Feb. 9, 1960 Z. S. FREDERICKS 2,924,261

STRETCH FORMING MACHINE WITH TENSION CONTROL

Filed Dec. 30, 1957 4 Sheets-Sheet 1

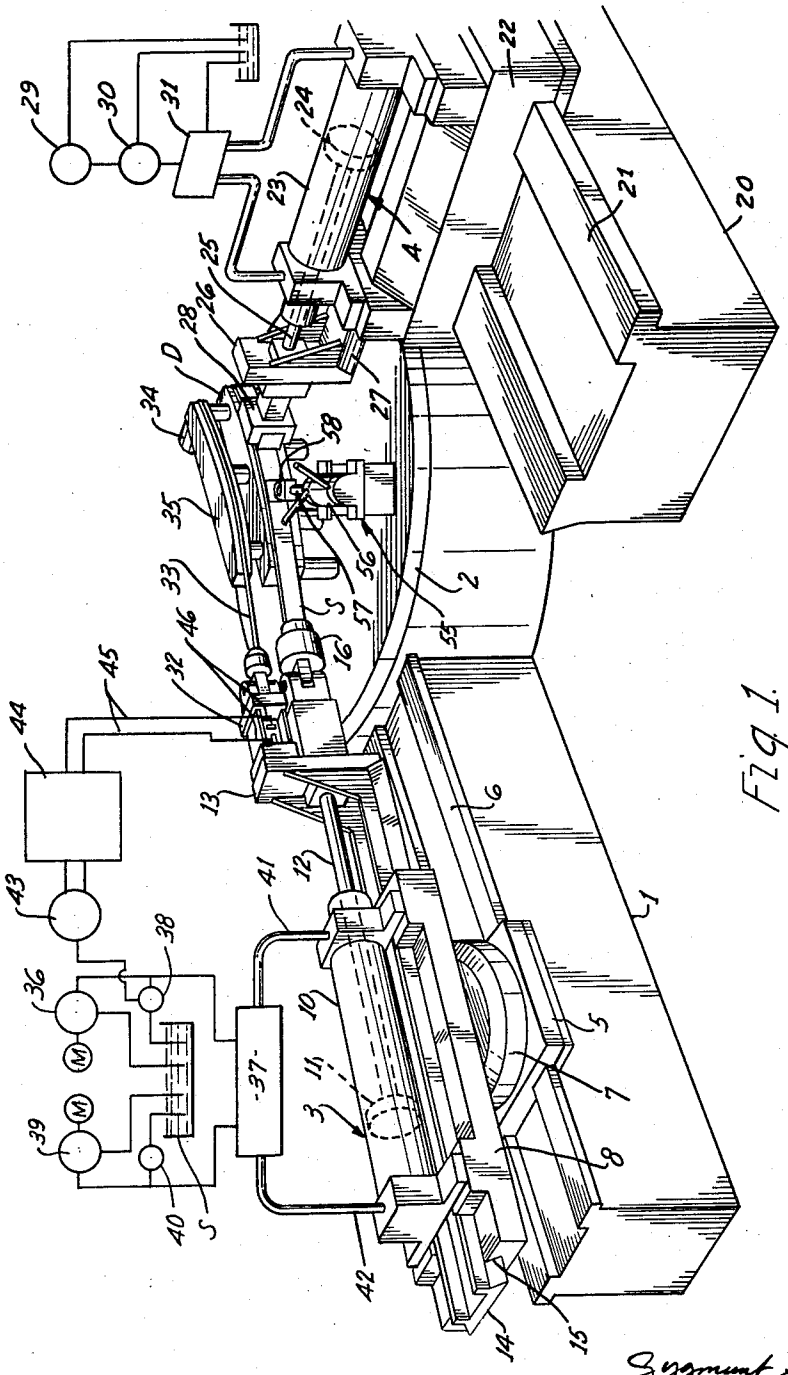

Fig. 1.

