June 13, 1961 L. R. GRAY 2,988,127

WIPER CONTROL SYSTEM FOR STRETCH-FORMING MACHINE

Filed Oct. 21, 1958 2 Sheets-Sheet 1

Fig. 1.

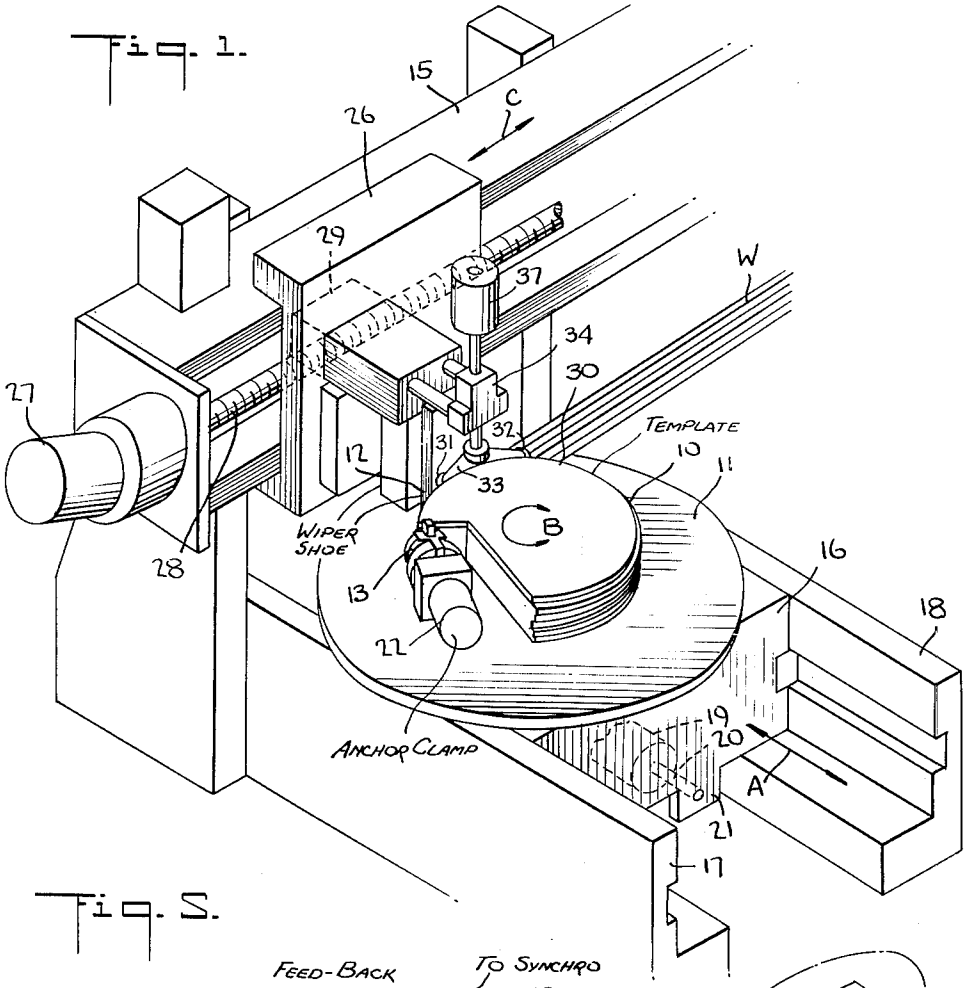
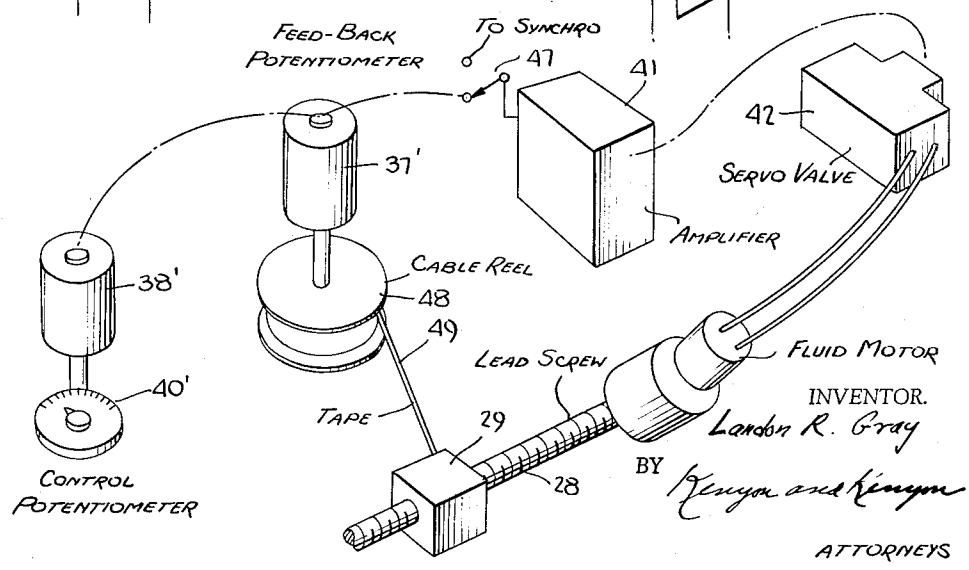


