

May 2, 1967

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3,316,745

METHOD OF DIELESSLY FORMING SURFACES OF REVOLUTION

Filed Feb. 8, 1965

2 Sheets-Sheet 1

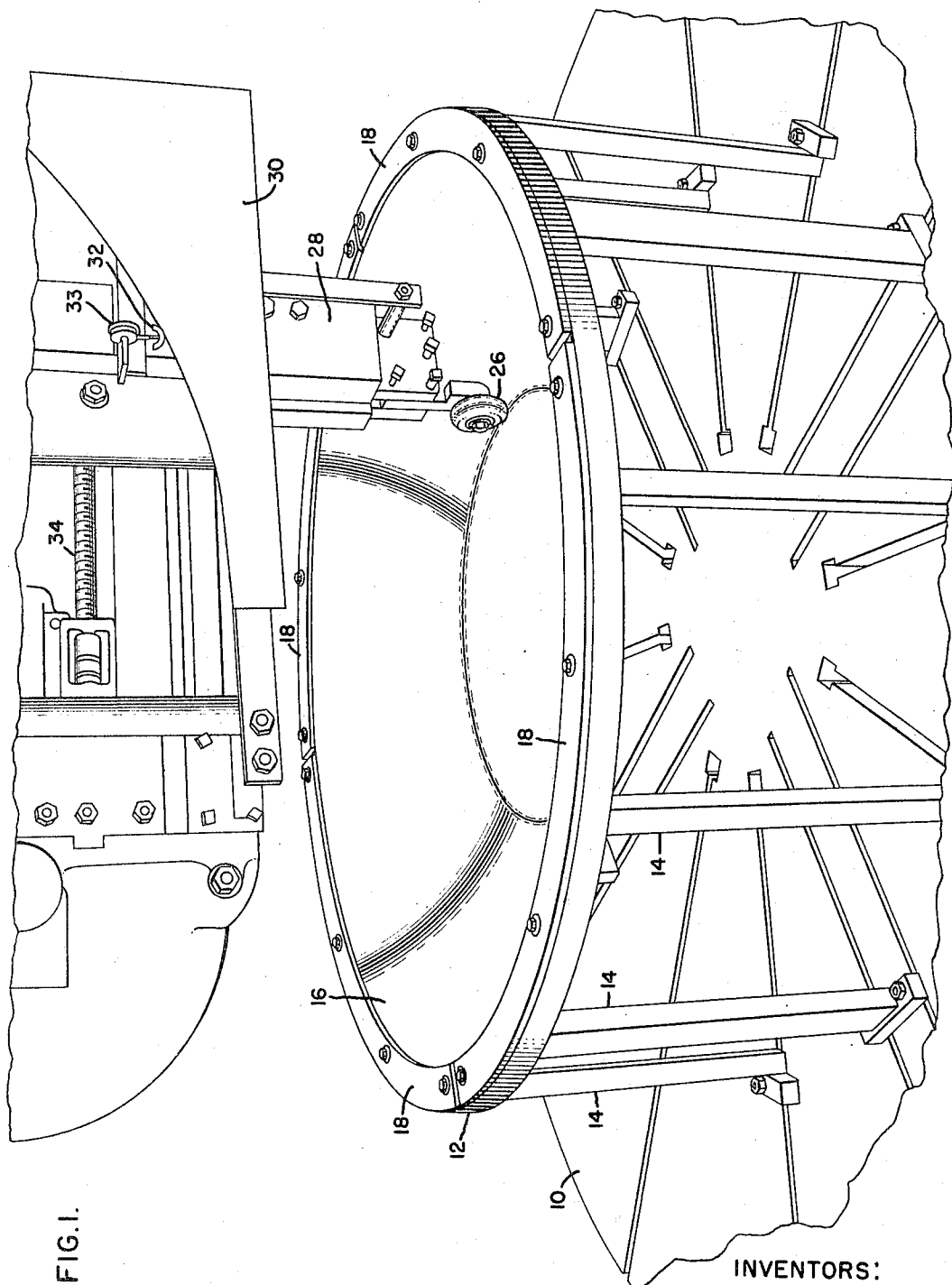


FIG. 1.

