July 8, 1969 F. M. WILLIAMSON 3,453,848

APPARATUS FOR DEEP DRAWING METAL WITH HYDRAULICALLY CONTROLLED DIES

Filed June 7, 1965 Sheet 1 of 3

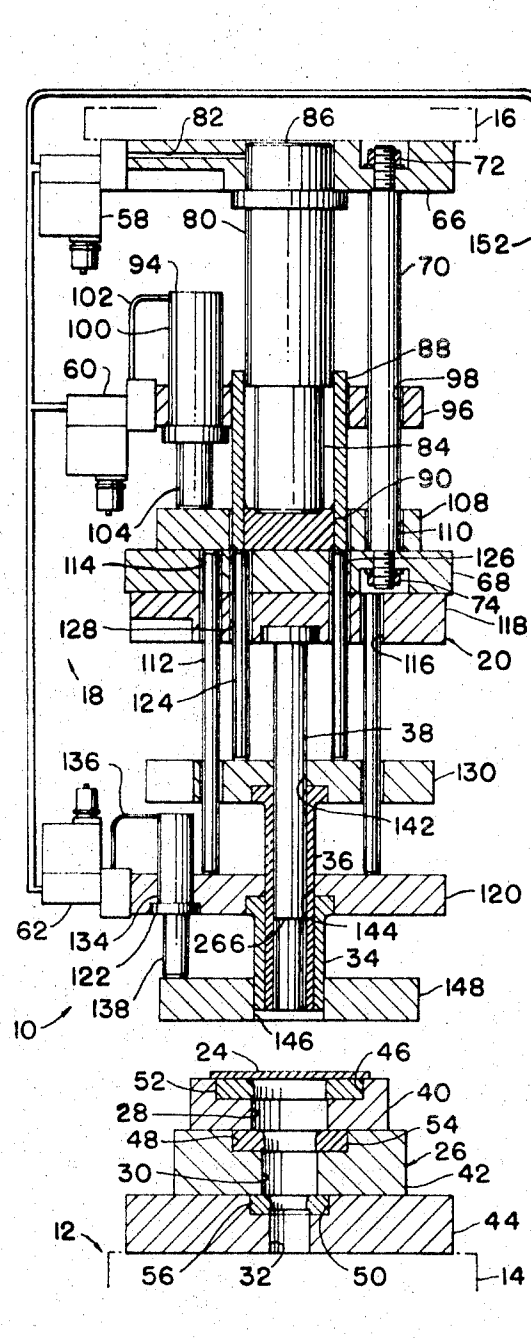

FIG. 1

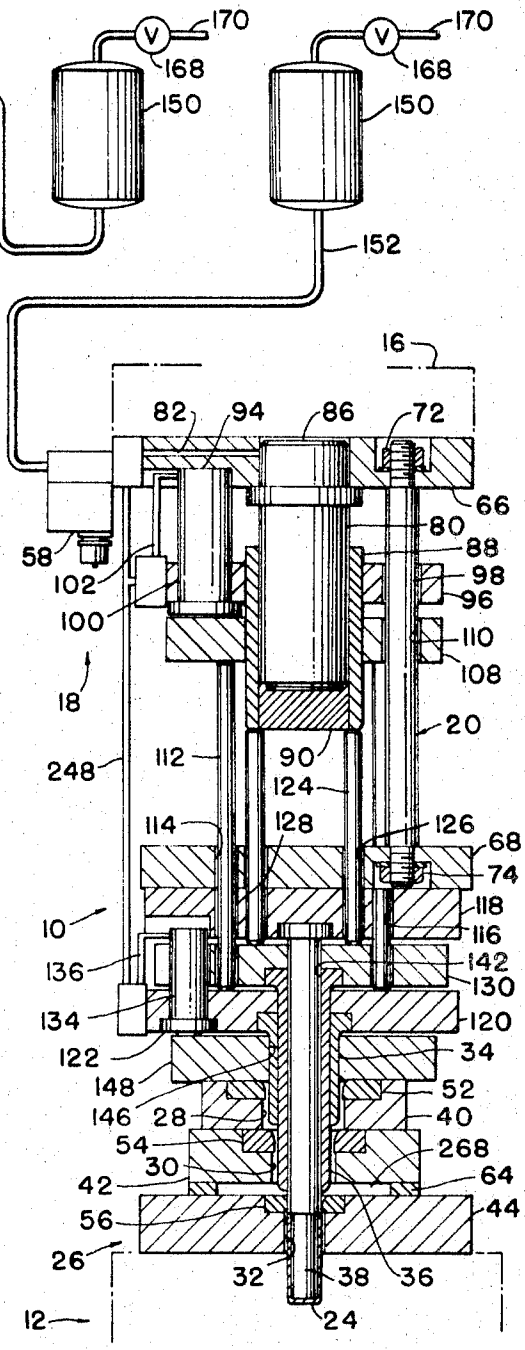

FIG. 2

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Filed June 7, 1965 Sheet 2 of 3