Fig. 2.



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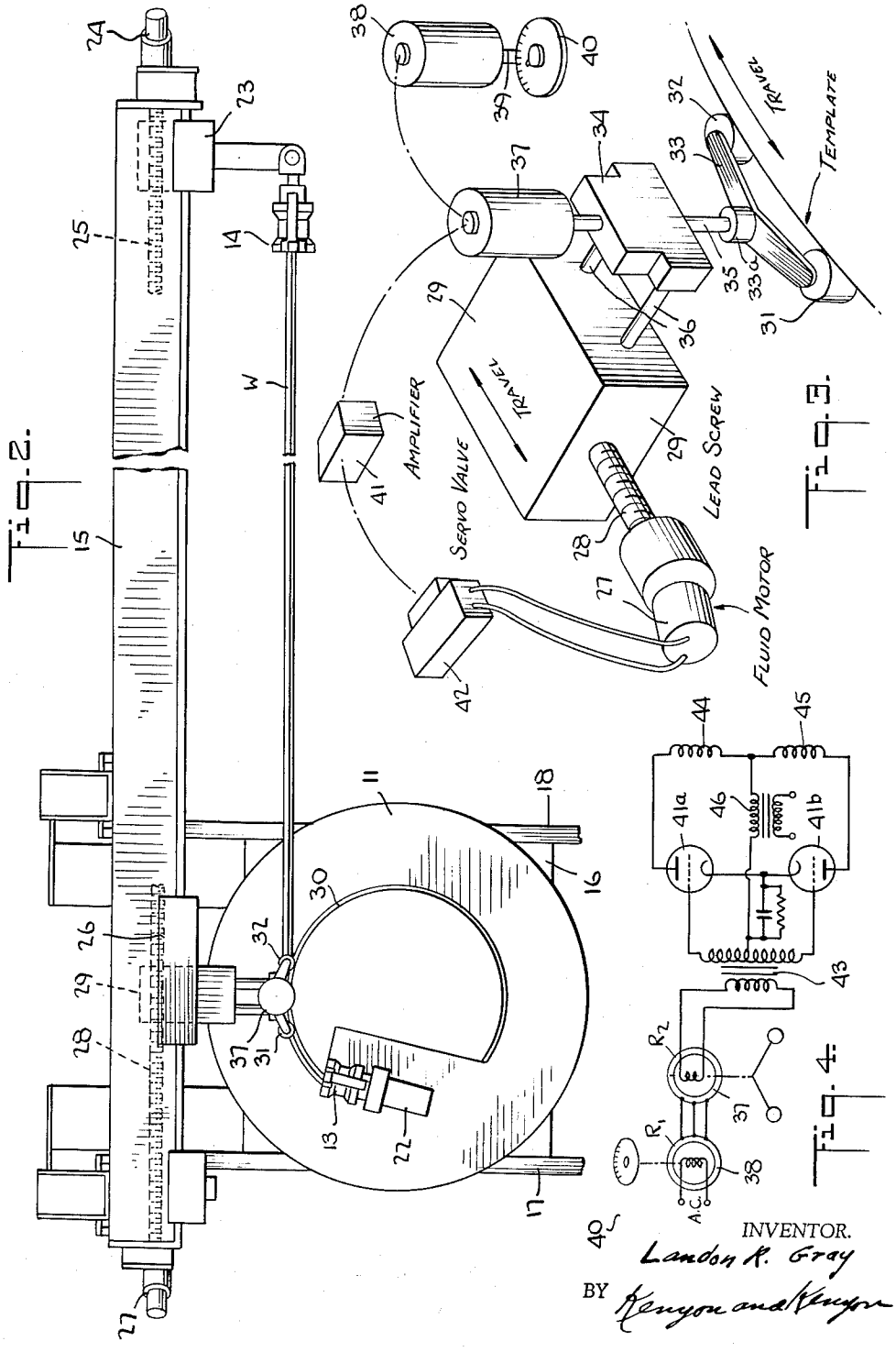


