(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 055 421**
A2

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **81110488.4**

(22) Date of filing: **16.12.81**

(51) Int. Cl.³: **B 21 D 22/21**
B 21 D 22/00

(30) Priority: **29.12.80 US 220346**

(43) Date of publication of application:
07.07.82 Bulletin 82/27

(84) Designated Contracting States:
DE FR GB IT SE

(71) Applicant: **FORD-WERKE AKTIENGESELLSCHAFT**
Ottoplatz 2 Postfach 21 03 69
D-5000 Köln 21(DE)

(84) Designated Contracting States:
DE

(71) Applicant: **FORD MOTOR COMPANY LIMITED**
Eagle Way
Brentwood Essex CM13 3BW(GB)

(84) Designated Contracting States:
GB

(71) Applicant: **FORD FRANCE SOCIETE ANONYME**
344 Avenue Napoléon Bonaparte B.P. 307
F-92506 Rueil Malmaison Cedex(FR)

(84) Designated Contracting States:
FR

(71) Applicant: **Ford Motor Company**

Dearborn County of Wayne Michigan(US)

(84) Designated Contracting States:
IT SE

(72) Inventor: **Liu, You Chao**
2001 E. Spinningwheel Lane
Bloomfield Hills Michigan 48013(US)

(74) Representative: **Ritzkowsky, Harald, Dipl.-Ing. et al,**
Ford-Werke Aktiengesellschaft Patentabteilung Z/DRR-2
Ottoplatz 2
D-5000 Köln 21(DE)

(54) **Method of reducing curling in pressed sheet materials.**

(57) A method of reducing curling in pressed sheet material is disclosed. The undeformed sheet material is pressed to sequentially form opposite and separated bend radii. During such pressing, the separating section between the bend radii is subjected to a sliding fulcrum to bend and unbend said section as well as rub one side of the panel to impart a first strain. The panel is counter rubbed on its opposite side to impart a strain opposite to the first strain to reduce or eliminate curling.

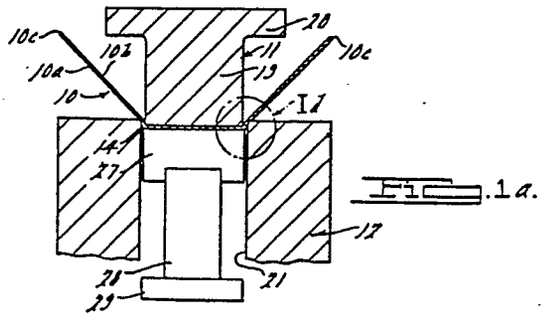

Fig. 1a.

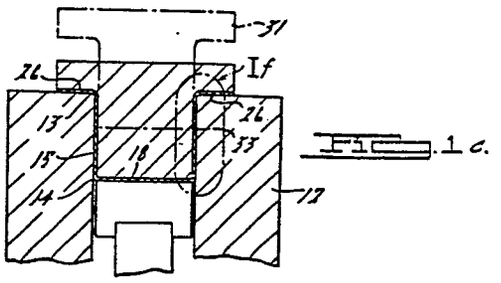

Fig. 1c.

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METHOD OF REDUCING CURLING IN PRESSED SHEET MATERIALS

BACKGROUND OF THE INVENTION

Complex formed sheet materials, particularly in metal panels, usually refers to panels that have some degree of reverse bending involved. In complex shaped panels, forces have been applied to the sheet material which cause spaced, but oppositely oriented, bend radii to be formed. If the sheet material is formed in a press with a single straight line stroke, the bends will be formed sequentially and the section of the sheet material between the bend radii will be subjected to progressive bending and unbending which may include some rubbing or shearing forces on one side. Such bending and unbending forces produce a type of springback which curls the separating section.

To illustrate, if a panel of sheet metal were to be formed into a hat section (complex configuration), a T-shaped male punch member would be struck downwardly upon the panel lying atop a female molding member. As the center zone of the panel is forced into the opening of the female molding member, the skirt of the panel is folded upwardly (at a first bend) until the panel edge margins are restrained by the overhanging head of the T-shaped punch. The head of the punch imparts a second bend opposite to the first bend, but spaced therefrom. Because such bends are formed sequentially, curling strain is involved. As the first bend proceeds, the panel is drawn more deeply into the female molding member. The panel edges become progressively more restrained as the punch head approaches closely the female molding member. With the panel edges increasingly restrained and the panel continuing to be

pulled into the female molding member, the intermediate panel section will be progressively bent and unbent along with being rubbed vigorously on one side. The bending and unbending (as well as rubbing) occurs by sliding contact of the intermediate section against the edge or mouth of the female molding member which acts as a fulcrum, creating differential stress and strain across the thickness of the intermediate section (between the inner and outer surfaces of the panel). Upon removal of the male punch and withdrawal of the complex formed sheet panel, the intermediate section will assume a curled condition, not conforming to the configuration of the female molding member in which it was struck.

Attempts to eliminate such curling have included restriking the same male punch and female molding members together with little success. An attempt has been made to adjust the female molding member to vary the die gap with the male punch member; this has not proved successful in removing curling when employed with the same male punch member during restrike. Varying the speed at which the press ram is moved to carry the male punch member has also demonstrated little or no effect upon solving the curling problem.

With the advent of high strength, low alloy steels having yield strengths in excess of 3515 bār in relatively thin sections, curling has become a severe problem in deeply formed sections because of the compound effect of both higher material strength and typically higher press speeds to form the material. Although lower speeds reduce the severity of curling, the problem remains. Moreover, lower speeds are not attractive because greater forces are required to form the material with greater friction between the parts of the die and molding member.

