

Nov. 6, 1962

W. R. ABBOTT
CONTROL OF TRAVERSING RIGHT ANGLE ATTACHMENT
FOR RADIAL DRAW FORMER

3,062,266

Filed June 29, 1956

3 Sheets-Sheet 1

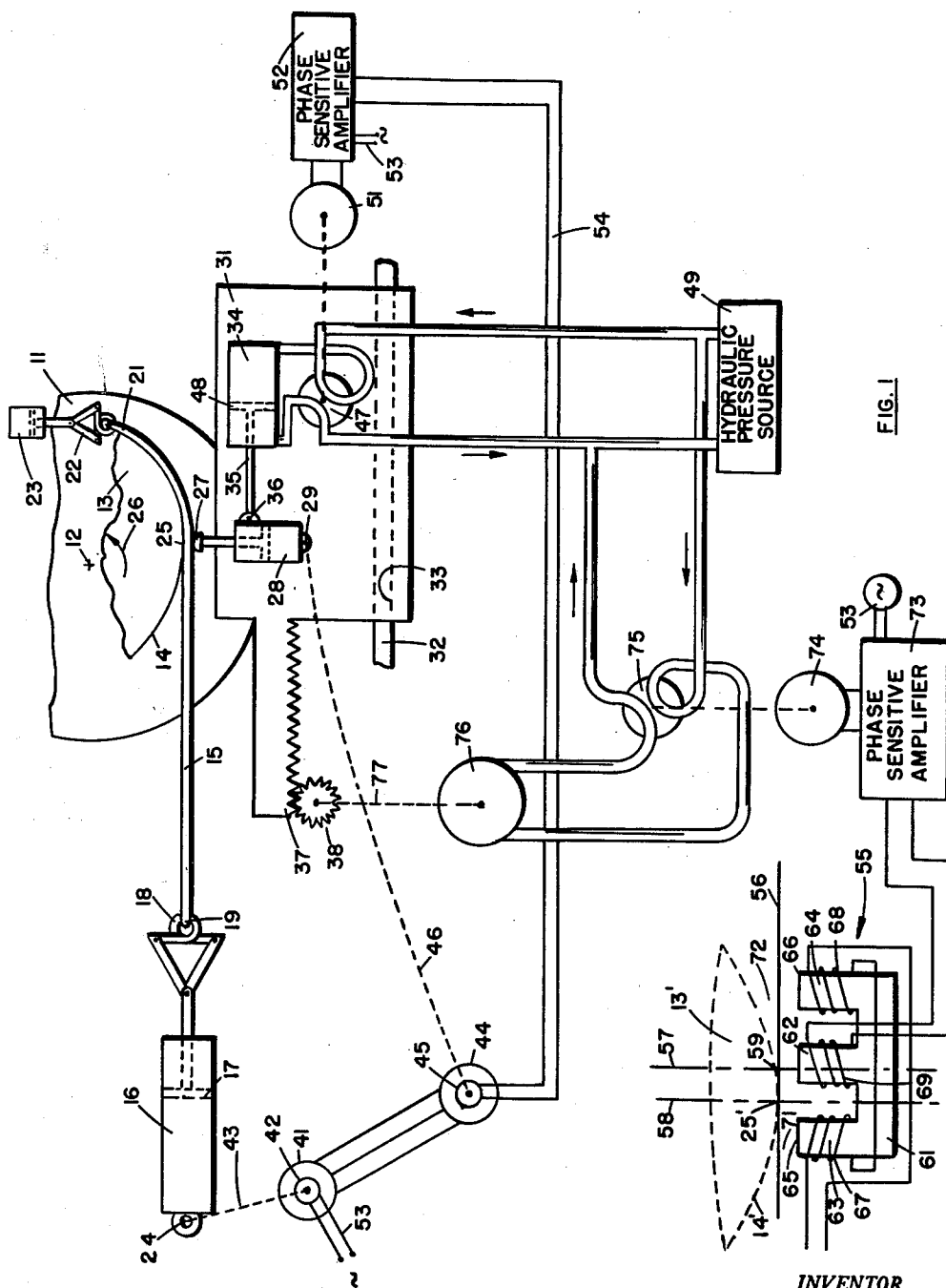


FIG. 1

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3 