Fig. 2.

Fig. 3.

Fig. 4.

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WIPER CONTROL SYSTEM FOR STRETCH-FORMING MACHINE

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This invention relates generally to metal-working machines for stretch-forming lengths of metal stock into curved or contoured shapes, and more particularly to a wiper control system incorporated in a stretch-forming machine and adapted automatically to maintain a tangential relation between a wiper element and the metal contour in contact therewith.

Stretch-forming is a technique which exploits a basic characteristic common to all metals, namely, the elastic ability of the metal to return to its original size and shape after being subjected to limited deformation. When a metal strip is tensioned a stretch occurs, and as long as the elastic limit is not exceeded the degree of stretch is proportional to the applied pressure. But if this elastic limit is exceeded, which condition is indicated by the fact that the degree of stretch is no longer proportional to the tonnage applied, then the strip will not return to its original dimension and shape when the pressure is relieved. On the contrary, the strip will remain deformed.

Conventional stretch-forming machines include a forming die and opposed clamps which engage the extremities of the work, these parts being mounted so that the die and the clamps are movable relative to each other thereby permitting the work extended between the clamps to be bent or wrapped around the die. The clamps are also arranged to move relative to each other and are provided with tensioning means for the purpose of tensioning or stretching the work while it is being bent around the forming die.

In the rotary stretch-forming machine, a side face die is fixedly mounted on a turntable for rotation therewith, one end of the metal stock being anchored in a fixed position relative to the die, the opposite end being gripped by a suitable tool which is mounted on a piston assembly. The piston assembly operates to exert and maintain a predetermined tension on the stock as the stock is wrapped about the side face die by rotation of the turntable. As a result of this operation, particularly if the stock is stretched close to its elastic limit during wrapping, the stock is made to conform to the side face of the die with little or no spring back.

In certain contour-forming operations on rotary machines, it is also necessary to apply a compressive force to the workpiece in addition to the tensioning stress thereon. Thus, as the piece which is being stretched to its elastic is laid upon the forming die, there is simultaneously exerted a compressive ironing or rolling force thereagainst. This compressive force is essential, for example, when negotiating corners or curves of relatively small radius, or forms having reverse curvatures.

The compressive force is ordinarily applied by a wiper element which in practice should be disposed tangentially to the surface of the forming die and normal to the contour thereof to obtain an effective action. However, since the forming die may have a highly irregular contour, it has heretofore been difficult to maintain the desired tangential relationship throughout the entire range of the die movement, as a result of which a loss of compression is experienced and the wiper is not fully effective.

In view of the foregoing, it is the principal object of the invention automatically to maintain the position of a wiper tangentially to the die contour during forming. More specifically the invention has for its object the positioning of a wiper shoe or roll linearly at a point normal to a contour which is in contact with the shoe regardless of the change of curvature in the contour as it is moved past the wiper shoe.

Also an object of the invention is to provide two separate and independent wiper control means, one functioning to linearly position the wiper during set-up of the machine and the other acting automatically to maintain the position of the wiper normal to the die contour during forming.

A further object of the invention is to provide a stretch-forming machine including a turntable for supporting a forming die, the turntable mounted on a slide and being shiftable by hydraulic means toward a wiper shoe to effect compressive engagement of the die and shoe whereby a compressive force is applied by the shoe to work being formed on the die.

