June 2, 1964 H. P. SCHANE 3,135,045

METHOD FOR FORMING ARTICLES FROM THIN SHEET MATERIAL

Filed April 19, 1961

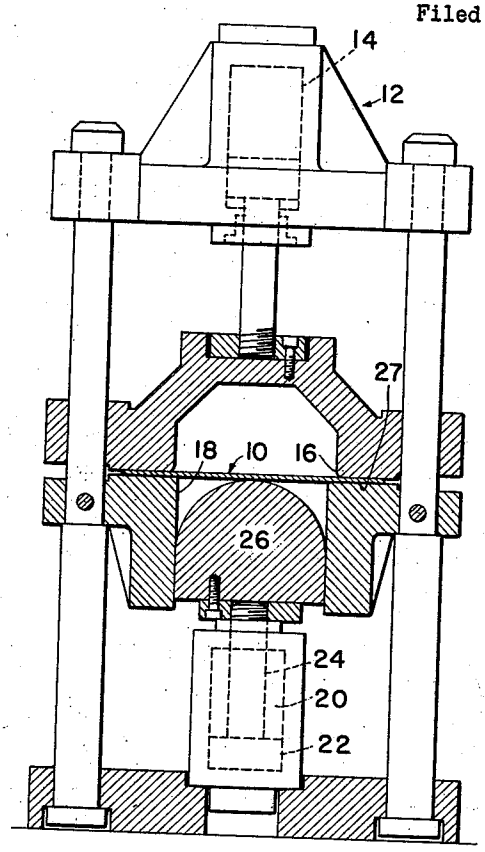


FIG. 1

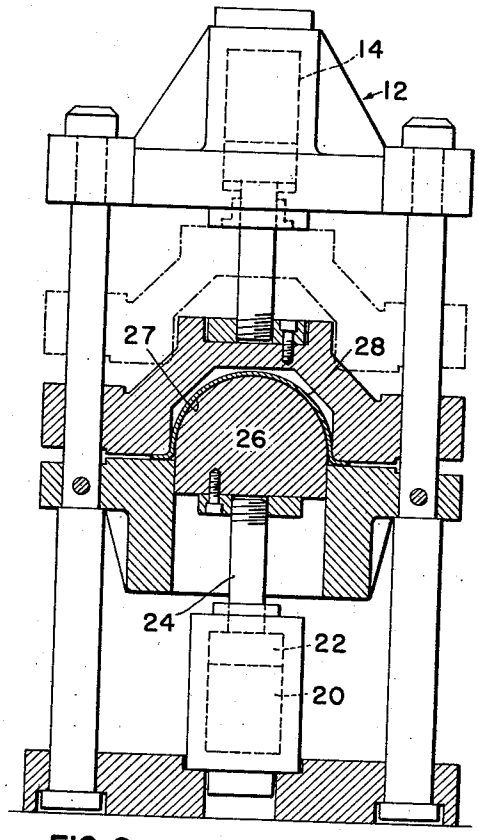


FIG. 2

FIG. 3

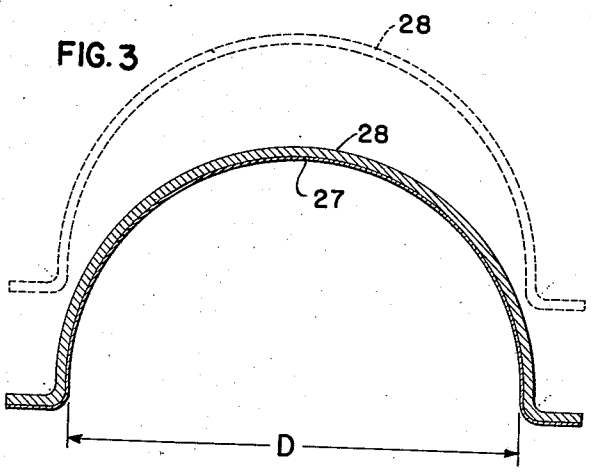


FIG. 4

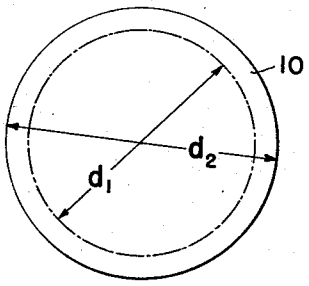
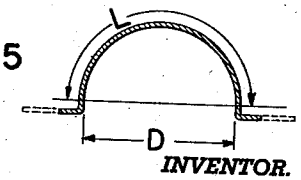


FIG. 5



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METHOD FOR FORMING ARTICLES FROM THIN SHEET MATERIAL

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This invention relates to a method of forming articles of sheet material and more particularly to the forming of large diameter hemispheres from extremely thin sheet material.

