PLUNGER-AND-DIAPHRAGM PLASTIC SHEET FORMING APPARATUS

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References Cited
UNITED STATES PATENTS
3,305,158 2/1967 Whiteford...................... 18/19 F UX
2,821,945 2/1958 Peccerill.......................... 72/63 X
3,180,776 4/1965 Hessel................................ 18/19 F X
3,315,313 4/1967 Steigman........................... 18/19
3,025,566 3/1962 Kostur............................ 18/19 F
3,074,110 1/1963 Mard et al........................... 18/19 F X
3,081,491 8/1963 Black............................. 18/19 F X
3,357,053 12/1967 Lyon et al.......................... 18/19 F

FOREIGN PATENTS OR APPLICATIONS
201,614 4/1956 Australia.............................. 72/63
1,107,620 1/1956 France....................... 72/63

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ABSTRACT
This application discloses plunger-and-diaphragm plastic sheet forming apparatus and method for forming plastic sheet blank material into hollow or cupped articles. The apparatus comprises a die-mold device, means for clamping a blank in the opening of the die-mold device, and a plunger-diaphragm device for forming the blank into a shaped article in the die-mold device by plunger action or by diaphragm action or by combined plunger and diaphragm action. In one embodiment of the invention, blank-holding means are associated with the die-mold device to leave the space between the die-mold device and the plunger-diaphragm device clear for the insertion of blanks and the removal of formed articles with a minimum of apparatus on the plunger side of the assembly, this being especially applicable to the formation of nonround articles. In another embodiment the blank holding means is associated with the blank-cutting means on the plunger or ram side of the assembly.

10 Claims, 6 Drawing Figures
Fig. 2

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Fig. 3

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1

PLUNGER-AND-DIAPHRAGM PLASTIC SHEET FORMING APPARATUS

This application is a continuation of Ser. No. 693,525, Dec. 26, 1967, now abandoned.

RELATED APPLICATIONS

In my application Ser. No. 561,871, filed June 30, 1966, now U.S. Pat. No. 3,566,650, there is disclosed apparatus and method for the solid state shaping or "cold-working" of plastic articles by an elastic deformable body under pressure which forms deeply cupped articles from relatively thick sheet blanks by drawing out inventory material in a controlled manner to form the sidewalls and stamped bottom of the article.

In my application Ser. No. 660,491, filed Aug. 14, 1967, now U.S. Pat. No. 3,546,740, there is disclosed the formation of articles from plastic sheet blanks by an elastic deformable diaphragm acting with a die-mold shaping device.

BACKGROUND OF THE INVENTION

It is often desirable to form cup-shaped or hollow articles having precisely controlled sidewall and bottom thickness. Heretofore such relative thicknesses have been attained to some extent by providing preshaped blanks, as for example in Whiteford U.S. Pat. No. 3,184,524, granted May 18, 1965. It is generally expensive to provide such preshaped blanks and it is preferable to start with a plain sheet blank and attain the relative controlled sidewall and bottom thicknesses in a single continuous operation in a single forming device.

Prior draw-methods and apparatus are typically applicable to draw ratios of depth-to-diameter of the articles in the order of about 0.5 to 1 (for polypropylene), and difficult to apply for greater ratios. Wall thicknesses from 8 percent to 40 percent of blank thickness typically can be attained.

The bottom will generally be thicker than the sidewall for low draw ratios and relatively thinner as the draw ratios increase and the bottom inventory material is drawn out into the sidewall. It has been especially difficult to control relative wall thicknesses for articles with flared sides or partly closed open ends.

The drawing effects are influenced by a number of factors, such as shape of forming members, shape of blank, surface finish, and relative friction coefficient between blank and forming elements, blank temperatures as a whole and in different zones, tool temperatures, speed of draw, and the like.