Yet another object of the invention is to provide a stretch-forming machine of sturdy and efficient design which is reliable in operation and which may be manufactured at relatively low cost.

Briefly stated, in a rotary stretch-forming machine in accordance with the invention, the turntable which supports the die is slideable on rails toward a wiper shoe assembly which is reciprocable along a horizontal guideway perpendicularly disposed relative to the rails. One end of a workpiece is held by tensioning means on the turntable, the other end being gripped in a clamp supported on a carriage disposed on the guideway.

A template is provided in conjunction with the die and having a corresponding contour. Mounted on the wiper shoe is a tangency sensing device including a pair of spaced contact rollers which engage the surface of the template, the rollers being supported on the arms of a yoke pivotally mounted at its center point on a shaft. As the radius of curvature of the die contour changes in the course of forming, the contact rollers are deflected accordingly to produce an angular rotation of the pivot shaft. The angular movement of the pivot shaft is transmitted through a servo system to a motor adapted to shift the position of the wiper shoe assembly in a direction along the guideway and to an extent correcting for deviations in the tangency of the shoe relative to the contour of the die.

For a better understanding of the invention as well as other objects and further features thereof, reference is had to the following detailed description to be read in conjunction with the accompanying drawings, wherein like components in the various views are identified by like reference numerals.

In the drawings:

FIG. 1 is a perspective view of the general assembly of a rotary stretch-forming machine in accordance with the invention.

FIG. 2 is a plan view of said general assembly.

FIG. 3 is a schematic view of the tangency sensing and correction system operating in conjunction with the machine.

FIG. 4 is a schematic circuit diagram of the synchro circuit for developing and amplifying an error signal when the wiper deviates from the desired tangency relation.

FIG. 5 is a schematic view of the wiper position control system for set up of the machine.

Referring now to FIGS. 1 and 2, a rotary stretch-forming machine according to the invention comprises a forming die **10** of the side face type fixedly mounted on a turntable **11** which acts to rotate the die relative to a wiper shoe **12** movably supported on a horizontal guideway **15**. A workpiece W, in the form of an elongated metal strip to be bent around the die **10**, is held under tension between a first jaw **13** disposed on the turntable and a second jaw **14** supported on the guideway **15**.

Turntable **11** is rotatably supported on a motor block **16** which is slidable along a pair of spaced rails **17** and **18**, the rails lying under the horizontal guideway **15** and extending perpendicularly thereto. The block **16** houses fluid motors or other suitable means to rotate the table **11**. A compressive rolling force is applied to the workpiece W by the wiper shoe **12**, this being accomplished by pulling the turntable and the die thereabove toward the wiper shoe by means of a hydraulic cylinder **19** whose piston **20** is connected to the rear end of the motor block **16** by a bracket **21**. Thus when piston **20** is hydraulically retracted within cylinder **19**, the die is urged toward the shoe and is caused to bear thereagainst, the compressive force being controlled by hydraulic pressure.

To subject the workpiece W to tension, the jaw **13** which grips one end thereof is connected to a tensioning cylinder **22** mounted on the turntable **11**, cylinder **22** acting to tension the workpiece. The second jaw **14** is mounted on a carriage **23** which is movable by a lead screw **25** in either direction along the guideway **15**. The guideway travel of carriage **23** is controlled by means of a tension cylinder motor **24** which turns the lead screw **25**.

The wiper shoe **12** is supported on a carriage **26** adapted to travel horizontally in either direction along the guideway **15**. The guideway position of wiper shoe carriage **26** is adjusted by means of a tension cylinder motor **27** which turns a lead screw **28** threadably engaging a follower block **29** attached to the carriage **26**. It will be appreciated that the horizontal position of the wiper shoe relative to the die determines its tangential relationship to the die contour.

In practice, means may also be provided for adjusting the vertical positions of the wiper shoe relative to its carriage, as well as the vertical position of the workpiece relative to the die so as to dispose the work effectively against a desired point along the die face. Such vertical adjusting means are well known in the art and have been omitted herein for purposes of simplicity, for the invention is concerned principally with the horizontal positioning of the wiper shoe.

