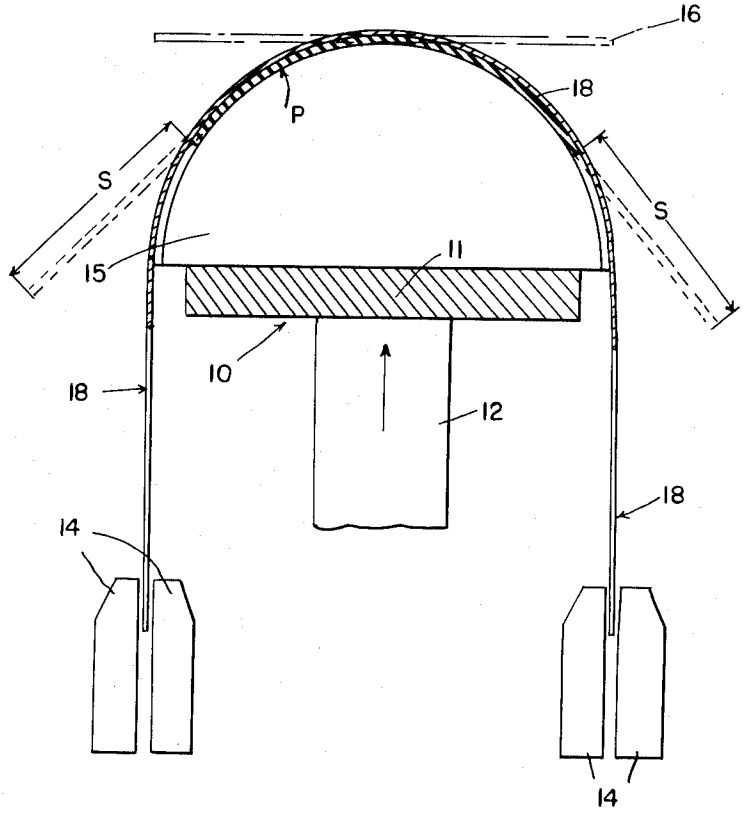
Dec. 14, 1965 J. S. KIRKPATRICK ETAL 3,222,911

FLEXIBLE OVERLAY FORMING

Filed April 16, 1962 3 Sheets-Sheet 1

FIG. 1.



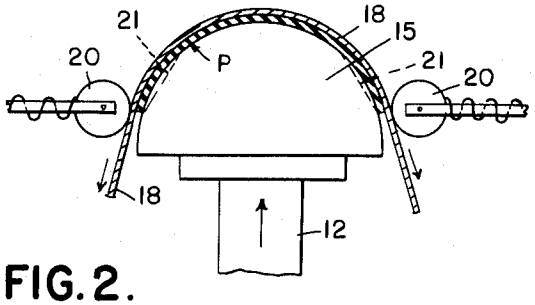


FIG. 2.

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FLEXIBLE OVERLAY FORMING

Filed April 16, 1962 3 Sheets-Sheet 2

FIG.3.

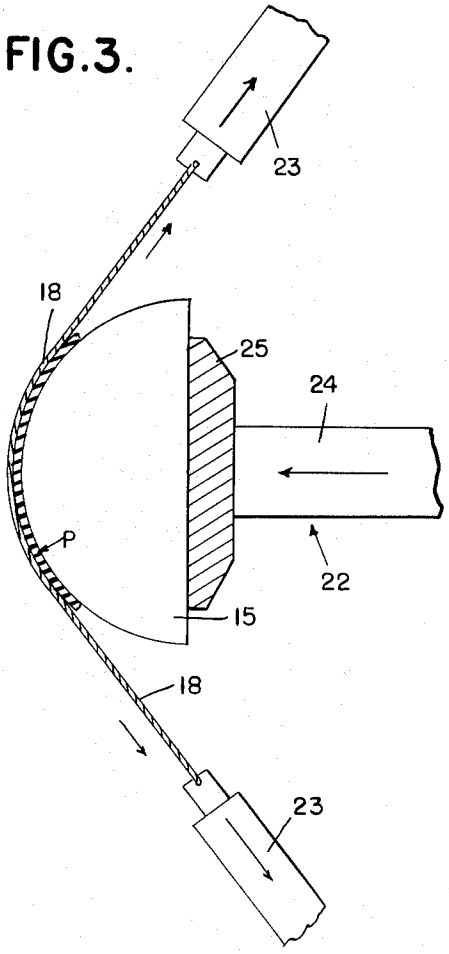
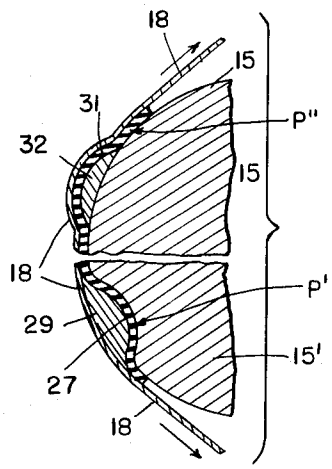