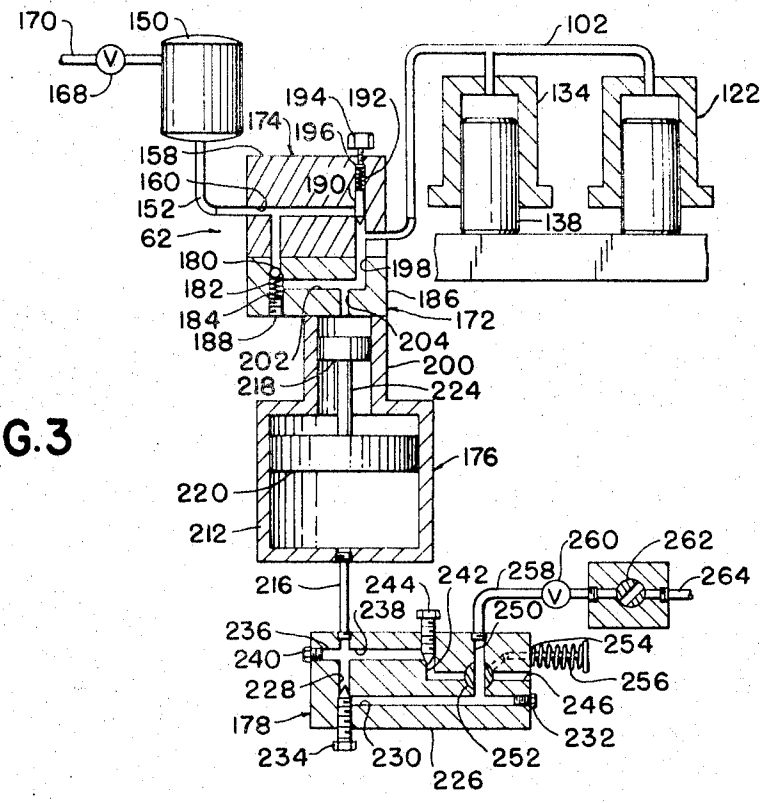

FIG. 3

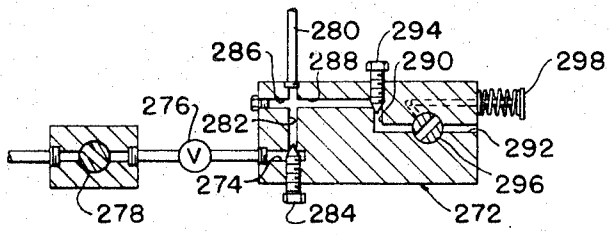

FIG. 4

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Filed June 7, 1965 Sheet 3 of 3

FIG. 5

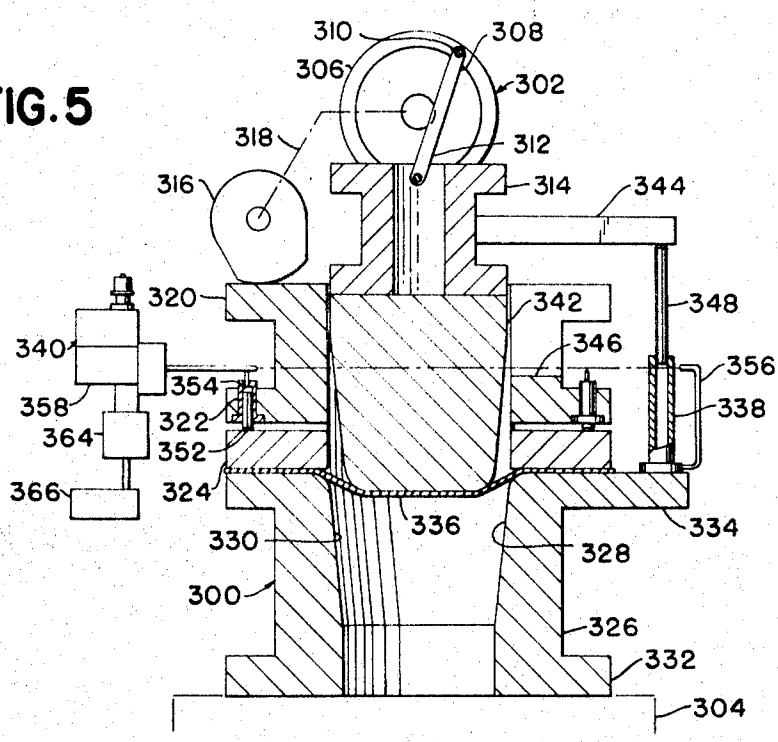
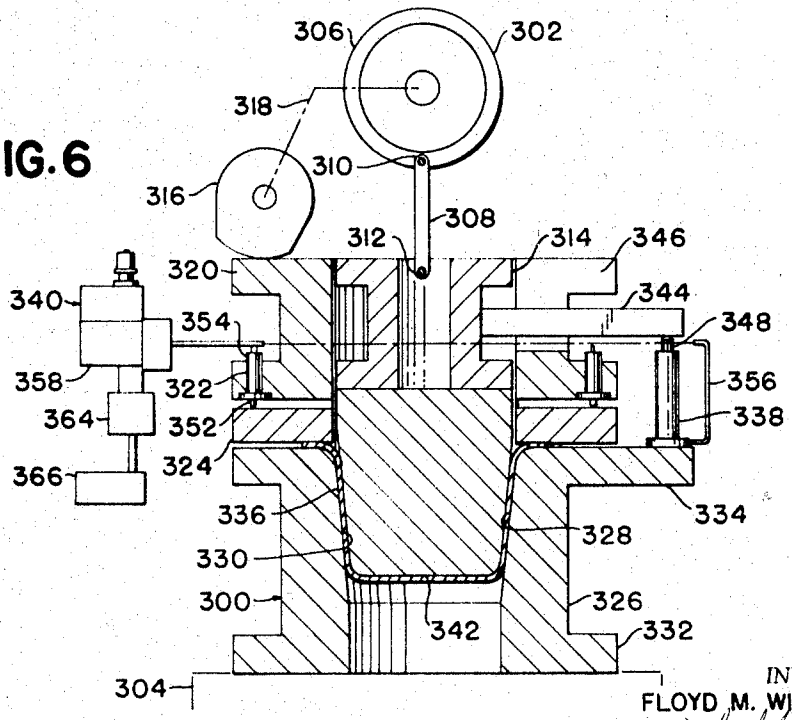


FIG. 6



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APPARATUS FOR DEEP DRAWING METAL WITH HYDRAULICALLY CONTROLLED DIES

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U.S. Cl. 72—28 16 Claims

ABSTRACT OF THE DISCLOSURE

Die structure for deep drawing metal parts including a first die part having an opening extending therethrough with stepped progressively smaller diameters proceeding away from the second die part and a second die part including a plurality of concentric telescoped die punches adapted to proceed through the opening in the first die part in progressive forming phases with one of the die punches remaining stationary at each step in the first die part and pressure pads engaged with each of said die punches and die control structure operably associated with each of said pressure pads for preventing movement of the particular die punch engaged by the pad with respect to the other die punches before a predetermined pressure is applied thereto and for providing a continually varying pressure on the pressure pad during forming of a workpiece and the method of deep drawing metal workpieces accomplished by the structure.