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FIG. 2.

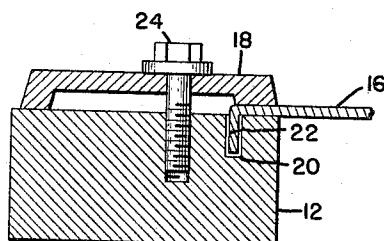
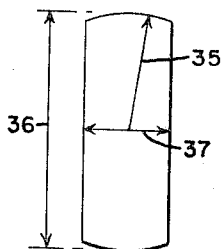


FIG. 3.



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3,316,745 METHOD OF DIELESSLY FORMING SURFACES OF REVOLUTION

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pany, a corporation of New York
Filed Feb. 8, 1965, Ser. No. 433,538
4 Claims. (Cl. 72-83)

This application is a continuation-in-part of our copending application entitled, "Method of Dieless Forming Surfaces of Revolution," Ser. No. 153,889, filed Nov. 21, 1961, and now abandoned.

This invention relates to a method for dieless forming of surfaces of revolution such as antenna dishes and more particularly to such a method for forming precision surfaces without dies while avoiding springback in the dish.

In the prior art, surfaces of revolution have been formed by means of dies against which metal may be pressed or rolled, requiring dies which involved considerable expense. In order to provide for a number of different shapes a large inventory of dies is also necessary.

Attempts have been made to form surfaces of revolution by spinning without the use of supporting or shaping forms or dies. However, since the upper and lower surfaces of the plate worked on were placed in tension and compression respectively, the result was a tendency to buckle or spring back. Such unstable surfaces would not be suitable for applications requiring high accuracy such as antenna dishes. Accordingly, it is an object of this invention to provide a method for forming surfaces of revolution without the use of dies.

Another object of the invention is to provide a method for cold working part of the formed portion of a surface of revolution, while cold working the unformed portion, to maintain the shape.

Still another object of the invention is to provide a dieless method of forming a surface of revolution by spinning which will minimize springback.

A further object is to provide a method of forming a surface or revolution by spinning which will be stronger and more stable than provided by previous spinning techniques.

A still further object is to provide a method of forming a stronger surface of revolution which will permit a lighter unit having the same strength as surfaces formed by prior methods.

A still further object of the invention is to provide a method of forming a surface of revolution without the use of dies including a unique mounting step for the material to be formed which will tend to reduce springback.

In accordance with one embodiment of the method, a surface of revolution is generated by mounting a metal plate to be formed in a clamping structure around its periphery. A working element such as a roller is moved in an inward spiral from the periphery toward the center of the sheet and is guided inwardly and downwardly in a programmed manner such as by a templet or numerically programmed head. The working element may be caused to overpenetrate the desired surface position in order to compensate for elastic recovery inherent in the material. The working element is proportioned with a radius of curvature from end to end to avoid accumulation of material inside of it if it is too small or too large a surface of contact and to cold work a part of the surface which is already formed while cold working the remainder of the surface in order to maintain its shape. The manner of mounting the sheet and forming with downward pressure places both of the surfaces of the sheet in tension thus reducing springback.

The novel features characteristic of the invention are set forth with particularity in the appended claims. The

method of the invention can best be understood by reference to the following description taken in connection with the accompanied drawings in which FIG. 1 is a three-dimensional view of one apparatus for carrying out the method of the invention using a boring mill and a guiding templet;

FIG. 2 is a cross section of a clamping ring for holding the material such as may be used in FIG. 1; and

FIG. 3 is a cross section of a typical roller through its center from end to end.