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STRETCH FORMING MACHINE WITH TENSION CONTROL

Filed Dec. 30, 1957 4 Sheets-Sheet 2

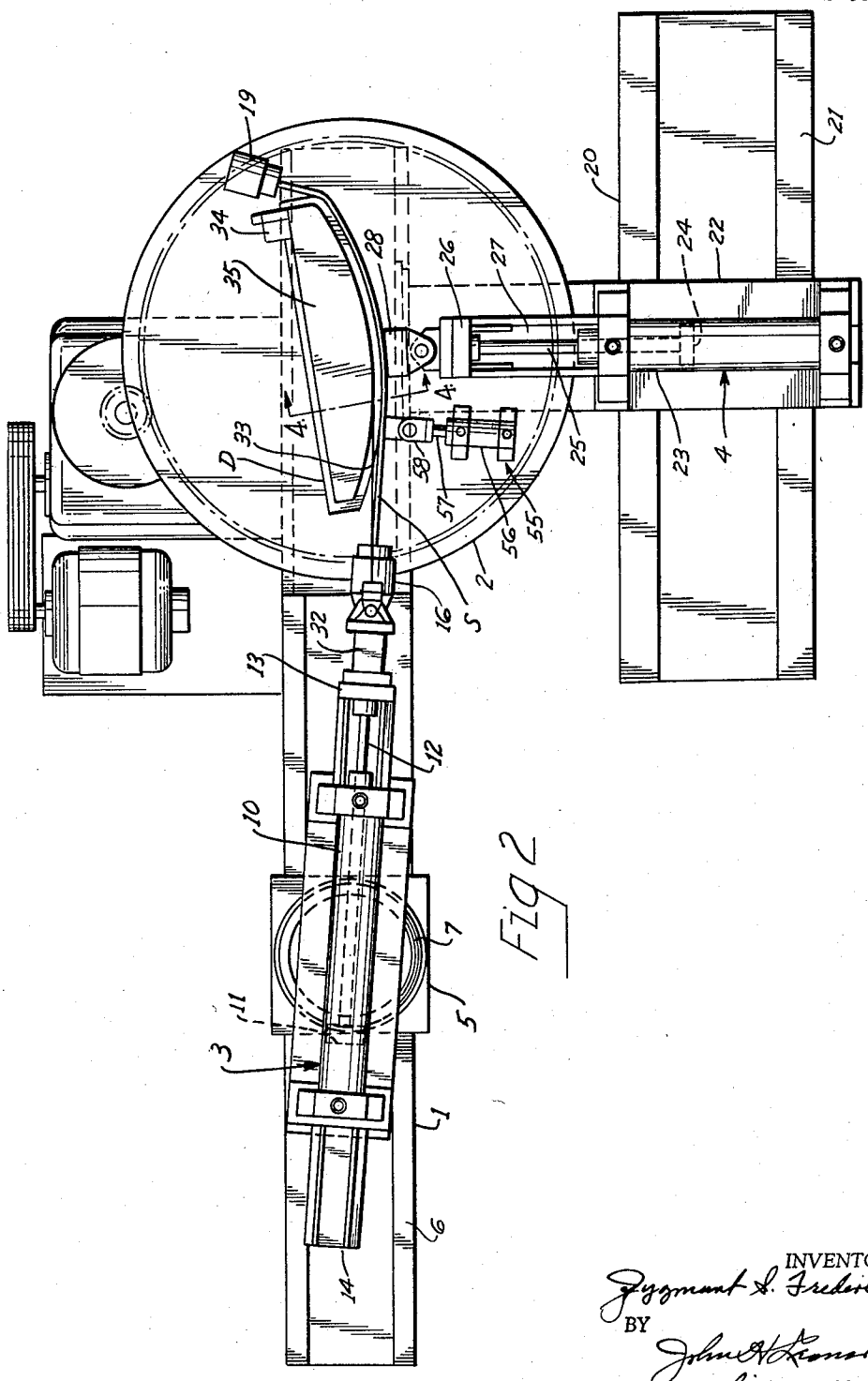

Fig 2

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STRETCH FORMING MACHINE WITH TENSION CONTROL

Filed Dec. 30, 1957 4 Sheets-Sheet 3