The invention relates to forming metal articles by a press operation and refers more specifically to a process of and structure for decelerating or gradually decreasing the draw pad pressure applied by work holding pressure pads in die structure during single stroke deep drawing of metal workpieces with novel hydraulic die control and die structure.

In the past drawing of long hollow, metal vessels, such as shells, tanks, bathtubs, baskets and the like has been difficult or impossible due to limitations in known drawing processes and die structures. Thus, in deep drawing process of the past the draw pad pressure holding a workpiece has usually not been decelerated as the workpiece is formed to compensate for the increased difficulty of forming the work as it conforms to a die and die punch. In fact, with past structure wherein draw pad pressure has been applied through springs, the force holding the workpiece normally tends to increase as the resistance to drawing increases.

Also, with past die structure deep drawing has often been accomplished in separate steps. The separate drawing steps are progressively more difficult due to work hardening and setting of the metal between the separate steps.

In addition prior processes of and structure for deep drawing a workpiece have not always been suitable for use with both hydraulic and crank presses. Prior deep drawing operations have also been somewhat restricted by space limitations resulting from the general requirement for a relatively long press ram construction supporting a relatively long die punch considered necessary to accomplish the drawing operation.

It is therefore one of the purposes of the present invention to provide an improved process for deep drawing a metal workpiece.

Another object is to provide a process for deep drawing a metal workpiece including gradually decreasing or decelerating the draw pad pressure restraining the workpiece during forming of the workpiece as resistance to the drawing of the workpiece increases.

Another object is to provide a process for deep drawing a metal workpiece as set forth above wherein the workpiece is continuously formed in multiple phases.

Another object is to provide improved structure for deep drawing a metal workpiece.

Another object is to provide structure for deep drawing a metal workpiece including means for applying draw pad pressure to the workpiece during forming thereof, and means for gradually decreasing or decelerating the draw pad pressure on the workpiece during forming of the workpiece as resistance to the drawing of the workpiece increases.

Another object is to provide structure as set forth above and further including means for preloading the pressure applying means before the workpiece is drawn.

Another object is to provide structure as set forth above wherein the structure for deep drawing a metal workpiece further includes a die having telescopic punch structure for continuously forming the workpiece in multiple phases.

Another object is to provide a die including telescopic die punches for continuously forming a workpiece in multiple phases.

Another object is to provide hydraulic die control apparatus for decelerating or gradually decreasing draw pad pressure applied to a workpiece drawn in drawing die structure on a press or the like as the press is cycled.

Another object is to provide a process of and structure for deep drawing a workpiece which is simple, economical and efficient.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating a preferred embodiment of the invention, wherein:

FIGURE 1 is a diagrammatic longitudinal section view of telescoping die structure and hydraulic control apparatus therefor mounted on a hydraulic press and constructed in accordance with the invention for performing the process of the invention shown with the die structure and press and in an open position.

FIGURE 2 is a diagrammatic longitudinal section view of modified telescoping die structure, press and hydraulic control apparatus similar to that illustrated in FIGURE 1 with the modified die structure and press in a closed position.

FIGURE 3 is a detailed diagrammatic representation, partly in section of hydraulic die control apparatus suitable for use in conjunction with the die structures and presses illustrated in FIGURES 1, 2, 5 and 6.

FIGURE 4 is a detailed diagrammatic representation, partly in section of a modification of a portion of the die control apparatus illustrated in FIGURE 3.

FIGURE 5 is a diagrammatic longitudinal section view of die structure and hydraulic control apparatus therefor mounted on a crank press and constructed in accordance with the invention for performing the process of the invention shown with the die structure and press in a partly closed position.

FIGURE 6 is a diagrammatic longitudinal section view of the die structure, press and hydraulic control apparatus therefor illustrated in FIGURE 5 showing the die structure and press in a substantially fully closed position.

With particular reference to the figures of the drawings, one embodiment of the present invention will now be disclosed in detail.

As illustrated in FIGURE 1 the telescoping die structure **10** is secured to a hydraulic press **12**. Only the

bed 14 and the ram 16 of the hydraulic press 12 are shown. Hydraulic die control apparatus 18 for controlling draw pad pressure in the die structure 10 in each of multiple phases of operation thereof is secured to the telescoping upper, punch part 20 of the die structure 10.

In operation a workpiece 24, initially in the form of a flat metal blank, which it is desired to form into a long cylindrical hollow vessel closed at one end, as illustrated in FIGURE 2, is placed on the stationary lower, die part 26 of the die structure 10 and the punch part 20 of the die structure 10 is moved toward the die part 26. The workpiece 24 is continuously drawn in multiple phases through the die members 52, 54 and 56 as it passes through openings 28, 30 and 32 in the die part 26. The drawing of the workpiece 24 is accomplished by the concentric telescoping hollow die punches 34 and 36 and the solid center die punch 38 of the punch part 20 of die structure 10 as the punch part 20 is moved toward the die part 26.

The hydraulic die control apparatus 18 provides gradually decreasing or decelerating draw pad pressures on the workpiece 24 during each of the multiple phases of a drawing operation of the die structure 10 to compensate for the increasing resistance to drawing of the workpiece during the drawing process.

More specifically the lower, die part 26 of the die structure 10 illustrated in FIGURE 1 includes the individual die blocks 40, 42 and 44 having the concentric centrally located openings 28, 30 and 32 therein of progressively smaller circular cross section. The openings 28, 30 and 32 are uniform in diameter throughout the length of each separate opening. The die blocks 40, 42 and 44 are further provided with circular recesses 46, 48 and 50 respectively therein concentric with the openings 28, 30 and 32 respectively in which the hardened annular die members 52, 54 and 56 respectively are positioned.