Turning now to the drawings, in FIG. 1 there is illustrated the rotatable boring mill table 10 upon which a clamping ring 12 is mounted by means of legs 14. Sheet material 16 which is to be formed into a surface of revolution is clamped to ring 12 by means of upper ring segments 18. This method of clamping is better illustrated by referring to FIG. 2 where it can be seen that ring 12 has a slot 20 in which a flanged edge portion 22 of sheet 16 may be placed to prevent the sheet 16 from pulling out of the clamping ring 12. The upper ring segment 18 may then be clamped down on sheet 16 on the inside and ring 12 on the outside by means such as bolt 24.

The working of sheet 16 may be performed by pressing working element or roller 26 of FIG. 1 downward against sheet 16 starting adjacent to the ring 12 as table 10 is rotated in order to cause the roller 26 which is supported by structure 28 to contact the sheet in a decreasing spiral path around the center of sheet 16. The roller 26 remains in a plane defined by the axis of rotation of table 10 and the line of its inward motion toward the center of sheet 16 as well as the line of motion of the roller toward the sheet. The degree of curvature generated by the spinning process is determined by a templet 30 against which a templet follower 32 corresponding in radius to the roller, mounted on an indicator 33, co-acts to determine the extent of the downward motion of supporting structure 28 while it is riding inward toward the center of sheet 16 along screw shaft 34 at a precisely predetermined rate.

In operation the axis of rotation for roller 26 is maintained substantially perpendicular to the axis of rotation for sheet 16. Keeping said axes in fixed spatial orientation with respect to each other during travel in a continuously decreasing spiral path of the roller toward the center of said sheet permits the desired cold working while the sheet is being formed. More particularly, the working face of said roller as defined by radius of curvature 35 accomplishes two distinct functions during the compound mode of roller travel. The area of the working surface making initial contact with the sheet does the forming essentially with the cold working being done by trailing areas along the same arcuate surface. In so doing, the roller makes initial contact with unformed portions of the sheet at different points along the arcuate working surface as it travels in the inward spiral path. The concurrent cold working step carried out in the above-described manner helps prevent or reduce the springback which would otherwise occur in formed portions of the workpiece thereby accurately reproducing the programmed shape.

The compound motion of the roller is obtained by causing said element to move in a line of motion by guide means toward the axis of rotation of the peripherally held sheet while also moving said element by separate guide means progressively in a line of motion toward said sheet. Guide means for said inward line of motion in the embodiment comprises screw shaft 34 whereas the separate guide means for said downward line of motion comprises template 30 in association with follower element 32 and indicator 33. The resultant path taken by the roller is regulated to lie on a predetermined curve.

By combining said two separate lines of motion in this predetermined manner, various curved shapes are obtained in the workpiece including a circular arc, an ellipse, a parabola and the like. As carried out in the above embodiment, the line of motion toward the axis of rotation of the workpiece is at a fixed rate of speed. The separately guided downward line of motion is orthogonal with respect to said inward line of motion and at a nonlinear rate of speed. It is not intended to limit the rates of travel for the separately guided lines of motion to those employed in said embodiment, however, since other combinations of travel will provide comparable results.

In embodiments utilizing a template for predetermining the final curvature it is advantageous to have a follower element 32 with the same radius of curvature as the arcuate work face on the working element. Such correspondence produces a final curvature in the workpiece which is substantially identical to the arcuate contour of the template. If said radii of curvature differ, there will be lack of correspondence between the template and workpiece curvatures. This is not to say that accurate reproduction between successive workpieces cannot be obtained from a given contour template. It means simply that some adjustment in the shape of the arcuate contour for the template will be necessitated to produce a predetermined curved shape in the workpiece when utilizing a template follower having a different radius of curvature than the radius of curvature for the working element.

A typical roller is shown in cross section in FIG. 3 having a radius of curvature 35 and a diameter 36. The radius referred to herein is from end to end of the roller whereas the diameter referred to is the over-all diameter of the roller. The roller also has a thickness or length 37 from end to end.