FIG.4.



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FLEXIBLE OVERLAY FORMING

Filed April 16, 1962 3 Sheets-Sheet 3

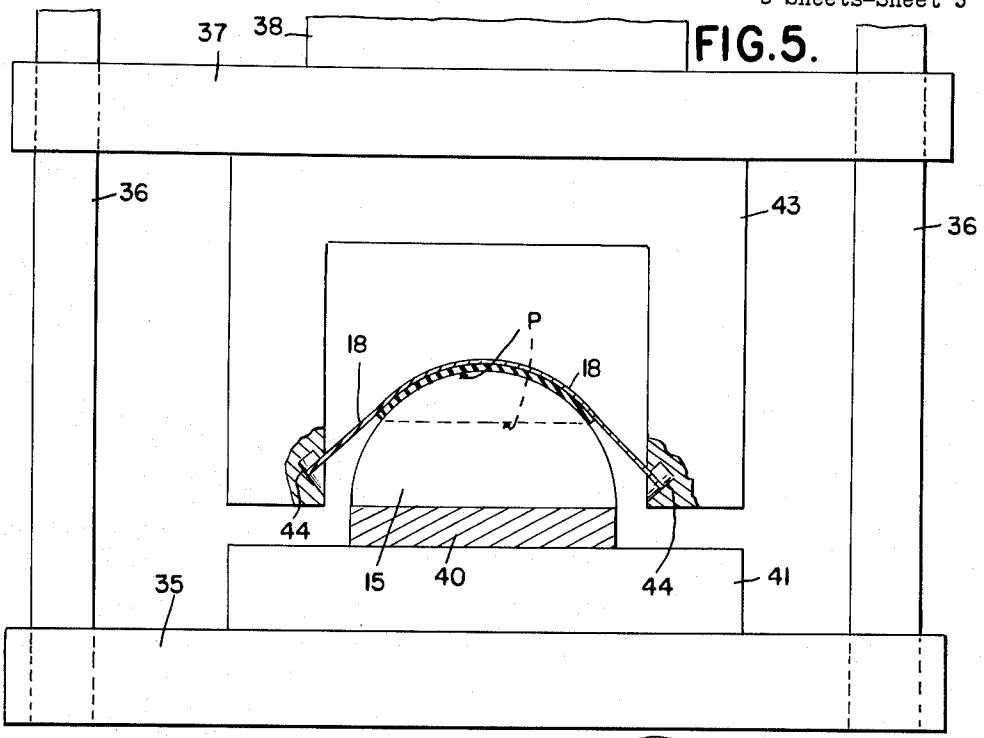


FIG.5.