SUMMARY OF THE INVENTION

This invention relates to a method of overcoming curling in sheet materials subjected to progressive opposed bending. The first step of this method comprises pressing a panel of material to sequentially form opposite and separated bend radii therein. During such pressing, the separating section of the panel between the bend radii is subjected to progressive bending and unbending about a fulcrum which relatively slides along one side of the panel to impart a first strain in the separating section. Secondly, the panel is counter rubbed on its opposite side to impart a strain opposite to the first strain to remove the curling. The counter rubbing is carried out either simultaneously or subsequent to the first pressing. The resulting sheet material panel will adopt the configuration imparted by the press with reduced curvilinear springback in the separating section.

This method has particular utility in forming hat sections having pairs of opposed bending radii and bend angles of about 90°. Such forms typically comprise a high percentage of automotive sheet metal requirements in chassis construction.

It is advantageous in carrying out the above method if the intermediate section of the sheet material panel (in which curling is a particular problem) has a length of at least 12,7 mm and the bend radii are within the range of 3,18 mm to 6,35 mm The die gap (space between the mated male punch member and female molding member) is preferably controlled during first pressing to 1.5 - 3.0 times the thickness of the sheet metal and, during counter rubbing, the die gap is preferably controlled to about the thickness of the material. Die gap is decreased in proportion to an increase in strength of the sheet metal.

One desirable mode for carrying out the method is to carry out a first pressing with one pair of male punch and female molding members, and to carry out the counter rubbing by use of a second, oversized male punch member in a second pressing or restrike.

In another mode of carrying out the invention, a binder element may be employed adjacent the entrance opening of the female molding member to guide the movement of the sheet material panel in a direction transverse to the pressing motion, thereby to insure a continuous and uniform bending and unbending during pressing. This mode may be further modified by incorporating a bead or knuckle on the binder element to impart a continuous pressure which strains the sheet metal panel on both sides causing the bending and unbending and counter rubbing to occur simultaneously during pressing.

Yet another mode comprises using a male punch member with negatively tapered sidewalls so that the necessity for a restrike is eliminated. The corner radius of the entrance opening to the female molding member imparts bending and unbending to one side of the sheet material panel during pressing, as in the preferred mode. The corner radius on the male punch member, formed by its negatively inclined walls and a flat punch face, counter rubs the other side of the sheet material panel during withdrawal of the male punch member from the female molding member.

Elimination or optimized reduction of curling can be obtained by reducing the residual die gap between the male and female members (minus the thickness of the material) to a value which is not substantially zero, but about 0,254 mm.

SUMMARY OF THE DRAWINGS

Figure 1 is a schematic flow diagram of the various sequences in carrying out the preferred method of this invention, the subfigures of 1d-1g representing enlarged portions of the operative phases in subfigures 1a-1c;

Figure 2 is a schematic diagram of press apparatus used to carry out an alternative mode of the method using a binder element; Figure 2a is a plan view of a portion of Figure 2;

Figure 3 is a series of diagramatic illustrations showing still another alternative method mode for carrying out the invention herein, subfigure 3d representing an enlarged portion of the structure shown in subfigure 3b;

Figure 4 is an illustration of yet still another alternative embodiment for the method employing a knuckle on the binder structure to apply counter rubbing;

Figure 5 is a diagramtic view of yet another arrangement for carrying out the method employing a counterpressure pad positioned at a predetermined distance below the female molding member; subfigure 5b being an enlarged view of the sheet metal after it is withdrawn from the press structure in subfigure 5a; and

Figure 6 is a photograph of sheet metal hat sections pressed with and without the use of this invention.

DETAILED DESCRIPTION

A press is the machine used most often for cold working of sheet material. A press consists of a machine frame supporting a bed and a ram, a source of power and a mechanism to cause the ram to move in line with and at right angles to the bed. A press, in and of itself, is not sufficient as a production machine, but must be equipped with tools commonly called punches and molds, each of which

are designed for certain specific operations and forming contour. Typically, as used in the examples of this invention, a male punch member is carried by the ram and is moved in a downward direction to contact the upper surface of a flat sheet metal panel which sits atop a female molding member designed to allow the male punch member to penetrate thereinto.

Presses can be conveniently classified into two broad types, including hydraulic and mechanical presses. This invention is applicable to the use of either type of such presses. Mechanical presses are desirable from a production standpoint because of their higher speed of cycling and more rapid production.

When working with such presses, this invention has discovered that if the sheet material is strained or stressed by counter rubbing on the surface of the sheet material opposite to the surface to which strain or stress was applied by bending and unbending during pressing to create curling, the curvilinear springback (or curling) can be eliminated or significantly reduced. Springback which results in an out-of-shape curled section may be due in part to (a) bending springback by progressive bending and unbending about a fulcrum of one of the pressing members, and (b) deformation strain imposed by shearing or surface rubbing forces creating a strain gradient across the metal thickness.

Curling is defined herein to mean curvilinear springback residing in a sheet material panel which has been subjected to separated and opposed sequential permanent bending during pressing, causing the panel to be bent and unbent about a fulcrum contacting one panel side as it is pulled into the female molding member during pressing. Sequential permanent bending is involved since one bend is imparted prior to the completion of the other bend which necessitates feeding and curling of the panel

around the form (fulcrum) for the second bend. Bend radii is used herein as referring to the bend in the sheet material resulting from pressing a corner of the male punch member or female molding member thereagainst.

A preferred method for carrying out the present invention comprises interposing a panel 10 of undeformed sheet metal between a male punch member 11 and a female molding member 12 carried by a press of the type described in "Techniques of Pressworking Sheet Metal", by D.F. Eary and E.A. Reed, 2nd Edition, Prentice-Hall, Inc., 1974.

First, the members 11 and 12 are moved together, such as by a rapid striking or pressing, to form progressively opposite and separated bend radii 13 and 14 in the sheet metal (see Figure 1c). The section 15 of the panel between the bend radii is subjected to bending and unbending about the fulcrum 30, as well as rubbing or shear forces, on one side, here being the outer surface 10a. As deformation proceeds, an unbalanced strain gradient is imparted across the thickness of the sheet metal material in this section. Secondly, either during pressing or independently thereof, the other or inside surface 10b of the separating section 15 of the sheet metal panel is counter rubbed (engaged by a fulcrum 33) to impose a strain generally equal and opposite to the first strain resulting in a reduction of curvilinear springback in the separating section.