So far there have been no single convenient means and method applicable in all cases for controlling sidewall and bottom thicknesses and for draw ratios below about 0.50 and above about 1.50, the most positive approach being to provide a preshaped blank. A thinned center offers less resistance to inventory flow, thus causing an absolute increase in sidewall thickness as well as a thinned bottom. If this is carried to a logical extreme by cutting a center hole of suitable size in the blank, it is possible to form a short bottomless cylinder of substantially uniform wall thickness. Differential zone heating of the blank is helpful in providing an article with a desired distribution of material between side and bottom but is somewhat more difficult to practice.

SUMMARY OF INVENTION

The present invention provides unitary means and method which combine the action of a plunger, punch or ram and a diaphragm acting with a blank holder and a die-mold device to form a cupped or hollow article with a desired thinned bottom from a sheet blank of uniform thickness prior to but along with the subsequent drawing and bottom forming operations, thus avoiding the need for preshaping a blank or for differential heating of various zones of the blank. By utilizing the diaphragm in this manner a greatly expanded hollow article can be formed, similarly to blow-molding, but with the usual malformations due to relative weak zones in the blank greatly reduced; and while supporting the bottom at any desired location, with the application of any desired pressure and relative coefficient of friction, the amount of bottom drawout and thinning can be closely controlled. By adding side-acting diaphragms, the sides of the article, as well as the bottom, may be expanded and shaped.

The invention, in one embodiment, provides improved blank-holding means associated with the die-mold, thus conserving head room in the press and leaving clear space for loading and unloading, the blank-holding means being especially suitable for the formation of nonround articles. In another embodiment, the blank-holding means is associated with blank-cutting means on the punch side of the assembly so that blanks can be cut from sheet stock which is fed out at a desired working temperature from closely associated heating means of desired type.

DRAWINGS

The objects of the invention, as well as various features of novelty and advantages, will be apparent from the following description of exemplary embodiments of apparatus, reference being made to the accompanying drawings, wherein:

FIG. 1 is a vertical section through a press and article forming means, the press plunger and blank clamping means being shown in retracted position for the insertion of a blank or the removal of an article;

FIG. 2 is a view like FIG. 1, but showing a blank introduced and clamped in position;

FIG. 3 is a view like FIG. 1, but showing the blank being preshaped by the expanding diaphragm;

FIG. 4 is a view like FIG. 1, but showing the parts at the completion of the article-forming action;

FIG. 5 is a view like FIG. 1, but showing the formed article ejected and ready for removal;

FIG. 6 is a partial section of a portion embodiment having both end and side-sleeve diaphragms and having a blank cutter associated with the blank rim clamp.

SPECIFIC EMBODIMENT

In the embodiment shown in FIGS. 1–5 there is a fixed press baseplate 10 and a reciprocable press headplate 11 operated by a ram or plunger rod 12. Upon the baseplate 10 there is secured a mold-die container 13 and to the headplate 11 there is secured a forming plunger or ram 14 of a size to enter the container 13 with predetermined clearance on the sides.

Within the mold container 13 there is mounted a bottom reaction die plate 15 carried on the upper end of a bottom plunger or ram 16 which is provided with power means for moving it up and down under controlled pressure. A conduit 17 supplies fluid through and to the upper surface of the bottom die plate 15 for controlling fluid pressure or lubrication below the article.

A deformable diaphragm 20, of elastomeric material, such as rubber, neoprene, or the like, is secured across the lower or forward acting end of the upper or main plunger 14, as by a backing member 21 and a retaining member 22. For a right cylindrical or round article the members 21 and 22 could be threaded on but for a nonround or rectangular article contemplated for formation by the specific apparatus shown herein, a press fit, soldering, welding, setscrews, or other suitable means of securement may be employed.

A fluid conduit 23 supplies and withdraws pressure fluid through a hole in the backing member 21 above the upper surface of the diaphragm to cause it to distort or retract, a vacuum being applied if necessary to cause full retraction. A fluid conduit 24, including a flexible elastic lengthenable hose 25, supplies and withdraws pressure or other fluid from the lower surface of the diaphragm 20, as to control pressure or friction between the diaphragm and the article being formed.