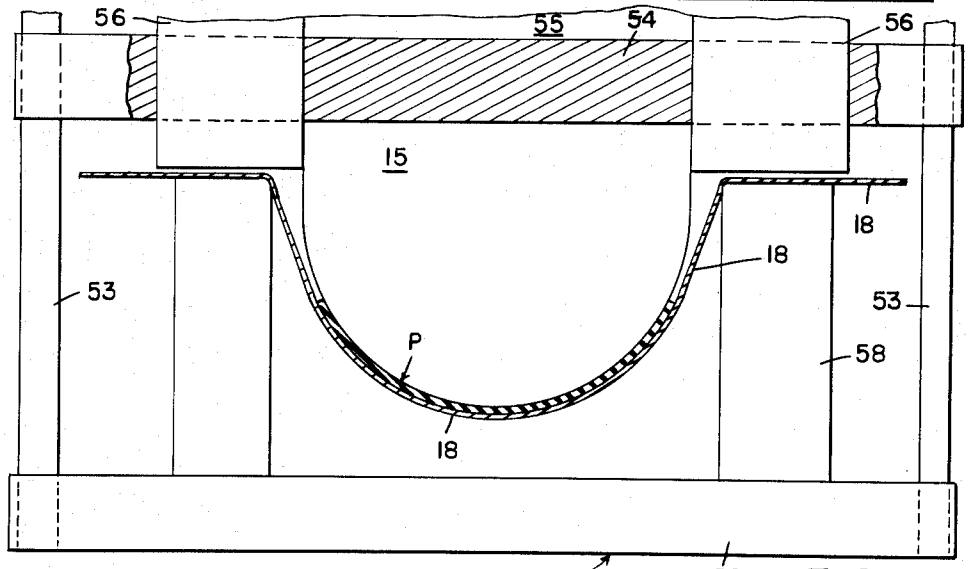




FIG.7.

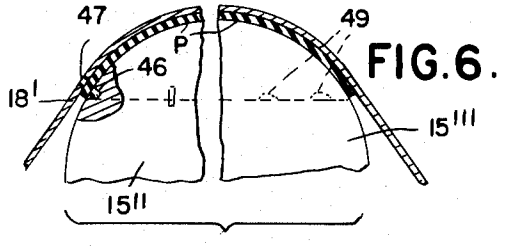


FIG.6.

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United States Patent Office 3,222,911
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3,222,911

FLEXIBLE OVERLAY FORMING

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Filed Apr. 16, 1962, Ser. No. 187,673
9 Claims. (Cl. 72—363)

The present invention relates to improvements in a method of flexible overlay forming. More particularly, the invention deals with an improvement in certain metal stretching or so-called stretch-forming operations heretofore used in the making, from sheet material, of specially contoured objects, most recently for use in the aircraft industry. Such methods have involved the forming of sheet metal blanks into a variety of different contoured shapes, compound or otherwise, by pulling the blank, either around a male forming member to conform the blank to the latter, or while the blank is between a set of male and female dies of a contour to provide a desired curvature, re-entrant or otherwise. The present improvements are of a character distinguishing from old established sheet forming procedures in a degree comparable to other more recent types of forming, such as electromagnetic forming, explosive forming, and the like.

It is commonly known that extreme and unusual material requirements have been imposed upon aerospace vehicles, due to extremely high aeronautic and astronautic operational temperatures and speeds. Materials are subjected to temperatures ranging from the relatively low combustion and friction-induced temperatures of normal aircraft to the tremendous temperatures of re-entry and orbital vehicles. In order to form these new materials to various shapes many new techniques have been evolved in the past few years, such as high energy procedures including impact forming, explosive forming, electromagnetic or electrostatic forming, cryogenic forming, etc., as mentioned above. Most of these techniques are for relatively low quantities since to date the aerospace industry seldom requires more than a few prototypes or experimental units.

The materials desired to be formed, and the cost thereof, vary from such relatively common metals as steel and steel alloy sheet, aluminum, magnesium, and the like, obtainable at reasonable prices, to such exotics as titanium, zirconium, hafnium, uranium, beryllium, columbium, molybdenum, etc., all at considerably higher prices. Some of these materials, for example certain ferrous alloys, columbium, etc., can be formed at room temperature, while others require the application of heat, examples being magnesium, titanium, zirconium, hafnium, beryllium, molybdenum, etc.

Thus, some of these materials cannot be handled by conventional procedures at room temperatures because they are brittle and do not allow themselves to be gripped; they thus do not permit forming pressure to be applied thereto, as in conventional punch and die forming, stretch-forming, and the like, without cracking.

A typical example of such a desirable material for use is beryllium. Its rigidity is about twice that of the best steel and its weight is comparable with that of magnesium. When melted, beryllium has a granular structure characterized by a relatively enormous grain size up to ¼ inch, hence the metal is very brittle, indeed. It is produecd in sheets by grinding to a finely powered particle

size, then sintering and rolling and/or machining to form sheets. As thus produced the beryllium sheet obviously is very brittle, and has little bendability and tensile strength such as are required by the stretch-forming method, an operation strictly limited in use at normal operating temperatures by the flexibility and pull strength of the material to be formed.

