Sept. 8, 1964 C. F. HAUTAU 3,147,792

TUBE AND BAR BENDING MACHINERY

Filed Sept. 25, 1961 3 Sheets-Sheet 1

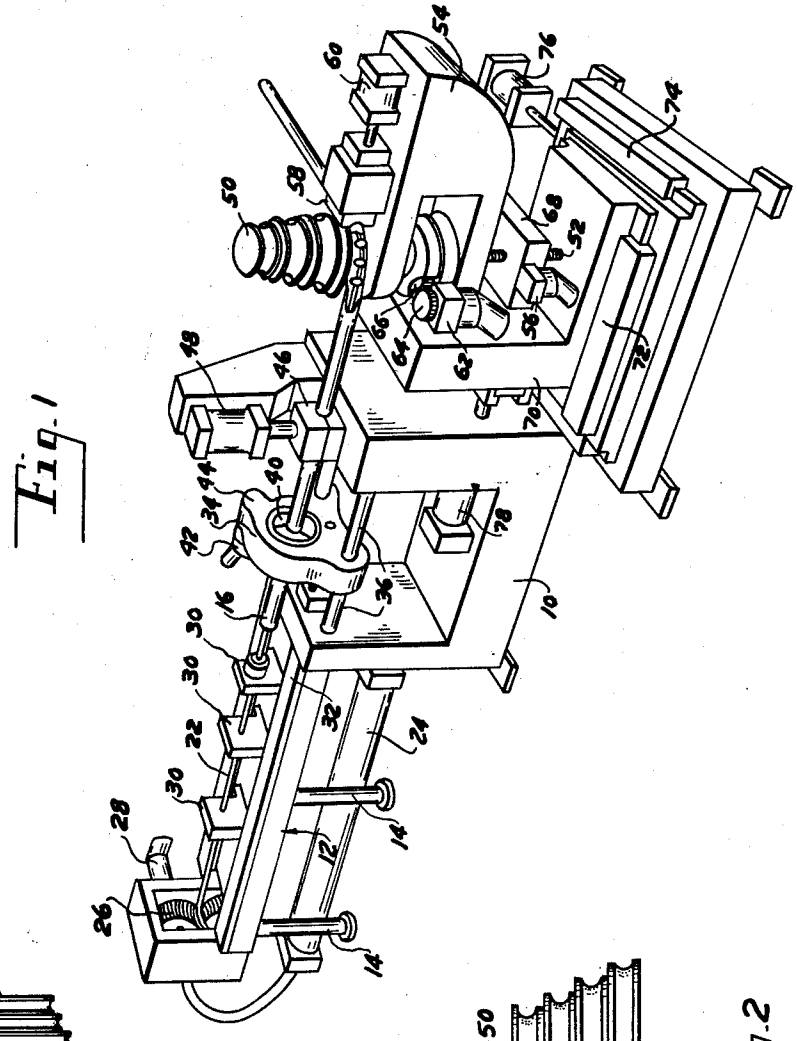


Fig. 1

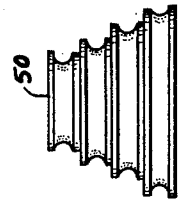


Fig. 2

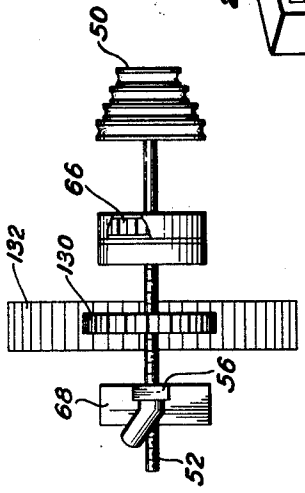


Fig. 3

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TUBE AND BAR BENDING MACHINERY

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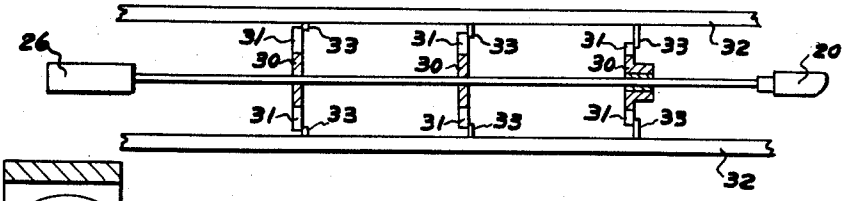