Sheets-Sheet 2

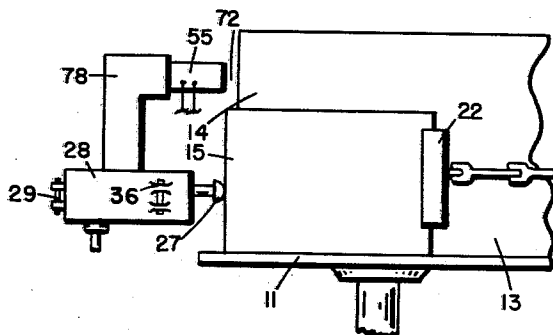


FIG. 1a

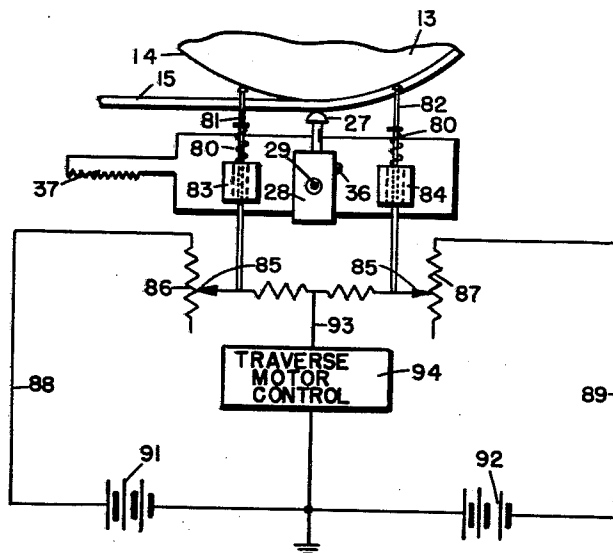


FIG. 2

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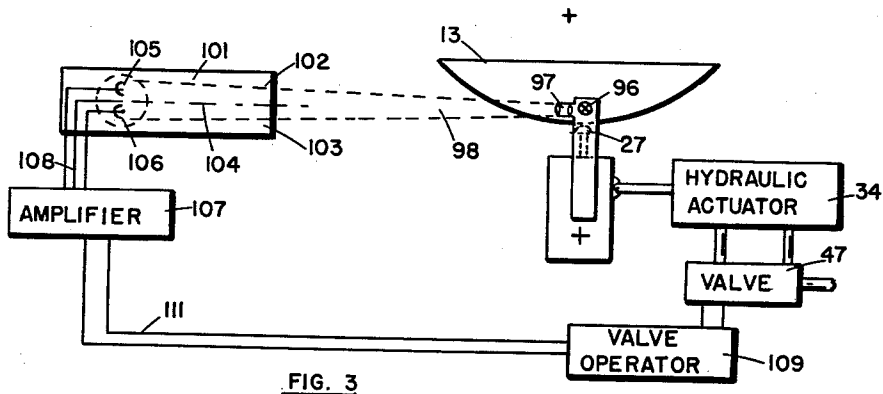