Generally considered, the present invention relates to an extension of or improvement upon the metal forming procedure commonly known today as stretch-forming. In this operation, which may be carried out with the metal in a hot or cold condition, depending upon its particular type, a sheet or blank is supported by gripping the same at two opposite sides, or at spaced points around its periphery, and is then conformed under tension to a male punch element by a relative movement of the punch and sheet. In many instances a coacting female die is employed.

It is readily seen, in addition to the fact that the conventional stretch-forming method may not lend itself practically to the production of parts composed of the various materials noted above, that where the cost of such materials is so high as to be figured in dollars per square inch, a saving of a few square inches area of the blank sheet to be formed may well amount to a considerable saving in the price of the final part. Thus, an elimination of the need for a considerable marginal area, subsequently scrapped, at which the sheet is necessarily gripped in stretch-forming to hold the same against the forming member or punch, will result in a great saving of material cost for a run of even limited size.

It is further a fact that some of the new, exotic materials mentioned above cannot be procured in pieces large enough to enable the formation of the part and still afford a flash zone to be gripped by the stretch-forming jaws.

Therefore, in accordance with the invention, the part is formed by employing a flexible overlay or overwrap pressure applying sheet of an area sufficiently greater than that of the sheet blank to be formed to enable the overlay sheet (as distinguished from the blank) to be conveniently gripped by the jaws of a conventional stretch-forming machine. The blank is interposed, in a cold or hot position, between such overlay sheet and the punch, about which punch it is then shaped through the action of the tensioned overlay.

This type of secondary or pressure wrap forming procedure enables the material of the production sheet or blank to be maintained at an absolute minimum area by eliminating the need for a direct grip thereof by the stretch-forming jaws.

Another object is to provide for the use of a flexible overlay sheet in the forming of metals, as described above, in which, in addition to a saving of material cost and avoiding the drawback of brittleness, the procedure enables the formation of materials which would be so soft, if subjected to conventional stretch-forming tension, as to be unable to pull themselves onto the contour of a punch, even if not being too brittle to permit this action.

The procedure also enables the formation of materials, such as the exotic ones, which are not weldable, so that the technique of welding gripper jaw material to the blank to be formed is not practical.

A further object is to provide a procedure which enables the overlay sheet to which forming pressure or tension is applied to be of not only a higher strength and

much less expensive material than the material being formed, but also of a resilient, flexible or ductile character having no tendency to fracture under tensile or bending stress.

As indicated above, the invention contemplates a procedure which may be used effectively for either the hot-forming or cold-forming of sheets. Moreover, the overlay member may, if desired, be chosen of a suitable material to act as a resistance heating element to heat the part being formed.

Materials which may be termed "reactive," in the sense that they cannot be formed in the atmosphere at elevated temperatures due to oxidation, but must be formed under heat in a non-reactive or inert surrounding, may in some cases be formed by the improved procedure, since in such cases it eliminates the need for heating to impart required forming ductility. The invention also lends itself to the production of forms from other materials as to which the temperature of forming may tend to impose a limitation on the practicality of following known forming techniques.

Yet another object is to provide a procedure which, employing as it does a flexible overlay sheet to exert direct forming pressure on the material to be formed, permits this pressure to be maintained while the formed part takes a set or cools, thereby eliminating spring-back.

Similarly, the flexible overlay procedure permits the insertion of suitable auxiliary pads of rubber or the like in supplementation of the overlay sheet to force certain contours into the part being formed against a forming member.

A further object is to provide a procedure of overlay forming of sheets, as described, wherein the overlay sheet may be provided with holes drilled therethrough adjacent a margin thereof, or with marginal or edge notches or the like, enabling the formation of locating holes or indentations on the formed piece. Such formations might, for example, be subsequently employed for reference in the location of a template over the formed workpiece, with the assistance of which template the piece is then trimmed to its final desired shape.

A still further object is to provide a procedure whereby a finished workpiece may be re-set to final shape between the overlay sheet and the member or punch against which the workpiece was initially formed, in the event the workpiece has been machined or otherwise handled in a manner which might tend to distort it.

