

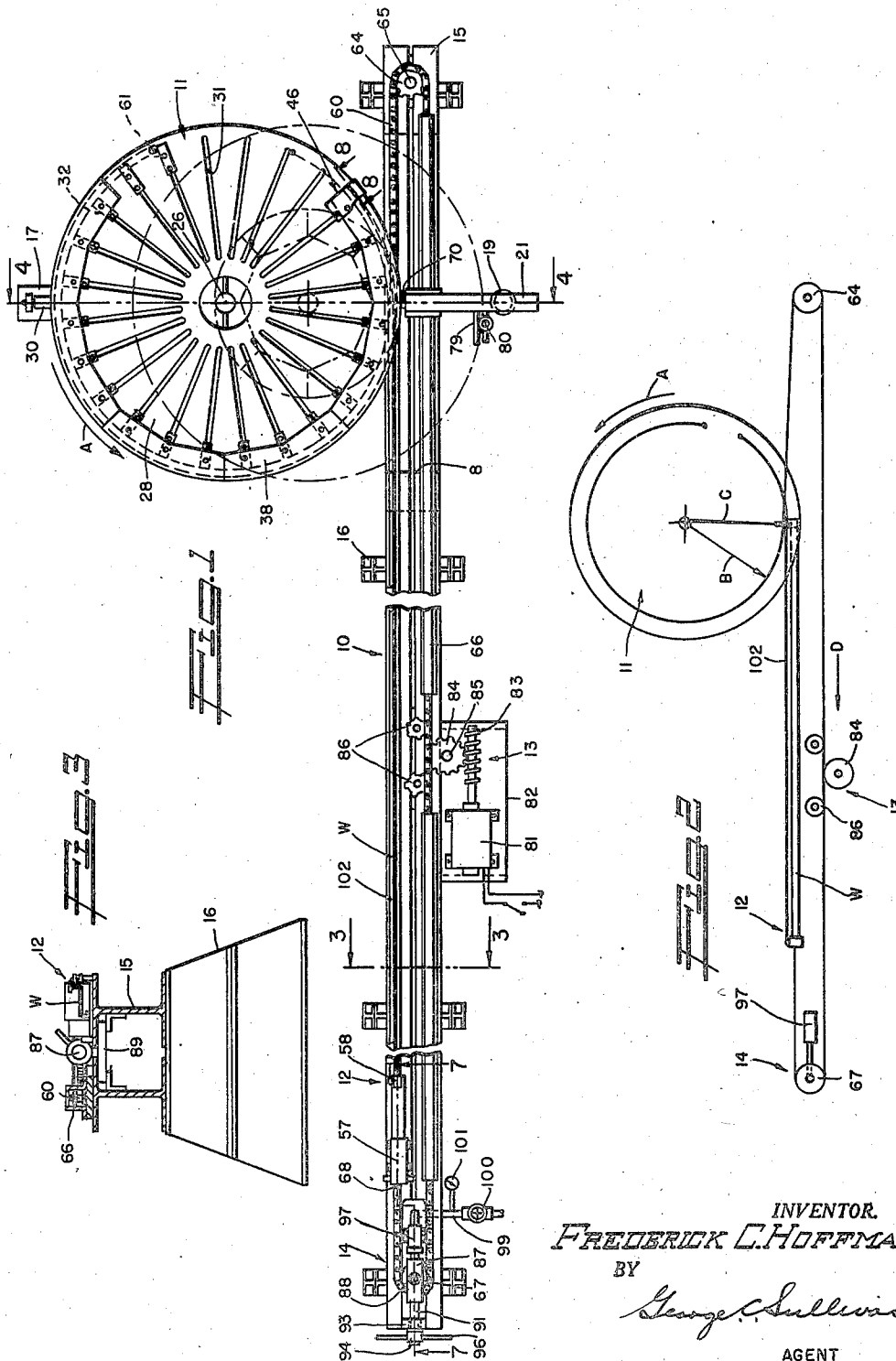
Dec. 17, 1946.