FIG. 3

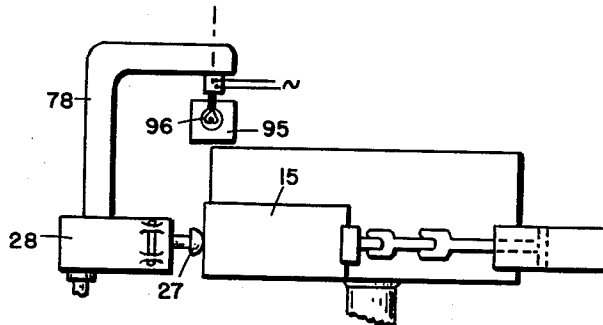


FIG. 4

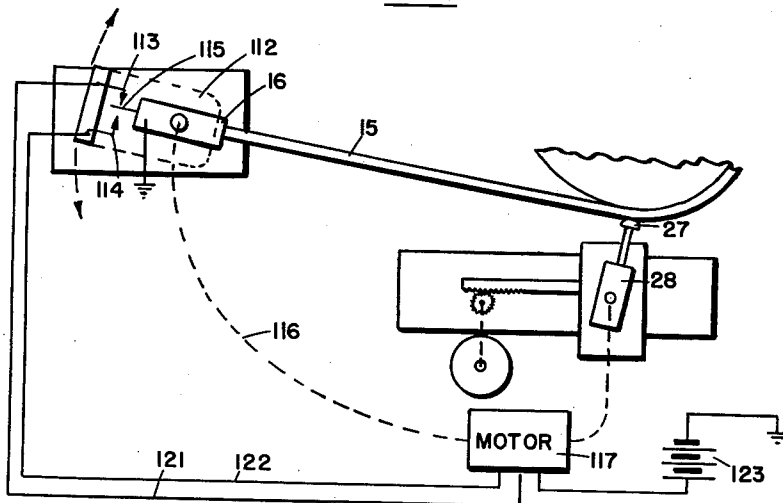


FIG. 5

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3,062,266
**CONTROL OF TRAVERSING RIGHT ANGLE AT-
TACHMENT FOR RADIAL DRAW FORMER**
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American Aviation, Inc.
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14 Claims. (Cl. 153-40)

This application relates to metal forming apparatus and concerns particularly radial draw formers and apparatus for forming metal sheets and bars or rods by both bending around a rotatable die and stretching the metal beyond the yield point.

In such apparatus improved results are obtained by pressing the metal against the die surface while it is being bent and stretched. I have found that the action is improved by causing the lateral pressure to act against the metal substantially along the normal to the surface of the metal at the point of tangency of the metal to the die surface.

It is accordingly an object of the invention to apply pressure perpendicularly at the point of tangency and to provide a lateral pressure-applying means such as a movable shoe with movable mounting means for permitting change in the direction of the force applied and the point of application of force as the die rotates to present successively different portions of the stretched metal to the die surface tangentially.

A further object of the invention is to control the angular position of the pressure-applying shoe automatically, responsive to the direction of the stretched metal between a stretching ram and the point of tangency to the die surface.

A further object is to adjust the lateral position of the pressure-applying die so that the pressure will be applied at the actual point of tangency of the metal with the die surface.

Still another object of the invention is to coordinate the automatic control of the position of the pressure-applying die with the other functions of the machine to render substantially the entire operation fully automatic.

Other and further objects, features and advantages of the invention will become apparent as the description proceeds.

In carrying out the invention in accordance with a preferred form thereof, a rotatable table is provided carrying a die with a pair of jaws or a metal holding chuck thereon for grasping one end of the metal, and a ram, or hydraulic cylinder and piston, is provided with a chuck, or jaws, for grasping the other end of the metal being formed, to maintain it in tension and preferably stretch it during the bending and forming operation. An axially movable shoe, preferably hydraulically controlled, is provided for pressing the tensioned metal laterally against the surface of the die. In order that the pressure will be applied at the actual point of tangency of the stretched metal to the die and in a direction perpendicular to the tangent, the shoe is mounted so as to have both pivotal and lateral movement. Mechanism is provided for moving a hydraulic actuator for the shoe around the pivotal mounting and also laterally with respect to the die surface.

In order that the position of the shoe may be adjusted automatically, means are provided responsive to the direction of the stretched metal before it has been bent around the die for controlling the pivotal position of the shoe so that its direction of application of force will be perpendicular to the direction of the unbent material. The unbent portion of the metal is that between the ram jaw and the point of tangency with the die or bending point. Moreover, in order to cause the force of the shoe to

be applied at the point of tangency of the metal with the die surface, a gaging means is provided for causing a lateral movement of the die mounting in the requisite direction. Such gaging means is responsive to any difference in spacing of gage points along either side of the shoe from the surface of the die.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawings in which

FIG. 1 is a schematic diagram of an embodiment of the invention;

FIG. 2 is a fragmentary diagram illustrating another embodiment of the invention;

FIG. 3 is a schematic diagram of another embodiment of the invention represented as seen in plan view;

FIG. 4 is a fragmentary elevation of the embodiment of FIG. 3; and

FIG. 5 is a schematic diagram representing still another embodiment of the invention.