Heretofore deep forming operations have changed the thickness of the metal sheet being formed. Methods associated with stretch-forming, cup drawing, stamping, hydro-forming, rubber die forming, all tend to thin the sheet material at the nose of the male punch or die. Methods associated with spinning may thin or thicken the sheet material at the nose depending upon whether spinning is done over a concave or convex form respectively.

Until recently there was no known method that would allow deep drawing of sheet material and yet maintain a constant sheet material thickness. This recent development is described and claimed in United States application for "Method of Deep Drawing Sheet Material" Patent 2,989,019, issued June 20, 1961, Serial No. 660,312, filed February 29, 1956 by Herbert D. Van Sciver. Although this recent development represents the most advanced state of the art, as the name implies it is a drawing operation which uniformly thins out the sheet material being drawn.

All of the above-mentioned methods have met with difficulties when applied to deep drawn objects having large diameters and have rarely exceeded a diameter to material thickness ratio of about 200 to 1. When a ratio of diameter to thickness exceeds approximately 200 to 1 the article buckles, wrinkles or puckers regardless of the method used or the hold down pressure applied to the blank holder of a press. Extremely high blank holder pressures are accompanied by extreme elongation and resultant failure in the sheet material. Although many attempts have been made to provide a method for deep drawing articles having diameter to thickness ratios exceeding about 200 to 1, none, as far as is known, has been successful when carried into practice on an industrial scale.

It has now been discovered that by a new process sheet material articles may presently be formed having diameter to thickness ratios of about 2000 to 1, and the upper limit may be defined by the equipment made available to carry out the process. The process contemplates the use of existing equipments and is adaptable to existing techniques. In carrying out the process it was discovered that the original thickness of the sheet material could be maintained within very close tolerances, without appreciable thinning, contrary to the rule in the prior art.

It is the principal object of this invention to provide a method of forming articles whose actual diameter to thickness ratio exceeds the critical theoretical diameter to thickness ratio of the article to be formed.

It is another object of the present invention to provide a method of forming flat sheet material into deep shaped articles while closely maintaining the original thickness of the sheet material.

It is another object to provide a method of forming flat sheet material into deep shaped articles having diameter to thickness ratios far in excess of those obtained by prior processes.

It is another object to provide a method for cold-forming thin steel sheets into hemispherical shapes and to preserve the original thickness and strength of the sheet material.

It is a further object to provide a new process for deep drawing sheets into improved articles by the use of existing machines and equipments.

The invention is achieved by providing a separate and distinct sheet of material area bonded to the principal sheet of material being formed prior to the forming operation, then forming the two bonded sheets as a single structural sheet, and later removing the sheet material bonded to the principal sheet.

Processes embodying the present invention may in general comprise the steps of: area bonding a relatively thick supporting layer to a relatively thin sheet to form a laminate sheet, providing a laminate sheet of a desired configuration, the area of said laminate sheet to be formed being equal to the surface area of the object to be formed, placing the laminate sheet into a hydraulic press brake having a male die and a hold down ring, adjusting the pressure of the hold down ring to allow said area of said laminate sheet to form around said die, said area of said die being approximately equal to said area of said laminate sheet being formed, moving said laminate sheet relative to said die to form an article, and removing said supporting layer of said laminate sheet to provide a relatively thin sheet article having a diameter to thickness ratio exceeding the critical diameter to thickness ratio of the thin sheet being formed.

Other features and objects of the invention will be found throughout the more detailed description of the invention which follows. Those novel features believed to be descriptive of the nature of the invention are described with particularity in the appended claims. To more clearly portray the invention and its manner of operation the description is supplemented with the accompanying drawings:

FIG. 1 is an elevation in partial section of a simplified hydraulic press for forming flat sheet material over a male die illustrating the press before forming has begun.

FIG. 2 is an elevation in partial section of a simplified hydraulic press illustrating the press of FIG. 1 in the formed position.