As shown in FIGURE 2, the die block 42 may be supported by convenient means, such as spacing blocks 64 or the like, on and in spaced relation to die block 44 to permit removal, transversely of the die structure 10, of material trimmed from the workpiece 24 by the die member 56 in conjunction with die punch 38. The trimming of material from the workpiece 24 by die punch 38 and die member 56 during drawing of the workpiece 24 will be considered in detail subsequently.

The upper, punch part 20 of the die structure 10 includes the mounting member 66 secured in a fixed position on the lower end of the ram 16 of the press 12 by convenient means (not shown) and the mounting member 68 rigidly secured in spaced relation to the mounting member 66 by means of rods 70 only one of which is shown which are positioned in spaced relation around the periphery of members 66 and 68 and are secured to the members 66 and 68 by convenient means, such as bolts 72 and 74 at the opposite ends thereof.

A hydraulic cushion 86 including cylinder 80 and piston 84 is secured to the mounting member 66 by convenient means (not shown). The interior of the cylinder 80 is hydraulically connected to the die control valve 58 of the hydraulic control apparatus 18 through passage 82 in mounting member 66. Piston 84 is engaged with block 90 connected to piston sleeve 88 and is positioned for vertical movement into and out of the cylinder 80. The hydraulic cushion 86 provides draw pad pressure for the third and final phase of forming of workpiece 24 through block 90, the end of sleeve 88, rods 124, punch supporting member 130 and die punch 36, as will be considered subsequently.

The sleeve 88 is further connected at the upper end to the annular hydraulic cushion supporting member 96 which is guided for vertical movement by the rods 70 extending through the angularly spaced apart peripheral openings 98 in member 96. Hydraulic cushions 94 are supported in angularly spaced relation about the periphery of member 96. Each cushion 94 includes a cylinder 100 connected to the die control valve 60 of the hydraulic control apparatus 18 through the hydraulic fluid conduit 102. A piston 104 is positioned within each of the cylinders 100 for vertical movement into and out of the respective cylinders.

An annular pressure pad 108 is sleeved over sleeve 88 for vertical movement with respect thereto. The pad 108 is also guided by the shafts 70 extending through angularly spaced openings 110 around the periphery thereof. Pressure pad 108 applies pressure to pistons 104 when the cushion supporting member 96 and pad 108 are moved toward each other. As will be seen subsequently, cushions 94 supply the draw pad pressure through pressure pad 108, rods 112, cushion and punch supporting member 120 and die punch 34 for the second phase of drawing of the workpiece.

The rods 112 extend in angularly spaced relation vertically through peripheral openings 114 in mounting member 68 and similar openings 116 in the punch supporting member 118. The rods 112 are in engagement at the top with the pressure pad 108. The punch and hydraulic cushion supporting member 120 to which the outer hollow cylindrical die punch 34 and hydraulic cushion 122 are secured is in engagement with the bottoms of rods 112.

Rods 124 pass through the angularly spaced apart peripheral openings 126 and 128 in the mounting member 68 and punch supporting member 118 respectively and are in engagement with the block 90 and bottom of sleeve 88. The punch supporting member 130 is engaged with the lower ends of the rods 124 and supports the inner hollow cylindrical die punch 36 which is rigidly secured thereto.

The punch supporting member 118 to which the center solid cylindrical die punch 38 is rigidly secured is in turn secured to the die mounting member 68 by convenient means (not shown).

Hydraulic cushions 122 each including a cylinder 134 and piston 138 are carried peripherally in angularly spaced relation by the member 120 and are connected by means of a hydraulic fluid conduit 136 to the die control valve 62 of the hydraulic control apparatus 18. The pistons 138 are positioned within the cylinders 134 for vertical movement into and out of the cylinders. The cushions 122 apply draw pad pressure to the workpiece 24 through pressure pad 148 during the first phase of drawing of workpiece 24 as will be seen subsequently.

Guide posts, stops and the like may be provided in conjunction with the pressure pad 148, cushion and punch supporting member 120 and punch supporting member 130 and in conjunction with the other members of the die structure where desired. Such die structure is well known and forms no part of the present invention and will therefore not be considered in detail herein.

As indicated above the die punch 38 is reciprocally mounted concentrically with and within the hollow die punch 36 and extends through the opening 142 in punch supporting member 130, while the die punch 36 extends through the hollow cylindrical die punch 34 and through the concentric opening 144 of the cushion and punch supporting member 120. The die punch 34 extends through the opening 146 in the pressure pad 148 on which pistons 138 bear.

The die control values 58, 60 and 62 are the same and are similarly supplied with hydraulic fluid from tank 150 through flexible hydraulic fluid line 152. Return of the hydraulic fluid to the tank 150 is also accomplished through hydraulic fluid line 152 in conjunction with control valves 58, 60 and 62. The hydraulic fluid in tank 150 is maintained at a predetermined pressure with air supplied to the tank 150 through pressure regulating valve 168 from air supply conduit 170.

Since the die control valves 58, 60 and 62 are all the same only die control valve 62 will be considered in detail. The die control valve 62 includes the check valve 172 positioned between the tank 150 and the hydraulic

cushions 122 and a parallel positioned pressure relief valve 174 illustrated best in FIGURE 3.

Check valve 172 includes the valve member 180 and spring 182 held in passage 184 in valve block 186 by plug 188. The valve member 180 permits flow of hydraulic fluid through conduit 152 to conduit 102 and into cylinders 134 but prevents reverse hydraulic fluid flow through the conduit 152.