In carrying out the first step, the press is preferably of a mechanical type having a power linkage to the ram which may be a crank, a cam, an eccentric, a power screw, a rack and pinion, a knuckle joint, a toggle, and even a pneumatic coupling means. As shown in Figures 1a-1c, the male and female members are each contoured to ultimately form a hat section (see Figure 1g) having pairs of oppositely opposed bend radii 13-14 and 16-17 separated by a desirably flat webbing 18. The male punch member 11 is preferably T-shaped, having a central punch body 19 with

an overhanging head 20. The body 19 is adapted to seat within the cavity 21 of the female molding member to create one bend 14 and the head 20 is adapted to seat against the shoulder 30 surrounding the entrance to the opening or cavity of the female molding member to form a second bend 13. The opening or cavity 21 of the female molding member 12 receives the body of the male member with a predetermined spacing or die gap 22 therebetween to accommodate not only the thickness 23 of the material, but also to provide a predetermined residual space 24. The depth of the opening within the female molding member is designed to be greater than the depth 25 of the body of the male punch member so that upon complete penetration of the male punch member within the female molding member, the head 20 will seat fully. The flanges 26, sidewalls 15, and webbing 18 of the sheet metal panel will be compressed to adopt the hat section configuration of the tooling. A counterpad 27 is preferably used to grip the sheet metal in cooperation with the punch member; counterpad 27 is typically stationed flush with the entrance to cavity 21 and resists the punch with a force of about 300 psi applied via a pin 28 and hydraulic or pneumatic actuator 29.

Sheet materials which respond to this method include metallic and nonmetallic materials having (a) an elongation of at least 1.5% permitting the material to be permanently bent, and (b) a melting temperature at least double the temperature at which pressing occurs (so that the material can be cold worked at conventional room temperature in a solid rigid form). In addition, the sheet material must have sufficient structural rigidity to withstand the shearing or rubbing in some modes. Typically, this necessitates a thickness of about 1,27 mm inches for conventional carbon steel and for HSLA steel when subjected to the mode of Figures 1 and 3.

During an early stage (Figure 1a) of pressing, the outer margin 10c of the sheet metal panel is free and out of contact with the head or body of the male punch member. The panel is drawn into the opening 21 of the female molding member 12 and is caused to be bent at first radii 14. The sections 15 flare outwardly out of contact with the male punch member. When the male punch member has entered the female molding member to a greater degree (as shown in Figure 1b), the flared margins 10c will contact the head 20 of the male punch member; the margins of the sheet metal panel will be restrained from freely folding upwardly and will bend downwardly. This increases the rubbing contact of the panel outer surface on the corner radius 30 of the female molding member. This strain continues to be imparted as the sheet metal is drawn more deeply into the female molding member (see Figure 1c, full line). This continuous and progressive bending and unbending of the outer surface of the sheet metal panel imparts a strain gradient across the metal thickness 23. Such differential strain is contained when the members are mated. However, upon withdrawal of the male punch member and its withdrawal from the female molding member, the deformed sheet metal panel, will respond to strain gradients therein and assume a shape as shown in subfigure 1g. The sidewalls or sections 15 are progressively curled along a curvilinear path. The bottom web 18 is flat because of the application of the counterpad, but would be crowned without such application.

Counter rubbing is preferably carried out with the deformed or pressed sheet metal panel remaining within the female molding member and the first punch member is withdrawn. A second, but oversized, male punch member 31 (see broken outline in Figure 1c) within a predetermined oversizing of 1,575 mm is restruck or pressed into the female molding member. This time, the inner surface 32

of the sheet metal panel will be engaged and rubbed by punch surface 31, imparting approximately equal and opposite strain to the first strain. The surface 31 of the oversized punch member 31 applies shearing or rubbing forces. Upon removal of the sheet metal panel from the female molding member after the restrike operation, the sheet metal will adopt substantially the configuration of the tooling members 11 and 12.

Uncompensated curling is due in part to two phenomena, one is the springback due to the progressive bending and unbending about a sliding fulcrum, and to the unbalanced rubbing strain after the sheet metal has contacted the overhanging head of the male punch member. To facilitate total removal of such curling, there must be fairly accurate oversizing of the male punch member to produce substantially comparable and opposite straining of the interior surface. This is difficult to accomplish throughout the entire height of the separating section 15. To eliminate this unpredictability of the degree to which counter rubbing must be applied to the inner surface, a modification of the method can be carried out as shown in Figures 2 and 2a. A binder or restraining element 34 is mounted atop the female molding member 12. Such binder element guides the sheet metal panel 10 in a horizontal direction 36 transverse to the line of movement 35 of the punch member. As the panel is fed to the pressed center zone, it is restrained against folding freely upwardly (flaring) to later engage the overhang of the head of the male punch member. Such restraint is afforded by the binder 34 which forms a slot 37 through which the panel may pass in a horizontal direction. Now the outer surface 10a of section 15 is uniformly rubbed throughout the entire stroke of the male punch member thereby facilitating equal

counter rubbing during restriking with an oversized male punch member. The first strain is now uniform throughout the section 15 so that the strain resulting from uniform counter rubbing during restriking is more accurately equal to the first strain.

Another alternative mode for the method is shown in Figures 3a-3d, which mode eliminates the necessity for a restrike motion. The male punch member 40 is formed with negatively inclined sidewalls 41 to the body 43 of the punch. This permits the corner radius 43 (formed between the negatively inclined walls 41 and the bottom face 44 of the punch) to have particular utility during withdrawal of the punch member. The male punch member contacts a fixed portion of the panel during the first downward pressing motion; contact is by the punch face 44 and corner radii 45 only. There is no relative rubbing action between the male punch member and the sheet metal as it is drawn with it. There is bending and unbending as well as rubbing of the outside surface 46 on the corner radius 43 of the female molding member to impart the curling strain.