Fig. 3

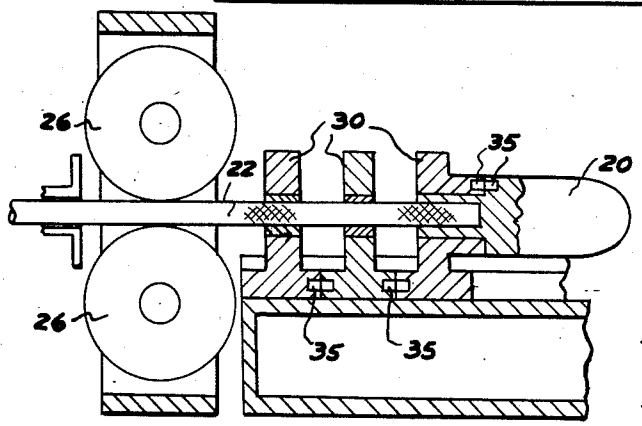


Fig. 4

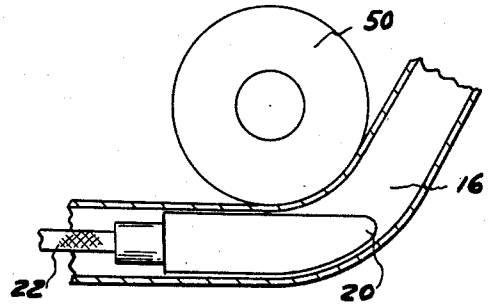


Fig. 5

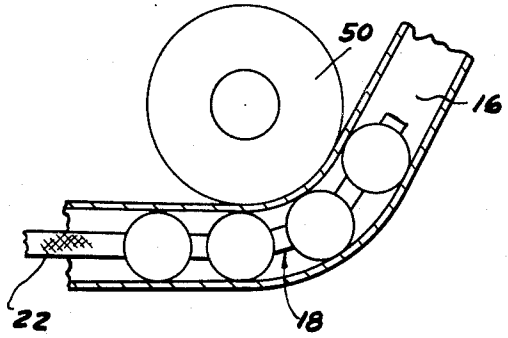


Fig. 6

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TUBE AND BAR BENDING MACHINERY

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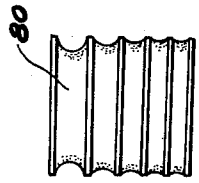