Roller 26 is proportioned both as to diameter and radius of curvature on the roller to avoid accumulation of material inside, or toward the center of sheet 16, of it if it is too small and to avoid too large an area of contact if it is too large. In one application of the above method, a two-inch radius roller having a four-inch diameter and a one-and-a-half inch length was used. It was found that a roller of one-half inch radius was too small and a three-and-a-half inch radius roller was too large. Naturally, this would depend in part on the thickness of the material being spun which in this application was .080". Material from .060-.125 inch has been successfully formed by this technique. The radius of curvature of the roller between its ends is also proportioned to provide progressive cold working under the roller of a portion of the dish which has already been formed to maintain its shape while performing additional cold working. Since the neutral axis is outside of the sheet, that is, since both the upper and lower layers of sheet 16 are in tension, the tendency to produce springback is substantially eliminated. This is due to the manner of supporting sheet 16 while it is being spun by holding it around its periphery. Roller 26 may be forced to overpenetrate, that is, it may be forced downward more than the desired curvature, in order to compensate for the elastic recovery of the metal in sheet 16.

While the principles of the method of the invention have now been made clear in the illustrated embodiments, there will be immediately obvious to those skilled in the art many modifications in the apparatus for carrying out the method of the invention which are particularly adapted for specific conditions without departing from the principles of the method of the invention. The appended claims are therefore intended to cover any such modifications that fall within the true spirit and scope of the invention.

What we claim as new and desired to be secured by Letters Patent in the United States is:

1. The method of forming a surface of revolution without the use of dies including the steps of supporting the

material to be formed in a circular clamp about its periphery, rotating said material about its center, providing a working roller having a radius of curvature small enough to provide a limited surface of contact and large enough to prevent accumulation of material inside of the roller, guiding the roller against the material in a predetermined line of motion while separately guiding said roller toward the center of the material in a different predetermined line of motion so that the resultant path taken by the roller is regulated to lie on a predetermined curve, and cold working a portion of the material already formed adjacent the portion being formed.

2. The method of forming a surface of revolution without the use of dies including the steps of supporting the material to be formed in a circular clamp about its periphery, rotating said material about its center, providing a working roller having a radius of curvature small enough to provide a limited surface of contact and large enough to prevent accumulation of material inside of the roller, guiding the roller against the material in a predetermined line of motion while separately guiding said roller toward the center of the material in a different predetermined line of motion, so that the resultant path taken by the roller is regulated to lie on a predetermined curve, the axis of rotation for said roller being kept in fixed spatial orientation with respect to the axis of rotation for the material, and cold working a portion of the material already formed adjacent the portion being formed.

3. The method of forming a surface of revolution without dies including the steps of supporting a sheet of material to be formed about its periphery, rotating said sheet about its center, providing a working roller having a radius of curvature small enough to provide a limited surface of contact and large enough to prevent accumulation of material inside of the roller, guiding the roller against the sheet in a predetermined line of motion and rate of travel while separately guiding said roller toward the center of the sheet in a different predetermined line of motion and rate of travel so that the resultant path taken by the roller is regulated to lie on a predetermined curve, the axis of rotation for said roller being kept in fixed spatial orientation with respect to the axis of rotation for the sheet, and cold working a portion of the sheet already formed adjacent the portion being formed.

4. The method of forming a surface of revolution without dies including the steps of supporting a sheet of material to be formed about its periphery, rotating said sheet about its center, providing a working roller having a radius of curvature small enough to provide a limited surface of contact and large enough to prevent accumulation of material inside of the roller, guiding the roller toward the center of the sheet in a predetermined line of motion at a fixed rate of travel while separately guiding the roller against the sheet in a different predetermined line of motion at a variable rate of travel regulated by a templet means so that the resultant path taken by the roller is regulated to lie on a predetermined curve, the axis of rotation for said roller being kept in a fixed spatial orientation with respect to the axis of rotation for the sheet, and cold working a portion of the sheet already formed adjacent the portion being formed.

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