Referring now to FIG. 1 of the drawing, there is a rotatable table 11 provided with suitable means (not shown) for rotating it around an axis 12 and carrying a die 13 having a surface 14 around which a length of metal, such as sheet metal 15 or a strip or a bar, rod or other metal shape, is to be formed in a shape corresponding to the curvature of the surface 14 of the die 13. A conventionally illustrated ram 16, comprising a hydraulic cylinder with a piston 17 is provided with a chuck or jaws 18, for grasping the end 19 of the metal 15 and subjecting it to tension, preferably stretching it beyond the elastic limit in a certain portion of the process. For securing the opposite end 21 of the metal to the work table 11 against the die 13 a conventionally indicated die chuck or a set of jaws 22 are provided shown as secured to a hydraulic actuator 23 to allow a small additional tension to be applied to the work after stretch forming and before releasing.

The ram 16 is provided with pivotal mounting to permit it to pivot around a supporting shaft or pin 24. It will be apparent that the portion of the metal between its point of tangency 25 with the die surface 14 and the jaws 18 will be a straight line as a result of the tension maintained by the ram 16 and the rotation of the die 13 in a direction indicated by the arrow 26.

Better forming is accomplished by pressing the metal 15 against the surface 14 at the point of tangency 25 and subjecting it to lateral compressive force simultaneously with the tensile stress resulting from the action of the turn table 11 and the ram 16. For this purpose, a shoe 27 may be provided having a suitable hydraulic actuator or minor ram 28. In accordance with the invention, the hydraulic actuator 28 for the shoe 27 is so mounted movably that the shoe 27 will not only apply force precisely at the point of tangency 25, instead of either to the right or to the left thereof, but will also act substantially perpendicularly to the tangent to the die 13 at the point 25. In the embodiment illustrated in FIG. 1, this is accomplished by providing both lateral and pivotal movement for the hydraulic actuator 28 of the shoe 27.

The shoe 27 and the actuator 28 are mounted pivotally around a pivot pin 29 carried by a traverse table 31. The traverse table 31 in turn is so mounted that it may move parallel to the surface 14 of the die 13 transverse to the axis 12 and to the shoe 27, being guided by a track or rail 32 cooperating with a channel or groove 33 in the under surface of the traverse table 31. For pivoting the shoe 27 around the pivot pin 29, suitable mechanism, such as a hydraulic actuator 34, is provided, which is mounted upon the traverse table 31 and has a piston rod 35 pivotally secured to an ear 36 on the actuator 28. For effecting movement of the traverse

table 31, suitable means, such as a rack 37 and pinion 38, are provided.

For automatically maintaining the shoe 27 perpendicular to the tangent to the surface 14, gaging means are provided for comparing the angular relationship between the straight portion of the stretched metal 15 and the shoe 27. Since the ram 16 is pivoted around the pivot pin 24, the angular position of the ram 16 corresponds to the direction taken by the metal 15 between the points 24 and 25 on a line tangent to the surface 14 extending through the ram jaws 18 and the ram pivot 24. Accordingly, a suitable angular indicator, such as a self-synchronous unit 41, of the type sold under the trade names Selsyn and Autosyn, is provided having a rotor 42 secured by a shaft represented schematically by dash lines 43 to the pivoting portion of the ram 16 so that the rotor 42 follows angular motion of the ram 16 around the pivot pin 24. A second self-synchronous unit 44 is provided having a rotor 45 with a mechanical connection or shaft represented schematically by a dotted line 46 to the actuator 28 of the shoe 27. The angular position of the rotor 45 represents the angular position of the shoe 27.