It is further an object of the invention to provide a method wherein the overlay forming sheet and punch may be supplemented by the provision of rollers coacting with the sheet to more effectively force the same and the workpiece against certain portions of the punch to conform to the latter, for example, in a zone at which tension on the overlay sheet might not normally be expected to exert, of itself, a sufficient force normal to the surface of the sheet to cause efficient forming.

The foregoing as well as other objects will become more apparent as this description proceeds, especially when considered in connection with the accompanying drawings illustrating preferred embodiments of the invention, wherein:

FIG. 1 is a fragmentary and highly schematic view in elevation illustrating suitable means for carrying out the improved method in a known type of vertically acting press of a sort employed in a stretch-forming operation, the view showing in dot-dash line the initial flat sheet metal blank to be formed and indicating in dotted line the saving of material made possible by the improved procedure;

FIG. 2 is a similar fragmentary view showing a slight modification in regard to the equipment of FIG. 1, involving the use of auxiliary mechanical sheet forming or ironing means in association with the press structure of FIG. 1;

FIG. 3 is a fragmentary schematic top plan view illustrating the manner of conducting the improved method using a horizontal stretch type of press embodying hydraulic gripper jaws;

FIG. 4 is a fragmentary view in axial section showing permissive modifications of the improved overlay type of forming in the production of contoured products having special protuberant or re-entrant form features;

FIG. 5 is a fragmentary schematic view illustrating the manner in which the method may be carried out on a standard single action hydraulic press, as distinguished from the preceding types more specially utilized in the aerospace industry;

FIG. 6 is a fragmentary view similar to FIG. 5 illustrating modifications contemplated by the invention to permit the making of certain template register formations on the formed product; and

FIG. 7 is a fragmentary schematic view illustrating the mode of performing the improved method upon a standard type of industrial double-action press.

In reference to FIGS. 1, 3, 5 and 7, showing various types of basic, mechanically or hydraulically operated press equipment commonly employed in the sheet metal forming industry, whether in aerospace or less specialized production, it is to be understood that the further special features of improvement or refinement specifically illustrated in FIGS. 2, 4 and 6 (to be described) are available for use with complete interchangeability or optionality and in common with the basic equipment of FIGS. 1, 3, 5 and 7, as with other known types not shown. That is, in none of the refinements appearing separately in FIGS. 2, 4 and 6 are these features mutually exclusive of one another, or to be considered as particularly special to the particular type of equipment with which they are shown associated. Obviously, to illustrate and describe each feature in all possible combinations with other subordinate features would in a highly undesirable way, and unnecessarily, complicate the disclosure.

In particular reference to the equipment of FIG. 1, it is schematically shown as a vertically acting stretch-forming type of press **10** as employed in the aircraft and aerospace industry, featuring a ram **11** mounted on the plunger **12** of a hydraulic cylinder (not shown) to be elevated and lowered by the plunger. In certain later models of this equipment the ram is operated in a horizontal direction; and in standard types of high production mechanical presses, of more general application, the ram **11** is driven downwardly by appropriate mechanical or hydraulic means.

In known methods of stretch-forming, a sheet of appropriately contoured metal to be formed is gripped about its periphery or at its edges by a series of pairs of gripper jaws, of the sort designated **14** in FIG. 1, being held by these jaws while an appropriately contoured male forming block or punch **15**, secured on ram **11**, is urged against the thus anchored sheet. As indicated above, this requires a sheet blank of considerable size to provide necessary marginal gripping area, as well as a sheet of considerable ductility and tensile strength to withstand the bending and tension stress of stretch-forming. The formed sheet is subsequently trimmed from the sheet blank, with a wastage of the trimmed material amounting to a substantial area permitting its grip by the jaws **14**; and this is the case even if the material of the sheet is sufficiently non-brittle and strong to permit of conventional stretch-forming.

In accordance with the improvement of the invention, the sheet to be formed, shown in dot-dash line and designated **16**, is initially flat and of a shape and area but little, if any, greater than that of the finished product (specially designated P in FIG. 1). This is shown typically as being a portion of a semi-cylinder, which is the illustrated shape of the male forming block member or punch **15**.