F. C. HOFFMAN
STRETCH FORMING MACHINE

2,412,731

Filed May 10, 1944

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

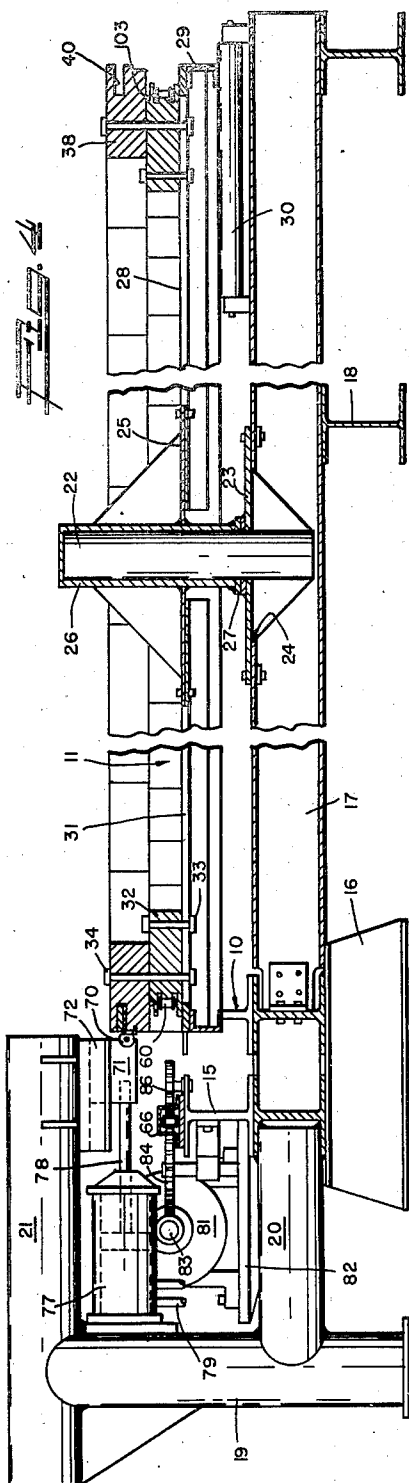


Fig. 5

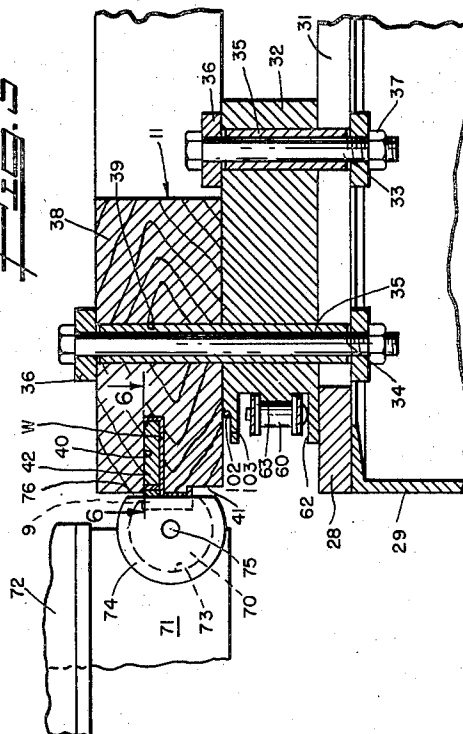
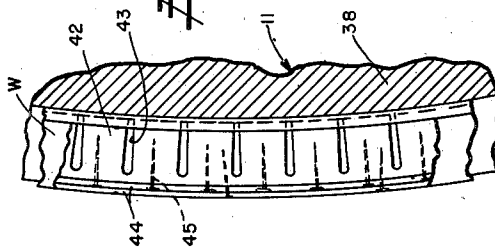


Fig. 6



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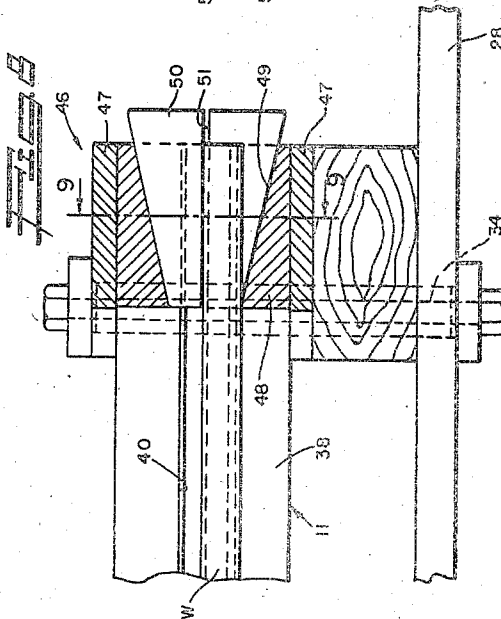
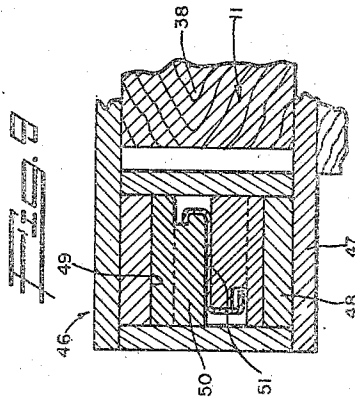
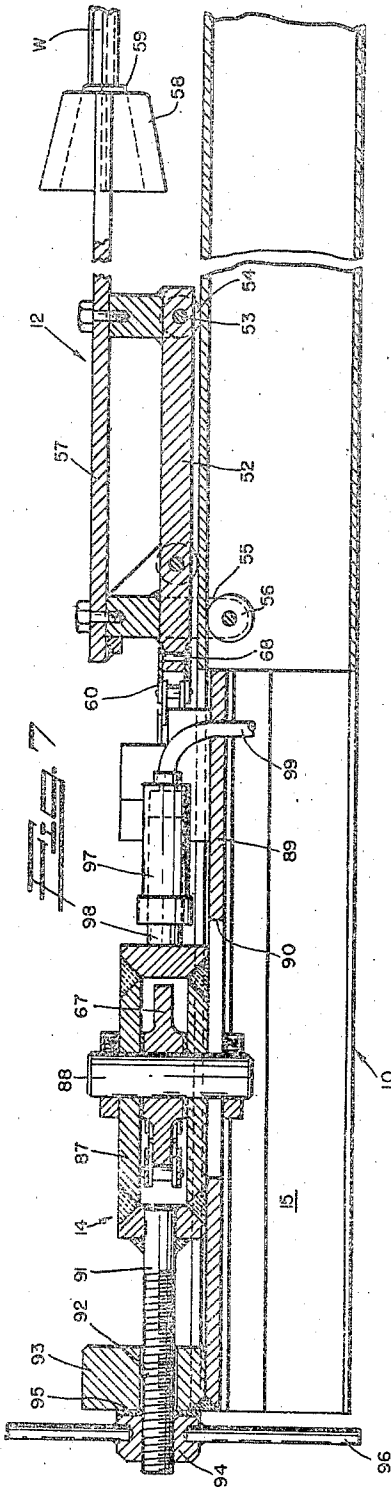
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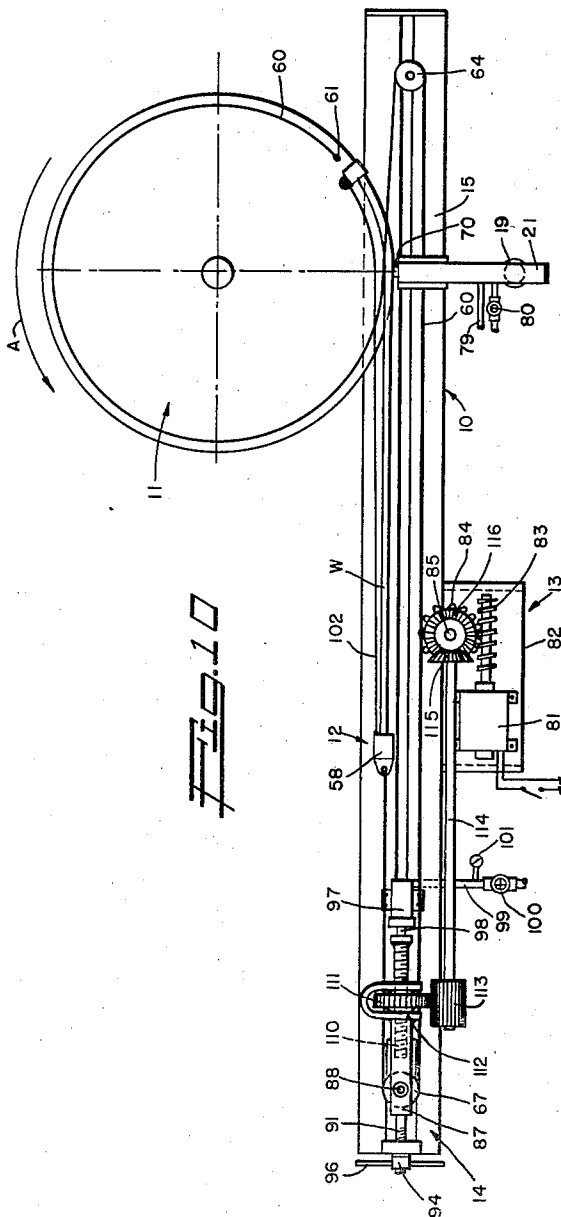
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UNITED STATES PATENT OFFICE

2,412,731

STRETCH FORMING MACHINE

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16 Claims. (Cl. 153—40)

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This invention relates to devices for shaping or forming metal parts, and has particular reference to machines for stretch forming preformed sections of aluminum alloys such as channels and extrusions and other elongate parts.