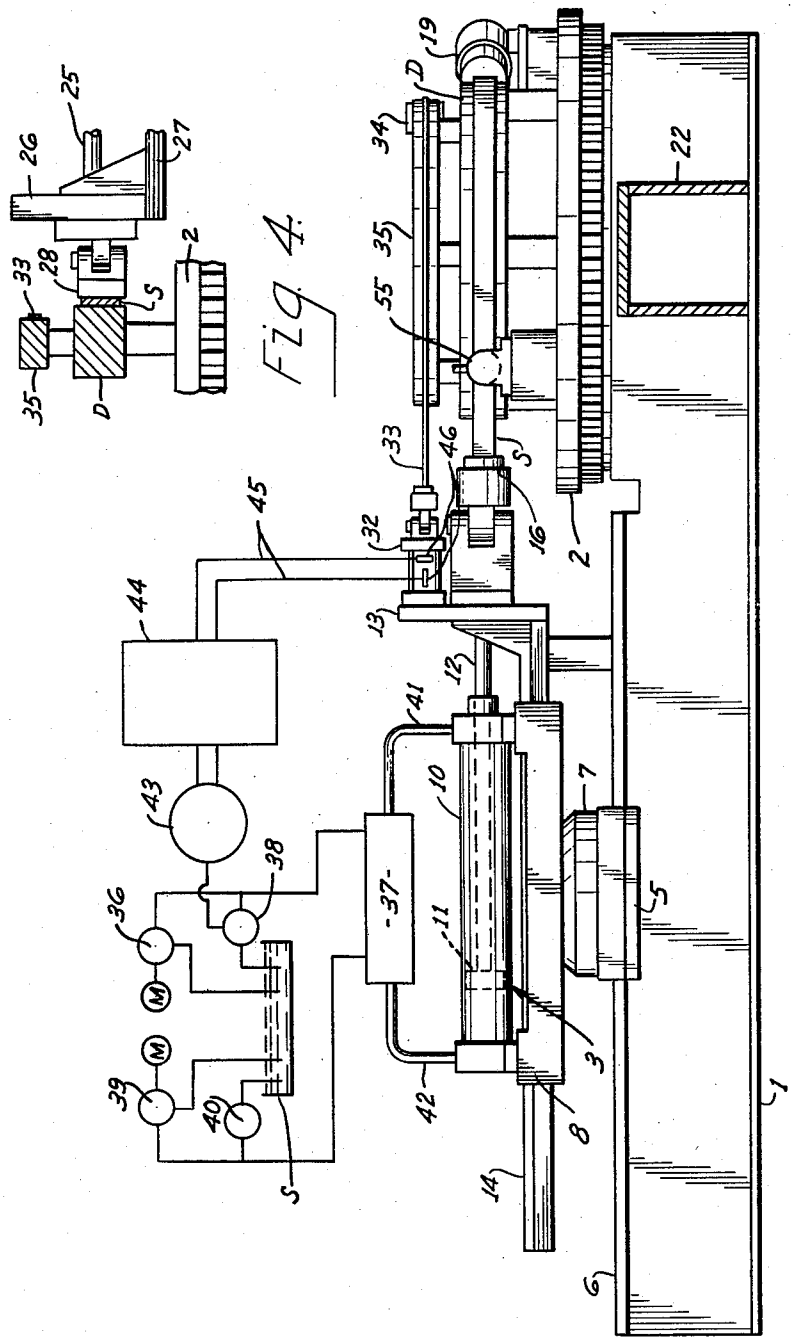

Fig. 4.

Fig. 3.

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Feb. 9, 1960 Z. S. FREDERICKS 2,924,261

STRETCH FORMING MACHINE WITH TENSION CONTROL

Filed Dec. 30, 1957 4 Sheets-Sheet 4

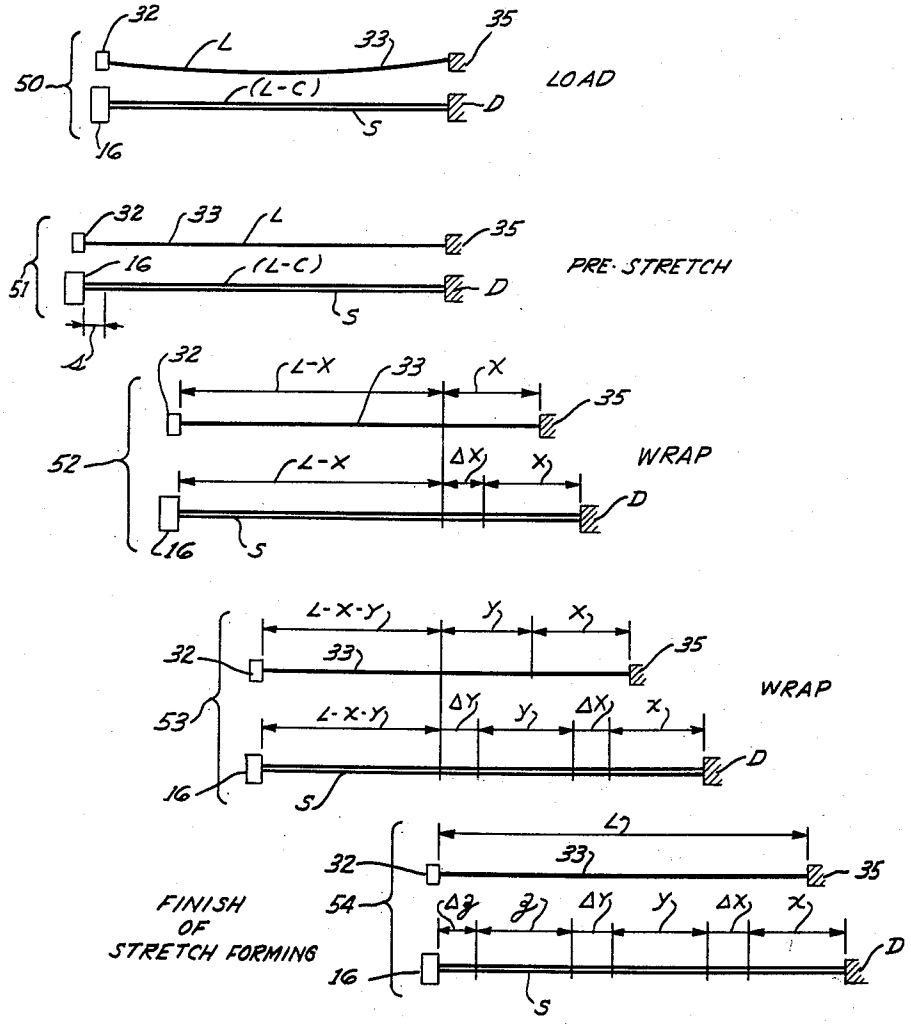

Fig. 5.