Counter rubbing occurs on withdrawal of the male punch member by bringing the corner radius 45 into a line contact with the separating section 48. The negative angle of the male punch member permits the sheet metal panel to have a slight overinclination 49 in the pressed condition. Thus, upon withdrawal of the male punch member, there is secure line contact to impart a substantially equal and opposite rubbing effect upon the inner surface 50, countering the effect of outer surface rubbing. Line contact concentrates forces to act more like the corner rubbing of the female molding member. This results in the elimination of the curling tendency without the necessity for a restrike. The use of a negatively inclined male punch member does make possible the elimination of a second striking action.

An alternative mode shown in Figure 4 retains the virtue of a single strike action while permitting the use of straight walled punches. A conventional male punch member 11 is employed having a straight-sided body 19. The binder element 53 has a bead 54 depending from the inner edge to impose a predetermined pressure upon the inner surface 10b of the sheet metal panel 10 as it is progressively drawn through the binder element into the opening 21 of the female molding member 12. As this occurs, equal and opposite strain is imparted simultaneously to the inner and outer surfaces 10a and 10b of the sheet metal panel, preventing any curling tendency. This is accomplished during the downward striking motion of the male punch member. The withdrawal of the male punch member does not enter into the sequence of removal of strain and thus can be extremely rapid.

The use of a counterpad 27 to assist in eliminating both curling and bending springback can be employed as shown in Figure 5a. The binder element is again used having a bead 54 to impose a continuous pressure during the downward striking of the sheet metal panel. The counterpad 27 is positioned a distance 55 below the mouth 56 of the female molding member 12. When the sheet metal panel is deformed by pressing through distance 55, there is counterpad pressure to confront the male punch member. A curvilinear form is imparted to web 18 of the panel. Upon confrontation of the male punch member with the counterpad, the web in the sheet metal will be flattened to spread apart the first bend loci A. Thus, upon further travel of the male punch member, the panel will be bent at a new loci B (spaced a slight distance from A). The initiation of a second bend, due to the spreading apart of the first bend loci, will compensate for bending springback in accordance with the concept and phenomemon taught in another copending application.

the disclosures which are incorporated herein by reference. The elimination of the bending springback facilitates a truer noncurled section 15 with extremely reduced out-of-flatness.

In carrying out tests utilizing the method mode shown in Figures 1a-1c, a first pressed specimen was prepared utilizing HSLA steel having a thickness of 1,45 mm and a tensile strength of 3515 bar. The bend radii were 3,18mm for the male punch member and 6,35mm for the female molding member. For each specimen, the male punch member, used for the first strike, had a width of 29,4 mm and a die gap of 3,15 mm Specimen 60 was not restruck (see Figure 6) and exhibited severe curling. Specimen 61 was restruck with an oversized male punch member having a width of 26,97 mm and resulted in a desirable hat section as shown in Figure 7. Successful reduction or elimination of curling was obtained with similar processing by varying the die gap during pressing to 1,016 to 1,778 mm the optimum 0,254mm added to the thickness of the material. The section between the bend radii should preferably be at least 12,7 mm to achieve noticeable elimination of curling. When using the method mode of Figures 3a-3d, the residual die gap (Δd) that proved to reduce curling the most was in the range of 0,20 mm to 0,559 mm and optimally at 0,30 mm, the metal thickness being about 1,448 mm.

CLAIMS

1. A method of reducing curling in sheet material panels subjected to progressive opposed bending, characterized by the following steps:

(a) pressing said panel to sequentially form opposite and separated bend radii therein, the separating section of said panel between said bend radii being subjected to progressive bending and unbending forces about a fulcrum slid along one side thereof to impart a first strain;

(b) rubbing said separating section on the opposite side of said panel to impart a strain opposite to said first strain whereby said pressed panel will adopt the configuration of said press with reduced curvilinear springback in said separating section.

2. The method as in Claim 1, characterized by that said pressing is carrying out with a male punch member and a female molding member designed to impart a hat section configuration to the panel, said hat section having pairs of opposed bending radii connected by a web.

3. The method as in Claim 2, characterized by that each of said bend radii have an angle of about 90° and the bend radii of each pair being separated by an intermediate section having a length of at least 12,7 mm.

4. The method as in Claim 1, characterized by that, the rubbing of said separating section in step (b) is carried out subsequent to the bending and unbending in step (a).

5. The method as in Claim 4, characterized in that, the rubbing of step (b) is carried out by the use of a second male punch member having an oversized cross-section effective to impart surface shearing forces to said opposite side of said separating section.

6. The method as in Claim 1, characterized in that, said pressing is carried out with the use of a male punch member and a mating female molding member which together, when mated, provide a die gap therebetween, said members being controlled to limit said die gap to 1.5-3.0 times the thickness of the sheet material during step (a).

7. The method as in Claim 6, characterized in that, the members are controlled to adjust the die gap in step (b) to substantially the thickness of said sheet material.

8. The method as in Claim 6, characterized in that, said members are controlled to progressively decrease said die gap in proportion to an increase in the material strength of said sheet material.

9. The method as in Claim 6, characterized in that the residual die gap between said members is adjusted to be about 0,254 mm during step (b).

10. The method as in Claim 1, characterized in that the bend radii each have a radius in the range of 3,18 mm to 6,35 mm.

11. The method as in Claim 1, characterized in that, a fixed binder element is employed during step (a) to engage and guide the travel of said opposite side of said intermediate section so that said panel is rubbed uniformly on said one side.

12. The method as in Claim 1, characterized in that, the male punch member is T-shaped with a central punch body and an overhanging head, said body and female molding member imparting a first bend to said panel during pressing followed by a second but opposite bend imparted by said overhanging head and female molding member, said panel being rubbed on said one side during the formation of said second but opposite bend.