Various devices and methods have been proposed for stretch forming elongate metal parts. Difficulty has been experienced in obtaining satisfactory uniform results with such machines owing to the fact that the parts spring back to a considerable extent following the forming operations. To compensate for this spring-back, it has been necessary to "scale" or proportion the forming surfaces of the machine in such a manner that the formed part will have the desired dimensions and contour subsequent to the spring-back. This scaling of the forming surfaces complicates the designing of the machine and materially increases its cost.

It is an important object of the invention to provide a machine for stretch forming parts which eliminates or minimizes the spring-back of the parts. In the machine of the present invention, the spring-back is overcome or is reduced to the extent that it is unnecessary to compensate for it in most cases in the design of the forming block. As a result, a substantial saving is effected in the designing and manufacturing of the machine.

Another object of the invention is to provide a machine of the character referred to embodying means for effecting a predetermined progressive rate of increase of stretch of the work part as the bending or forming occurs. This increased stretching puts the entire cross-sectional area of the part under a tension exceeding the elastic limit, during the forming, so that substantially all the residual elastic stresses are eliminated and the resultant spring-back avoided. The tensioning of the entire cross-sectional area of the part also eliminates the tendency for the inner side of the part to distort or buckle as a result of compression.

Another object of the invention is to provide a stretch forming machine that is operable to stretch form particularly long workpieces through substantially 360°. While not restricted in its application to the character or length of the work, the machine of the invention is particularly well suited to form the tension rings or circumferential bulkhead rings of airplanes and similar elongate parts of substantial length.

A further object of the invention is to provide an effective stretch forming machine that may

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be readily adjusted to handle work parts having wide ranges of proportions, curvatures, etc.

Other objects and features of the invention will be readily understood from the following detailed description of typical preferred forms of the invention wherein reference will be made to the accompanying drawings in which:

Figure 1 is a plan view of a stretch forming machine of the invention;

Figure 2 is a diagrammatic or schematic view of the machine illustrated in Figure 1;

Figures 3 and 4 are enlarged transverse detailed sectional views taken as indicated by lines 3—3 and 4—4 respectively on Figure 1;

Figure 5 is an enlarged fragmentary vertical section of a portion of the form block showing the pressure member in elevation;

Figure 6 is a fragmentary horizontal sectional view taken as indicated by line 6—6 on Figure 5;

Figure 7 is an enlarged fragmentary vertical detailed sectional view taken as indicated by line 7—7 on Figure 1;

Figure 8 is an enlarged fragmentary vertical sectional view taken substantially as indicated by line 8—8 on Figure 1;

Figure 9 is a fragmentary vertical detailed sectional view taken as indicated by line 9—9 on Figure 8; and

Figure 10 is a diagrammatic plan view of another form of the invention.

The embodiment of the invention illustrated in Figures 1 to 9 inclusive may be said to comprise generally a supporting structure 10, a rotatable form block 11, means 12 for associating the workpiece W with the form block 11 to be stretch formed upon rotation thereof, means 13 for rotating the form block 11, and means 14 for imposing an initial tension on the workpiece.

The frame or supporting structure 10 may vary considerably in machines of different design, proportion, etc., and the invention is not to be considered as limited to the particular frame structure illustrated. As shown, the supporting structure has an elongate track or bed comprised of a pair of horizontal beams 15 carried by longitudinally spaced pedestals or supports 16. The beams 15 may be in the nature of I beams arranged with their intermediate webs in spaced vertical planes and their lower flanges may be suitably secured to the supports 16. The upper flanges of the beams 15 present broad supporting or working surfaces. The form block 11 is arranged adjacent one end of the elongate bed just described. In the particular machine illustrated, the form block 11 is horizontally disposed and

is positioned at one side of the bed. The supporting frame includes one or more beam members 17 projecting horizontally from the elongate bed adjacent one of its ends. The beam 17 is suitably secured to the adjacent beam 15 of the bed and is supported by spaced legs 18. A supporting pedestal 19 is arranged at the opposite side of the elongate bed in alignment with the beam member 17. The pedestal 19 may be constructed of pipe or tubular stock and has a lower horizontal arm 20 fixed to a beam 15 of the bed. A second arm 21 is fixed to the top of the standard or pedestal 19 and extends toward the form block 11 to project over the bed. The purpose of the pedestal 19 will be later described.

The form block 11 is the active work-shaping or forming element of the machine. The block 11 may be horizontally arranged as illustrated, or may, if desired, be mounted to occupy a vertical or inclined plane. In accordance with the invention, the form block 11 is supported for free rotation, and where the block is horizontally arranged it is mounted for rotation about a vertical axis. The beam member 17 above referred to carries an upstanding axle or trunnion 22 for supporting the form block 11. The trunnion 22 is fixed to a plate 23, which in turn, is secured to the beam 17. One of a plurality of spaced openings 24 in the member 17 receives the lower portion of the trunnion 22 and the plate 23 is secured to the beam member around the opening. The form block 11 has a hub 25 fixed to an elongate cup-like bearing member 26 freely rotatable on the trunnion 22. The end of the bearing member has a thrust bearing 27 engaging with the mounting plate 23. If desired, suitable anti-friction bearing means may be associated with the trunnion 22 and bearing member 26. The body 28 of the form block 11 is a flat disc-like element or assembly reinforced at its under side by a channel sectioned rim member 29. The form block 11 may be large in diameter and it is desirable to support it against tipping or deflection. One or more rollers 30 may be provided on the beam member 17 for engagement by the under surface of the rim member 29 to aid in supporting the form block and to prevent such tipping.