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United States Patent Office

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Patented Feb. 9, 1960

2,924,261

STRETCH FORMING MACHINE WITH TENSION CONTROL

Zygmunt S. Fredericks, Chesterland, Ohio, assignor to The Cyril Bath Company, Solon, Ohio, a corporation of Ohio

Application December 30, 1957, Serial No. 705,940

8 Claims. (Cl. 153—40)

This invention relates to a stretch forming machine of the general type disclosed in U.S. Letters Patent No. 2,514,830, issued July 11, 1950, to Cyril J. Bath, and particularly to a new and improved stretch forming machine and control combination by virtue of which the tension applied to the stock during the formation thereof can be controlled and varied as desired as the forming of the stock progresses.

Heretofore, in stretch forming metal stock, the custom has been to anchor one portion of a length of stock in fixed position relative to the operating face of a side face die, to grip the stock at another portion by a suitable tensioning assemblage, usually a piston and cylinder assemblage, and to form the stock by moving the die and assemblage in a direction to wrap the stock progressively onto the side face of the die while maintaining the stock under tension near to the elastic limit of the stock. Heretofore, attempts have been made to maintain constant tension on the stock, and thereby to obtain uniform elongation of the stock by maintaining the pressure fluid supplied to the piston and cylinder assemblage at constant pressure. However, constant pressure supplied the piston and cylinder assemblage does not produce a constant tension nor a constant elongation due to a large number of variables inherent in the assemblage itself. These variables, such as the changes in friction and binding stresses as the assemblage extends and retracts and shifts in alignment laterally from its starting position are complicated further by changes in the cross section and physicals of the metal. In fact, to obtain constant tension on the stock, the exact reverse is true, variable pressure, not constant, must be provided in the assemblage.

One prior attempt to obtain proper control was to circumvent the use, for control, of variable pressure and its inherent difficulties and, instead, to provide continuously sufficient pressure in the piston and cylinder assemblage to stretch the stock far beyond its elastic limit, or even to its breaking point, and then to control the movement of the gripping head of the stretch forming assemblage by a positioning device. This type of control means operates on the principle that, regardless of the higher pressure applied by the head to the stock, the head is stopped in position as soon as the stock has been stretched a predetermined amount. The positioning device is related in operation to the forming of the stock by means of a tape which is wrapped about a template having a curvilinear face substantially the same in contour as, and coaxial with, the face of the die. One end of the tape is secured for movement with the template and the other is secured to the positioning device located on the part of the stretch forming assemblage to which the stretching head is secured. The positioning device operates a servo-valve which controls the direction and rate of flow of pressure fluid to and from the sides of the piston to cause the piston and cylinder assemblage to extend and retract in relation to the extension and retraction of the positioning device as operated by the tape. This solution requires a template which is precisely shaped relative to the die, so that for each unit length of tape which is wrapped onto the template, an equal unit length of stretched stock is wrapped onto the die face. Thus, regardless of the stretching force applied by the piston and cylinder assemblage and the resistance of the stock being formed, the stock is elongated a very definite and positive amount by linear dimensional control only. The relative movement of the stretch forming head follows a predetermined accurate dimensional path with respect to the die regardless of the tonnage applied, of the cross sectional area of the stock, of the characteristics of the material, or of the personal characteristics of the machine operator. This positive position control has certain advantages and limitations.

Another control is one in which the elongation of the stock is controlled by controlling the tensioning force applied to the stock, the measurements of the tension applied being measured between the stock and the stretch forming assemblage so as to eliminate the various frictional and binding stresses and the like inherent in the assemblage itself. In this type of control, examples of which are described in copending applications of Henry W. Hein and Zygmunt S. Fredericks, Serial No. 568,553, now abandoned, filed February 29, 1956, and of Richard L. Curtner, Serial No. 667,376, now Patent No. 2,849,048 filed June 24, 1957, all of the extraneous binding stresses and the like inherent in the stretch forming assemblage and its position are combined with the force due to the pressure fluid and only the resultant single force and stress due to these forces and that caused by the applied pressure fluid pressure is measured and controlled. Accordingly, the stress applied to the stock can be maintained constant or can be varied, depending upon the desires of the operator.

In the Curtner application, the tension applied to the stock is controlled by varying the pressure in the high pressure side of the stretch forming assemblage by variable venting of the pressure fluid in the high pressure side of the piston and cylinder assemblage. The variable venting is by means of a relief valve discharging to a sump, and under the control of a motor device which, in turn, is operated in response to the changes in a load cell strain produced on the load cell by the single resultant force applied by the stock and assemblage, the load cell being located between the assemblage and its stock gripping head for this purpose.

In accordance with the present invention, the elongation and tensioning of the stock is controlled also by varying the pressure in the high pressure side of the stretch forming piston and cylinder assemblage, but, instead of this pressure being varied in response to a load cell subjected to the tension applied to the stock itself, it is varied in response to a load cell operated by a tape which, in turn, is wrapped about a template concurrently with the wrapping of the stock about the side face of the die.

In general, in case the stretch forming machine is of the type disclosed in the above identified Bath patent, a rotatable die is mounted on a turntable and the template is mounted with its axis coincident with the axis of the side face of the die. One end of a length of tape is fastened in fixed relation to one end of the template, and the other end is fastened in fixed relation endwise of the stretch forming assemblage relative to the gripping head of the assemblage which grips the stock. The load cell is interposed between the latter end of the tape and the stretch forming assemblage, so that it is strained due to the tension applied by the tape. The load cell is provided with strain gauges and the signals therefrom, due to changes in the strain of the load cell, are used to control the variable relief valves in a manner described in the above Curtner application.