The linear movement of the turntable bearing the die toward and away from the wiper shoe in a direction perpendicular to the guideway is represented by arrow line A, the angular movement of the turntable about its vertical axis is represented by the arrow arc B, and the linear movement of carriage **26** back and forth along guideway **15** is indicated by arrow line C.

As pointed out previously, it is important that the wiper position be maintained normal to the curvature of the forming die. This relationship is automatically maintained by means including a template **30** which is fixedly mounted above die **10** and is formed with a peripheral curvature which corresponds exactly to the curvature of the die.

As best seen schematically in FIG. 3, operating in conjunction with the wiper shoe is a tangency sensing device including a pair of spaced contact rollers **31** and **32** supported at the opposing ends of a yoke **33**. Yoke **33** is pivotally mounted below a platform **34** by means of a pivot shaft **35** connected at its lower end to the center hub **33***a* of yoke **33**. Platform **34** is secured to block **29** by a pair of rods **36** projecting forwardly therefrom. To the upper end of pivotable shaft **35** is attached the rotor of an electrical synchro **37**. Rollers **31** and **32** engage the contoured surface of template **30** at spaced positions thereon and are deflected as the radius of curvature changes to produce an angular rotation of pivot shaft **35**, the rollers being equidistant from the shaft.

The operating principles underlying the tangency sensing device are as follows: A force normal to a curved surface may be approximated if the force is perpendicular to a short chord drawn between two points on the surface of the curvature. Since the two contact rollers are equally distant from the pivot shaft, when these rollers are in contact with the curved template surface these rollers provide the points between which a theoretical chord is established.

The horizontal wiper force below the template passes through the center line between the contact rollers. As the radius of curvature of the contour changes, the contact rollers are displaced relative to each other to produce an angular rotation of the vertical pivot shaft to an extent and in a direction depending on the displacement. By means of a servo system which responds to the angular rotation of the shaft, the wiper carriage is caused to travel in a direction and for a distance restoring the desired angular position of the wiper relative to the die curvature. The structure of the servo system and its operation will now be described.

As shown schematically in FIG. 3, the angular position of the rotor of the template curvature-sensing synchro **37** is adjusted in the course of wiper operation. The field coils of synchro **37** are connected electrically to those in a reference synchro transformer **38** at a control console. The angular position of the rotor **39** of the reference synchro is adjusted by a control dial **40** and is locked in the selected position.

So long as the rotor in the sensing synchro **37** occupies the same angular position as that in the reference synchro **38**, no error voltage will be generated. But when the curvature of the template and hence that of the die changes as it moves past the wiper, the contact rollers **31** and **32** are deflected accordingly and the rotor of the sensing synchro **37** is displaced angularly with respect to the rotor of the reference synchro **38**.

The voltage thus produced is fed to an electronic amplifier **41** and the amplified voltage is applied to the torque motor of a servo valve **42** so as to control the fluid torque motor **27** which operates lead screw **28**. The valve spool is displaced in a direction and to an extent equal to the polarity and magnitude of the error signal and always in a direction necessary to rotate the lead screw so as to move the wiper control carriage back to a new null or zero error voltage positions, thereby maintaining the desired tangency relation. This completes the feedback loop of the servo system and renders the control entirely automatic.

The manner in which the error signal is produced is shown in FIG. 4, wherein the stator windings of the sensing synchro **37** are connected to the corresponding stator windings of the reference synchro **38**. An alternating input voltage is applied to rotor winding R_1 of the reference synchro **37** and if the rotor winding R_2 of the sensing synchro occupies the same angular position, no error signal is generated, but if the angle of the sensing rotor is displaced from that of the reference, then an error signal is developed in the output of rotor R_2 having a phase and amplitude depending on the direction and extent of displacement.

The amplifier circuit comprises triode tubes **41***a* and **41***b* which are connected in push-pull relationship, the grids of the tubes being connected to the ends of the secondary of an input transformer **43**, the anodes being connected to the ends of the serially-connected armature windings **44** and **45** of the valve torque motor. Plate voltage is supplied through a transformer **46** whose primary is connected to the same A.-C. supply which energizes the synchros, the secondary being connected between the center tap of the input transformer secondary and the junction of the armature windings **44** and **45**.