Fig. 8

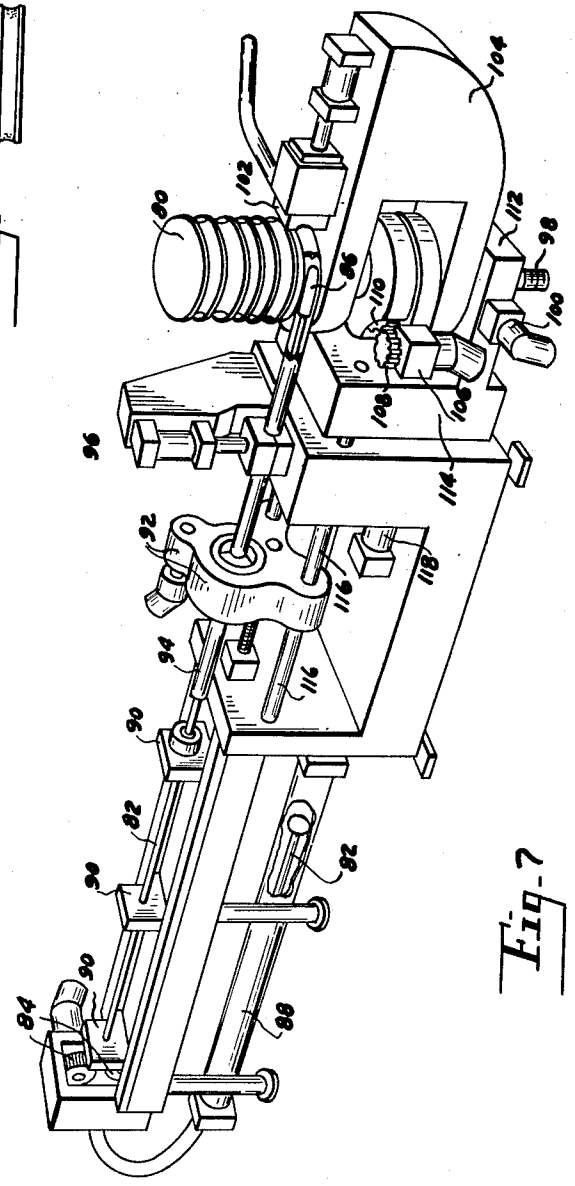


Fig. 7

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TUBE AND BAR BENDING MACHINERY

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8 Claims. (Cl. 153—46)

This invention relates to a machine for bending tubing and more particularly to apparatus for bending tubing by stretching it beyond the yield strength but below the ultimate strength of the tube material.

One method of bending tubing involves forcing the tubing about a form by means of a wiper bar. Due to the tendency of the metal on the inside face of the bend to buckle or wrinkle and since such wrinkling depends on the ratio between pipe diameter and wall thickness, this conventional method is limited as to the size and type of tubing which may be successfully bent. One method of preventing such wrinkling is to simultaneously bend the metal and stretch it beyond its yield or elastic limit but below its ultimate or breaking strength. When stretched beyond its yield strength, metal becomes plastic and is readily bent to new shapes. By stretch forming tubing, therefore, the plasticity of the metal above its yield strength is utilized to prevent wrinkling or buckling of the tube walls. In addition, this cold working of the metal work hardens it and results in a substantial increase in the strength and hardness of the material.

The present invention contemplates a device for simultaneously stretching the tubing beyond its yield strength and bending the tubing about an annular form through a desired arc distance. In two preferred embodiments of the present invention which will subsequently be described in detail, the workpiece is placed in the machine and positioned for bending by a series of clamps and hydraulic motors in a manner similar to that described in my pending application Serial No. 16,846. After the workpiece is firmly clamped in position so as to prevent movement along its axis, a bending clamp locks the tube against an annular form and both the clamp and form rotate about the axis of the form. A hydraulic cylinder resists the tendency of the form and bending clamp to "walk" back along the tube. The tubing is therefore stretched as it is bent around the form. The cylinder is set to allow such "walking" only when the force exerted on the tube is in excess of the yield limit but less than the ultimate limit of the metal.

It is therefore an object of this invention to provide means for simultaneously bending tubing and stretching it beyond the yield strength, but below the ultimate strength, of the tube material.

Another object of the present invention is to provide a machine having a series of rotatable bending forms, an arm which clamps the workpiece to the forms, means for clamping the tubing to prevent longitudinal movement, means for rotating the form and the arm and means for preventing the forms and arm from "walking" back along the tube until a predetermined stress is exerted on the bent portion of the tubing.

Another object of this invention is to provide means for preventing the formation of wrinkles on the inside wall of the bend during bending operations.

A further object of the present invention is to provide means for work hardening the tubing during the bending operation.

Further objects of the present invention will be made apparent by the following detailed description wherein are disclosed two preferred embodiments of the present invention. The description makes reference to the accompanying drawings in which:

FIGURE 1 is a perspective view of one embodiment of the present invention.

FIGURE 2 is an elevational view of the bending forms shown in FIGURE 1.

FIGURE 3 is a detailed sectional view of a mandrel and support blocks which may be employed in either of the embodiments of the present invention subsequently described in detail.

FIGURE 4 is a detailed sectional view of a mandrel which may be employed in either of the embodiments of the present invention.

FIGURE 5 is a detailed sectional view of the mandrel of FIGURE 4.

FIGURE 6 is a detailed sectional view of a second mandrel which may be employed with either of the two embodiments of the present invention which will subsequently be described in detail.

FIGURE 7 is a perspective view of a second embodiment of the present invention.

FIGURE 8 is an elevational view of the bending forms shown in FIGURE 7.

FIGURE 9 is a detailed elevational view of an alternative embodiment of the means for preventing the forms and bending clamp from "walking" back along the tube.