The body 28 of the form block 11 has a multiplicity of circumferentially spaced radial slots 31. The slots 31 extend inwardly from adjacent the periphery of the form block, and are preferably equally spaced around the block. Adjustable strips or blocks 32 carry spaced rods or bolts 33 and 34 which pass vertically through the slots 31. As shown in Figures 4 and 5, the two bolts 33 and 34 of each block 32 extend through the respective slot 31 of the block. Tubular spacers or bushings 35 extend through the vertical openings in the blocks 32 and washers 36 are provided under the heads and nuts 37 of the bolts. It will be seen that when the nuts 37 are loosened the blocks 32 may be adjusted radially on the form block 11. As shown in Figures 4 and 5, the outer edges of the adjustable blocks 32 are adjacent the rim or periphery of the form block, it being understood that the blocks may be adjusted inwardly as required in the particular stretch forming operation.

The form block 11 is further provided with segments 38 for receiving or acting on the workpiece W. The segments 38 are carried on the above described blocks 32 and are capable of limited radial adjustment with the blocks. As illustrated, each segment 38 is supported by three adjacent blocks 32. Openings 39 in the segments 38 receive

the outer bolts 34 and their bushings 35 whereby the segments are secured to the form block 11 by the bolts 34. The outer edge surfaces of the segments 38 are arcuate or curved so that the series of segments presents a continuous surface which is curved concentrically with the axis of rotation of the form block 11. The opposite ends of the segments 38 may be radial so that they may have flush engagement one with the other. The number of segments 38 employed depends upon the length of the curvature to be formed in the workpiece W. In the case illustrated, the series of segments 38 extends well over 200° around the form block 11. It is to be understood that the segments 38 are removable and are adapted to be replaced by segments shaped to form a curvature of any selected radius in the workpiece.

The curved or arcuate active faces of the segments 38 are preferably prepared to receive the workpiece W. The formation or configuration of the segments 38 will depend upon the character of the workpiece to be stretch formed. The particular workpiece W illustrated is substantially Z shaped in transverse cross section having a broad web and edge flanges extending in opposite directions therefrom. Slots or grooves 40 are provided in the active edges of the segments 38 to receive the workpiece W. The grooves 40 of the several segments 38 are aligned and register to constitute a continuous peripheral groove extending throughout the series of segments. The grooves 40 are formed and proportioned so that the web of the workpiece may lie against one side wall, with the inner workpiece flange engaged with the bottom wall of the groove. The outer flange of the workpiece cooperates with the arcuate outer faces of the segments 38 and the faces of the segments may be stepped at 41 to receive the bead on the outer workpiece flange. The inner or bottom wall of the groove 40 is curved concentrically with the outer active surfaces of the segments 38. Figure 5 clearly illustrates the manner in which the workpiece W engages in the grooves 40 and conforms to the outer surfaces of the segments 38.

Work parts of the configuration illustrated, and workpieces of other cross sectional configurations may tend to distort or assume irregular cross sectional shapes as a result of the stretch forming operation. For example, in the particular case illustrated, the broad web of the workpiece W may tend to bulge, buckle or wrinkle when the work is stretch formed into the groove 40. In order to prevent this, I prefer to employ a spacer or filler 42. The filler 42 is adapted to occupy that portion of the groove 40 which is not filled or occupied by the workpiece W. In practice the filler 42 may be a strip of wood or other material having considerable flexibility. Multiplicities of spaced notches or slots 43 of substantial depth are formed in the inner edge of the filler 42 to increase the flexibility of the filler. Superimposed strips 44 of wood, or the like, extend along the outer edge of the filler 42 and are secured thereto by nails 45, or the equivalent. The strips 44 add strength to the filler 42 and prevent it from cracking or breaking by reason of the deep slots 43. It is preferred to employ a minimum number of nails 45 or other securing members in the outermost strip 44. The filler 42 and its reinforcing strips 44 are proportioned to completely occupy that portion of the groove 40 not filled by the workpiece W and the surface of the outer strip 44 may lie substantially flush

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with the surface of the outer edge flange on the workpiece. This is clearly illustrated in Figure 5. It will be observed that the surface of the workpiece flange is free and exposed at the face of the series of segments 38.

The particular segments 38 illustrated are proportioned and arranged to impart a curvature of maximum radius to the stretch formed work. In the event that it is desired to give the work a curvature of small radius the form block 11 is adjusted or moved to have its axis of rotation closer to the elongate bed of the supporting means 10 and suitable segments of the required contour are secured in the correct positions on the form block. The broken lines in Figure 1 show the form block 11 arranged with its axis of rotation relatively close to the elongate bed of the supporting structure, and illustrates a series of segments on the block presenting a forming surface of relatively small radius. The supporting bed is cut away as at 8 to allow such adjustment of the form block 11. There may be a plurality of form block mounting stations comprising spaced openings 24 in the beam member 17 and the machine may be equipped with several sets or series of segments 38 of graduated radii whereby the machine is adapted for the formation of any stretch formed curvature within its extreme ranges of operation. In this connection, it is to be understood that the segments 38 are radially adjustable to some extent on the form block 11, to give the machine a substantial flexibility of adjustment.

The means 12 for associating the workpiece W with the form block 11 for stretch forming thereby includes a holding device or grip 46 for releasably securing the workpiece to the block. This grip 46 includes a housing having upper and lower plates 47 which engage about the end portion of the segment 38 that is foremost relative to the direction of active rotation of the form block 11. The grip housing plates 47 may be secured to the form block 11 by the endmost bolts 33 and 34 of the segment. A pair of blocks 48 having opposing convergent surfaces 49 is fixed in the grip housing. Gripping wedges 50 conform to and slide on the surfaces 49, and have opposing surfaces 51 shaped to conform to the workpiece W. The surfaces 51 may be serrated or roughened to effectively grip the same. The workpiece W is readily engaged between the wedges 50, and when tension is applied to the work the wedges 50 are automatically actuated by the convergent surfaces 49 to grip the work. While I have shown automatically energized mechanical grip means, it is to be understood that other suitable forms of grips may be employed if desired. As shown in Figure 8 of the drawings, the grip 46 is located at the forward end of the groove 40 relative to the active direction of rotation of the form block 11, and arranged so that the work extending from it immediately enters the groove 40.

The end of the workpiece W which is remote from the form block 11, prior to the stretch forming operation, is operatively connected with a carriage or traveler 52 movable along the elongate horizontal bed of the supporting structure 10. The carriage 52 is capable of riding or moving along the upper flange of one of the beams 15 and comprises a horizontally disposed body equipped with axles 53 carrying freely rotatable wheels 54. The pairs of wheels 54 roll along the top of the beam 15. Lugs or ears 55 depend from the opposite sides of the carriage 52 and

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carry rotatable wheels or rollers 56 which engage the under side of the upper beam flange to prevent displacement of the carriage from the beam. A plate 57 is secured to the upper side of the carriage 52 and projects forwardly from the carriage. The forward end of the plate 57 carries a grip 58 for releasably connecting the workpiece W with the movable carriage 52. The grip 58 may be of the self-energizing type, and may be similar to the above described grip 46, having a pair of wedges 59 for gripping the workpiece when the assembly is put under tension.