In the container 13 there is provided a seat 26 for a sheet workpiece or blank W. The blank will be at the desired temperature, in the solid-state coherent condition above the glass transition temperature but as near the melting point as possi-
ble while still retaining the coherent solid-state or “cold-workable” properties.

Means are provided for clamping the periphery of the blank on the seat 26, the means here shown being associated with the die-mold device and including clamp bars or jaws 30 secured on levers 31 pivoted at 32 on supports 33 secured to the die-mold device. Power unit means, such as a fluid cylinder or piston unit 34, are provided for operating the clamp levers, the power units being pivoted at 35 to the levers and at 36 to fixed supports 37.

The clamping bars illustrated are generally linear for the linear sides of a rectangular blank but if the blank is circular or irregular in shape the clamping bars will be shaped to fit it. The location of pivots, lengths of lever arms and amount of power can easily be adjusted to secure various clamping pressures, or changes during one forming cycle, if desired. The final blank-clamping movement is in an axial direction.

The action in formation of a cupped or hollow article from a flat sheet blank is detailed in the successive views.

In FIG. 1 the clamps 30 are retracted, the main plunger 14 is raised, and the lower plunger 16 and die plate 15 lowered. There is ample clear space in the press and a sheet blank W is being introduced.

In FIG. 2 the blank has been inserted and clamped and the main plunger 14 brought down toward the clamped blank.

In FIG. 3 the main forming plunger 14 has been brought down and the blank 15 has been brought up against the lower surface of the blank, and the diaphragm 20 has been distended to shape the central portions of the blank. Relative clamped areas of the blank and plate and diaphragm, relative pressures on the blank, relative frictional surface engagement, and the like, can be controlled by relative surface materials and finishes and also by fluids supplied through the conduits 24 and 17.

In FIG. 4 the main plunger 14 has been brought down to the bottom of its stroke, thereby stretching the intermediate sidewall portion of the blank, after the diaphragm has previously been distended to draw out the central portion of the blank to any desired extent, part way or all the way to the bottom, and the bottom of the formed article W1 is being finally pressure-shaped by the plunger between the deflated diaphragm and the bottom die plate 15. The clearance between the plunger and the sides of the container at the clamping zone will be a factor in determining the thickness of the sidewall of the article. Rim-clamping pressure and rim width will also affect factors in the feed-out of inventory material from the rim into the sidewall of the article. The cross section shown will not have much inventory material to feed out but may be as wide as desired, and if the final desired rim width is narrower than the formed rim the excess width can be cut off.

In FIG. 5 the rim has been released from the clamping jaws, the main plunger and diaphragm retracted upward and out of the article (with relief through tube 25), and the article W1 pushed up and ejected from the container by the bottom plate 15 and bottom plunger 16. If the article tends to adhere to the plate 15 it may be forced off by pressure fluid applied through conduit 17. There is ample clearance space for the removal of the article. The bottom plate 15 then retracts to the bottom of the die-mold container ready for another blank to be introduced.

The apparatus is very versatile as to the different methods of action which it can produce. In addition to the method just described, some others may be noted. The article may be removed after the diaphragm has distended partially or fully without bringing the main plunger down into the container. The main plunger may be brought down without distending the diaphragm. The diaphragm may expand the body of the article to a transverse dimension greater than the top opening, a divided separable container being provided in this case, the overspill being effected either without bringing the main plunger fully down or after it has retracted from its bottom position. The main plunger may be advanced below the top edge of the container to begin establishment of top sidewall thickness before the diaphragm begins distension, or together.

The embodiment of FIG. 6 is similar in many respects to that of FIGS. 1-5 and similar parts are given the same reference numbers. In FIG. 6, however, the die-mold is flared at the top and has a greater transverse dimension in part than the plunger; the clamping means is associated with the plunger instead of being on the die-mold side of the assembly; cutting means is associated with the clamping means to cut a blank from an advancing sheet of heated material; the plunger is provided with a side-sleeve diaphragm; and a plunger and side-sleeve retaining guide is provided on the clamping assembly.