With reference to the drawings, FIGURE 1 shows a preferred embodiment of the present invention. The machine is illustrated with the hydraulic and electronic systems removed for simplicity. These systems may be of a class well known to those skilled in the art and a particular variety is described in greater detail in my copending application Serial No. 16,846.

The machine is supported on a base 10 which may be welded plate construction. To the left of the machine, as shown in FIGURE 1, a pipe stand 12 which is supported on two legs 14 is adapted to support the pipe 16 as it enters the machine. A mandrel snake 18 or shoe 20 is attached to the end of a flexible cable 22 which may be constructed of small steel wires or of any suitable material such as will allow the cable 22 to take compressive forces over short lengths when it is stored, but will also be sufficiently flexible so as to allow the cable to easily conform to a large radius. The cable is stored in a storage tube 24 disposed parallel to the supporting structure of the machine. A pair of wheels 26, of suitable material so as to engage the cable 22, is powered by a hydraulic motor at 28.

The cable 22 is of such length that in its retracted position, the mandrel snake 18 or shoe 20 will be situated just short of the free end of the longest workpiece which the machine can accommodate. If the workpiece is of less than this maximum length, the mandrel 18 and its adjacent cable 22 will be required to move through some distance to reach the end of the pipe 16. To provide support for the cable 22 as it moves through this distance, and to guide it toward the interior of the pipe 16, a series of movable blocks 30 surround the cable 22 behind the mandrel 18 and move in a channel 32 disposed parallel to the extension of the tubing 16 and slightly below it. The guide blocks 30 are fitted with T extensions 31 of various widths which are accommodated by stops 33 extending perpendicularly from the flanges of the channel 32. When the cable 22 is initially energized to move the mandrel toward the free end of the tubing 16, the guide blocks 30 are moved forward by the attraction of magnets 35 sunk in the surfaces of the blocks 30 and the mandrel 18, as shown in FIGURE 4, and station themselves at regular intervals along the otherwise unsupported length of the cable 22 between its storage tube 24 and the tube to be bent. An alternative method of spacing the blocks 30 consists of utilizing a series of detent attachments between the guide blocks 30 and the cable 22.

The wheels 26 and the motor 28 are arranged so as to propel the mandrel 18 through the tubing to its normal station during the bending process. If a snake type man-

drel 18 (FIGURE 6) is employed, the snake 18 would have to project from the free end of the tube. If a shoe type mandrel 20 (FIGURE 5) is employed, the shoe 20 would be disposed with its end projecting just beyond the point at which bending begins.

A chuck 34, slidably mounted on slide rods 36, is positioned along the slide rods 36 by a hydraulic motor 38. The chuck 34 has jaws 40 which may be opened or closed by a hydraulic cylinder 42 or revolved by a hydraulic motor 44 by means of gears (not shown) in a manner well known to the art. A stationary clamp 46, operated by a hydraulic cylinder 48, locks the pipe in place during the bending operation.

The bending apparatus consists of a column of annular bending forms 50 of varying diameters mounted on a threaded shaft or screw 52, and an arm 54 fixed so as to rotatably move about the screw 52. As shown in FIGURE 2, each of the forms 50 permits a different radius of bend. A hydraulic motor 56 engages a gear (not shown) which is mounted on the screw 52 so that rotation of the motor 56 revolves the screw 52 and enables the desired bending form 50 to be moved vertically into position adjacent the pipe 16. A bending clamp 58, operated by a hydraulic cylinder 60, locks the workpiece firmly between the clamp 58 and the form 50. A hydraulic motor 62 rotates a pinion 64 which engages a gear 66 permanently affixed to both the forms 50 and the arm 54 in such a manner as to rotate the forms 50 and the arm 54 at the same rate. The screw 52 is located in a housing 68 which is permanently affixed to a slide block 70, slidably mounted in longitudinal ways 72. The entire assembly of forms 50, arm 54, slide block 70 and longitudinal ways 72, is slidably mounted in lateral ways 74 and may be moved in the lateral ways 74 by a hydraulic motor 76. The movement of the slide block along the longitudinal ways 72 is limited by a passive hydraulic cylinder 78 which is preset to prevent movement of the slide block 70 until the stress in the pipe 16 reaches a value in excess of the yield strength, but less than the ultimate strength, of the pipe material.