The means for actively associating the workpiece W with the form block 11, further includes a flexible element secured at one end to the form block, to be wrapped thereon when the block is rotated, and secured at its other end to the carriage 52, which in turn is connected with the free end of the workpiece W. This flexible element may be a rope, wire, cable or chain. In the particular embodiment of the invention illustrated, the flexible element is in the nature of a chain 60. The chain 60 has one end anchored or fixed to the form block 11 at 61 adjacent or beyond the trailing end of the series of segments 38 relative to the direction of active rotation of the form block as indicated by the arrow A in Figure 1. The chain 60 is wrapped or trained about the form block 11 to cooperate with the forward edges of its radially disposed plates or blocks 32.

The forward edges of the plates or blocks 32 are shaped to have effective cooperation with the chain 60. Chain locating notches 62 are provided in the edges of the blocks 32 and lugs 63 on the walls of the notches are operable to fit within the links of the chain 60; see Figures 4 and 5. The engagement of the multiplicity of the spaced blocks 32 with the chain 60 assures an adequate traction or drive relation between the form block 11 and the chain 60. It is important to note that I have shown the effective chain-engaging radius of the blocks 32 as being shorter than the effective radius of the work-receiving groove 40 of the segments 38. In Figure 2 the line B designates the effective chain-engaging radius of the blocks 32 and the line C represents the effective work-engaging radius of the segments 38. The differential in radii as indicated in Figure 2 results in the portion of the chain 60 leaving the form block 11 being made increasingly shorter in relation to the portion of the work W being drawn onto the form block and gradually increases the tension on the workpiece as the stretch forming operation progresses. This action and its purpose will be more fully described. It is to be understood that the differential in the radii B and C may be varied to suit different operations, and in some instances the radii may be identical.

The chain 60 passes tangentially from the form block 11 at or adjacent the elongate bed of the supporting structure 10 and extends along the top of the adjacent beam 15 to an idler or a direction changing sprocket 64. The sprocket 64 is rotatably carried by a vertical shaft 65 projecting from the supporting bed. The chain 60 engages substantially 180° around the sprocket 64 to continue longitudinally over the upper flange of the second beam 15. A suitable guard or safety housing 66 is preferably provided on the beam 15 to enclose the major portion of the chain 60. The chain 60 extends from the sprocket 64 to a second direction changing sprocket 67 located adjacent the opposite end of the supporting bed. The chain 60 passes substantially 180° around

the sprocket 67 to return over the top of the supporting bed to the above described carriage 52. The chain 60 is suitably secured to the carriage at 68. The sprocket 67 is supported by the means 14 to rotate about a generally vertical axis as will be hereinafter described. It is to be observed that the chain 60, the workpiece W and the intervening carriage 52 constitute a continuous flexible assembly having its opposite ends secured to the rotatable form block 11. Upon imparting axial movement to this loop-like assembly, the form block 11 is rotated in the direction A to draw the work W onto it for forming thereby. The means 13, to be later described, imparts the longitudinal movement to the chain and workpiece linkage or assembly.

In order to assure proper contact of the workpiece W with the form block segments 38 and to assure correct forming of the work to the contour of the segments, it is desirable to employ a pressure foot or pressure member 70 for acting on the work as it moves onto the segments. The pressure member 70 is carried by a block 71, which in turn is guided for horizontal movement toward and away from the form block 11; see Figure 4. The shiftable block 71 is directed for horizontal movement in a direction radially with respect to the form block 11 by a suitable guide 72 on the under side of the pedestal arm 21. The pressure member 70 is a generally cylindrical roller-like part engaged in a correspondingly shaped notch or recess 73 in the forward end of the block 71. The member 70 is supported and retained for partial rotation in the recess. Discs 74 are secured to the block 71 at the ends of the recess 73 and carry a shaft 75 for retaining the pressure member 70. The cylindrical surface of the pressure member 70 may directly bear on the wall of the recess 73 and the shaft 75 need not assume the heavy active loads. The pressure member 70 has a chordal surface 76 for contacting the workpiece W. The surface 76 is capable of automatically conforming to the exposed flange of the workpiece W even in situations where the flange is pitched or irregular. Rollers 9 may be rotatably mounted in the member 70 to be exposed at the surface 76 to engage the work part. The rollers 9 will reduce the friction between the pressure member 70 and the work part W.

Means is provided for maintaining the pressure member 70 in effective pressure engagement with the workpiece W as it moves onto the form block 11. This means comprises a cylinder and piston mechanism 77 secured to the standard 19 under the arm 21. The piston rod 78 of the mechanism 77 is operatively connected with the block 71. Fluid pressure lines 79 connect with the cylinder of the mechanism 77 and the mechanism is under the control of a suitable manually operable valve 80. The mechanism 77 forces the pressure member 70 against the workpiece under a constant or uniform pressure during the stretch forming operation.

The actuating means 13 is operable to impart axial movement to the chain 60 to produce rotation of the form block 11 and to cause the workpiece W to be drawn onto the block for forming thereby. As described above, the chain 60, the workpiece W, and the carriage 52 constitute a continuous loop-like assembly whose opposite ends are connected to the form block 11 so that axial movement imparted to the chain 60 in the direction of the arrow D in Figure 2 produces rotation of the form block 11 in the direction A. The means 13 may comprise any selected or suit-

able form of prime mover or power means. In the particular form of the invention illustrated, this power means comprises an electric motor 81 mounted on a suitable support 82 on one side of the elongate supporting bed. The motor shaft carries or drives a worm 83. The worm drives a sprocket 84 carried by a vertical shaft 85 mounted on the support 82. The protective housing 66 for the chain 60 is interrupted at the sprocket 84 and the sprocket has meshing or driving engagement with the chain. Spaced idler sprockets 86 are rotatably mounted on the supporting bed to cooperate with the chain 60 at longitudinally spaced points to hold it in proper engagement with the driving sprocket 84. It will be understood how the motor driven sprocket 84 operates to advance the chain 60 in the direction D to rotate the form block 11 so that the work W is drawn onto the block. In this connection it will be noted that the differential in the radii B and C results in the work W being drawn onto the form block 11 more rapidly than the chain 60 leaves the block. This differential in movement results in a gradual increase in the tension on the workpiece W, this action continuing throughout the stretch forming operation.