The pressure relief valve 174 includes a valve member 190 urged toward a closed position by spring 192, the tension on which is adjustable by means of the adjusting screw 194 acting on plug 196 in valve passage 198 in valve block 158. When the pressure in the cylinders 134 exceeds a predetermined value set by the adjustment of the adjusting screw 194, the valve member 190 is caused to move up, as shown in FIGURE 3, to permit draining of hydraulic fluid from the cylinders 134 through the passage 160 back to the tank 150.

The dies control valves 58, 60 and 62 permit operation of the die structure 10 in multiple phases to be considered in detail subsequently. With only the die control valves 58, 60 and 62 the pressure applied to the workpiece by cushions 86, 94 and 122 in each phase of operation of the die structure 10 may be different but the pressure on the workpiece in each phase of operation will be the same during the phase of operation as determined by the setting of the pressure relief valve.

In the modified die structure illustrated in FIGURE 2 wherein the same reference numerals are used to designate the same elements as in FIGURE 1, only the upper die control valve 58 is used. The cushions 94 and 122 are supplied with hydraulic fluid through valve 58 and the flexible fluid supply line 248 connecting with passage 82 in junction block 270. With the structure of FIGURE 2 the different pressures on the workpiece in the different phases of operation of the die structure will be determined by the different total cross-sectional area of the cushion pistons associated with the phase of operation, as will be considered subsequently.

With only the die control valves 58, 60 and 62 the pressure initially applied to the workpiece is limited by the pressure applied to the hydraulic fluid in the tank 150. Also, deceleration or controlled decreasing of the pressure applied to the workpiece during the phases of operation is not possible with only the die control valves 58, 60 and 62. Therefore, any of the die control valves 58, 60 or 62 or all of them may be further provided with an intensifier unit and/or a decelerating valve, such as the intensifier unit 176 and decelerating valve 178, illustrated in FIGURE 3 in conjunction with die control valve 62.

The intensifier unit 176 includes a small diameter cylinder 200 in communication at the upper end with passage 202 in valve block 186 through passage 204 therein. The small diameter cylinder 200 is also in communication at the lower end thereof with the upper end of the large diameter cylinder 212. The lower end of the cylinder 212 is in communication with the decelerating valve structure 178 through the conduit 216. A small diameter piston 218 is positioned in the small diameter cylinder 200 and is rigidly connected with the large diameter piston 220 by the rigid shaft 224. Thus, on application of a relatively small force per unit area in the lower portion of the cylinder 212, a relatively large force per unit area will be provided in the upper end of the small diameter cylinder 200.

The decelerating valve 178 includes a valve block 226 having a passage 228 therein connected with the conduit 216 from the intensifier 176 at one end and extending at right angles to and connected at the other end to the passage 230 in the valve block 226. One end of passage 230 is closed by a plug 232 as shown in FIGURE 3. An adjustable limiting valve 234 is secured in the valve block 226 between the intersecting other ends of passages 228 and 230.

An offset passage 236 is provided in the block 226 having the portion 238 at one end in communication with the passage 228 and extending substantially parallel to the passage 230 which portion 238 is closed by the plug 240 in the valve block 226. The passage 236 further includes the portion 242 extending substantially parallel to the passage 228 and in communication with the portion 238. A bleeder valve 244 for timing of the escape of air from the lower portion of cylinder 212 is provided between the portions 238 and 242 of passage 236.

The passage 236 further includes the portion 246 again extending substantially parallel to the passage 230 and offset from the portion 238 of the passage 236 and which is open at the end, as illustrated in FIGURE 3 to provide for escape of air under pressure from intensifier 176 when it is desired to decelerate the pressure in the cushions 122. If the pressure in the cushions 122 is to be accelerated a source of air under pressure is connected to portion 246 of passage 236.

A further passage 250 extends through the valve block 226 substantially perpendicular to and intersecting both the passages 230 and 236, as shown in FIGURE 3. A two-way valve 252 is provided at the intersection of the passage 250 and the portion 246 of passage 236. Valve 252 is operated by the mechanical linkage 254 and may be biased by spring 256 into the position shown in FIGURE 3 wherein the passage 250 is in communication with the passage 230 and passage 236 is closed. Rotation of valve 252 ninety degrees will open passage 236 and close passage 250. Actuation of the mechanical linkage 254 to rotated valve 252 may be by a mechanical connection to the ram 16 of press 12 on lowering of ram 16. Alternatively of course electrical actuating means for the mechanical linkage 254 may be provided actuated on closing of a limit switch or the like by ram 16 of press 12.

The passage 250 in die block 226 is connected through conduit 258 to a pressure regulating valve 260 and an on-off valve 262 connected to a source of air under pressure, such as conduit 170 through conduit 264.

The over-all operation of the die structure 10 will be considered assuming that all of the die control valves 58, 60 and 62 are provided as in FIGURE 1 and each are operably associated with an intensifier unit 176 and a decelerating valve, as in FIGURE 3. With the die structure 10 initially in the position illustrated in FIGURE 1, the cylinders 80, 100 and 134 will be filled with hydraulic fluid from the tank 150 through check valves 172 in the respective die control valves 58, 60 and 62. The valve 252 of the decelerating valve 178 of the die control valves will be in the position shown in FIGURE 3 and the valve 262 will be open whereby air under pressure from conduit 264 is supplied through the pressure regulating valve 260 through the conduit 258, passage 250, passage 230 and passage 228 past the partially open adjustable valve 234 and into the lower end of cylinder 212. The pressure will be multiplied through the intensifier unit 176 whereby hydraulic fluid at a substantial pressure will be applied to the pistons 84, 104 and 138 to initially hold the pads 108 and 148 and sleve 88 together with block 90 in an extended position, as shown in FIGURE 1.

The pressure is initially maintained at predetermined fixed values in the cylinders 80, 100 and 134 due to the setting of the pressure relief valves 174. If necessary to maintain an initial pressure against losses if hydraulic a preload cylinder and piston may be employed in conjunction with any or all of the cushions 86, 94 and 122 as will be considered in more detail subsequently along with the die structure of FIGURES 5 and 6.