13. The method as in Claim 11, characterized in that, said binder element supports a knuckle to simultaneously rub the opposite side of said panel during pressing to impart a deformation strain opposite to the strain imparted to said one side.

14. A method of reducing curling in sheet metal panels subjected to sequential opposed bending, characterized by the following steps:

(a) pressing an undeformed sheet metal panel into an opening of a female molding member by use of a mating male punch member, said female molding member having at least one corner radius defining an edge of said opening and said male punch member having a punch body with negatively inclined sidewalls intersecting with a bottom face to define acute angled corner radii, one side of said sheet metal panel being caused to rub against said one corner radius of said female molding member during pressing to impart a deformation strain to said one side; and

(b) withdrawing said male punch member from said female molding member so as to uniformly rub the other side of said sheet metal panel with said acute angled radii of said male punch member so as to impart a strain substantially equal and opposite to the strain in said one side of said sheet metal panel.

15. The method as in Claim 14, characterized in that said male punch member is pressed to seat against the bottom of the female molding member during step (a).

16. A method of reducing springback in pressed sheet panels subjected to progressive opposed bending, characterized by the following steps:

(a) placing said sheet panel within at least one binder element slotted to closely conform to the thickness of said panel and oriented to allow the panel to pass therethrough in a first direction;

(b) pressing said sheet panel into a female molding member having an entrance opening defined by corner radii, said pressing being along a second direction transverse to said first direction causing one side of said panel to be progressively curled and rubbed against said corner radius of said female molding member to impart a first deformation strain thereto; and

(c) while pressing, rubbing the opposite side of said panel to impart a second deformation strain generally opposite to the first deformation strain.

17. The method as in Claim 16, characterized in that the step (c) is carried out by the use of a knuckle on said binder element effective to apply a predetermined pressure force to said opposite side of said sheet metal panel.

18. The method as in Claim 16, characterized in that in step (b) said male punch member confronts a counterpad prepositioned a distance below the entrance opening of said female molding member, said counterpad resisting further pressing movement to flatten the sheet metal engaged by said counterpad causing said punch to form new bend radii in said sheet metal panel during the remainder of said pressing.

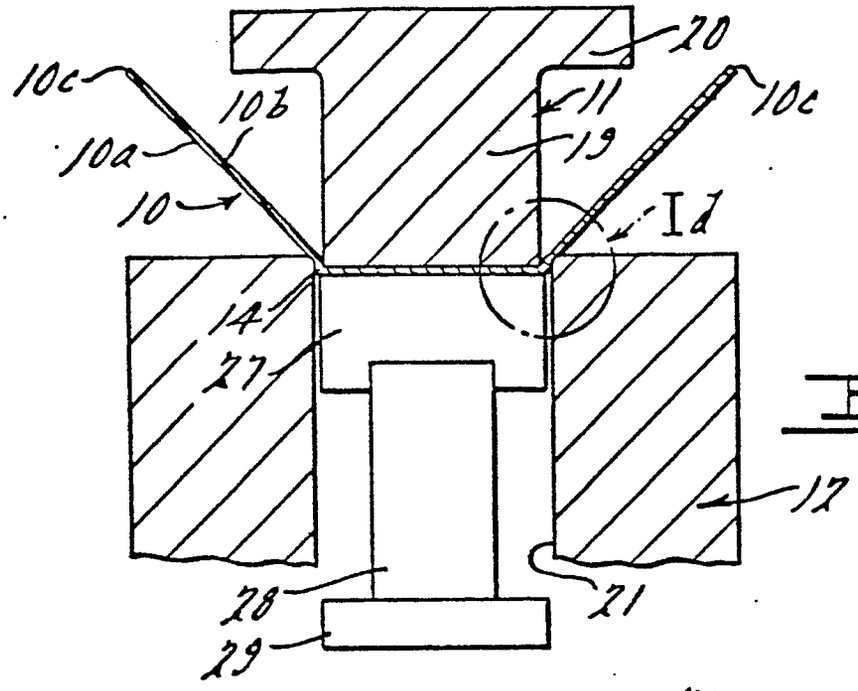

Fig. 1a.

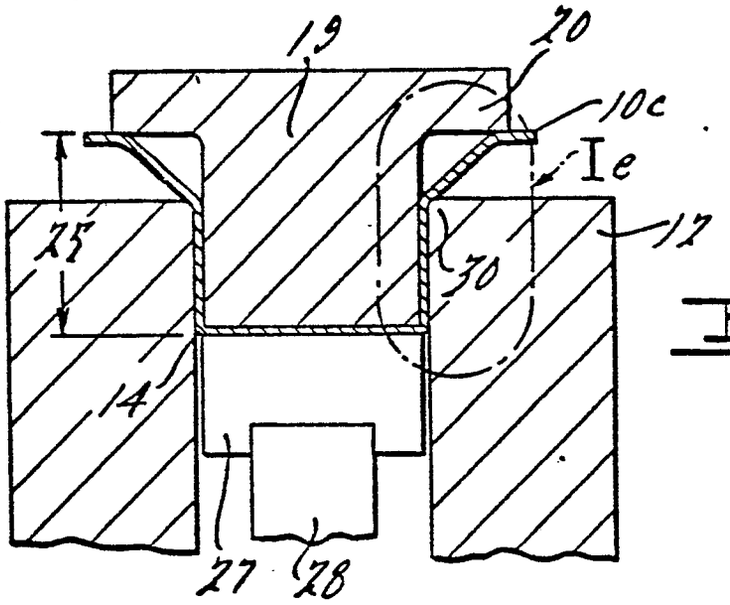

Fig. 1b.