The means 14 is operable to impose an initial tension on the work W preparatory to the actual stretch forming operation and is preferably operable to maintain the initial tension or vary the tension as conditions may require during the forming of the work. The means 14 includes a bracket or slide 87 carrying the above referred to sprocket 67; see Figure 7. The vertical shaft 88 of the sprocket 67 has its opposite end portions supported by the slide 87 and the shaft projects beyond the lower side of the slide. The bracket or slide 87 is an open sided box-like structure containing the sprocket 67 and the chain 60 enters and leaves its opposite open sides. A plate 89 is fixed to the beams 15 of the supporting bed and the slide 87 is engaged on the upper surface of the plate for free sliding movement longitudinally of the bed. A longitudinal slot 90 in the plate 89 receives the projecting lower portion of the sprocket shaft 88 to assist in guiding the slide 87 and to limit its axial movement.

The means 14 further includes screw thread means for moving or advancing the slide 87 to tension the workpiece W. This means includes a threaded stud or screw 91 fixed to the slide 87 as by welding. The screw 91 projects from the end of the slide 87 and passes freely through an opening 92 in a flange or block 93 fixed on the end of the supporting bed. A nut 94 is threadedly engaged on the screw 91 to react or bear against the block 93. In practice a washer 95 may be interposed between the nut 94 and the block 93. Radially projecting handles or levers 96 are provided on the nut to facilitate its manual operation. It will be seen that when the nut 94 is rotated in one direction the slide 87 is drawn toward the block 93 to tension the workpiece W connected between the chain 60 and the form block 11 and to incidentally tension the chain. The screw 91 and nut 94 thus constitute a means for initially tensioning the workpiece prior to the actual stretch forming operation, and if desired, the nut 94 may be subsequently operated to increase or reduce the tension on the workpiece as desired during the actual stretch forming operation.

The tensioning means 14 also preferably includes a fluid pressure actuated mechanism 97 for imposing tension on the workpiece W, where-

by the tensile strain may be conveniently varied at will during the stretch forming of the work. The cylinder and piston mechanism 97 is suitably fixed to the plate 89, or to other structure on the supporting bed 10, and its piston or ram 98 may act directly on the inner end of the slide 87. A pipe or line 99 carries the actuating fluid pressure to the inner end of the cylinder and piston mechanism 97. A manually operable valve 100 controls the line 99 and is preferably such that the pressure exerted on the ram 98 may be readily and precisely controlled. A pressure gauge 101 may be connected in the line 99 to indicate the pressure exerted on the ram 98 and thus disclose the tension being imposed on the workpiece W.

The invention preferably includes means for restoring or returning the form block 11, chain 60 and carriage 52 to their initial positions subsequent to the work forming operations. This means comprises a pullback line or cable 102 attached to the form block 11. Notches 103 in the edges of the blocks 32 receive and guide the cable as it is wrapped on the form block during stretch forming of the workpiece; see Figure 5. The cable 102 extends from the form block 11 and its outer end is connected to the movable carriage 52. The cable is readily accessible at the top of the supporting bed to be grasped and pulled to restore the form block 11, chain 60 and carriage 52. A prime function of the cable 102 is to serve as a safety means to prevent sudden rotation of the form block 11 in the event the work part W breaks while under tension.

To prepare for the stretch forming operation, the ends of the workpiece W are engaged in the grips 46 and 58 in the position to correctly enter the groove 40 of the form block segments 38. At this time the pressure member 70 is in the retracted position. The filler 42 is associated with the workpiece and started in the groove 40. At this stage of the operation, the grip 46 on the form block 11 is adjacent the pressure member 70. With the workpiece engaged in the grips 46 and 58, the pressure member 70 is actuated against the workpiece by supplying fluid pressure to the mechanism 77 and the nut 94 is rotated to impose the initial tension on the workpiece W. The automatic grips 46 and 58 are actuated by this initial tensioning of the work. The actuation of the nut 94 may apply the full initial tension to the workpiece or the mechanism 97 may be utilized to assist in imposing the initial tension. In either case, this initial tension while relatively low is sufficient to put the metal of the workpiece in the plastic condition for ready forming to the contour of the form block segments 38.

With the workpiece W conditioned as above described, the motor 81 is put into operation to advance the chain 60 and rotate the block 11 in the direction A. The tensioned work is drawn onto the rotating form block 11 to be shaped or formed to the contour of the groove 40, which in the instance illustrated, has a cylindrical curvature. It is to be understood that all fibers of the workpiece are in tension at the commencement of the forming operation. The combination of the bending and tensile forces effectively forms the work to the active shaping surfaces of the form block segments 38.

Owing to the configuration of the workpiece W and the curvature being imparted thereto, the fibers in the outer zones of the workpiece are more highly tensioned than the fibers in the inner zones, the terms "inner" and "outer" here hav-

ing reference to the axis of rotation of the form block 11. The invention automatically provides for sufficient tensioning of the fibers of the inner zones of the workpiece without tensioning the outer fibers beyond the maximum limit, thereby eliminating wrinkling or other distortion of the inner sides of the workpiece, and more important, completely eliminating or reducing to a minimum, the spring-back that is often present in other stretch forming procedures.

In accordance with the invention, it may be preferred that the tension on the workpiece be accelerated or continuously increased as the operation progresses; thus continuously increasing tension acting to maintain the fibers in the inner zones of the workpiece under tension without unduly tensioning the fibers in the outer zones. The continuously increased tension imposed on the workpiece throughout the forming operation assures the maintaining of the fibers in the inner zone of the workpiece under sufficient tension to eliminate or minimize spring-back. The increased elongation of the workpiece and the accelerated stretching of its inner fibers are produced by releasing the chain 60 from the smaller radius B of the form block while simultaneously drawing the workpiece onto the larger radius C. The chain releasing radius B, being shorter than the work forming radius C, causes the portion of the chain 60 leaving the form block to be increasingly shorter in relation to the unformed portion of the workpiece W being drawn onto the block. Further, the portion of the tensioned workpiece between the form block 11 and the outer grip 52 is increasingly shorter as the operation progresses and this further results in increasing the tensile strain on the workpiece. These two factors or actions assure the application of sufficient tension to the inner fibers of the workpiece throughout the entire stretch forming operation to maintain these fibers under sufficient tension to eliminate spring-back, or to reduce spring-back to an absolute minimum. In practice, I have found that by employing a proper relation between radii B and C no, or only negligible, spring-back occurs in many cases, and as a result it is unnecessary to take spring-back into consideration when designing the form block 11. This materially reduces the cost of designing and fabricating the block. The machine of the invention assures uniform results even when handling work parts that necessitate designing or proportioning the form block to compensate for spring-back. The mechanism 97 and/or the nut 94 may be employed to vary the tensile strain on the workpiece W at any phase of the operation. When the form block 11 has been rotated to draw substantially the entire workpiece W onto the segments 38, the motor 81 is deenergized and the formed workpiece is removed from the machine. The cable 102 may then be employed to restore the parts to their original positions for the next forming operation. The machine when employed as just described, is operable to uniformly stretch form parts with no residual spring-back or with only negligible spring-back, and uniform results are consistently obtainable.