As the ram 16 of press 12 descends the draw pad 148 initially contacts the workpiece 24 to provide pressure on the workpiece in conjunction with the lower die part 26. Continued descent of ram 16 changes the position of the valve 252 in the decelerating valve 178 associated with die control valve 62 to open the portion 246 of the

conduit 236. Thus, as the die punch members 34, 36 and 38 acting as a unit begin to draw the workpiece 24 through the die member 52 and the opening 28 in the die block 40, the pressure applied to the cylinders 134 and thus to the workpiece 24 through pistons 138 begins to decelerate or decrease as the pressure in the lower end of cylinder 212 bleeds out through open passage 236 past bleed valve 244.

On continued movement of the ram 16 in a downward direction the die punches 34, 36 and 38 acting as a unit pass through the opening 146 in pad 148 through die member 52 and into opening 28 through die block 40. Pad 148 eventually abuts against the cushion and punch supporting member 120 with the pistons 138 forced into the cylinders 134. The workpiece 24 in the first phase of the continuous draw is thus drawn through die member 52 into the opening 28 with the edges thereof held by the pressure pad 148 with a decelerating pressure controlled by the setting of the bleed valve 244 of the decelerating valve structure 178 associated with the die control valve 62.

Further downward movement of the punch supporting member 120 is at this time prevented by the lower end of the hollow punch 34 which will now press the bottom of the now cup-shaped workpiece 24 against the top of the annular die member 54 in die block 42 with an initial draw pad pressure determined by the setting of the pressure relief valve associated with the die control valve 60.

Continued downward movement of the ram 16 of press 12 will cause the cushion and punch supporting member 130 to move toward the punch supporting member 120. Movement of the member 130 toward the member 120 on downward movement of ram 16 is resisted by cushions 94 acting through pressure pad 108 and rods 112. During movement of the member 130 toward member 120, the hollow cylindrical punch 36 will pass out of the lower end of the hollow cylindrical punch 34 along with the solid die punch 38 acting as a unit therewith into the opening 30 in the die block 42 through die member 54 to form the workpiece 24 in the second of the continuous drawing phases.

The pressure pad 108 again initially offers large resistance to relative movement of the members 120 and 130 toward each other which is determined by the setting of the pressure relief valve in the die control valve 60 associated therewith, as indicated above. As the ram continues its downward movement the pressure in the hydraulic cushions 94 is gradually decelerated or decreased as the resistance to drawing the workpiece 24 through die member 54 into the opening 30 in die block 42 increases as before due to actuation of a mechanical linkage, such as linkage 254 on a decelerating valve associated with the die control valve 94.

When the ram 16 has moved down to the point where the punch supporting member 120 is almost in contact with the cushion and die supporting member 130, the pistons 104 are almost completely inserted in the cylinders 100. The lower end of the die punch 36 will at this time rest on the bottom of the cup-shaped workpiece immediately above the top of the die member 56 to apply drawing pad pressure on the workpiece initially determined by the setting of the pressure relief valve in the die control valve 58 during the third and final phase of the continuous forming of workpiece 24.

Continued movement downward of the ram 16 of press 12 will produce continued downward movement of the center, solid, die punch 38. The rods 124 at this time will urge the sleeve 88, block 90 and piston 84 movable therewith into the cylinder 80 again against a decelerating pressure applied to the cylinder 80 from the decelerating valve associated with the die control valve 58.

The die 10 at the end of the downward stroke of the press ram 16 will be in a position as indicated in FIGURE 2 with the workpiece 24 formed into a deep drawn cylinder closed at the lower end.

Approximately fifty percent of the draw is performed through the first die member 52 with twenty-five percent of the draw being through each of the die members 54 and 56. The difference in the draw through the die members 52, 54 and 56 is due to the greater difficulty in drawing the metal workpiece 24 after it has been drawn in the first phase through the die member 52.

It will be understood that in the operation considered above that any or all of the die control valves 58, 60 and 62 may be provided without an intensifier unit 176 and without a decelerating valve 178. However, wrinkles, tears and the like in workpiece 24 are more completely eliminated due to the gradually relieved pressure holding the workpiece peripherally in each of the successive phases of the draw when decelerating valves 178 are provided.

As illustrated in FIGURE 2 the lower die member 42 may, if desired, be raised above the die member 44 and positioned on spacing blocks 64 to permit removal of the portion of the workpiece 24 which is trimmed from the workpiece 24 between the shoulder 266 formed on the lower end of the die punch 38 in conjunction with the annular die member 56. The upper end of the workpiece 24 will be pinched between the die member 56 and the shoulder 266 on die punch 38 as the punch 38 passes through the die member to trim the finished workpiece 24 to a predetermined length. The trimmed portion of the workpiece may be removed through the space 268.

The decelerating valve structure 272 illustrated in FIGURE 4 is a modification of the decelerating valve structure 178 illustrated in FIGURE 3. The valve structure 272 differs from the valve structure 178 in that the air under pressure is supplied through a passage 274 from regulating valve 276 on opening of the valve 278 and is supplied to the lower portion of the intensifier unit 176 through conduit 280 from passage 282. A valve 284 is provided between the passages 274 and 282. The air pressure is exhausted through the offset passage 286 having the portions 288, 290 and 292 and including the bleed valve 294 therein positioned as shown in FIGURE 4. The valve 296 is positioned in the passage 286 to open and close the passage 286 on actuation of the mechanical linkage 298.

In operation of the valve structure illustrated in FIGURE 4 the air under pressure is again bled out of the intensifier unit 176 through the conduit 280 and passage 286 in response to downward movement of the press to actuate the linkage 298 and open the passage 286 to atmosphere through the valve 296. Again the release of the air pressure in the intensifier and the consequent deceleration of pressure in the hydraulic cushions is controlled by the setting of the valve 294.