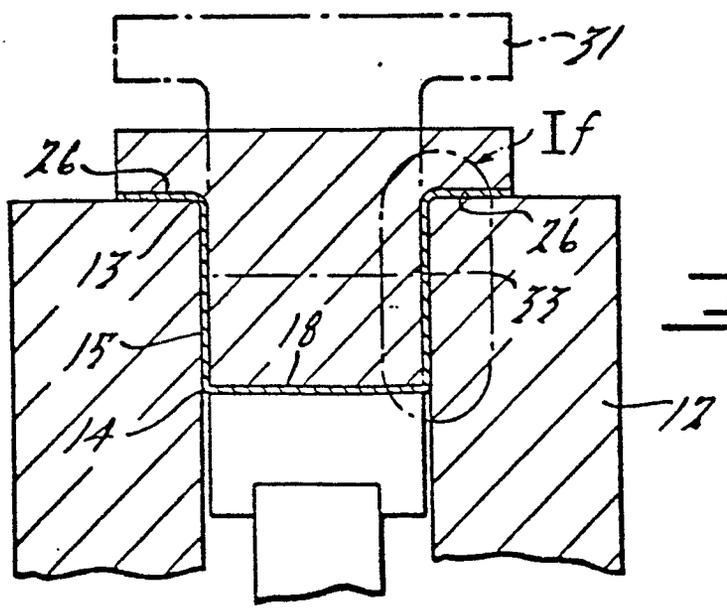

Fig. 1c.

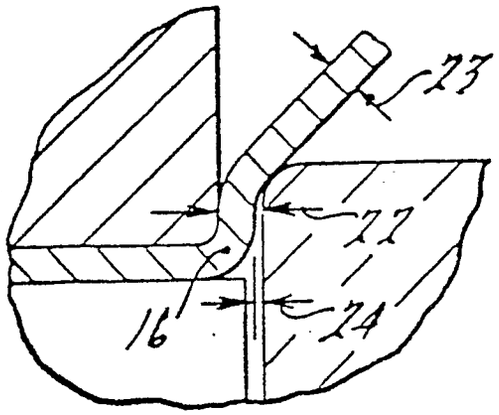

Fig. 1d.

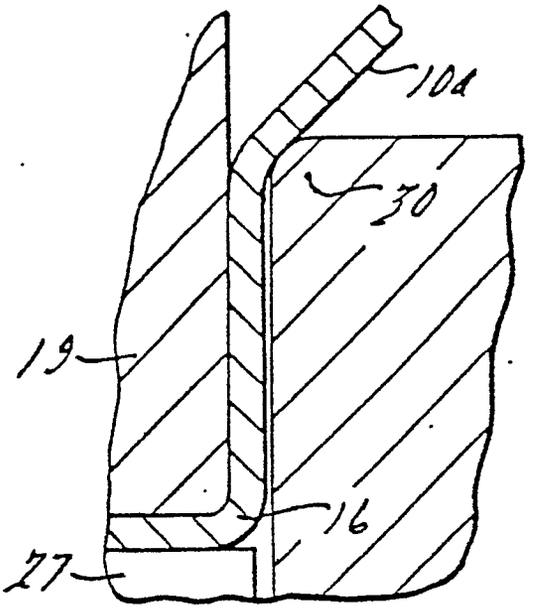

Fig. 1e.

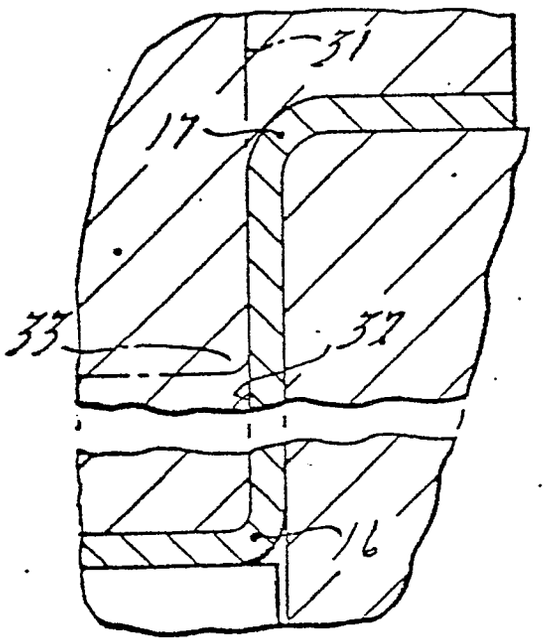

Fig. 1f.

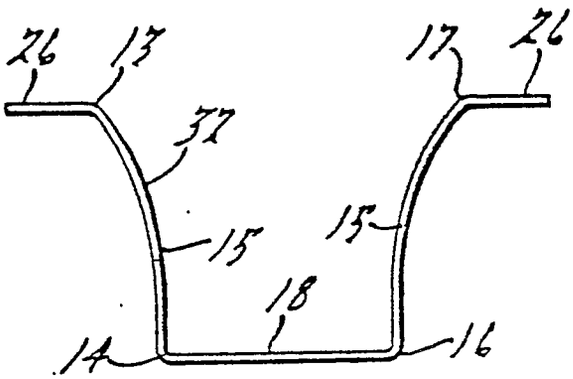

Fig. 1g.