If desired, the self-synchronous units 41 and 44 may be sufficiently large and powerful so that the rotor 45 directly controls the angular position of the shoe 27 (as shown by dotted lines 46) in response to change in angular position of the ram 16. Preferably, however, a servo follow-up system is employed which may take the form of a hydraulic actuator 34 having a four-way valve 47 to control the supply of pressure fluid to either side of the piston 48 from a conventional fluid pressure source 49. For controlling the angular position of the valve 47, a torque motor 51 is provided responsive to a phase-sensitive amplifier 52 having an energizing and synchronizing energy source 53 common to the transmitter self-synchronous unit 41 and a pair of control lines 54 extending between the stator winding of the self-synchronous unit 44 and the phase-sensitive amplifier 52. It is to be understood that in the initial adjustment of the apparatus, the angular position of one or the other of the self-synchronous rotors 42 or 45, with respect to its shaft 43 or 46, is so adjusted that a null voltage appears in the control line 54 when the axes of the hydraulic actuators 16 and 28 are perpendicular to each other, indicating a perpendicular relationship between the direction of stretch of the metal 15 and the direction of application of force of the shoe 27.

For operating the pinion 38 and rack 37 to position traverse table 31, a control system is provided including a sensing means 55. The sensing means is arranged to respond whenever the actual point of application of force by the shoe 27 deviates from the point 25 at which the strip 15 is tangent to the surface 14. This is accomplished by providing a sensing means which actually compares the spacing at a fixed distance on either side of the shoe 27 from the surface 14.

To avoid confusion in the drawing of FIG. 1, the sensing means is shown with the die 13 separately represented in dotted outline 13'. The sensing means 55 is illustrated as taking the form of an E-coil sensing device. It is illustrated in displaced position representing a condition requiring movement of the traverse table 31. As shown schematically, the metal 15 follows a direction 56 which is the tangent to the surface 14' at the actual point of tangency 25'; whereas the center line 57 of the E-coil sensing device 55 lying in the same vertical plane as the center line of the shoe 27 is displaced from a line 58 which is perpendicular to the tangent 56 to the surface 14' at the point 25' where the lines 57, 58 and 14' intersect. The condition represented assumes a lateral displacement of the traverse table 31 slightly to the right so that the actual point of application 59 of force of the shoe 27 is to the right of the point of tangency 25' of the metal 15 with the surface 14. The control arrange-

ment is such as to maintain the lines 57 and 58 in coincidence continuously, automatically.

The E-frame sensing device 55 comprises a core 61 with a middle leg 62 and the outer legs 63 and 64 having pole faces 65 and 66, respectively. The pole faces 65 and 66 serve as magnetic gages of the distances to the surface 14 of the die 13, which it will be understood is composed of steel or other ferromagnetic material. The outside legs of the core 61 are provided with windings 67 and 68 which are connected in series to the energizing and synchronizing alternating-current source 53, with the windings 67 and 68 so wound as to act in opposition with respect to flux flowing upwardly in the outer core legs 63 and 64. In consequence, voltage is induced in the center leg winding 69 only when the air gaps 71 and 72 above the pole faces 65 and 66 to the die surface 14' are unequal, which is the condition illustrated in FIG. 1 indicating that the point 59 of application of force by the shoe 27 is not at the actual point of tangency 25' of the material strip 15 with the die surface 14. Means are provided for causing any voltage induced in the center leg winding 69 to actuate mechanism for restoring the traverse table 31 to the proper position.

In the form of apparatus illustrated in FIG. 1, a servo system is provided comprising a phase-sensitive amplifier 73 having an energizing and synchronizing alternating-current source 53 in common with that energizing the windings 67 and 68, and a torque motor 74 controlling the angular position of a four-way valve 75 controlling the flow of fluid from the hydraulic pressure source 49 to a hydraulic motor 76 connected by a shaft 77 to the pinion 38 meshing the rack 37.