Figure 10 schematically illustrates another form of the invention in which the continued increase in the tension on the workpiece W during the forming operation is obtained by an automatic means supplementing or replacing the differential radii B and C of the form block. The differential in the radii B and C of the work and chain receiving surfaces of the block 11 may

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be maintained as Figures 1 to 9, may be reduced, or may be eliminated so that the radii are equal. The general construction of the machine may be the same as above described and corresponding reference numerals are applied to corresponding parts. In this form of the invention, the screw 91 at the outer end of the slide, together with its actuating nut 94, may be retained and the cylinder and piston mechanism 97 may also be included in the machine. A screw 110 is held against rotation by a sliding connection with the ram 98 and its opposite end is slidably associated with the slide 87. A nut 111 threadedly engages the screw 110 and is engaged between spaced flanges 112 secured to the pulley supporting slide 87. Upon rotation of the nut 111, the screw 110 and slide 87 are moved longitudinally of the supporting bed. The ram 98 of the mechanism 97 may act against the inner end of the screw 110 so that the mechanism may advance the pulley slide 87 through the medium of the screw. The periphery of the nut 111 is in the form of a gear which meshes with a pinion 113.

Any suitable or selected means may be employed to drive the pinion 113 at a given rate relative to the rate of advancement of the work W onto the form block 11. I have shown the pinion 113 keyed or fixed to one end of a shaft 114. A beveled gear 115 is fixed to the opposite end of the shaft to mesh with a mating gear 116 formed on or rotating with the sprocket 84. With a selected pitch of the threads on the screw 111 and a selected ratio in the gearing, the slide 87 may be moved at a speed to produce the desired gradual increase in the tension in the workpiece W. When the sprocket 84 is motor driven during the stretch forming operation, the nut 111 is rotated through the medium of the gearing, and rotation of the nut produces translation of the slide 87 in an outward direction. This outward travel of the slide 87 increases the tension on the workpiece. The unformed portion of the workpiece between the form block 11 and the grip 58 becomes increasingly shorter as the operation progresses. This factor, coupled with the automatic outward movement of the tensioning sprocket 67 and the optional actuation of the nut 94 and mechanism 97 amplifies the tensile strain imposed on the workpiece and maintains the inner fiber of the workpiece under tension throughout the entire forming operation to prevent spring-back. The cylinder and piston mechanism 97 may be employed to supplement the action of the gear and screw thread means or may be utilized independently of the gear and screw thread means to obtain a constant, variable or increasing tension on the workpiece during the stretch forming operation. The mechanism 97 may be readily operated or governed by the valve 100 or other suitable valve mechanism.

During operation of both forms of the invention herein disclosed sufficient tension may be imposed on the part being formed or bent to maintain its entire cross-sectional area under a tensile strain exceeding the elastic limit of the material to bring about the permanent "stretch forming" of the part and the accelerated or increasing tension operating as above described eliminates or reduces to a minimum the undesirable spring-back.

Having described only typical forms of the invention, I do not wish to be limited to the specific details herein set forth, but wish to reserve to myself any variations or modifications that

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may appear to those skilled in the art or fall within the scope of the following claims.

I claim:

1. A stretch forming machine comprising a rotatable form block having a curved forming surface and a second surface means closer to the axis of rotation of the block than the forming surface, means for associating an elongated workpiece with the form block to be drawn onto said forming surface and formed thereto when the block is rotated, and means for rotating the form block and tensioning the workpiece as the block rotates, including an element connected between the block and a part of the workpiece which is remote from the block and trained over said second surface means to be unreel'd therefrom as the block rotates.

2. A machine of the character described comprising a rotatable form block having a forming surface and a second surface means closer to the axis of rotation of the block than the forming surface, means for engaging an elongated workpiece to be formed with the forming surface, the block being rotatable to form the part, and means for tensioning the part operable to increase the tension as the workpiece is formed by said surface, the last named means comprising a flexible element wrapped on said second surface means and connected with the form block and a point on the workpiece remote from the block to be unwrapped from said second surface means as the block rotates.

3. A machine of the character described comprising a form block having a forming surface, means for engaging an elongated workpiece with the block, the block being rotatable to cause said surface to form the workpiece, and means for tensioning the workpiece and operable to increase the tension as the workpiece is formed by said surface upon rotation of the block, the last named means comprising a second surface on the block substantially coaxial with the forming surface and closer to the axis of rotation of the block than the forming surface, and a flexible element connected between the block and a portion of the workpiece remote from the block and wrapped on the second surface to unwrap therefrom at a rate slower than the rate at which the workpiece is formed on said surface.

4. A machine of the character described comprising a rotatable form block having a curved forming surface and a second curved surface, said surfaces being substantially concentric with the axis of rotation of the block, the radius of curvature of the second surface being shorter than the radius of curvature of the forming surface, means for connecting an elongated part to be formed with the block to be drawn onto and formed by the forming surface upon rotation of the block, and means for tensioning the part and operable to increase the tension thereon as the block rotates to form the part, the last named means including a flexible element connected with the portion of said part remote from the block, secured to the block and wrapped on the second surface of the block to be unwrapped therefrom as the part is drawn onto the forming surface.

5. A machine of the character described comprising a rotatable form block having a curved forming surface and a second curved surface, said surface being substantially concentric with the axis of rotation of the block, the radius of curvature of the second surface being shorter than the radius of curvature of the forming surface, means for connecting an elongated part to be formed

with the block to be drawn onto and formed by the forming surface upon rotation of the block, and means for tensioning the part and operable to increase the tension thereon as the block rotates to form the part, the last named means including a flexible element connected with the portion of said part remote from the block, connected with the block and wrapped on the second surface of the block to be unwrapped therefrom as the part is drawn onto the forming surface, and means for acting on said element to impose an initial tension on the part.