There is a baseplate 10, a press head plate 11, a plunger rod 12, a mold-die container 13, a plunger or ram 14, a bottom die plate 15, a bottom plunger or ram 16, a fluid conduit 17 therefor, a bottom diaphragm 20, a backing member 21 for the bottom diaphragm, a retaining member 22 for the bottom diaphragm, a fluid conduit 23 for inflating and deflating the bottom diaphragm 20, a fluid conduit 24 and flexible elastic hose 25 for supplying fluid through the bottom diaphragm 20, a seat 26 for a workpiece W, workpiece clamping or holddown means 30, and operating means 34 for the clamping means.

In the second embodiment the clamping means 30 has a cutter 40 for cutting out a blank from a sheet 41 of material which is drawn out as needed from a heater 42 by rolls 43.

The plunger is provided with a side-sleeve diaphragm 44 which overlies an annular concavity 45 in the side of the plunger 14. Fluid is supplied to or withdrawn from the concavity 45 by a fluid line 46 which is connected to fluid supply and withdrawal means. As shown, the diaphragm 44 is formed integrally with the bottom diaphragm 20 and is secured at its lower end by the same member 22 which secures the bottom diaphragm, but the two diaphragms may be separate parts with suitable alteration of the securing means to mount them. The plunger assembly is secured together by any suitable means, such as tie bolts, screws or the like, but such means are omitted for clarity of drawings.

A guide sleeve 47 is carried by the blank clamping assembly to guide the plunger into accurate position on the die-mold container top and to aid, if needed, in the return of the side diaphragm 44 to its retracted position on the plunger.

The equipment shown in FIG. 6 has a wide range of selective action. One type of action is indicated by the successive broken line representations of the article in various stages of formation. The original blank W is shown in flat form on the holddown seat 26. The blank as partially drawn out by the distending bottom diaphragm 20 is shown in FIG. 1, as further drawn out by the bottom diaphragm at W/2, and as finally shaped by the plunger 14 (after retraction of the bottom diaphragm 20) and side diaphragm at W/3. The inwardly extending portion of the clamping member 30 prevents the side diaphragm 44 from blowing out at its upper end when distended to form the sidewall of the article. The side diaphragm is retracted before the plunger is retracted. Thereafter the article is forced up by the bottom plunger 16 and removed.

If considerable side expansion of the article is desired, a split mold and bottom delivery of the finished article can easily be arranged.

The side diaphragm is very helpful in setting the article in final form so there will be substantially no spring-back; it allows the plunger proper to be made undersize and without close fit in the die-mold container; and it also serves to force material readily into side formations in the die-mold, as to make articles with splines and protruberances in the sidewalls which could not readily be formed, if at all, by a shaped plunger.

The bottom diaphragm serves generally to thin the bottom of the blank and article and this thinning action may be modified by controlling relative friction with the article by relative pressures of the bottom plate 15 and the kind and degree of pressure of fluid ejected through the bottom plate and bottom diaphragm during the forming action. The character of the diaphragm and bottom plate will also influence the degree of
friction and flow of blank material. If a thick bottom wall is wanted, the plunger can be brought down without distending the bottom diaphragm and the sidewalls of the article then formed by distending the side diaphragm. Any of these actions can be started and stopped at various stages of article formation. Local variations in the article can be achieved by local thickening or thinning of the diaphragms; also by local configurations and relative heating of various areas of the blank, though the latter is more difficult to achieve in practice.

The apparatus and method are applicable to certain plastic metals and materials, other than polymer plastics, which can advantageously be formed in accordance with the invention. The following plastics have been formed or appear to be suitable for forming in accordance with the invention: polypropylene, polyethylene, polyvinyl chloride, polystyrene, fluorocarbon polymers, acrylic polymer, cellulose acetate, cellulose butyrate, cellulose nitrate, polyether, ionomers, polycarbonate, polyester, polyphenylene oxide, polysulfone, polyurethane, and possibly others which have not yet been investigated.