The hydraulic die control structure illustrated in FIGURE 3, is not only suitable for use in conjunction with the telescoping die structure 10, as illustrated in FIGURES 1 and 2, with hydraulic press 12 but is also suitable for use in conjunction with other die structures and press types, such as the die structure 300 and the crank press 302 illustrated in FIGURES 5 and 6. The die structure 300 illustrated in FIGURES 5 and 6 is useful in deep drawing articles having inwardly inclined sides, such as for example, a bathtub.

As shown in FIGURES 5 and 6 the crank press 302 includes the bed 304, the rotating crank wheel 306 and the mechanical link 308 pivoted at the opposite ends 310 and 312 to the crank wheel 306 of the press 302 and the upper forming die supporting member 314 of the die structure 300, respectively. The press structure 302 also includes the cam member 316 which has a mechanical connection 318 to the crank wheel 306 so as to be synchronized in rotation therewith. The cam 316 forces the binder 320 of the press structure 302 downward to place the hydraulic cushions 322 carried by the binder 320 into contact with the die structure pressure pad 324 for a predetermined time during a cycle of the press 302.

The die structure 300 includes the bottom forming die

326 having a cavity 328, including the tapered sides 330 rigidly secured to the bed 304 of the crank press 302. The bottom die member 326 includes the mounting flanges 332 and flanges 334 for supporting a workpiece 336 in position for forming and for supporting the preload cylinder 338 of the hydraulic control apparatus generally indicated 340.

The die structure 300 further includes the die supporting member 314, previously indicated connected to the crank wheel 306 of the crank press 302 by mechanical link 308 for vertical reciprocation thereby. The upper forming die 342 is connected to the die supporting member 314 by convenient means, such as bolts (not shown).

An actuating member 344 is secured to the die supporting member 314 for vertical movement therewith into and out of the slot 346 cut therefor in the binder 320 for moving the preload piston 348 in the preload cylinder 338 during downward movement of the upper forming die 342.

The hydraulic control apparatus 340 for the die structure 300 includes the preload cylinder and piston noted above, a plurality of hydraulic cushions 322 including pistons 352 and cylinders 354 connected to a die control valve 358 including a pressure relief valve 360 and a check valve 362 and an intersifier unit 364 and pressure decelerating valve 366 connected to the die control valve 358 as before. A tank for supplying hydraulic fluid under air pressure, as illustrated in FIGURE 3, and pressurized air supply means will be provided in conjunction with the hydraulic control apparatus 340 connected as illustrated in FIGURE 3.

Thus, in operation of the die structure illustrated in FIGURES 5 and 6, with the crank wheel 306 of the press 302 in a position to fully retract the upper forming die 342, the cam 316 is in a position with respect to the binder 320 to permit the binder to assume a position wherein the pressure pad 324 is allowed to move away from the lower forming die. The workpiece blank 336 is positioned on the top of the lower forming die 326 and the crank wheel 306 is rotated to start the upper forming die 342 down.

The actuating member 344 then contacts the preload piston 348 to drive hydraulic fluid from the preload cylinder 338 and provide a predetermined pressure in the hydraulic cushions 322 carried by binder 320 set by the pressure relief valve 360 in the die control valve 358. The cam 316 then forces the binder 320 down so that the pistons 352 engage the pressure pad 324 and forces it into contact with the outer periphery of the workpiece 336 to provide an initial drawing pressure holding the workpiece 336 between the pressure pad 324 and the upper flange 334 of the lower forming die 326.

The binder 320 is maintained in this position by the cam 316 during the remainder of the downward stroke of the press structure 302. During the remainder of the downward stroke of the press 302 the upper forming die 342 forms the workpiece 336 in conjunction with the lower forming die 326. The pressure applied to the pressure pad 324 during forming of workpiece 336 is again decelerated to prevent wrinkling and tearing of the workpiece 336 through action of the decelerating valve 366 in the die control valve 358 due to actuation of the decelerating valve by the press structure 302 in its downward movement.

On the subsequent upward stroke of the press structure 302 the preload cylinder 338 is again filled with hydraulic fluid from hydraulic fluid line 356 to extend the piston 348, as shown in FIGURE 5. The position of the press 302 and die 300 at the finish of the forming stroke is illustrated in FIGURE 6.

While one embodiment of the present invention and modifications thereof have been disclosed in detail, it will be understood that other embodiments and modifications are contemplated. It is the intention to include all embodiments and modifications of the invention as are defined by the appended claims within the scope of the invention.

What I claim as my invention is:

1. In combination a press, die structure including first and second die parts secured to the press for forming a metal workpiece positioned therebetween on relative movement of the die parts toward each other on actuation of the press and at least one pressure pad and hydraulic die control apparatus connected to the die structure for providing a varying pressure on the workpiece through the pressure pad during forming of the workpiece, said hydraulic die control apparatus including a source of hydraulic fluid under pressure, at least one hydraulic cushion operably associated with the pressure pad for applying hydraulic pressure to the pad, check valve structure between the source of hydraulic fluid and hydraulic cushion for applying hydraulic fluid to the cushion at a pressure substantially equal to the pressure from the source of hydraulic fluid, a pressure relief valve positioned between the source of hydraulic fluid and the hydraulic cushion for returning hydraulic fluid from the cushion to the supply of hydraulic fluid at a selected cushion fluid pressure, an intensifier connected to the hydraulic cushion for increasing the pressure of the hydraulic fluid therein and a decelerating valve connected to a source of air under pressure and the intensifier for activating the intensifier to increase the pressure of the hydraulic fluid in the cushions and for decelerating the pressure in response to movement of the press structure.

2. Structure as set forth in claim 1 wherein the decelerating valve comprises a valve block, a first passage extending through said valve block, one end of which is plugged and the other end of which is connected to the intensifier, an adjustable metering valve in said first passage, a second passage in said valve block in communication with the first passage between the end thereof connected to the intensifier and the metering valve closed at on end adjacent the connection to the first passage and open at the other end, a third passage in said valve block in communication with both the first and second passages, a two-way valve operable between the second and third passages for alternatively opening the other end of said second passage and closing the third passage and for opening said third passage and closing said other end of said second passage in response to movement of the press, and a bleed valve positioned in the second passage between the connection between the first and second passages and the two-way valve.