FIG. 3 is an enlarged sectional elevation of the composite sheet drawn to a hemispherical shape.

FIG. 4 is a plan view of blank of sheet material used in forming hemispheres.

FIG. 5 is an elevation showing the comparative size change of the blank of sheet material of FIG. 4.

Referring now more in detail to the several figures of the drawings: FIG. 1 shows a composite sheet **10** held in a simplified hydraulic press **12**. The press **12** has a hydraulic cylinder **14** for exerting pressure on the movable

upper hold down ring 16 which co-acts with the lower stationary hold down ring 18. Composite sheet 10 is held between the respective hold down rings 16 and 18 with sufficient pressure to prevent buckling while the sheet is being formed. The pressure required varies with the type of material being formed and may be in accord with shop forming practice such as that recommended in the book: Principles and Methods of Sheet-Metal Fabrication by George Sachs, Reinhold Publishing Corporation, New York, N.Y., 1951. In the forming operation a standard hydraulic press was employed and the forming operation was not noticeably affected by the rate of draw or change in the hold down pressure on the blank holders. To further verify that the hold down pressure could be held practically constant the area of blank between the blank holders was lubricated to create a uniform coefficient of friction in the blank holders. This uniform pressure was further verified by providing a draw bead groove and mating projection in the hold down rings.

Hydraulic cylinder 20 having a piston 22 and an operating rod 24 is connected to a die 26 by suitable connecting means. Die 26 is shown in a lowered position in FIG. 1 prior to forming with the hold down rings 16 and 18 in their clamped or pressure position. After pressure is applied to the hold down rings by means of hydraulic cylinder 14, the die 26 is moved relative to the composite sheet 10 causing the sheet to be formed around the die as shown in FIG. 2. Hold down ring 16 is then raised and die 26 is lowered enabling the removal of the composite sheet 10 which has been formed in the shape of a hemisphere in a preferred embodiment here illustrated.

FIG. 3 shows the composite sheet in its formed state, and comprising at least two layers of sheet material. In the illustrated embodiments the composite sheet comprises a relatively thin sheet of material 27 and a relatively thick supporting sheet 28 which is bonded to sheet 27. When the two sheets are forced together they act as one sheet to prevent buckling. In order to provide a hemispherical shape which has a diameter to thickness ratio much greater than the critical diameter to thickness ratio it is only necessary to remove the relatively thick supporting sheet 28 after forming operations leaving the thin fragile shell 27. Prior to removal of sheet 28 by conventional means, such as heating or chemical etching, the composite formed sheet may be annealed to reduce internal stresses created by cold working.

Although contrary to conventional drawing practice it has been determined by actual practice that the use of a bonded composite sheet in a press permits the forming of the thin sheet while maintaining very closely its original thickness.

While it is practically impossible to explain completely the physical phenomena which cause the sheet to flow into a preferred shape and still maintain its original thickness there are several factors which influence the result.

In conventional deep drawing operations employing male dies the sheet material at the nose of the male punch or die tends to thin out due to elongation of the metal sheet. Also in conventional deep drawing with a press the flange under the hold down ring tends to compress circumferentially and thicken as it is drawn into the die area. The tangential area of metal between the hold down ring and nose of the punch is in radial tension and circumferential compression. In conventional practice a force great enough to cause thinning has been maintained to prevent buckling in the tangential area. By placing the thin sheet of the composite sheet to be formed adjacent to the male die it has been discovered that the thin sheet flows in both tension and compression but maintains a constant wall thickness. This is not to say that the composite sheet comprising the thin sheet and a supporting layer does not change in wall thickness, even though the thin sheet maintains its original wall thickness.

One of the most difficult shapes to form is a large diameter hemisphere from very thin high strength stainless steel. The present process obviates any difficulty in deep drawing such large diameter shapes from thin strong material, and produces consistent desirable results.

FIG. 4 shows a plan view of a blank of composite sheet material 10 wherein the sheet 10 is made by area bonding a thin layer of stainless steel 27 to a relatively thick layer of carbon steel 28. Several methods of bonding are acceptable for the process such as soldering, brazing, welding and hot roll bonding. It is probably more economical to hot roll the two sheets together to achieve a physical bond than to connect them by other methods, but the method of bonding may be influenced by the method of removal preferred. It has been discovered that the thin layer 27 may be supported between two supporting layers 28 which may be more easily removed than one hot roll area bonded layer.