As illustrated more clearly in FIG. 1A, the E-frame sensing device 55 is mounted upon a bracket 78 carried by the hydraulic actuator 28 or the means supporting the shoe 27, so that the center line 57 of the sensing device 55 lies in the same plane containing the center line and the line of direction of force applied by the shoe 27. The die 13 is so designed as to have a vertical dimension exceeding the maximum vertical dimension of sheet or strip material 15 to be formed upon the die 13 so that the sensing device 55 may be mounted above the shoe 27 and yet bear the same spatial relationship to the surface 14 of the die 13 as the shoe 27. The magnetic response of the sensing device 55 will thus be rendered independent of whether the material 15 being formed is magnetic or non-magnetic.

The invention has been described and illustrated with respect to the embodiment employing hydraulic mechanism for providing the requisite motions of rotation and translation of the pressure applying shoe 27, utilizing self-synchronous units for angular sensing or gaging and an electromagnetic type of unit for gaging with respect to motion of translation. It will be understood, however, that the invention is not limited to the specific embodiment hereinbefore described and illustrated, and does not exclude, for example, the use of light-sensitive sensing units or units employing light beams for angular gaging or mechanical feelers for gaging, for example. As illustrated in FIG. 2, the gaging function of the E-coil sensing device 55 may be accomplished by a pair of feelers 81 and 82 slidably mounted in guides or slots 83 and 84 to permit longitudinal or axial motion of the feelers 81 and 82. The guides 83 and 84 are preferably mounted upon the same pivotal structure which carries the shoe 27. However, the invention is not limited thereto. Where the space between the shoe, or more specifically its point of application of force to the metal 15, is not excessively far from the pivot axis 29, the guides 83 and 84 may be mounted upon the traverse table 31 as shown in FIG. 2 to simplify the mechanical structure.

In order to maintain the tips of the feelers 81 and 82 against the surface 14 biasing springs 80 are preferably provided. For enabling the feelers 81 and 82 to control the position of the traverse table 31, they are con-

nected to a suitable electrical control device such as the taps 85 of potentiometers 86 and 87, respectively, arranged normally to balance electrical circuits 88 and 89. The latter are energized in series circuit relation by voltage sources 91 and 92 in such a manner that the voltages in the potentiometers 86 and 87 oppose each other and a null voltage will occur in the bridging circuit 93 when the feelers 81 and 82 are in the same relative position, indicating equal spacing of the selected points such as the guides 83 and 84 from the surface 14 of the die 13. If any deviation occurs, indicating a deviation of the point of the application of force of the shoe 27 from the point of tangency of the metal strip 15 to the surface 14, a voltage will be induced in the bridge circuit 93 of one polarity or the other in case of direct-current energization as illustrated, or in one phase relation or the other in the event of alternating-current energization. A suitable polarized or phase-sensitive traverse motor control circuit represented by the rectangle 94 is provided with input terminals connected in the bridge circuit 93. Since direct-current, directional motor control circuits are well-known to those skilled in the art, the details thereof need not be illustrated or described.

It will be understood that as in the case of the embodiment illustrated in FIGS. 1 and 1A, the die 13 is of sufficient height, assuming a vertical axis of rotation, that the feelers 81 and 82 may be mounted above the upper edge of the metal 15 which is being formed.

The employment of light beams for angular sensing is illustrated in FIGS. 3 and 4 wherein the hydraulic actuator or other pivotal support for the pressure applying shoe 27 is provided with a bracket 78 bearing a lamp chamber 95 containing a lamp 96 and having a lens or focusing system 97 for confining the light emitted from the lamp 96 to a narrow beam 98.

Upon the main ram 16 is mounted a photocell housing 101 having two light admitting openings 102 and 103 separated by a light shield 104 containing a pair of series-connected phototubes or photocells 105 and 106, such that light from the lamp 96 falls upon the phototubes 105 and 106 equally when the axis of the pressure applying shoe 27 and the direction of the metal strip 15 are perpendicular to each other. The direction of the metal strip 15 coincides with the projections of the center line of the phototube housing 101 and the light-separating shield 104.