In operation, the arm 54 is swung to its open position perpendicular to the axis of the pipe 16, with the bending clamp 58 in an open position. The bending forms 50 are raised or lowered until the form having the desired radius of bend is at the same elevation as the pipe 16. The entire assembly of forms 50, arm 54, slide block 70, and longitudinal ways 72 is moved laterally until the bending form 50 is immediately adjacent to the pipe 16. The cable 22 and snake 18 or shoe 20 are retracted (to the left in FIGURE 1) and the stationary clamp 46 opened so as to allow the pipe 16 to be placed in the chuck 34. The hydraulic cylinder 42 and motors 38, 44 are activated, positioning the desired point on the pipe 16 between the bending clamp 58 and the forms 50. The stationary clamp 46 is closed and the cable 22 moved forward (to the right in FIGURE 1) until the snake 18 or shoe 20 is disposed at the point of bending. The bending clamp 58 is closed, locking the pipe 16 between the clamp 58 and the form 50. The hydraulic motor 62 is activated, rotating the arm 54 and forms 50, pulling the pipe 16 around the form 50.

Due to the resistance in the pipe length between the stationary clamp 46 and the forms 50, there is a tendency for the arm 54 and forms 50 to move or "walk" towards the stationary clamp 46 as the pipe 16 is pulled around the forms 50. The hydraulic cylinder 78 resists such movement with the result that the pipe 16 is stretched between the bending clamp 58 and the stationary clamp 46. When the stress on the pipe 16, and hence the force on the slide block 70, reaches a predetermined value in excess of the yield stress but less than the ultimate strength of the pipe material, the resistance of the cylinder 78 is overcome and the arm 54, forms 50, and slide block 70, move towards the stationary clamp 46. The pipe 16 is thus simultaneously bent and stretched past its yield limit but below its ultimate limit.

In an alternative method (FIGURE 9) of providing resistance to the movement of the forms 44 towards the clamp 40, a gear 130 is fixed to the screw 52 so that it engages a stationary rack 132. The rotation of the forms 44 would then walk the entire bending section toward the clamp along the rack. The ratio of the diameter of the column of forms 44 to the diameter of the driving gear would then determine the tension that is applied to the tubing. This ratio could be calculated to stretch the tubing with a stress above the yield stress but below the ultimate limit of the metal.

After the arm 54 and forms 50 have rotated through the desired arc distance, the bending clamp 58 is opened and the chuck assembly 34, 40 actuated to rotate the pipe 16 and move it forward (to the right in FIGURE 1) along its axis to its new desired position adjacent the forms 50. The bending operation is then repeated.

FIGURE 7 illustrates a second embodiment of the present invention, in which a cylindrical column of bending forms 80 is utilized, each form thus permitting the same radius of bend, but suitable for bending pipe of a different diameter. A mandrel assembly is comprised of a cable 82 disposed to be engaged and moved by wheels 84. The cable 82, which terminates in a mandrel 86, is stored in a tube 88 and supported along its length by a series of movable blocks 90. A chuck assembly indicated generally at 92 positions the pipe 94 before the forms 80. A stationary clamp 96 locks the pipe 94 in position during the bending operation.

The bending apparatus consists of the cylindrical column of annular bending forms 80 mounted on a screw 98 so as to be moved vertically as the screw 98 is rotated by a hydraulic motor 100. A bending clamp 102, mounted on an arm 104 disposed to rotate about the axis of the forms 80, locks the pipe 94 against the forms 80. A hydraulic motor 106 rotates a pinion 108 which engages a gear 110 permanently affixed to both the forms 80 and the arm 104 in such a manner as to rotate the forms 80 and the arm 104 at the same rate. The screw 98 is located in a housing 112 which is permanently affixed to a pressure block 114, slidably mounted on the extensions of slide rods 116.

As the arm 104 and forms 80 rotate, the resistance in the pipe 94 tends to pull the arm 104 and forms 80 towards the stationary clamp 96. This movement is limited by a hydraulic cylinder 118 connected to the pressure block 114. The cylinder 118 resists movement of the pressure block 114 until the stress in the pipe material reaches a value in excess of the yield strength but less than the ultimate strength of the material.

