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BDX-613-868

DEEP DRAWN STAINLESS STEEL COVERS

Technological Spinoff Report

R. E. Mitchell, Project Leader

March 1973

MASTER

Prepared for the
United States Atomic Energy Commission
Under Contract Number AT(29-1)-613 USAEC

**Kansas City
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Project Leader:
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Department 822

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DEEP DRAWN STAINLESS STEEL COVERS

BDX-613-868, UNCLASSIFIED Technological Spinoff Report, March 1973

Prepared by R. E. Mitchell, D/822

The depth of draw for a rectangular cover fabricated by the hydroform process is directly proportional to the size of the cover's corner radii; for steel alloy, it is normally limited to six times the corner radii. A process combining hydroforming and mechanical deep drawing techniques has been developed which increased the depth of draw to 14 times the corner radii. It was used to fabricate two deep drawn stainless steel rectangular covers, needed for electromechanical assemblies, on a 12-inch-diameter hydroforming machine. Each cover required a different blank size and blank configuration, and different drawing pressures to prevent deformation of its sides, edges, and corners.

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SUMMARY

The MX0000 electromechanical assembly utilizes two deep drawn rectangular 304 stainless steel covers; they consist of an inner cover 0.030 inch thick and an outer cover 0.060 inch thick.

Rectangular covers identical except for size are being used on the MY0000. A process utilizing expensive conventional mechanical forming dies had been developed for these covers. The production quantities for the MX0000 made it desirable to develop a more economical concept for tooling and at the same time alleviate the need for the excessive hand forming experienced on the thicker cover for the MX0000. A process was developed using hydroforming techniques which takes advantage of less expensive tooling concepts.

The hydroform process produces covers with virtually no side deformation, reducing the need for excessive hand forming. This factor, plus the reduced tooling cost, has resulted in cost avoidance of approximately 35 percent for the two covers, even though actual cycle time for the hydroform process is slightly greater.

The rectangular covers required for the MX0000 assembly were formed in two draws on a 12-inch-diameter Cincinnati Hydroform. Although the normal depth for hydroforming such a cover is six times the corner radii, the 0.030-inch-thick cover required a depth of 28 times the corner radii, and the 0.060-inch-thick cover 11.3 times the corner radii.

The first draw for the 0.030-inch-thick cover was made on standard hydroform tooling--a punch and draw ring. The second and final draw was made by using a hydromechanical draw tool--a sleeve around the punch and outer sleeve--and by increasing the cover's corner radii. This process permitted a drawing depth of 14 times the corner radii, and controlled the flow of material at the corners to prevent side deformation and corner wrinkling. A subsequent mechanical sizing operation reduced the corner radii to produce a cover depth of 28 times the corner radii.

A similar process was used to form the 0.060-inch-thick cover, but no corner sizing was necessary. A 0.050-inch minimum wall thickness had to be maintained around the bottom edge of the 0.060-inch-thick cover because a lip was to be machined there. The material thickness was maintained by adjusting the blank size, the preform depth, and the outer sleeve's clamping pressure during the second draw.

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DISCUSSION

SCOPE AND PURPOSE

The MX0000 electromechanical assembly utilizes two deep drawn rectangular 304 stainless steel covers: an inner cover 0.030 inch thick and an outer cover 0.060 inch thick (Figure 1).

The inner cover is used to position and contain the interworking mechanisms of the unit. The outer cover, being larger in size, creates space between the inner and outer covers to permit shock and vibration mitigating capabilities. In addition, a lip machined on the outer cover's open end is rolled over a mating plate to complete the enclosures of the unit.

Rectangular covers identical except for size are being used on the MY0000. A process previously developed for these covers utilizes expensive conventional mechanical forming dies. The production quantities for the MX0000 made it desirable to develop a more economical concept for tooling and at the same time alleviate the need for the excessive hand forming experienced on a thicker cover for the MY0000. A process was developed for a 12-inch-diameter Cincinnati Hydroform press in two draws which takes advantage of less expensive tooling concepts. The cost for such tooling when compared to tooling costs for a mechanical forming process shows a component cost avoidance of 44 percent for the two MX0000 covers. Table 1 summarizes the results of the hydroforming.

ACTIVITY

Smaller Cover 0.030 Inch Thick

The first draw on the 0.030-inch cover used a preform punch (Figure 2), and a 6- by 7-inch octagonal blank. The preform was drawn 1.5 inches deep with 15,000 psi, then annealed to remove work hardening before the second draw.