The reference numeral **18** designates an overlay sheet of substantially greater area than that of the sheet **16** to be

formed, and fabricated of a material not only greater in tensile strength and flexibility than the sheet **16**, but also less expensive usually in nature. In accordance with the invention the overlay sheet **18** may be of a suitable grade of steel, steel alloy, non-ferrous metal or other material appropriate to the purpose.

The male forming block **15** may be suitably heated, in the event the process has to be carried out at elevated temperature due to a characteristic of the sheet **16**. Heating may be by electrical resistance through inserted electrical units (not shown), or by gas ring combustion of a gas, or the like. As indicated above, the overlay sheet **18** may itself be employed as a resistance element for the purpose in some instances, if fabricated of a suitable electrically resistive material.

With the sheet **16** laid over the forming block in flat form, as indicated in dot-dash line in FIG. 1, the overlay sheet **18** is applied over the same and, being gripped by pairs of jaws **14** or a series of such pairs about the edge of the sheet **18**, the latter is caused to exert forming pressure on sheet **18** as the punch or block **15** is advanced upwardly. This operation is carried out until sheet **16** is contoured finally to form the product P in a set condition, ready for a further marginal trimming or other operation thereon.

FIG. 1 graphically depicts the economic desirability of the improved method, whether as performed by the equipment of FIG. 1 or by that of other figures to be described. As shown in dotted line in FIG. 1, there is a saving of otherwise scrapped stock represented in area by the longitudinal dimension S times its width or circumferential extent, possibly of a very expensive material, which would be required in the conventional stretch-forming procedure (even were that procedure permissible for the forming of such material); and the need for this wastage is eliminated by the utilization of the stretch-forming sheet **18**. Such material is normally trimmed from the finished part or product in a later stage of the production, and because the trimmed-off material has been greatly reduced in length as compared with the dimension of the original blank it is of course no longer available as a standard blank size for a further forming operation.

It has been proposed to weld suitable gripper jaw material to the part to be formed in order to permit of the conventional stretch-forming operation. However, this is in many cases not practical for the technical reasons that many of the new materials presently referred to as exotic materials are not weldable, as well as being too expensive to justify wastage arising from welding.

It may be found desirable, as illustrated in FIG. 2 of the drawings, to supplement the pressure exerted by the overlay sheet under tension in the forming of the product P, in order to build up a forming force on the blank **16** which the overlay sheet **18** possibly could not exert against the sheet, in certain areas thereof, in a direction at 90° to its surface. This can be done, for example, by the use of opposed forming or ironing rollers **20**. These may be resiliently spring-urged, or otherwise yieldably urged, against the overlay sheet **18** during the forming operation, for the purpose of amplifying the direct, radially effective forming force on the overlay sheet **18**, and, through it, upon the form product P.

Furthermore, if it is desired, provision may be made for producing a flat or re-entrant or other special surface contour on the product P, as by providing one or more flats or grooves **21** on the male punch or block, with the pressure applied through the overlay sheet **18** (alone or as supplemented by the ironing means **20**) causing the sheet blank **16** to contour itself properly against such special surface or surfaces **21**.

FIG. 3 of the drawings shows the overlay sheet forming technique as performed with the use of a horizontally acting hydraulic stretch press **22**. This press features hydraulically operated gripper jaws **23** clamping the overlay forming sheet **18** at its edge, the opening and closing of the jaws being controlled concurrently with the operation of a hydraulic plunger **24**, which urges the forming punch head or block **15** to the left, as viewed in FIG. 3. Block **15** is mounted fixedly to the horizontally acting ram **25**. Many types of gripper jaws **23** are available in horizontal stretch presses of the sort shown in FIG. 3.

FIG. 4 of the drawings illustrates a further refinement according to the invention, by recourse to which other special or non-symmetric products may be formed by practicing the method of the invention. Thus, should it be desired to form a product, specially designated P' (lower portion of FIG. 4) having one or more cavities or re-entrant formations **27** therein, the forming member (specially designated **15'**) is contoured to provide a mating concavity or depression **28**; into which formation the material of the sheet blank to be formed is forced by interposing a suitable rigid or non-rigid auxiliary filler or adapter **29** between the blank sheet and the overlay sheet **18**. The latter acts on the exterior of the piece **29** to produce requisite forming force.