Porous open-cell or closed-cell foamed material or even perforated blanks can be handled because of the use of supporting diaphragms. Blanks with multi-ply or laminar makeup of the same or different materials can be handled. Blanks of different thickness, color, melting point, or of other physical or chemical properties can be handled.

Suitable working temperatures are readily determined for each blank material. Illustrative of those considered most suitable for working prevalently isotropic polypropylene, are those in the range from about 150°F to just below the crystal melting point of 335°F, a preferred range being between about 300°F and about 330°F. These temperatures are in the solid-state or cold-working range in which this material is work-strengthenable.

The materials named above as being suitable for being processed in accordance with the invention, have the characteristic of being softenable below the melting point (or below the degrading point if not having a pronounced melting point) and of being cold-work strengthened when stressed in the solid state and brought to a suitable stable temperature while stressed.

It will be desirable in many cases to control the temperature of the blank and article while being formed and for this purpose various heating and cooling means may be desirable for the apparatus and fluids used; however, such heating or cooling means are generally routine in the plastics and die-molding arts and have been omitted for simplicity of illustration and description.

The invention, as stated, is very suitable for making laminated articles of the same or different plastic polymers or metals. The feature of working in the solid state permits the use of laminates of a much wider range of materials than would be possible if molten material were used because it is only necessary to have the lamina of lowest melting point at its highest below-melting point, the other laminae of higher melting point still being softened and formable at the limiting temperature established for the material of lowest melting point.

Either bonded or unbonded laminates may be formed, the choice depending on the articles to be formed and the materials available. The bonding substances for the laminae, of course, will be such that they will not be degraded at working temperatures required; and if the bonding substances are themselves plastic polymers, as normally they will be, they will be in the state below their melting point.

The lower end of the plunger, on at least the periphery, as at the diaphragm securing ring, 22 or 22a, may be formed of a material having a low coefficient of friction or lubricating character. Various materials are known which are suitable, among them being nylon or a porous metal carrying graphite, "Teflon" or the like, as known for self-lubricating bearings.

In the embodiment of FIGS. 1-5, the clearance space between the nose periphery of the plunger and the side of the die-mold container at the top will cause pull-out of material from a blank which is thicker than the width of the blank if the diaphragm has not been distended before the plunger is operated, the blank material being thinned as pulled out through the space.

In both embodiments the supply of fluid through the bottom diaphragm into the article and through the lower plunger beneath the article will provide assistance in formation and assure release of the article from the plunger assembly and die-mold.

While certain embodiments of the invention have been described for purposes of illustration, it is to be understood that there may be various embodiments and modifications within the general scope of the invention.

1. Apparatus for forming cupped articles, having a top rim flange, sidewalls, and a bottom, from stretchable flat sheet blank workpiece material of uniform thickness, including weak and fluid-permeable sheet material, comprising in combination, a die-mold unit having an annular blank-holding rim seat and a forming chamber therebeyond, axially movable annular clamping means for holding a blank rim portion on said seat securely against edge pull-in, a forming plunger, and within said annular blank-holding means for independent relative axial movement toward and from said die-mold unit, a distendable and retractable elastic diaphragm mounted on the forward end and within the forward edge of said forming plunger, said forming plunger and diaphragm having movement into and out of said die-mold unit chamber beyond and within the clamped annular rim portion of the blank, and means for causing said diaphragm to be distended and retracted relative to the end of said forming plunger at any axial forming position of the plunger.

2. Apparatus as set forth in claim 1, in which forming plunger has a transverse bottom end wall extending completely thereacross closely behind and supporting said end diaphragm when the diaphragm is in its retracted position on the forming plunger.