Thus the present invention distinguishes from that of the Curtner application primarily in that the strain of the load cell is effected by means of tension applied by a tape and a template or other means movable in fixed relation to the side face forming die, rather than by the tension on the stock itself.

The present invention has an advantage in that, by changing the template, the tension applied to the stock at different points along the length of the stock are being progressively laid onto the side face die, may be varied so that the tension at any instantaneous point of tangency of the stock and side face die can be readily preselected.

Further, it has an advantage in that, when the stock is laid onto the die and it is found that the finished piece does not quite conform to that desired, the tension can be varied by modifying the template slightly until exactly the right stress is obtained for the particular piece.

The present invention also has great advantages when a wipe forming shoe is used in connection with the stretch forming, or when a suitable clamp such as described in the above Bath patent, is mounted on the table and holds the stock firmly into engagement with the side face of the stretch forming die, after a predetermined portion of the length of the stock has been formed. In such instances, it is apparent that by holding the formed portion of the stock firmly against the side face die at the instantaneous line of tangency, greater pressures can be applied at the unformed portion of the stock. Again, the tension can be increased or decreased where desired, as the stock is progressively laid onto the side face of the die, depending upon the cross section of the metal, degree of curvature, and the like.

Further objects and advantages will become apparent from the following description wherein reference is made to the drawings which illustate a preferred embodiment of my invention, and in which:

Fig. 1 is a perspective view of a machine illustrating an embodiment of my invention;

Figs. 2 and 3 are top plan view and front elevation, respectively, of the apparauts illustrated in Fig. 1;

Fig. 4 is an enlarged cross sectional view taken on the line 4—4 in Fig. 2; and

Fig. 5 is a diagrammatic illustration showing certain physical relations between the tape, stock, template and die.

Referring to the drawings, the machine comprises a base 1 on which is mounted a rotatable turntable 2, a stretch forming piston and cylinder assemblage 3, and a wipe forming piston and cylinder assemblage 4. A carriage 5 is mounted on slideways 6 on the frame 1 for movement toward and away from the table 2 to different adjusted positions. Mounted on the carriage 5 is a support 7 which is rotatable about an upright axis and which supports a saddle 8 on which the assemblage 3 is carried. The assemblage 3 comprises a cylinder 10 which is mounted in fixed position on the saddle 8 with its axis extending generally toward and away from the table in a plane normal to the table axis. A piston 11 having a piston rod 12 is mounted for reciprocation in the cylinder 10, and is fixedly connected at its outer end to a pedestal 13 of a slide 14 which, in turn, is mounted in guideways 15 of the saddle for movement parallel to the axis of the cylinder 10. Mounted in fixed position endwise of the assemblage 10 on the pedestal 13 is a stretch forming head 16 which is adapted to grip one end of a length of stock S. The head 16 is mounted on the pedestal for rocking movement about an upright axis for facilitating its alignment with the line of pull exerted on the stock.

The turntable 2 carries a side face die D about which the length of stock is to be wrapped. A piston and cylinder operated clamp 19 is provided for gripping the opposite end of the length of stock S and securing it in fixed position relative to the die D.

As pointed out in the above entitled patent, it is often desirable to subject the stock to both stretch forming and wipe forming concurrently, and it has been found desirable that a wipe forming piston and cylinder assemblage be arranged for reciprocation alongside the face of the stock being formed on the die, in addition to its being operative to force a wipe forming shoe toward the face of the die. For this purpose, the base or frame 1 has a lateral extension 20 which is located alongside the turntable 2, and which has guideways 21 on which a suitable saddle or carriage 22 is mounted for reciprocation alongside the table. The wipe forming piston and cylinder assemblage 4 is mounted on the carriage 22 and has a cylinder 23 in fixed position on the carriage 22. The assemblage has a piston 24 having a rod 25, which is connected to a pedestal 26 of a slide 27. The wipe forming shoe or tool 28 is connected to the pedestal in a position so as to be pressed laterally against the stock as it is being wrapped along side face die. If desired, the wipe forming cylinder may be controlled by separate power means and fluid pressure means including a motor driven pressure fluid pump 29 connected to a variable pressure relief valve 30, and therethrough to a reversing valve 31, by which the fluid pressure can be delivered to the head end or the rod end of the cylinder 23, selectively, and to a sump, selectively, in each instance.

In order to control the tension applied to the stock by the stretch forming assemblage 3, with which the present invention is particularly concerned, a load cell 32 is connected to the pedestal 13 at one end so as to be in fixed relation thereto. The other end of the load cell 32 is connected to a tape 33 the opposite end of which is connected by a clamp 34 to a template 35. The template is preferably arranged so as to be supported above the die D with its operating face as near as may be parallel to the operating face of the die D, but offset therefrom towards the axis of the turntable 2. Thus, as the assemblage 3 and die D are moved relative to each other so as to wrap the stock progressively about the die face, the tape 33 is concurrently progressively wrapped about the side face of the template 35.