The second draw was performed with a sleeve the size of the first punch with a punch of the final size inside it (Figure 3). The draw was made 1.75 inches deep--28 times the corner radius--using 15,000 psi. But the part wrinkled at the corners, starting 0.25 inch from the top of the part. The preform was too large, as evidenced by the excess material, and the corner radius was too small.

Figure 1. Electromechanical Assembly Stainless Steel Covers. 0.060-Inch-Thick Cover on Left; 0.030-Inch-Thick Cover on Right

Table 1. Results of Drawing Operations Using Different Blank Sizes

Cover Size (Inch)	Blank Size	First Draw		Second Draw		Corrective Action
		Pressure Used (psi)	Results	Pressure Used (psi)	Results	
0.030	8 by 7 inches with 1.5 inches inches on 45°	15,000	Good	15,000	Wrinkled in corners	Redesigned tooling and reduced blank size
	6-inch diameter	15,000	Wrinkled all around edge			Increase blank size
	6.5-inch diameter	15,000	Good	15,000	Wrinkled in corners	Redesigned second draw tooling to add outside sleeve
	6.5-inch diameter	15,000	Good	1200	Good	
0.060	9 by 11 inches with 1.5 inches on 45°	15,000	Good	1500	Good form but excessive material thin-out	Reduce blank size
	7.5-inch diameter	15,000	Good	1500	Excessive thin-out still present	Reduce pressure
	7.5-inch diameter	14,000	Wrinkle around edges	1400	Pressure would not hold sleeve down	Reduce blank and increase pressure back to 15,000 and 1500 psi
0.060	7 inches diameter	15,000	Wrinkles around edge			Change blank configuration
	7.5 by 6.75 inches with 1.5 inches on 45°	15,000	Good	1500	Thin-out still present but not below 0.050 minimum

Figure 2. Preform Punch

Figure 3. Tooling Used for Second Draw, Including 8- by 3-Inch Punch

To correct this problem, the preform was redesigned to reduce the excess amount of material (Figure 4), and the blank size was reduced to a 6-inch diameter. This blank size proved to be too small: the first draw wrinkled all around the edges. So the blank diameter was increased to 6.5 inches.

The first draw of this 6.5-inch blank was successful. The drawing cycle remained at 1.5 inches deep at 15,000 psi, followed by annealing. The second draw also remained at 1.75 inches deep at 15,000 psi. The sleeve was reduced to the same size as the preform, and the corner radii on the final form punch were each increased to 0.125 inch, making the depth of the second draw 14 times the corner radius. The wrinkles still appeared in the corners of the cover, indicating that the Hydroform diaphragm did not have enough pressure to hold the material when the rubber had to fold around sharp corners.

An outer sleeve (similar to the female portion of a mechanical die) was made to fit over the punch and sleeve (Figure 5). The sleeve trapped the material and controlled its flow as the punch moved upward. Only 1200 psi were needed to hold the outer sleeve in place during operation.

The clearance between the inner sleeve and outer sleeve proved to be critical: the part wrinkled with too much clearance; the part broke with too little clearance because the sleeves clamped the material and prevented it from flowing. Once the correct clearance of 0.035 inch was established, the covers were made (Figures 6 and 7). The parts were then sized with a sizing die which changed the corner radius from 0.125 to 0.060 inch.

Larger Cover 0.060 Inch Thick

The tooling design for the larger cover was similar to that for the smaller cover, and both covers were hydroformed in the same way (Figure 8). The first draw was made with standard hydroform tooling--a punch with large corner radii and a draw ring. The blank was a 9- by 11-inch octagon (Figure 9). The preform cover was drawn using 15,000 psi and was made without difficulty. After annealing to remove work hardening, the excess material was sheared off in preparation for the second draw.

The second draw used the same type of hydromechanical tooling developed for the smaller cover, an inner and outer sleeve. The tooling worked as before to form a box-like cover with straight walls and no wrinkles. No difficulty in forming the cover had been expected since the draw depth was only 11.3 times the corner radius. A problem involving the final wall thickness did develop, however.