A conventional type of balanced-phototube control circuit may be employed for effecting angular motion of the shoe 27 whenever the phototubes 105 and 106 are unbalanced with more light impinging on one or the other. For example, as illustrated schematically, there is a phototube amplifier 107 having three input conductors 108 from the phototubes 105 and 106, one of the phototube terminals being a common terminal. If desired, a hydraulic actuator 34 and control valve 47 may be employed as in the embodiment of FIG. 1 together with a suitable, polarized, valve operator 109 responsive to polarity of the output of the amplifier 107 through the control line 111.

In applications where less precision is required and simplified structure is desired, a switch type of angular sensing control may be employed as illustrated in FIG. 5, where the main ram 16 has an angularly movable switch plate 112 mounted thereon carrying a pair of contacts 113 and 114, fixed relative to the switch plate 112, and the ram 16 carries a contact 115 which is fixed relative to the ram 16 but movable relative to the contacts 113 and 114 so that any deviation between the switch plate 112 and the ram 16 results in electrical contact between the center contact 115 and one or the other of switch contacts 113 and 114. A suitable mechanical connection such as a flexible cable shaft 116 is provided for maintaining a fixed angular relationship between the switch plate 112 and the pivotal support 28 for the shoe 27. A two-winding reversible motor 117 is provided which is

also connected to the shoe support 28 mechanically, having separate field windings connected through conductors 121 and 122 to the contact 113 and 114 of the switch plate 112, so that formation of an electrical circuit through either of said contacts results in the running of the motor 117 in one direction or the other to bring the shoe 27 into perpendicular relationship to the direction of the tensioned metal 15. Since directional controls for two-winding or double-field motors are well-known, the circuit need not be explained in detail, but it will be understood that if the contact 115 is grounded, the contacts 113 and 114 will be insulated as well as the motor terminals. The motor 117 is energized by a suitable current source 123 of direct current or alternating current, depending on the type of motor.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

I claim:

1. In a radial draw former, the combination of a curved surface die carrying a metal grasping chuck, means for rotating the die, a stretch cylinder having a piston carrying a metal grasping chuck, means for subjecting the piston to pressure for tensioning metal between the two chucks around the die, a shoe for pressing metal against the die, a traverse table for carrying the shoe laterally with respect to the die surface, a pivotal mounting for the shoe, means for controlling the angular position of the shoe in said mounting for causing a direction of pressure applied by the shoe to remain perpendicular to a line between the shoe and the piston chuck, and means for controlling the position of the traverse table to maintain the shoe at the point of tangency of a tangent to the die extending toward the piston chuck, at least one of said position controlling means comprising a control system having a position sensing gage and a motor responsive thereto for positioning said shoe in accordance with the gage detected position thereof.

2. In radial material stretching apparatus, the combination of a curved-surface die, a ram having jaws, means for actuating the ram for tensioning material between the jaws around the die, a shoe for passing material against the die, a traverse table for carrying the shoe laterally with respect to the surface of the die, a pivotal mounting for the shoe, means for controlling the angular position of the mounting for causing the direction of pressure applied by the shoe to remain perpendicular to a line tangent to the die surface and extending toward the ram chuck, and means for controlling the traverse table to maintain the shoe at the point of tangency of said line tangent to the die, said angular position controlling means comprising servo means for slaving the angular position of said shoe to a predetermined relation with respect to the direction of the tensioned material extending between said jaws and die.

3. In metal forming apparatus of the type having a rotatable die with a circumferential surface around which sheet metal may be formed simultaneously with stretching, a shoe for pressing metal against the die, a traverse table for carrying the shoe laterally with respect to the die surface, a pivotal mounting for the shoe, means for controlling the angular position of the shoe in said mounting for causing the direction of pressure applied by the shoe to remain perpendicular to metal tangent to the die surface, the means for sensing the angles between a normal to the direction of pressure of the die at the point of contact with the surface and the die circumference on either side of the point of contact, and means for controlling the traverse table in accordance with the sensed angles.

4. In metal forming apparatus of the type having a

rotatable die with a circumferential surface and means for stretching metal around the die surface, a shoe for pressing metal against the die, a mounting for movably supporting said die, position comparing means and means responsive thereto for controlling the position of the die in said mounting for causing the direction of pressure applied by the shoe to remain perpendicular to a tangent to the die surface at the point of application of said pressure.