In the type of machine illustrated, this relative movement is effected by rotation of the turntable 2. Since the pressure maintained in the piston and cylinder assemblage 3 is sufficient to stretch the stock, it is, of course, greater than that which would be necessary to elongate the load cell 32 by the relatively weak tape. However, as the tension on the load cell 32 increases, the means responsive to the load cell are operative to reduce the tension and, as the tension decreases beyond a predetermined minimum, they are responsive to increase the tension. For this purpose, the piston and cylinder assemblage 3 is connected in a hydraulic circuit which includes a high pressure motor driven pump 36, a directional reversing valve 37, and a high pressure adjustable relief valve 38 which is connected between the pressure side of the pump and the directional valve 37. The circuit also includes a low pressure motor driven pump 39 and a low pressure adjustable relief valve 40 which is connected between the pressure side of the pump 39 and the directional valve 37. The directional valve is connected to opposite ends of the cylinder 10 by lines 41 and 42.

In one position of the valve 37, the controlled high pressure fluid is supplied to the rod end of the cylinder 10 through the line 41 and concurrently the low pressure fluid is supplied to the head end through the line 42. Thus, the pull exerted on the piston by the stock is yieldably resisted by the high pressure fluid, the unit pressure of which is controlled by the load cell device 32, diminished to a slight extent by the pressure exerted on the head end of the piston by the low pressure fluid. As the piston is extended, the excess volume of high pressure fluid is exhausted to sump from the rod end of the cylinder 10 through the line 41 and the high pressure relief valve 38. As the piston is retracted, the excess low pressure fluid is exhausted to sump from the head end

of the cylinder 10 through the line 42 and the low pressure relief valve 40.

If it is desired to extend the piston the directional valve is reversed so that the low pressure fluid is directed through line 41 to the rod end of the cylinder 10 and the high pressure fluid is directed through line 42 to the head end, thus extending the piston. The excess fluid in the rod end of the cylinder 10 vents through the low pressure relief valve.

The differential between high and low pressure is sufficiently great at all times to effect this proper direction of movement selected.

The control of the pressure to the high pressure or rod end of the cylinder 10 is preferably effected by varying the setting of the high pressure relief valve 38. This valve is of the type described in the above identified copending application, and is driven by a reversible motor 43 to different settings to increase and decrease the pressure at which the valve vents to sump. The motor 43 is controlled, in turn, by a suitable amplifier and control 44, which may be such as described in the above application, the signals therefor being supplied through suitable electric lines 45 from strain gauges 46 arranged on the load cell 32. The load cell 32 is preferably of the I-beam construction but relatively light so as to be readily strained by the tension applied by the relatively weak metal tape 33. Thus, when the tension of the tape increases unduly, the motor 43 operates the valve 38 to increase its venting and thus reduce its pressure, and, as the pressure decreases unduly, it closes down the venting of the valve 38 so as to increase the pressure. The pressure supplied by the pump 36 is always considerably above that required for the stretch forming operation. Accordingly, the tension applied to the stock is controlled by varying the pressure supplied to the rod end of the cylinder 3 in response to the tension exerted by the tape 33 on the load cell 32, and the resultant strain of the load cell.

The permanent stretching of the stock adds a substantial amount to its final length, but the tension on the tape is insufficient to cause a corresponding elongation thereof. Consequently, the length of the face of the template 35 is made less than the length of the face of the die, inasmuch as it is required that a tension be continuously maintained on the tape as the stock is laid on the die, and to allow for the stretching and elongation of the stock as it is laid on the die.

In order to understand the operation and how it distinguishes from a positional control, reference is made to Fig. 5, wherein the relative lengths of the tape and stock and the distance of the stock driving head and the load cell from their starting points, measured along the template and die faces, respectively, are shown by diagrams in a number of operating positions.

The first position, indicated by diagram 50, shows the tape 33 as connected at its right end to the template 35 and the stock S as connected at its right end to the die D. It is to be noted that the length L of the tape 33 is greater than the length of the stock S, as the stock will be stretched prior to any rotation of the table 2. The amount of elongation which the stock must have to make the finished part can be determined readily in advance with one or two test pieces. This elongation is constant for subsequent lengths of stock for the same article. Accordingly, the length of the stock measured between its point of connection with the die and the stretching head is equal to L minus a constant, or L minus c, in the starting position. However, before rotation of the table, when the stretching fluid pressure is introduced into the rod end of the cylinder 10 for prestretching the stock, the stock length is increased by an amount s, as indicated in diagram 51. When the amount of stretch s is sufficient so that the length of the stock and the tape are equal, the stretching force is reduced by the control action of the tape, so as not to cause further stretching after the initial stretch takes the slack out of the tape and strains the load cell 32 the preselected amount. Therefore, at the beginning of the forming operation, s equals c, and the length of the tape and the length of the prestretched stock are equal.