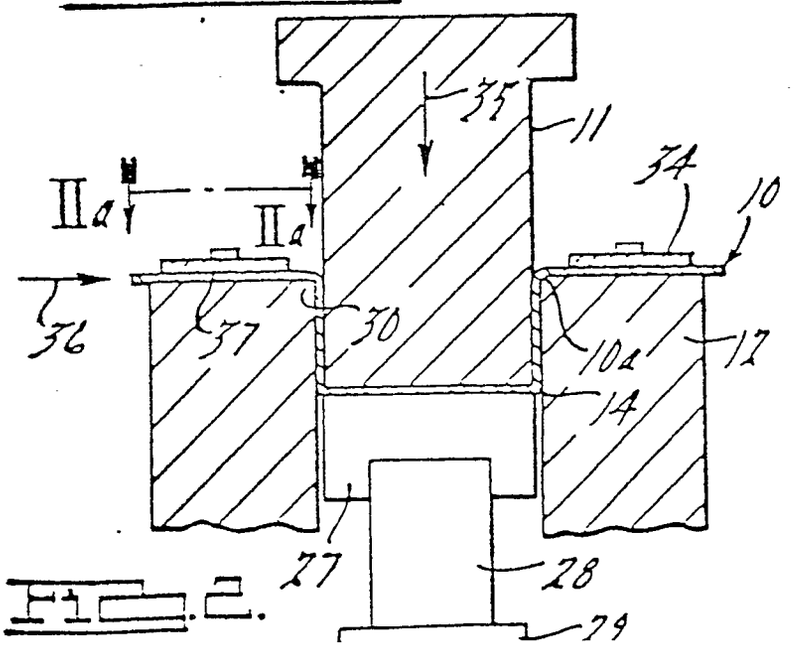

Fig. 2.

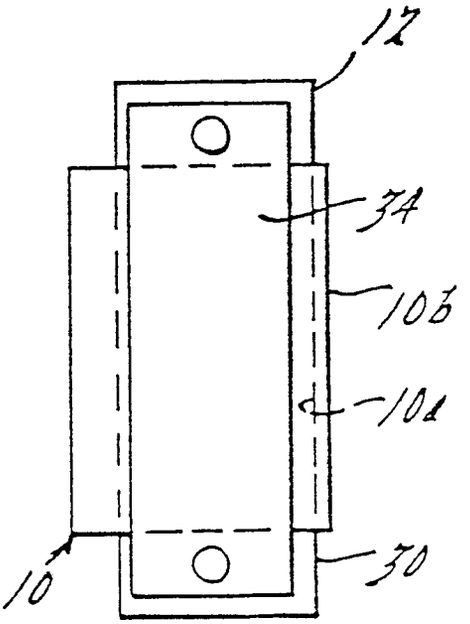

Fig. 2a.

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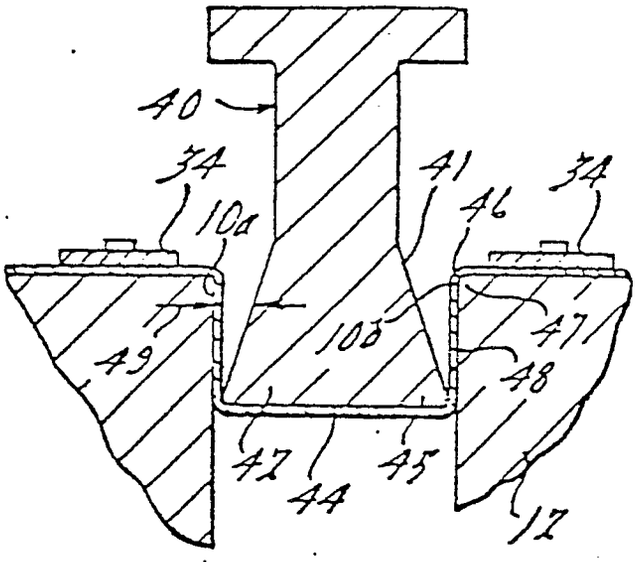

FIG. 3a.

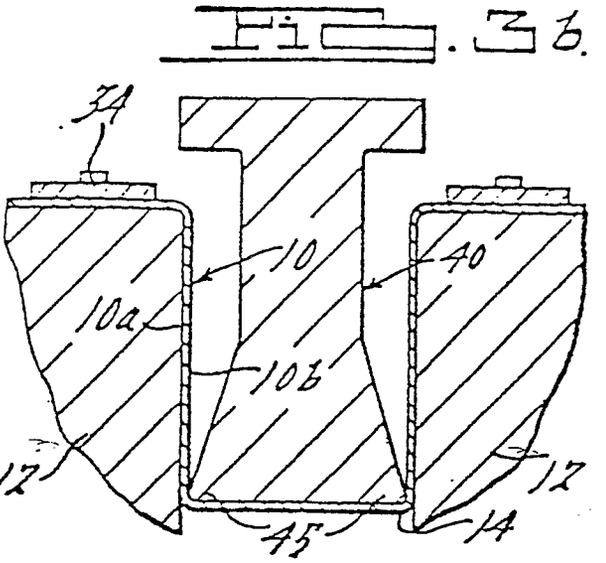

FIG. 3b.

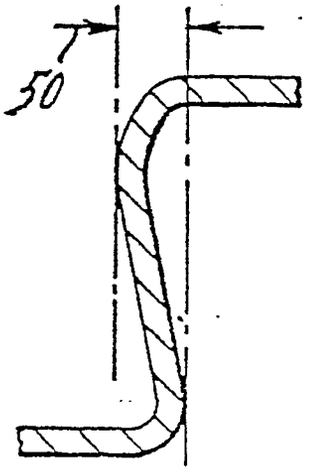

FIG. 3c.

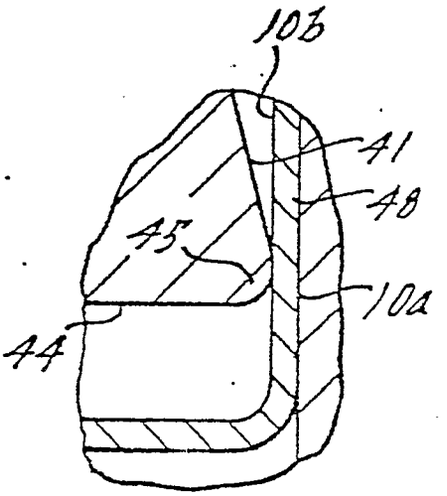

FIG. 3d.