So long as the relatively thick supporting layer is an effective area contact bond to prevent buckling and wrinkling it is not always necessary that the two sheets be bonded by high strength adhesives etc, but to be effective the supporting layer must be held adjacent in area contact bond to the layer to be supported to affect metal flow in tension and compression.

The blank size may vary according to the method of drawing used, but the blank of FIG. 4 is preferred wherein the diameter $d1$ represents the area of the blank to be drawn and the diameter $d2$ represents the area of the blank including a trim edge held in the blank holders. When the area of the blank to be formed,

$$A_b=\frac{\pi d1^2}{4} \qquad \text{(Fig. 4)}$$

is made equal to the area of the hemisphere to be formed,

$$A_h=\frac{\pi D^2}{4} \qquad \text{(Fig. 5)}$$

the hemisphere may be made from a sheet having a uniform thickness "t" and be formed into a shape having the same uniform thickness "t." If the areas A_b and A_h are equal, then $d_1=1.414D$ and the length of arc L described by the diameter

$$D \text{ is } \frac{\pi D}{2}$$

It can be seen that the diameter of the blank d_1 is stretched radially to extend to the distance L, where

$$L=\frac{\pi D}{2}=\frac{\pi D1}{2.828}=1.11d_1$$

or about eleven percent elongation. Elongation or drawing tends to cause the metal to thin out, but the compressive forces mentioned above tend to overcome thinning. For example, the circumference of the blank at diameter $d1$ is πd_1. The metal at d_1 is drawn into the die area and will appear at the hemisphere diameter D where the new circumference is πD. It can be seen that a circumferential band of metal at diameter d_1 shrinks from πd_1 to πD where $d_1=1.414D$ or a reduction of about thirty percent. Circumferential compression tends to thicken the sheet while the tension forces tend to thin the sheet. It has been discovered by experience that a relatively thick layer of carbon steel bonded to a thin layer of stainless steel will permit the thin layer to be formed without changing noticeably the thickness of the thin sheet in the formed object.

For example, a 35 inch hemisphere was formed from a composite layer of .025 inch stainless steel bonded to .175 inch carbon steel. The blanks were designed so that the area of the blank being formed was equal to the

area of the hemisphere to be formed. A hemisphere was drawn without buckling or wrinkling having a .025 wall thickness and deviations that did not exceed the deviations of the original sheet. The diameter to thickness ratio for this hemisphere is fourteen hundred to one, far in excess of the critical ratio. Strong light hemispheres such as this may be welded into various shapes for use as containers in rockets or missiles.

In another embodiment a 10 inch hemisphere was formed from a composite of .005 inch stainless steel sandwiched between two supporting layers of .039 inch carbon steel. The thin layer was held in contiguous contact with the supporting layers by the hold down ring and the tension of the supporting layers. A hemisphere was drawn without buckling or wrinkling having a .005 wall thickness and deviations that did not exceed those in the original .005 inch sheet. The diameter to thickness ratio of this hemisphere is two thousand to one. This achievement can be appreciated when two such hemispheres are connected to form a sphere weighing only six and one-half ounces which may be easily supported on an air stream.

This method is not limited to hemispherical shapes or any particular type of forming apparatus, but could be adapted to the several types of forming.

What is claimed is:

1. The method of cold forming a thin shell hemisphere of constant thickness, area bonding a thin sheet of stainless steel having small variations in the wall thickness to a relative thick sheet of carbon steel having small variations in the wall thickness to provide a composite sheet of combined random wall thickness, drawing said composite sheet into a hemisphere having a different combined random wall thickness, removing said carbon steel leaving a thin shell stainless steel hemisphere of wall thickness equal to the original thickness of the stainless steel sheet.

2. The method according to claim 1 wherein said carbon steel is removed by chemical etching.

3. The method according to claim 2 wherein the further step of annealing said formed composite sheet is performed prior to removal of said carbon steel.