Next, the table is started. As it rotates, the tape 33 is being wrapped on the template progressively from its anchored end. Let it be assumed that a length of tape equal to x has been wrapped on the template, leaving an unwrapped portion of $L-x$. Since the length of the die face is greater than the length of the template, in that the template face is offset toward the axis of the turntable from the die face at all points along its length, the wrapping of an amount of tape equal to length x results in the wrapping of an amount of stock equal to a length $x+\Delta x$, wherein Δx is the increment by which the stock S is elongated over and above its initial stretch or elongation s. This leaves, as the unwrapped remainder of the stock, a length equal to $L-x$, as illustrated in diagram 52.

As the wrapping continues and the additional length y of the tape 33 is wrapped on the template, leaving an unwrapped length of $L-x-y$, the length of the stock wrapped on the die is equal to $x+y+\Delta x+\Delta y$, Δy being the additional stretch of the piece of stock leaving an unwrapped portion of the stock equal to $L-x-y$, the same as for the tape, as indicated in diagram 53.

At the end of the wrapping operation, as indicated in diagram 54, all of the tape of length L having been wrapped, as indicated successively by the lengths $x+y+z$, the stock also has been fully wrapped and the wrapped portion is equal to $x+\Delta x+y+\Delta y+z+\Delta z$, in which Δx and Δy and Δz are the increments of stretch imparted to the stock S in addition to the prestretch s originally imparted to the stock, as indicated at s in Fig. 1.

Sometimes a constant tension is maintained on the stock throughout the forming operation. However, in some instances the stock, at different locations along its length, has different cross sections or different degrees of bend or indentation both laterally of the die face and endwise of the die face. In other instances, the stock is wider at one portion than at another. As a result, it is desirable to vary the total stretching force to maintain the desired unit force for forming the particular portions. Accordingly, the face of the template does not necessarily have to remain at all times parallel to, or offset the same distance inwardly from the face of the die toward the axis of the turntable or in the direction in which the stock is moved to approach the die face. Instead, its contour may be such as to approach and recede from the face of the die different amounts at different portions along its length so that the pressure can be varied in accordance with the demands of stock.

For example, it may be desired in Fig. 5 that the portion x be stressed at a degree different from the portion y of the stock. If, for a unit length along the die face, the length of the template corresponding to that unit length is increased, more tape is wound onto the template and this increases the strain on the load cell, causing a reduction in pressure fluid pressure. On the other hand, if, for a unit length of the die face, the face of the template is decreased correspondingly, then less tape is wound onto the template and accordingly the tension on the tape decreases and decreases the strain on the load cell which responds with a signal for more pressure in the cylinder and a greater tension on the stock. It is apparent that, with this arrangement, the tension applied to the stock can range from the maximum of which the hydraulic system is capable down to zero.

These variations in pressure are particularly desirable when the stock is concurrently wipe formed and stretch formed, as the wipe shoe itself affects the tension on the stock.

If extreme cases so require, one or more holding piston and cylinder assemblages may be provided on the table, as described in the above identified Bath patent. As illustrated in Fig. 3, a holding piston and cylinder

assemblage **55** is shown as mounted on the turntable **2**. A typical holding assemblage includes a cylinder **56** and a piston having a rod **57** on which is carried a clamping head **58** or joggling tool, or the like. The piston and cylinder assemblage **55** is detachable from the table and may be secured thereon in predetermined positions, one or more being used as required. Under such conditions, it is possible to go to extremes in the amount of tension to which different portions of the length of stock are subjected. For example, beginning with the stock at the right-hand end of the die being stretched under light pressure, it may be desirable beyond the point at which the clamp **58** is positioned to greatly increase the pressure. In such a case, the clamp **58** is applied just beyond the instantaneous point of tangency in a direction toward the starting end of the die, and is held firmly clamped to the die during continued rotation of the table. During this continued rotation, the tension is greatly increased between the clamp **58** and the stretch forming head **16**. In such an instance, the face of the template **35** is farther removed from the face of the die D at the location of the clamp **58** so that for a given unit length of the die, the length of the template is still further decreased than normal. This results in slackening the tape and therefore a demand for greater tension. The tension is increased until the stock is stretched enough to remove the slack in the tape. This increase continues to the point desired. If it is desired to reduce the tension, the face of the template is shaped to approach more closely to the face of the die, thus increasing the tension on the tape and calling for a reduction in pressure on the stock which would then be subjected to less tension.

It is apparent that, with the present structure, a wide variety of effects in combined wipe and stretch forming can be obtained and all are within the scope of the present invention.