5. In metal forming apparatus including a rotatable die having a circumferential surface around which metal may be stretched to form it, a shoe for pressing metal against the surface of the die, a traverse table for carrying the shoe laterally with respect to the die surface, gaging means mounted on either side of the shoe for measuring variation in spacing from the die surface of points on either side of the shoe, and means responsive to said gaging means for moving the traverse table in one direction or the other to equalize said spacing for causing the shoe to apply pressure toward the die surface along a normal to a tangent to the die surface at the point of contact.

6. Metal forming apparatus comprising a curved-surface, rotatable die with jaws for clamping sheet metal to be formed, a ram with jaws for clamping sheet metal to be formed whereby the metal is stretched around the die surface between the two sets of jaws and extends along a tangent to the die surface, a shoe for pressing the metal against the die surface at the point of tangency of the stretched metal with the die surface, a pivotal mounting for said shoe and means responsive to deviation between the angular position of said shoe and a normal to said stretched metal between the ram jaw and the point of tangency for maintaining the direction of pressure application perpendicular to the length of metal between the ram jaw and the point of tangency.

7. In a movably mounted pressure applying device for cooperation with a curved surface, gaging means carried by the pressure applying device and equidistant from either side thereof for comparing the spacing from the curved surface to the pressure applying device on either side thereof, and means for moving the pressure applying device and gaging means in one direction or the other responsive to said gaging means for equalizing said spacing and causing the pressure applying device to act in direction perpendicular to a tangent to the surface at the point of application of force.

8. Means for simultaneously subjecting material to tension and to compression in a direction perpendicular to the tensioning force, comprising a shoe for applying compressive force, a pivotal mounting for the shoe, means for comparing the angular position of the shoe with material being subjected to tension, and mechanism responsive to said comparing means for adjusting the angular position of said shoe to maintain it perpendicular to the direction of tension application.

9. In a machine for simultaneously subjecting material to tension and to compression in direction transverse to the tensioning force, said machine having a shoe for applying compressive force and a movable mounting for the shoe, the improvement comprising means for sensing the direction of said tensioning force, and means responsive to said sensing means for adjusting the position of the shoe to cause it to act perpendicular to the tensioning force.

10. Means for simultaneously subjecting material to tensioning in a given direction and to compression in a direction transverse thereto, comprising means for supporting the material between two points in a line of tension, a movable shoe applying compressive force to the material, means for detecting the direction of said tensioning, and means responsive to said detecting means for adjusting the position of the shoe to maintain the compressive force perpendicular to the line of tension.

11. In a radial draw former wherein a workpiece is drawformed on a die under tension beyond its yield point, means for compressing said workpiece while being drawformed, means responsive to the direction of said tension and the position of said compressing means for positioning said means for compressing at right angles at the point of tangency of said workpiece and said die.

12. In a radial draw former wherein a workpiece is drawformed on a die, means for compressing said workpiece while being drawformed, means for positioning said means for compressing at right angles at the point of tangency of said workpiece and said die, wherein said means for positioning comprises servo means responsive to the direction of the tangent to said die at said point for controlling the direction angle of said compression means and means for controlling the lateral position of said compression means.

13. In combination with first and second members of which the second has a curved surface adapted to be contacted by the first, gage means for sensing the position of said first member relative to the point of intersection of said surface with a predetermined line tangent thereto, and drive means responsive to said gage means for effecting relative motion of said members substantially parallel to said tangent in a sense to move the point of contact between said members toward said point of intersection with said predetermined tangent line.

14. In combination with first and second members of which one has a curved surface adapted to be contacted by the other, gage means for sensing the angular relation between said first member and a line tangent to said surface, drive means responsive to said gage means for effecting relative pivotal motion of said members in a sense to maintain said first member normal to said line, second gage means sensing the position of said first member relative to the point of intersection of said surface with said tangent line, and drive means responsive to said second gage means for effecting relative motion of said members in a sense to move the point of contact between said members toward said point of intersection with said tangent.

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