In operation, the cable 82 is retracted and the pipe placed in the machine and positioned for bending. The desired bending form is moved vertically into position and the stationary clamp 96 closed. The mandrel and cable 82 are moved forward into position, the bending clamp 102 locked, and the arm 104 and form 80 rotated about the axis of the forms 80. The hydraulic cylinder 118 resists the tendency of the arm 104 and forms 80 to walk back towards the stationary clamp 96. The pipe 94 is thus simultaneously bent and stretched past its yield limit but below its ultimate limit.

If the shoe mandrel 20 (FIGURE 5) is utilized with either of the above embodiments of the present invention, means must be provided to retract the mandrel 20 at the same rate that the forms 50 and the arm 54 walk back towards the stationary clamp 46. This may be accomplished by connecting the hydraulic motor 28 which moves the cable to the fluid relief valve in the passive hydraulic cylinder 78 in such a manner that the wheels 26 will retract the cable 22 and mandrel 20 when fluid is forced out of the hydraulic cylinder 78. If the snake mandrel 18 (FIGURE 6) is employed, such retracting

means are not necessary since the snake 18 may be bent with the pipe around the form 50.

For bends of large radii or of radii other than those on the column of bending forms, an incremental bending technique may be utilized with either of the above embodiments of the present invention. This technique consists of forming a series of small arc bends in close proximity with one another so as to form the longer desired radius of bend.

Although the above embodiments illustrate the present invention incorporated in an automatic stretch bending machine, the invention may also be successfully employed in machines of the non-automatic variety and in machines which employ different bending techniques. The present invention is also adaptable to stretch bending solid rods or shafts in addition to hollow tubes or pipes.

The mandrel equipment shown in the above embodiments is not necessary for the successful stretch bending of all sizes and varieties of tubing. Although the mandrel adds extra support for the metal on the inside face of the bend during the bending operation, the necessity for such support would depend on the particular tubing to be bent.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiments of the invention are therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

Having thus described my invention, I claim:

1. A machine for bending an elongated member, comprising: a support for said member; a bending form having its axis extended perpendicularly to the axis of said elongated member, said form being rotatable about its axis and movable in a direction parallel to the extension of said member; a first clamp operative to restrain a first point on the length of said elongated member from movement with respect to said support; a second clamp operative to clamp a second point on said elongated member against the perimeter of said bending form, said second clamp being rotatable about the axis of said bending form and movable in a direction parallel to the extension of said member; means for rotating said bending form and said second clamp about the axis of said bending form so that a section of said elongated member between said first and second points is pulled around said bending form thereby stressing said member between said first and second points; and means for restraining motion of said bending form and said second clamp in the direction parallel to the axis of said elongated member in such a manner that the motion of said bending form and said second clamp toward said first clamp occurs only upon the imposition of a predetermined stress upon the member between said first and second points.

2. A machine for bending an elongated member, comprising: a support for said member; a bending form having its axis extending perpendicularly to the axis of said elongated member, said form being rotatable about its axis; a first clamp operative to restrain a first point on the length of said elongated member from movement with respect to said support; a second clamp operative to clamp a second point on said elongated member against the perimeter of said bending form, said second clamp being rotatable about the axis of said bending form; a platform supporting said second clamp and said bending form, said platform being movable in a direction parallel to the axis of said elongated member; means for rotating said bending form and said second clamp with respect to said platform and about the axis of said bending form so that a section of said elongated member between said first and second points is pulled around said bending forms, thereby stressing said member between said first and second points; and means for restraining motion of said platform in the direction parallel to the axis of said elongated member in such a manner that the motion of said platform toward said first clamping means occurs only upon the imposition of a predetermined stress upon the member between said first and second points.

3. The structure defined in claim 1, wherein said means for restraining motion of said bending form and said second clamp in the direction parallel to the axis of said elongated member comprises: a hydraulic cylinder and piston having one end connected with respect to said support and one end connected with respect to said bending form so as to cause said piston to move within said cylinder as said bending form and said second clamp move with respect to said support; and means for allowing motion of said piston within said cylinder only after the exercise of a predetermined force between said piston and said cylinder.