By the same token, and again referring to FIG. 4, a product P'' may be formed featuring one or more special protuberances **31** by interposing one or more special, similarly conformed auxiliary make-up, filler or shim pieces **32** between the normally contoured surface of the male punch **15** and the overlay sheet **18**.

FIG. 5 shows the application of the basic principles of the invention to forming through the agency of a standard industrial press, which may be mechanically or hydraulically operated. It comprises a fixed, massive bolster plate **35** disposed horizontally and provided with upright press columns **36**, upon which the movable press head plate **37** is guided for up and down action, being operated through the usual hydraulically or mechanically actuated press ram **38**.

A suitable material forming block or punch **15** is fixedly secured to a mounting member **40** and spacer **41** fixed on bolster plate **35**. The pressure head **37** sustains a jaw carrying member **43** provided with suitable jaws **44** to grip the edge of the overlay forming sheet **18**; and thereby form the product P as the press plate **37** and member **43** carry the jaws **44** downwardly relative to the male forming punch or block **15**.

It is usually desirable to perform subsequent trimming or like operations upon the formed product P, in turn requiring accurate template register of the latter in relation to the trimming or like operating instrumentalities. Therefore, in accordance with the invention as illustrated in FIG. 6, it may be desirable to form the male punch member or block, designated **15''**, with one or more radial holes **46** extending laterally therein (left-hand side of FIG. 6); and to similarly form the overlay sheet, here specially designated **18'**, with a corresponding number of apertures **47**, through which a suitable tool (not shown) may be driven into the apertures **46** to form register openings in the product P adjacent or around its free edge.

Referring to the right-hand side of FIG. 6, an alternative provision is represented by the provision of means to form marginal serrations or register notches on the product, for example by the provision of appropriate formations **49** on the block **15'''** to coact with a marking tool applied to the exterior of the overlay sheet at openings of the latter.

FIG. 7 of the drawing illustrates an adaptation of the improved process to be carried out using a standard industrial double-action press, designated **51**, wherein the function of the gripper jaws of the preceding embodiments is performed by certain coacting parts of the press.

Here, the press **51** comprises a fixed horizontal bottom bolster **52**, upright press columns **53**, and a first action ram-actuated press plate **54**, guided by the columns **53** for vertical up and down movement. Plate **54** is

driven by a first action or ram component **55**; and a second action or component of the press is constituted by the gripper heads **56**, which are suitably guided for movement relative to the press plate **54**. The male forming tool, block or punch **15** is fixedly mounted in depending relation to press plate **54**; and the bolster **52** is equipped with upright gripping posts **58** aligned with and adapted to coact with the gripper heads **56**.

In the operation of the dual-acting press **51**, the gripping heads **56** are first advanced downwardly to grip the overlay sheet **18** tightly against the respective fixed gripping posts **58** on bolster **52**. Thereupon, the first ram compoment or action **55** drive press plate **54** and forming block **15** downwardly against the material to be formed, as interposed between overlay sheet **18** and the contoured surface of block **15**. As in all other embodiments, the equipment of FIG. 7 may be operated hot or cold, depending upon the requirements of the product P being formed.

In any of these embodiments the tensile force applied to overlay sheet may range from 10 to 500 tons.

It is seen from the foregoing that the illustrated and described process permits the formation to special contoured shapes of certain materials that to the best of our knowledge have not heretofore been formable by other techniques; that the method in enabling even a few square inches to be saved on each workpiece, can result in a great price reduction of the final part; and that the method permits the working of certain new materials which cannot even be procured in pieces large enough to form a part by conventional stretch-forming, leaving still a flash or stretch jaw zone available.

Further the improved technique enables the forming of material which would fail and be unable to be pulled onto a punch contour when the edges are gripped by another type. The material of the overlay sheet may often be of a much less expensive material than that formed, just as it is ordinarily of much higher strength and more ductile as compared with a brittle part being formed.

The process can be used effectively either for hot forming or for cold forming, with the possibility that the overlay member being used may also act as a resistance element furnishing heat to the operation if such is required.