3. Apparatus for forming cupped articles, having a top rim flange, sidewalls, and a bottom, from stretchable flat sheet blank workpiece material of uniform thickness, including weak and fluid-permeable sheet material, comprising in combination, a die-mold unit having an annular blank-holding rim seat and a forming chamber therebeyond, axially movable annular clamping means for holding a blank rim portion on said seat securely against edge pull-in, a forming plunger mounted within said annular blank-holding means for independent relative axial movement toward and from said die-mold unit, said plunger having a forward bottom end wall extending completely thereacross, a distendable and retractable elastic diaphragm mounted on the forward end and within the forward edge of said forming plunger over said bottom end wall, said forming plunger and diaphragm having movement into and out of said die-mold unit chamber beyond and within the clamped annular rim portion of the blank, means for causing said diaphragm to be distended and retracted relative to the end of said forming plunger at any axial forming position of said forming plunger, an axially movable bottom die retraction plunger unit in said die-mold unit, and means for moving said bottom die unit axially up and down in said die-mold unit to engage the workpiece and press it and the diaphragm toward a solid portion of the bottom end wall of the axially movable forming plunger.

4. Apparatus as set forth in claim 3, which further comprises means for supplying and exhausting pressure fluid through said movable bottom die unit to the space between the movable bottom die unit and blank.

5. Apparatus for forming cupped articles, having a top rim flange, sidewall, and a bottom, from stretchable flat sheet blank workpiece material of uniform thickness, including weak and fluid-permeable sheet material, comprising in combination, a die-mold unit having an annular blank-holding rim seat and a forming chamber therebeyond, axially movable an-
nular clamping means for holding a blank rim portion on said seat securely against edge pull-in, a forming plunger mounted within said annular blank-holding means for independent relative axial movement toward and from said die-mold unit, said plunger having a forward bottom end wall extending completely thereacross, a distendable and retractible elastic diaphragm mounted on the forward end and within the forward end edge of said forming plunger over said bottom end wall, said forming plunger and diaphragm having movement into and out of said die-mold unit chamber beyond and within the clamped annular rim portion of the blank, means for causing said diaphragm to be distended and retracted relative to the end of said forming plunger at any axial forming position of said forming plunger, a distendable and retractible elastic surrounding sleeve diaphragm mounted on the side of said forming plunger, and means for distending and retracting said sleeve diaphragm on said forming plunger at any axial forming position of said forming plunger.

6. Apparatus as set forth in claim 5, in which the blank-holding means is mounted on the same side of the assembly as said plunger, and includes a guide sleeve surrounding said forming plunger and said surrounding side-sleeve diaphragm thereon in a position to inhibit distension of said surrounding side-sleeve diaphragm until it enters the forming chamber of the die-mold unit.

7. Apparatus as set forth in claim 6, in which said surrounding side-sleeve diaphragm confining guide sleeve is brought into guiding position when the blank-holding means is brought into blank-holding position.

8. Apparatus as set forth in claim 1, wherein said forming plunger, around said end diaphragm is provided with a circumferential annular tip of a material having a coefficient of friction different from that of the diaphragm.

9. Apparatus for forming cupped articles, having a top rim flange, sidewalls, and a bottom, from stretchable sheet blank workpiece material, including weak and fluid-permeable sheet material, comprising in combination, a die-mold unit having an annular blank-holding rim seat and a forming chamber therebeyond, axially movable annular clamping means for holding a sheet blank rim portion on said seat, a forming plunger mounted for independent relative axial movement toward and from said die-mold unit, said forming plunger having a transverse forward end wall and a peripheral wall with interior open space, a distendable elastic sleeve diaphragm sealingly secured at axially spaced points along the length of the peripheral wall of said forming plunger and forming an annular fluid chamber between the peripheral wall and diaphragm, and means for supplying fluid through the side of the plunger between the points of securement of the diaphragm into said annular chamber for distending and retracting said side-sleeve diaphragm on said plunger.

10. Apparatus as set forth in claim 9, in which the forming plunger has an end member which secures one end of the side-sleeve diaphragm, and a guide and confining rigid sleeve surrounding said forming plunger and sleeve diaphragm when the end of the forming plunger is in a position to engage a clamped blank.