4. The structure defined in claim 1, wherein said means for restraining motion of said bending form and said second clamp in the direction parallel to the axis of said elongated member comprises: a gear fixed about the axis of said bending form; means for engaging said gear in such a manner that rotation of said bending form translates said gear and said bending form in a direction parallel to the axis of said elongated member, said engaging means translating said gear and said bending form through such a distance for a given rotation of the form that a predetermined stress is exerted on said elongated member between said first and second clamps.

5. The structure defined in claim 1, wherein said means for restraining motion of said bending form and said second clamp in the direction parallel to the axis of said elongated member comprises: a gear fixed about the axis of said bending form; a rack fixed to said support and disposed adjacent said gear so that said gear engages and walks along said rack as said bending form moves toward said first clamp, the ratio of the diameter of said bending form to the diameter of said gear being such that a predetermined stress is exerted on said elongated member between said first and second clamps.

6. A machine for bending an elongated member, comprising: a support for said member; a shaft having its axis extending perpendicularly to the axis of said elongated member, said shaft being rotatable about its axis and movable in a direction parallel to the extension of said member; a series of annular bending forms fixed about said shaft; means for vertically moving said shaft with respect to said support so as to bring the desired bending form into position opposite said second clamp; a first clamp operative to restrain a first point on the length of said elongated member from movement with respect to said support; a second clamp operative to clamp a second point on said elongated member against the perimeter of one of said bending forms, said second clamp being rotatable abont the axis of said shaft and movable in a direction parallel to the extension of said member; means for rotating said shaft and said second clamp about the axis of said shaft so that a section of said elongated member between said first and second points is pulled around one of said bending forms thereby stressing said member between said first and second points; and means for restraining motion of said shaft and said second clamp in the direction parallel to the axis of said elongated member in such a manner that the motion of said shaft and said second clamp toward said first clamping means occurs only upon the imposition of a predetermined stress upon the member between said first and second points.

7. A machine for bending an elongated member, comprising: a support for said member; a shaft having its axis extending perpendicularly to the axis of said elongated member, said shaft being rotatable about its axis and movable both in a direction parallel to the extension of said member and in a direction perpendicular to the axis of said elongated member and perpendicular to the

axis of said shaft; a series of annular bending forms of varying diameter fixed about said shaft; means for moving said shaft vertically with respect to said support and in a direction perpendicular to the axis of said elongated member and perpendicular to the axis of said shaft, so as to bring the desired bending form into operative position; a first clamp operative to restrain a first point on the length of said elongated member from movement with respect to said support; a second clamp operative to clamp a second point on said elongated member against the perimeter of one of said bending forms, said second clamp being rotatable about the axis of said shaft and movable in a direction parallel to the extension of said member; means for rotating said shaft and said second clamp about the axis of said shaft so that a section of said elongated member between said first and second points is pulled around one of said bending forms thereby stressing said member between said first and second points; and means for restraining motion of said shaft and said second clamp in the direction parallel to the axis of said elongated member in such a manner that the motion of said shaft and said second clamp toward said first clamping means occurs only upon the imposition of a predetermined stress upon the member between said first and second points.

8. A machine for bending tubing, comprising: a support for said tubing; a bending form having its axis extending perpendicularly to the axis of said tubing, said form being rotatable about its axis and movable in a direction parallel to the extension of said tubing; a first clamp operative to restrain a first point on the length of said tubing from movement with respect to said support; a second clamp operative to clamp a second point on said tubing against the perimeter of said bending form, said second clamp being rotatable about the axis of said bending form and movable in a direction parallel to the extension of said tubing; means for rotating said bending form and said second clamp about the axis of said bending form so that a section of said tubing between said first and second points is pulled around said bending form thereby stressing said tubing between said first and second points; means for restraining motion of said bending form and said second clamp in the direction parallel to the axis of said tubing in such a manner that the motion of said bending form and said second clamp toward said first clamp occurs only upon the imposition of a predetermined stress upon the tubing between said first and second points; a mandrel movable along the axis of said tubing; a stationary support for said mandrel; means for moving said mandrel with respect to said support forward into the interior of said tubing until said mandrel is situated adjacent the interior wall of said tubing at said second point on said tubing; and means for retracting said mandrel at the same rate that said bending form and said second clamp move towards said first clamp.

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