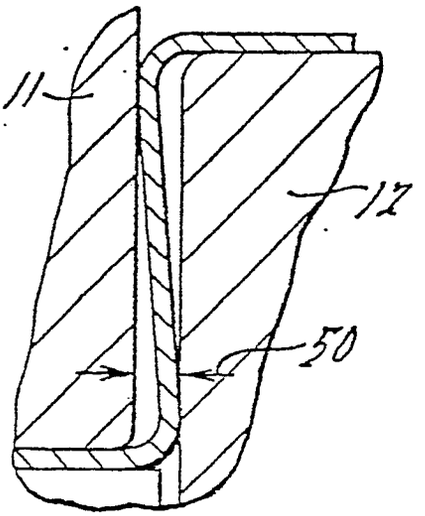

FIG. 5a.

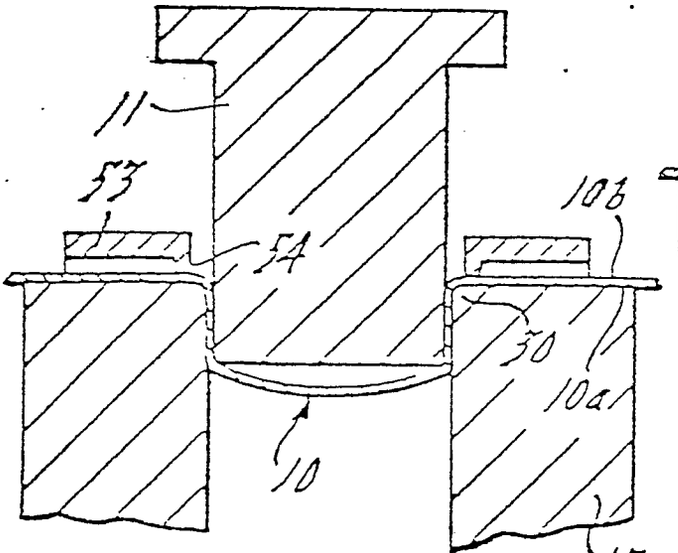

FIG. 4.

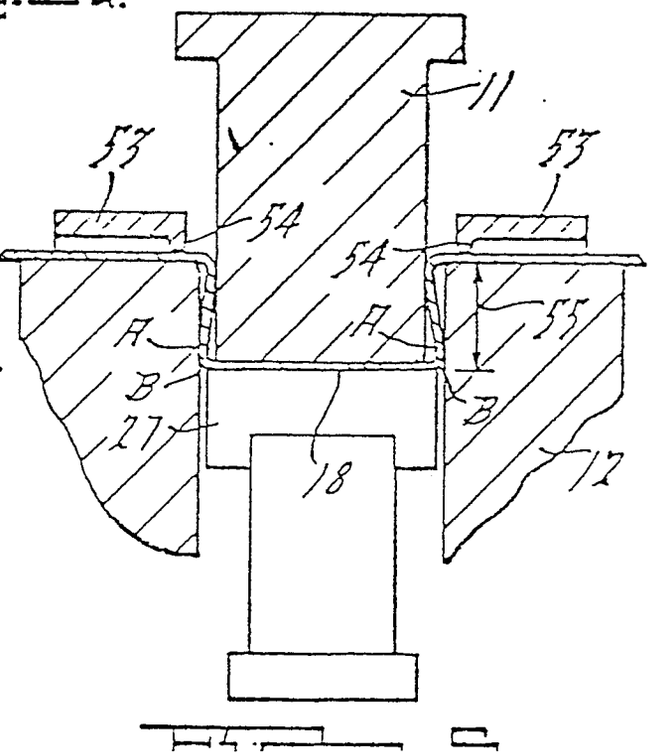

FIG. 5b.

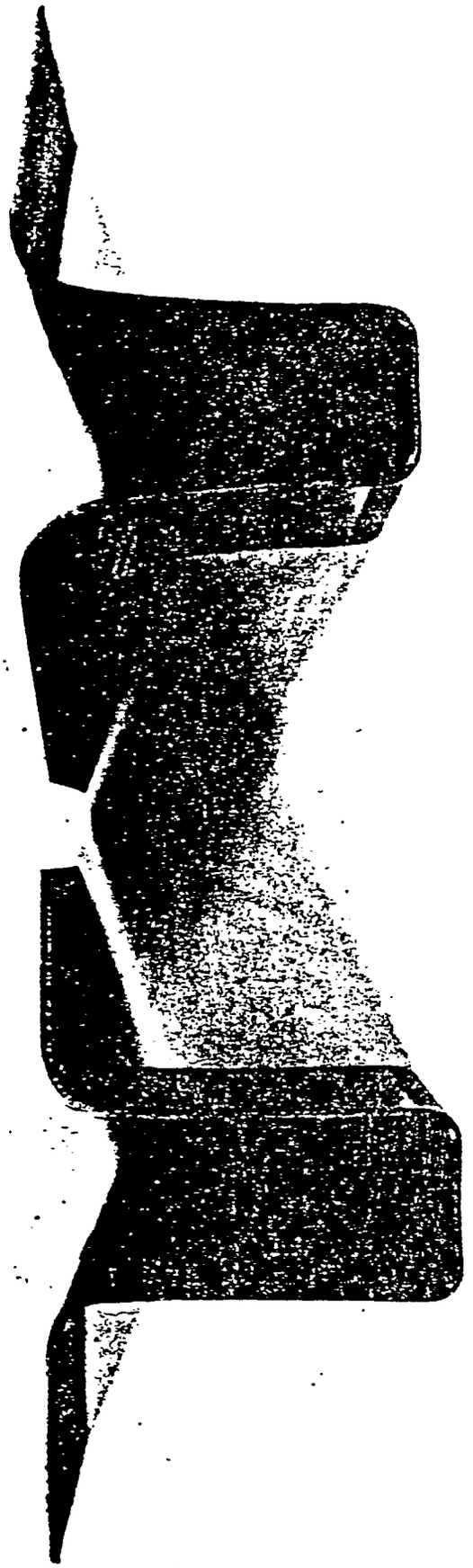

Fig. 6