3. Structure as set forth in claim 1 wherein the decelerating valve comprises a valve block, a first passage extending through said valve block connected at one end to the intensifier, a metering valve in the first passage, a second passage extending through said valve block closed at one end and open to the atmosphere at the other end, said second passage communicating with said first passage adjacent the closed end of the second passage, a valve in the second passage adjacent the open end thereof and means connected to the valve for opening the second passage on downward movement of the press and a bleed valve in the second passage positioned between the intersection between the first and second passages and the valve in the second passage.

4. Structure as set forth in claim 2 wherein the second die part has an opening extending therethrough with stepped progressively smaller diameters proceeding away from the first die part and the first die part includes a plurality of concentric telescoped die punches adapted to proceed downwardly through the opening in the lower die part in progressive forming phases with one of the die punches remaining stationary at each smaller diameter in the second die part and pressure pads operably associated with each of said die punches and die control structure for preventing movement of the die punches with respect to each other before a predetermined pressure is applied therebetween.

5. Structure as set forth in claim 4 wherein separate die control structure is provided in conjunction with each separate pressure pad.

6. Structure as set forth in claim 4 wherein a single die control structure is provided for control of all of the separate pressure pads.

7. Structure as set forth in claim 4 wherein the center die punch of the telescoped punches is provided with a reduced diameter outer end cooperable with the smallest diameter of the second die portion for trimming the edges of a finished workpiece drawn through the second die portion.

8. In combination with a crank press including a crank wheel and a press bed and means synchronized with said crank wheel, die structure including a bottom forming die member secured on the bed of the press having a die cavity therein, a pressure pad positioned directly above the bottom die member, a binder positioned directly above the pressure pad for engagement by said synchronized means during a predetermined portion of the cycle of the press for moving the binder toward the pressure pad into a predetermined position with respect thereto, a plurality of hydraulic cushions supported by the binder adapted to exert a decelerating hydraulic pressure on the pressure pad with the binder in the predetermined position, an upper forming die member, a die supporting member secured to the upper forming die member and means securing the die supporting member to the crank wheel of the press for moving the upper forming die member vertically into and out of the cavity in the lower forming die member.

9. Structure as set forth in claim 8 and further including a preloading cylinder operably associated with the die supporting member for supplying hydraulic pressure to the hydraulic cushions on downward movement of the die supporting member before the hydraulic cushions engage the pressure pad on movement of the binder toward the pressure pad.

10. A decelerating valve comprising a valve block, a first passage extending through said valve block, one end of which is plugged and the other end of which is open, an adjustable metering valve in said first passage, a second passage in said valve block in communication with the first passage between the outlet end thereof and the metering valve therein closed at one end adjacent the connection to the first passage and open at the other end, a third passage in said valve block in communication with both the first and second passages, a two-way valve operable between the second and third passages for alternatively opening the other end of said second passage and closing the third passage and for opening said third passage and closing said other end of said second passage in response to a condition external of the valve, and a bleed valve positioned in the second passage between the connection between the first and second passages and the two-way valve.

11. A decelerating valve comprising a valve block, a first passage extending through said valve block open at both ends, a metering valve in the first passage, a second passage extending through said block closed at one end and open at the other end, said second passage communicating with said first passage adjacent the closed end thereof, a valve in the second passage adjacent the open end thereof and means connected to the valve for opening the second passage in response to a condition external of the valve and a bleed valve in the second passage positioned between the intersection between the first and second passages and the valve in the second passage.

12. In combination a press, die structure including first and second die parts secured to the press for forming a metal workpiece positioned therebetween on relative movement of the die parts toward each other on actuation of the press and at least one pressure pad and hydraulic die control apparatus connected to the die structure for providing a gradually varying pressure on the workpiece through the pressure pad throughout the formation of the workpiece, said hydraulic die control apparatus including a source of hydraulic fluid under pressure, at least one hydraulic cushion operably associated with the pressure pad for applying hydraulic pressure to the pad, check valve structure between the source of hydraulic fluid and hydraulic cushion for applying hydraulic fluid to the cushion at a pressure substantially equal to the pressure from the source of hydraulic fluid, a pressure relief valve positioned between the source of hydraulic fluid and hydraulic cushion for returning hydraulic fluid from the cushion to the supply of hydraulic fluid at a selected cushion fluid pressure and means connected to the hydraulic cushion for gradually decelerating the pressure in the cushion in response to movement of the press structure.

13. Die structure including a first die part having an opening extending therethrough with stepped progressively smaller diameters proceeding away from a second die part and a second die part including a plurality of concentric telescoped die punches adapted to proceed through the opening in the first die part in progressive forming phases with one of the die punches remaining stationary at each step in the first die part and pressure pads engaged with each of said die punches, hydraulic cushion structure and die control structure operably associated with each of said pressure pads for preventing movement of the particular die punch engaged by the pad with respect to the other die punches before a predetermined pressure is applied thereto, intensifier means connected to the hydraulic cushions for increasing the pressure therein and decelerating valve means connected to the intensifier means for activating the intensifier means to increase the pressure of the hydraulic fluid in the cushions and for decelerating the pressure in response to movement of the press structure.

14. Structure as set forth in claim 13 wherein a separate die control structure is provided for control of each separate pressure pad.

15. Structure as set forth in claim 13 wherein a single die control structure is provided for control of all of the separate pressure pads.

16. Structure as set forth in claim 13 wherein the center die punch of the telescoped punches is provided with a reduced diameter outer end cooperable with the smallest diameter of the first die part for trimming the edges of a finished workpiece drawn through the first die part.

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72—349, 351