Under appropriate circumstances, rigid or resilient inserts, adapters or pads can be put under the material doing the work to force certain contours into the part being formed; and the process can be adapted to many existing standard pressure exerting tools, or may be carried out by a specially designed type of tool or equipment.

The drawings and the foregoing specification constitute a description of the improved flexible overlay forming in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention the scope of which is indicated by the appended claims.

What we claim as our invention is:

1. A method of forming a metal sheet blank into an object of non-planar shaped cross sectional contour, comprising providing a rigid forming member of a contour generally corresponding to the desired object contour, providing a flexible metal overlay sheet of an area exceeding that of said blank in the portion thereof desired to be contoured, disposing said sheet blank in a position between said forming member and overlay sheet to be covered by the latter at said portion, causing said overlay sheet to be tensioned from points outwardly of said portion so as to wrap and conform said sheet and sheet blank about said forming member, and said blank sheet to assume and retain said cross sectional contour as an object so conformed, and employing said overlay sheet to form a register mark upon the conformed object while the latter is positioned between said overlay sheet and forming member, by manipulating a tool from the exterior of said overlay sheet to form a register indicium on said object.

2. A method in accordance with claim **1**, in which the manipulation of said tool involves the positioning of said tool relative to said object by reference to said overlay sheet.

3. A method in accordance with claim **1**, in which the manipulation of said tool involves the thrusting of the same through an opening of said overlay sheet.

4. A method in accordance with claim **1**, in which the manipulation of said tool involves the thrusting of the same through an opening of said overlay sheet and into the material of said object to provide said indicium.

5. A method in accordance with claim **1**, in which the manipulation of said tool involves the thrusting of the same through an opening of said overlay sheet and into the material of said object in spaced relation to a margin of the latter to provide said indicium.

6. A method in accordance with claim **1**, in which the manipulation of said tool involves notching of a margin of said object by a tool positioned relative to the object by reference to said overlay sheet.

7. A method of forming a metal sheet blank into an object of a non-planar shaped cross sectional contour, comprising providing a rigid forming member of a contour generally corresponding to the desired object contour, providing a flexible metal overlay sheet of an area exceeding that of said blank in the portion thereof desired to be contoured, disposing said sheet blank in a position between said forming member and overlay sheet to be covered by the latter at said portion, causing said overlay sheet to be tensioned from points outwardly of said portion so as to wrap and conform said sheet and sheet blank about said forming member, and said blank sheet to assume and retain said cross sectional contour as an object so conformed, and employing said forming member to form a register mark upon the conformed object while the latter is positioned between said overlay sheet and forming member, by manipulating a tool from the exterior of said overlay sheet to form a register indicium on said object.

8. A method of forming a metal sheet blank into an object of a non-planar shaped cross sectional contour, comprising providing a rigid forming member of a contour generally corresponding to the desired object contour, providing a flexible metal overlay sheet of an area exceeding that of said blank in the portion thereof desired to be contoured, disposing said sheet blank in a position between said forming member and overlay sheet to be covered by the latter at said portion, causing said overlay sheet to be tensioned from points outwardly of said portion so as to wrap and conform said sheet and sheet blank about said forming member, and said blank sheet to assume and retain said cross sectional contour as an object so conformed, and employing said overlay sheet and forming member in coaction with one another to form a register mark upon the conformed object while the latter is positioned between said overlay sheet and forming member, by manipulating a tool from the exterior of said overlay sheet to form a register indicium on said object.

9. A method of forming a metal sheet blank into an object of a non-planar shaped cross sectional contour, comprising providing a rigid forming member of a contour generally corresponding to the desired object contour, providing a flexible metal overlay sheet of an area exceeding that of said blank in the portion thereof desired to be contoured, disposing said sheet blank in a position between said forming member and overlay sheet to be covered by the latter at said portion, causing said overlay sheet to be tensioned from points outwardly of said portion so as to wrap and conform said sheet and sheet blank about said forming member, and said blank sheet to assume and retain said cross sectional contour as an object so conformed, and employing said overlay sheet and forming member in coaction with one another to form a register mark upon the conformed object adjacent a margin of the latter while the latter is positioned

between said overlay sheet and forming member, by manipulating a tool from the exterior of said overlay sheet to form a register indicium on said object.

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