4. The method of deep forming hemispheres from flat sheet material over a male die without changing the thickness of the flat sheet, which comprises, area bonding a thin flat sheet of metal to a thick sheet of metal at least five times the thickness of the thin sheet, clamping the bonded sheets around the outer peripheral edges, deforming the peripheral edges between a draw bead and groove, maintaining a constant restraining force at the peripheral edges, forcing a hemispherical punch into engagement with the peripherically restrained area bonded sheets so as to wrap said thin sheet around said male punch while radially compressing and axially tensioning said thin sheet compensating amounts to form a hemisphere of constant thickness having a sheet thickness approximately equal to the original sheet thickness of said flat thin sheet.

5. A method of cold forming stainless steel hemispheres from thin flat sheet material characterized by irregular thickness and non-uniform yield strength,

area bonding by hot rolling said thin flat stainless steel sheet material to a flat uniform plate of carbon steel to form a composite plate structurally responsive as a single plate,

cooling said composite plate,

clamping said composite plate between circular margin holders at the perimeter of said composite plate with the stainless steel sheet adjacent a male drawing die,

deep drawing by cold forming over said male drawing die said composite plate with said stainless steel sheet on the compression side of said composite plate to form a hemisphere of said composite plate,

removing said formed body from said margin holders,

annealing said formed body, and removing said area bonded carbon steel plate from said formed body in an acid solution to provide a thin wall stainless steel hemisphere having a wall thickness substantially the same as the original thin flat sheet of stainless steel.

6. A method of forming steel shapes from thin flat sheet material characterized by irregularities of thickness and strength,

area bonding said thin flat sheet to a thick plate of substantially uniform strength and thickness carbon steel plate to form structurally a unitary composite plate,

clamping the edges of said composite plate between a pair of margin holders,

deep drawing the central section of said composite plate over a male die to form composite plate structure,

annealing said composite plate structure,

and removing said area bond between said thin flat sheet and said thick plate to provide a deep drawn shape of thin sheet material unaffected by its irregularities of thickness and strength.

7. A method of deep drawing thin stainless steel sheet characterized by irregularities in wall thickness and strength of the sheet caused by rolling in the manufacture of said sheet comprising,

bonding a face area of a thin wall stainless steel sheet to a face area of a carbon steel sheet to provide a composite sheet at least five times the thickness of said thin wall stainless steel sheet, said carbon steel sheet being characterized by irregularities in wall thickness,

clamping the edges of said sheet in a pair of margin holders,

deep drawing said composite sheet over a male drawing die while maintaining sufficient clamping pressure at said margin holders to reduce the wall thickness of said carbon steel sheet,

and removing said stainless steel sheet from said carbon steel sheet providing a thin wall deep drawn shape whose irregularities and thickness are substantially the same as the original sheet of stainless steel.

8. The method of deep drawing thin wall hemispherical shapes of non-homogeneous sheet material to provide a shape having the same wall thickness before and after deep drawing comprising,

area bonding a flat thin wall stainless steel sheet to a flat thick wall plate to provide a composite plate in which the diameter of the hemisphere to be formed is two hundred times or less the thickness of the composite plate,

clamping said composite plate between margin holders,

simultaneously free forming said composite plate by deep drawing with a hemispherical shaped male drawing die the side of said composite plate having the thin walled stainless steel sheet and wrapping said stainless steel sheet over said male die in compression to form a hemispherical shape,

annealing said hemispherical shaped composite plate,

removing in an acid bath said thick wall plate leaving a thin wall hemispherical shape having the same thickness as said flat thin wall stainless steel sheet.

9. A method of deep drawing extremely thin steel sheets having variations in thickness and strength that would cause non-uniform stresses and strains during drawing comprising,

area bonding a flat steel sheet to a flat plate of steel,

clamping the edges of the area bonded sheet and plate in flat face retainer rings,

free forming the steel plate by engaging a male punch with said steel sheet wherein the flow of the steel sheet is determined by the flow of said area bonded plate,

removing the formed area bonded sheet and plate from said retainer rings,

annealing said area bonded sheet and plate,

removing said steel sheet from said steel plate by releas-

ing said area bond providing a deep drawn shape unaffected by variations in strength and thickness in the original thin steel sheet and having a wall thickness substantially the same as said original steel sheet.

10. A method of deep drawing as set forth in claim 9 wherein said male punch is hemispherical in shape and the ratio of the diameter of said hemisphere to the thickness of said steel sheet is in excess of one thousand to one.

11. A method of deep drawing as set forth in claim 10 wherein said steel plate is at least five times as thick as said steel sheet.

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