Figure 4. Redesigned Preform Punches. Punch for 0.030-Inch Cover (Left) Measured 4 by 2-7/8 Inches With 7/8-Inch Corner Radius. Punch for 0.060-Inch Cover (Right) Measured 4-1/2 by 3-1/2 Inches With 1-Inch Corner Radius

Figure 5. Redesigned Second Draw Tooling With Outer Sleeve

Figure 6. Outer Sleeve Ready to be Placed Over Preform for Second Draw

Figure 7. Tooling and Cover After Second Draw

Figure 8. Stages of 0.060-Inch Cover Production. Clockwise From Bottom: Unformed Blank, Blank Formed by First Draw, First Draw Formed Into Partial Second Draw, and Completed Second Draw

Figure 9. 11- by 9-Inch Octagonal Blank and 7-1/2-Inch-Diameter Round Blank for 0.060-Inch Cover

The wall thickness problem occurred because the finished cover had a 0.035-inch minimum step milled around the bottom edge with a 0.010-inch minimum edge remaining (Figure 10). The edge was to be crimped over a plate during final assembly. To hold these dimensions, a minimum wall thickness of 0.050 inch had to be maintained. When first drawn, the covers had areas of wall thickness below 0.045 inch. These were local areas about 0.75 inch in diameter in the end portions of the cover.

Each of the two draws reduced wall thickness by 0.008 inch, bringing the material thickness to 0.044 inch. To control wall thickness, the amount of stretch in the cover had to be reduced.

The amount of stretching in a cover can be reduced by using a smaller blank, less pressure, or a combination of both. The size of the blank was reduced from the 9- by 11-inch octagonal shape to a 7.5-inch diameter disc (Figure 9). This size blank made a part with a wall thickness of 0.055 inch, an increase of 0.003 inch over the previous preformed parts. Reducing the pressure failed to improve the thickness: parts could not be drawn at pressures less than 15,000 psi without wrinkling.

The second draw still produced parts with wall thicknesses of 0.045 inch; the second-draw pressure of 1500 psi was reduced to try to improve this. But a reduction of only 100 psi let the outer sleeve slip out of place; consequently, the 1500 psi was needed to hold the sleeve in place. Shims 0.060-inch-thick were placed under the outer sleeve to prevent it from closing up and clamping the material as it was formed by the punch, and to reduce pressure on the part. This resulted in a part with a wall thickness of 0.048 to 0.049 inch in the thinnest area. Good assemblies could have been made with these improved thicknesses, but a 0.050-inch wall thickness was still needed in the area to be machined.

Any hydroform or mechanical deep drawing process using a flat blank thickens the blank material proportionally more toward the blank edge as the draw progresses. To get this thick portion of the material into the area of the machined lip, the blank size and draw depth were changed once more. A 7-inch-diameter blank wrinkled around the edge on the first draw so the blank was changed to a new 6.75- by 7.25-inch octagonal configuration. The depth of the first draw was reduced by 0.125 inch, from 1.750 to 1.625 inches. Less material was left to make the second draw.

The depth and size of the second draw were not changed. Drawing the final form used almost all of the material from the first draw. Some flange was left in the corners, but the majority of the thicker material was drawn up into the sides of the cover. A 0.050-inch minimum wall thickness was therefore maintained in the area to be machined.

Figure 10. Details of Cover Wall Thickness Requirements

ACCOMPLISHMENTS

The following conclusions were reached as a result of this investigation.

Hydromechanical tooling provides latitudes for more deeply drawn rectangular covers by the hydroform process and results in a product with no wrinkles or side deformation when the proper blank size and drawing cycle have been established. While this process requires more cycle time per part than conventional processes, a significant cost avoidance was realized.

The developed process for the 0.030-inch-thick cover increased the labor required per part by 18 percent over the mechanical process. This was because of the slower loading and cycle time required for hydroforming. However, the economic trade-off of less expensive tooling did yield a cost avoidance of approximately 33 percent.

Since the hydroform process produced covers with no side deformation, the need for hand forming was reduced. This factor, plus the economic trade-off of less expensive tooling brought about a cost avoidance of approximately 37 percent for the 0.060-inch-thick cover.

The blank size must be controlled to minimize wrinkles and material thinout. By selecting the right blank size and shape, the wall thickness reduction caused by stretching can be reduced: the thicker flange material will be drawn up into the sides of the cover, aided by the drawing cycle.

The draw depth and pressure also affect the amount of stretching during drawing. When drawing pressures cannot be changed to alleviate material thinout during the second draw, the depth of the first draw can be regulated to the point that thicker material is directed to the areas needed for the second draw. In the case of the 0.060-inch-thick cover, material was directed to the open end.

FUTURE WORK

The tooling and methods used in this investigation will be considered for application for all future rectangular covers made by hydroforming. A process development project is being considered which further investigates hydromechanical tooling. Particular effort will be directed to establish a relationship of critical clearances between the inner and outer sleeves to material thickness. Hydromechanical forming of other materials will also be studied.