Having thus described my invention, I claim:

1. A stretch forming machine for stretch forming a length of metal stock against a curved side face die progressively from one location to another on the face while the stock is held under tension endwise, including a curved side face die, means adapted to secure the stock at one portion in fixed position relative to the die, tool means adapted to be connected to the stock at another portion for transmitting endwise tensioning force to the stock, tensioning means connected to the tool for applying said tensioning force to the tool, settable means settable in different operating positions for controlling the tensioning means and thereby the tension applied to the stock, means supporting the die and tensioning means for relative movement in a direction transversely of the die for wrapping the stock onto the die face progressively endwise from one location on the face to another, power means for effecting said relative movement, a load cell, having substantial resistance to elongation by tension applied thereto, connected to the assemblage for endwise movement therewith in fixed endwise relation to the tool, reversible motor means connected to the settable means and operative, when energized, for setting the settable means, strain sensing means carried by the load cell so that changes in the strain of the load all produce related changes in the condition of the sensing means, and said sensing means being operatively connected to the motor for effecting operation of the motor in opposite directions as the strain on the cell increases and decreases, respectively, a side face template in fixed position relative to the die, a tension tape, capable of exerting sufficient tension to elongate said load cell, connected at one portion in fixed relation to the template and at another portion in fixed relation to the load cell for wrapping of the tape onto the template face during said relative movement of the die and assemblage, so as to strain the load cell and in proportion to the tension applied by the tape.

2. The structure according to claim 1 characterized in that the length of the template face is less than the length of the die face.

3. The structure according to claim 1 characterized in that the ratio of the length of the template face, measured from the starting position of the tape to the instantaneous line of tangency of the tape and template, and the length of the die face measured from the starting position of the stock to the instantaneous line of tangency of the stock and die, is different for different locations of the point of tangency of the die and stock.

4. The structure according to claim 1 characterized in that the distance between the faces of the die and template, in said direction of relative movement, is different at different locations endwise of the die face, whereby the stock is subjected to different preselected tension at different portions along its length as it is wrapped onto the die.

5. The structure according to claim 1 characterized in that said load cell is strainable for operation at tension less than that required to impart a permanent stretch to the stock.

6. The structure according to claim 1 characterized in that the tensioning means is a piston and cylinder assemblage connected in a circuit to a source of pressure fluid, the settable means is a variable relief valve and is arranged in said circuit between the source and the pressure side of the cylinder so as to change the tension applied by the cylinder.

7. A stretch forming machine for stretch forming a length of metal stock against a curved side face die progressively from one location to another on the face while the stock is held under tension endwise, including a curved side face die, means adapted to secure the stock at one portion in fixed position relative to the die, tool means adapted to be connected to the stock at another portion for transmitting endwise tensioning force to the stock, a fluid pressure operated piston and cylinder assemblage connected to the tool for applying said tensioning force to the tool in relation to the pressure of working pressure fluid supplied to the assemblage, a fluid circuit for supplying said pressure fluid from a source to the assemblage, a variable relief valve means in the circuit and settable in different operating positions for controlling the pressure of the operating fluid supplied to the assemblage, means supporting the die and assemblage for relative movement in a direction transversely of the die for wrapping the stock onto the die face progressively endwise from one location on the face to another, power means for effecting said relative movement, a load cell, having a substantial resistance to elongation by tension applied thereto, connected to the assemblage for endwise movement therewith in fixed endwise relation to the tool, reversible motor means connected to the valve and operative, when energized, for setting the valve, strain gauge means mechanically connected to the load cell so that changes in the strain of the load produce related changes in the condition of the strain gauges, and operatively connected to the motor for effecting operation of the motor in opposite directions as the strain increases and decreases, respectively, a tension tape, capable of exerting sufficient tension to elongate said load cell, connected at one portion to the load cell, means connected to the tape at another portion and movable relative to the load cell and in predetermined relation to the die for causing the tape to apply tension to the load cell in a predetermined relation to the tension applied to the stock by the assemblage.

8. A stretch forming machine for stretch forming a length of metal stock against a curved side face die progressively from one location to another on the face while the stock is held under tension endwise, and including a curved side face die, means adapted to secure the stock at one portion in fixed position relative to the die, tool means adapted to be connected to the stock at another portion for transmitting endwise tensioning force to the

stock, tensioning means connected to the tool for applying said tensioning force to the tool, settable means for controlling the tensioning means and thereby the tension applied to the stock, means supporting the die and tensioning means for relative movement in a direction transversely of the die for wrapping the stock onto the die face progressively endwise from one location on the face to another, power means for effecting said relative movement, reversible motor means connected to the settable means and operative, when energized, for setting the settable means, tension sensing means, having substantial resistance to elongation by tension applied thereto, connected to the assemblage for endwise movement therewith in fixed endwise relation to the tool, and connected to the motor for effecting operation of the motor in opposite directions as the tension on the tension sensing means increases and decreases, respectively, clamping means movable with the die and operable for clamping the formed stock against the die in fixed position at preselected locations, respectively, so as to isolate the tension applied to the unformed portion of the stock from the formed portion, a side face template in fixed position relative to the die, a tension tape, capable of exerting sufficient tension to elongate said load cell, connected at one portion in fixed relation to the template and at another portion in fixed relation to the tension sensing means for wrapping the tape onto the template face during said relative movement of the die and assemblage, the length of the template face being less than the length of the die face so as to strain the tension sensing means by, and in proportion to the tension applied by the tape during stretch forming, and the ratio of the length of the template face, measured from the starting position of the tape to the instantaneous line of tangency of the tape and template and the length of the die face measured from the starting position of the stock to its instantaneous line of tangency, being different for different locations of the point of tangency of the die and stock.

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