The error signal from the synchro rotor R_2 is applied to the grids of tubes **41***a* and **41***b* in phase opposition, whereas the plate voltages are in phase coincidence. Because the synchro devices are operated from the same A.-C. line as the servo-amplifier, each grid voltage is either in phase or 180° out of phase with the plate voltages.

Plate currents can flow in tubes **41***a* and **41***b* only during the half cycles in which the plate voltages are positive relative to the cathode. Therefore, periodic pulses of

current are obtained. If the applier error voltage is zero, then the resultant absence of grid voltages gives rise to in-phase anode pulses in the push-pull tubes. But since the anode currents flow in opposing directions in the armature winding halves, the currents balance out and no field is produced, as a result of which the torque motor is not actuated.

For an error voltage in one direction, the opposing grid voltages will produce a greater anode current flow in one tube than the other, thereby upsetting the balance in the armature winding and producing a motor torque in the direction determined by the error signal. If the error signal is reversed in polarity, the relative current flowing in the tubes will also be reversed, and the torque motor will turn in the opposite direction. While the motor load has been shown as connected in the anode circuit, it is obvious that the load may be cathode-coupled to the push-pull amplifier.

One example of a suitable servo valve is shown in my U.S. Patent No. 2,824,594, issued February 25, 1958.

The wiper position control device shown in FIG. 5 is designed to position the wiper during machine set up. It is constituted by a sensing synchro **37'** and a reference synchro **38'** or potentiometers which provide an equivalent function. The rotor position of reference synchro is adjusted by a dial **40'**. The error voltage output of the sensing synchro **37'** is fed through a selector switch **47** to the servo amplifier **41** whereby the servo system for controlling the position of the wiper carriage may respond to the output of the tangency control device (FIG. 3) or to the output of the wiper position control device.

The rotor of the sensing synchro is coupled through a spring-loaded reel **48** from which is extendable a tape **49** connected at one end to the follower block **29** of the wiper shoe carriage. The physical construction of the reel and tape may be as disclosed in connection with FIG. 6 in the Gray Patent 2,824,594 mentioned above. The amount of tape withdrawn from reel **48** is determined by the position of block **29** on the screw **28** and the angular position of reel **48** is determined accordingly. Thus, as the tape is played out, the rotor of synchro **37'** is turned in the clockwise direction and as the tape is retracted with a change in block position, the rotor is moved in the counterclockwise direction.

It will be seen that in the wiper position control any rotation of the dial **40'** of the reference synchro **38'** or potentiometer will introduce an error voltage between it and the sensing synchro **37'** and the lead screw **28** until the follower block **29** has pulled the tape on its reel sufficiently to bring the sensing synchro **37'** into "null" with the reference synchro **38'**. This control is used to pre-position the wiper shoe at its starting point during initial set-up. At this point the wiper position control is switched out by selector **47** and the automatic wiper tangency control is switched in at the operator's console.

While there has been shown what is considered to be a preferred embodiment of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. It is intended, therefore, in the annexed claims to cover all such changes and modifications as fall within the true scope of the invention.

What is claimed is:

1. In a machine of the kind described, a turntable, a die mounted on said turntable and having a curved contour, means to clamp one end of a workpiece to said turntable for forming about said die as said turntable rotates, a wiper shoe to apply a compressive force to said piece against said die, means for sensing the tangential relationship of said shoe relative to the curvature of said die as said turntable rotates to produce a control signal, said sensing means comprising a follower member engaged with a surface having the curvature of said die, bidirectional means to shift the tangential position of said shoe relative to said die curvature, and means responsive to said control signal to operate said shift means in a direction and to an extent maintaining said shoe normal to the die curvature in the course of forming operation.

2. In a machine of the kind described, a turntable, a die mounted on said turntable and having a curved contour, means to clamp one end of a workpiece to said table for forming about said die as said table rotates, a wiper shoe to apply a compressive force to said piece against said die, means including a template correlated and attached to said die and a pair of spaced rollers engaging said template to sense the tangential relationship of said shoe relative to the curvature of said die to produce a control signal, means to shift the tangential position of said shoe relative to said die curvature, and means responsive to said control signal to operate said shift means in a direction and to an extent maintaining said shoe normal to the die curvature.

