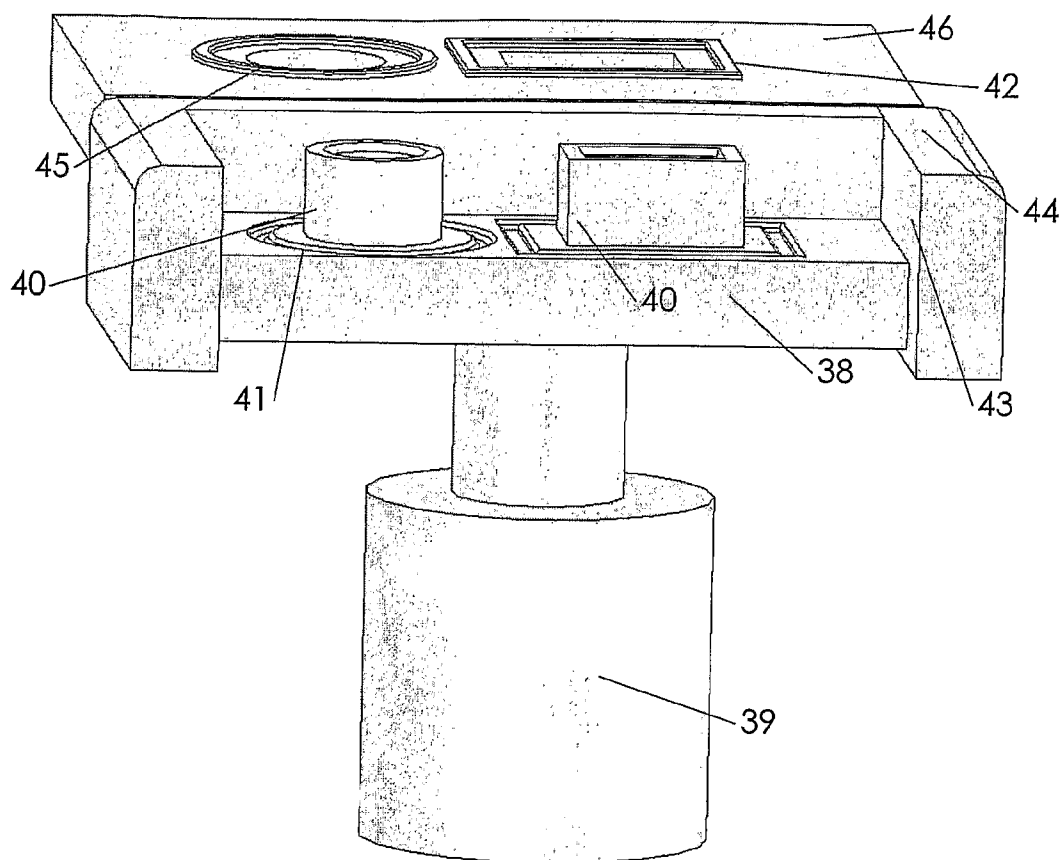


Fig. 5

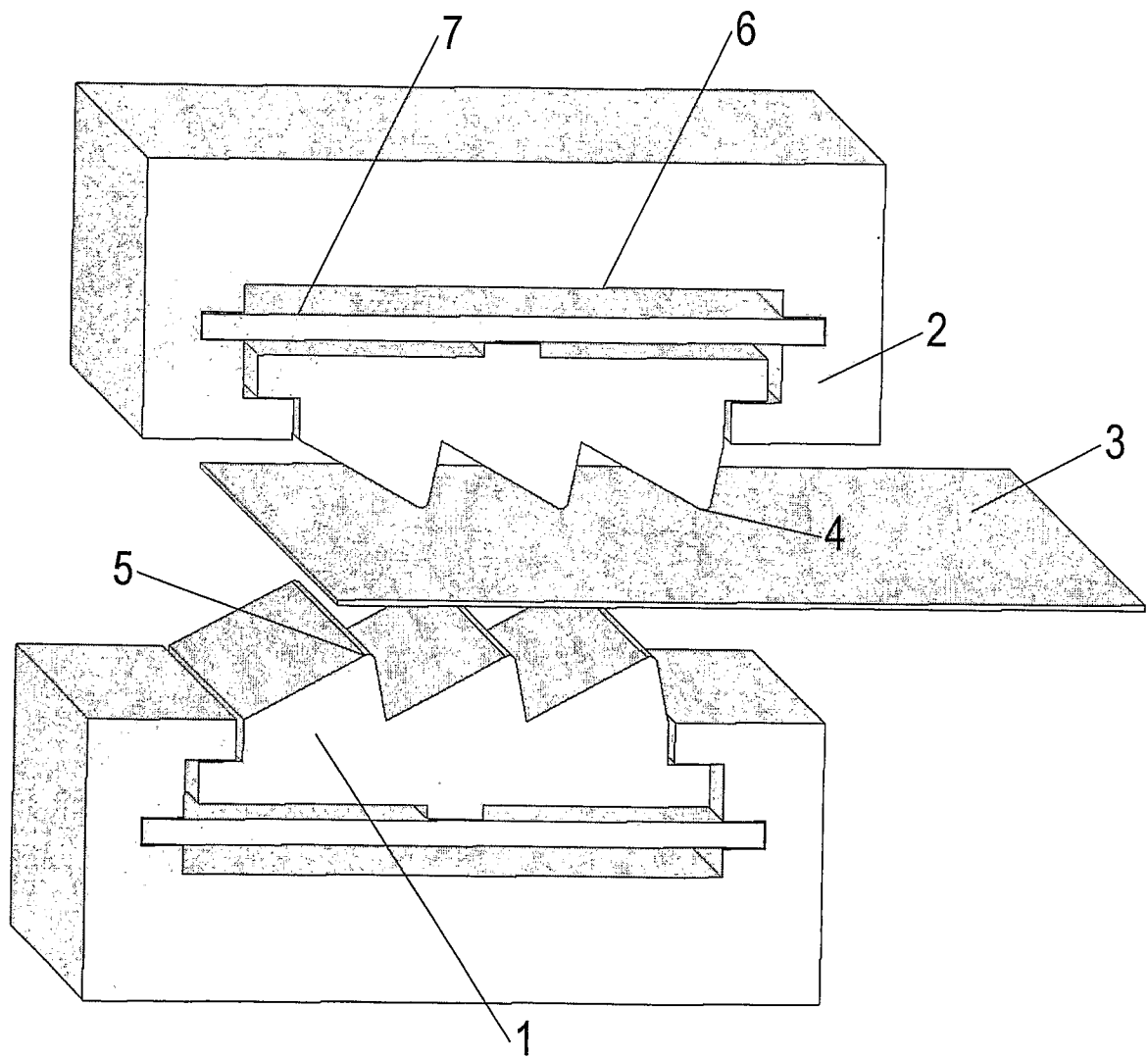


Fig. 1