6. A machine of the character described comprising a rotatable form block having a curved forming surface and a second curved surface, said surfaces being substantially concentric with the axis of rotation of the block, the radius of curvature of the second surface being shorter than the radius of curvature of the forming surface, means for connecting an elongated part to be formed with the block to be drawn onto and formed by the forming surface upon rotation of the block, and means for tensioning the part and operable to increase the tension thereon as the block rotates to form the part, the last named means including a flexible element connected with the portion of said part remote from the block, connected with the block and wrapped on the second surface of the block to be unwrapped therefrom as the part is drawn onto the forming surface, and means for acting through the medium of the element to impose an initial tension on the part and operable to vary the tension on the part as it is drawn onto the forming surface.

7. A machine of the character described comprising a rotatable form block having a curved forming surface and a second curved surface, said surfaces being substantially concentric with the axis of rotation of the block, the radius of curvature of the second surface being shorter than the radius of curvature of the forming surface, means for connecting an elongated part to be formed with the block to be drawn onto and formed by the forming surface upon rotation of the block, and means for tensioning the part and operable to increase the tension thereon as the block rotates to form the part, the last named means including a flexible element connected with the portion of said part remote from the block, connected with the block and wrapped on the second surface of the block to be unwrapped therefrom as the part is drawn onto the forming surface, and screw thread means for exerting an initial tension on the part.

8. A machine of the character described comprising a rotatable form block having a curved forming surface and a second curved surface, said surfaces being substantially concentric with the axis of rotation of the block, the radius of curvature of the second surface being shorter than the radius of curvature of the forming surface, means for connecting an elongated part to be formed with the block to be drawn onto and formed by the forming surface upon rotation of the block, and means for tensioning the part and operable to increase the tension thereon as the block rotates to form the part, the last named means including a flexible element connected with the portion of said part remote from the block, connected with the block and wrapped on the second surface of the block to be unwrapped therefrom as the part is drawn onto the forming surface, and screw thread means acting through the medium of said element for imposing an initial tension on the part.

9. A machine of the character described comprising a rotatable form block having a curved forming surface substantially concentric with the axis of rotation, means for connecting an elongated part to be formed with the block to be drawn onto and formed by said surface upon rotation of the block and means for rotating the block and for tensioning the part during such rotation including a flexible element connected between the block and the portion of the part remote from the block, means for exerting a longitudinal pull on the element to rotate the block, and means acting on the element to tension the part comprising surface presenting means on the block substantially concentric with the axis of rotation of the block on which the element is wrapped and having an effective radius which is shorter than the effective radius of said forming surface, the element being unwrapped from said surface means as a result of said pull.

10. A machine of the character described comprising a rotatable form block having a forming surface curved generally about the axis of rotation of the block, means for connecting an elongated part to be formed with the block to be drawn onto and formed by said surface upon rotation of the block and means for rotating the block and for tensioning the part during such rotation including a second surface means on the block closer to the axis of rotation of the block than the forming surface and curved generally about said axis, a flexible element connected between the block and the portion of the part remote from the block and reeled on said second surface means to unreel therefrom upon rotation of the block in a direction to draw said part onto the forming surface, means acting on the element to rotate the block in said direction, and means acting on the element to tension the part comprising a fluid pressure actuated part movable to tension the element and part.

11. A machine of the character described comprising a rotatable form block having a curved forming surface curved generally about the axis of rotation of the block, means for connecting an elongated part to be formed with the block to be drawn onto and formed by said surface upon rotation of the block and means for rotating the block and for tensioning the part during such rotation including a second surface means on the block closer to the axis of rotation of the block than the forming surface and curved generally about said axis, a flexible element connected between the block and the portion of the part remote from the block and reeled on said second surface means to unreel therefrom upon rotation of the block in a direction to draw said part onto the forming surface, means acting on the element to rotate the block in said direction, and means acting on the element to tension the part comprising a sprocket for driving the element and means for moving the sprocket.

12. A machine of the character described comprising a rotatable form block having a curved forming surface curved generally about the axis of rotation of the block, means for connecting an elongated part to be formed with the block to be drawn onto and formed by said surface upon rotation of the block and means for rotating the block and for tensioning the part during such rotation including a second surface means on the block closer to the axis of rotation of the block than the forming surface and curved generally about said axis, a flexible element connected between the block and the portion of the part re-

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mote from the block and reeled on said second surface means to unreel therefrom upon rotation of the block in a direction to draw said part onto the forming surface, means acting on the element to rotate the block in said direction, and means driven by the last named means and acting on the element to tension the part.

13. A machine of the character described comprising a rotatable form block having a curved forming surface curved generally about the axis of rotation of the block, means for connecting an elongated part to be formed with the block to be drawn onto and formed by said surface upon rotation of the block and means for rotating the block and for tensioning the part during such rotation including a second surface means on the block closer to the axis of rotation of the block than the forming surface and curved generally about said axis, a flexible element connected between the block and the portion of the part remote from the block and reeled on said second surface means to unreel therefrom upon rotation of the block in a direction to draw said part onto the forming surface, means acting on the element to rotate the block in said direction, and means acting on the element to tension the part comprising a movable sprocket engaging the element, and screw thread means actuated by the block rotating means for moving the sprocket.

14. A machine of the character described comprising a rotatable form block having a forming surface curved generally about the axis of rotation of the block, means for connecting an elongated workpiece with the block to be drawn onto and formed by said surface upon rotation of the block and means for rotating the block and for tensioning the workpiece during such rotation including a flexible element connected between the block and the workpiece, means acting on the element to rotate the block,

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and means acting on the element to tension the workpiece comprising surface presenting means on the block curved generally about the axis of rotation of the block on which the element is wrapped and having an effective radius which is shorter than the effective radius of said forming surface, and means acting on the element for varying the tension on the workpiece during rotation of the block.

15. A machine of the character described comprising a rotatable form block having a forming surface and a second surface, the surfaces being curved about the axis of rotation of the block, a flexible element having one end connected with the form block and being wrapped on said second surface, means for connecting the other end of the element with one end portion of an elongated workpiece, means for connecting the other end portion of the workpiece with the form block so that the workpiece is drawn onto the forming surface upon rotation of the block, and means associated with the element for rotating the block to cause the workpiece to be formed by the block.

16. A machine of the character described comprising a rotatable form block having a forming surface and a second surface, the surfaces being curved about the axis of rotation of the block, a flexible element having one end connected with the form block and being wrapped on said second surface, means for connecting the other end of the element with one end portion of an elongated workpiece, means for connecting the other end portion of the workpiece with the form block so that the workpiece is drawn onto the forming surface upon rotation of the block, means for rotating the block to draw the workpiece onto the forming surface, and means associated with the element for tensioning the workpiece as it is formed.

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