3. A machine of the kind described comprising a turntable, a curved die on said table, means to clamp one end of a workpiece to said table for forming about said die as said table rotates, a wiper shoe to apply a compressive force to said workpiece as said turntable is rotated, a template mounted on said turntable and having the same peripheral curvature as said die, means to sense variations in the curvature of said template including a pair of rollers engaging the periphery of said template and supported at the ends of a centrally pivoted yoke, and means responsive to the pivotal motion of said yoke in the course of the rotation of said turntable to maintain said shoe normally disposed relative to the curvature of the die.

4. A rotary stretch-forming machine comprising a turntable, a die on said table and having a peripheral curvature, a wiper shoe to apply a compressive force against said die, a motor block for rotatably supporting said table, a pair of base rails, a horizontal guideway lying over said rails and extending perpendicularly relative thereto, a first carriage reciprocable on said guideway for supporting said wiper shoe, said motor block being slidable on said rails for effecting compressive engagement between said die and said wiper shoe, a second carriage reciprocable on said guideway for supporting a jaw piece, means on said turntable to clamp one end of a workpiece, the other end being held in said jaw, a template mounted above said die on said turntable and having the same peripheral curvature as said die, means to sense variations in the curvature of said template including a pair of rollers engaging the periphery of said template and supported at the ends of a centrally-pivoted yoke, and means responsive to the pivotal motion of said yoke in the course of the rotation of said turntable to maintain said shoe normally disposed relative to the curvature of the die.

5. A rotary stretch-forming machine comprising a turntable, a contoured die on said table, a wiper shoe to apply a compressive force against said die, a motor block for rotatably supporting said table, a pair of base rails, a horizontal guideway lying over said rails and extending perpendicularly relative thereto, a first carraige reciprocable on said guideway for supporting a wiper shoe, said motor block being slidable on said rails for effecting engagement between said die and said wiper shoe, a second carriage reciprocable on said guideway for supporting a jaw piece, means on said turntable to clamp one end of a workpiece, the other end being held in said jaw, means for sensing the tangential relationship of said shoe relative to the curvature of said die as said turntable rotates to produce a control signal, bidirectional means to shift the tangential position of said shoe relative to said die curvature, and means responsive to said control signal to operate said shift means in a direction and to an extent maintaining said shoe normal to the die curvature in the course of forming operation.

6. A rotary stretch-forming machine comprising a turn-

table, a peripherally contoured die on said table, a wiper shoe to apply a compressive force against said die, a motor block for rotatably supporting said table, a pair of base rails, a horizontal guideway lying over said rails and extending perpendicularly relative thereto, a first carriage reciprocable on said guideway for supporting said wiper shoe, said motor block being slidable on said rails for effecting engagement between said die and said wiper shoe, a second carriage on said guideway for supporting a jaw piece, means on said turntable to clamp one end of a workpiece, the other end being held in said jaw, a template mounted on said turntable and having the same peripheral curvature as said die contour, means to sense variations in the curvature of said template including a pair of rollers engaging the periphery of said template and supported at the ends of a centrally pivoted yoke, synchro means responsive to the pivotal motion of said yoke in the course of the rotation of said turntable to produce a control signal and servo means responsive to said control signal to shift said first carriage in a direction maintaining tangency between said shoe and the contour of said die.

7. A rotary stretch-forming machine comprising a turntable, a die on said table and having a peripheral curvature, a wiper shoe to apply a compressive force against said die, a motor block for rotatably supporting said table, a pair of base rails, a horizontal guideway lying over said rails and extending perpendicularly relative thereto, a first carriage reciprocable on said guideway for supporting said wiper shoe, said motor block being slidable on said rails for effecting engagement between said die and said wiper shoe, a second carriage reinforceable on said guideway for supporting a jaw piece, means on said turntable to clamp one end of a workpiece, the other end being held in said jaw, a template mounted on said turntable and having the same peripheral curvature as said die, means to sense variations in the curvature of said template including a pair of rollers engaging the periphery of said template and supported at the ends of a centrally pivoted yoke, a sensing synchro having a rotor coupled to said yoke, means electrically connecting said sensing synchro to a reference synchro to produce an error voltage when the wiper shoe deviates from tangency with the die contour, and means responsive to said error voltage to correct the position of said first carriage to restore said tangency.

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