United States Patent [19]

Bibighaus

[11] **3,813,911**

[45] **June 4, 1974**

[54] **TUBE ROLLING MILL FOR PRODUCING TUBING WITH VARIOUS INTERNAL CONFIGURATIONS**

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[73] Assignee: **Superior Tube Company,** Norristown, Pa.

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[52] **U.S. Cl.** **72/208,** 72/214

[51] **Int. Cl.** **B21b 25/00**

[58] **Field of Search** 72/209, 208, 214, 178, 72/224, 476, 97, 193, 220

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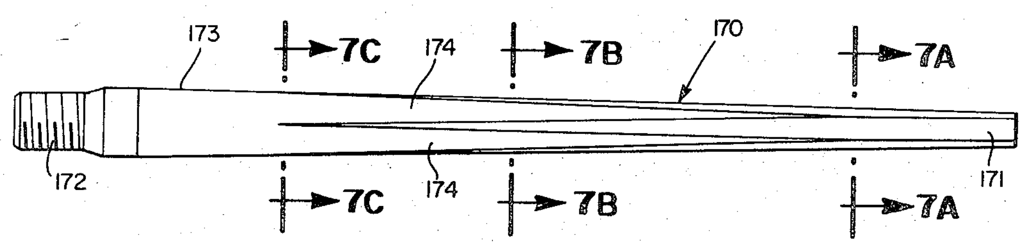
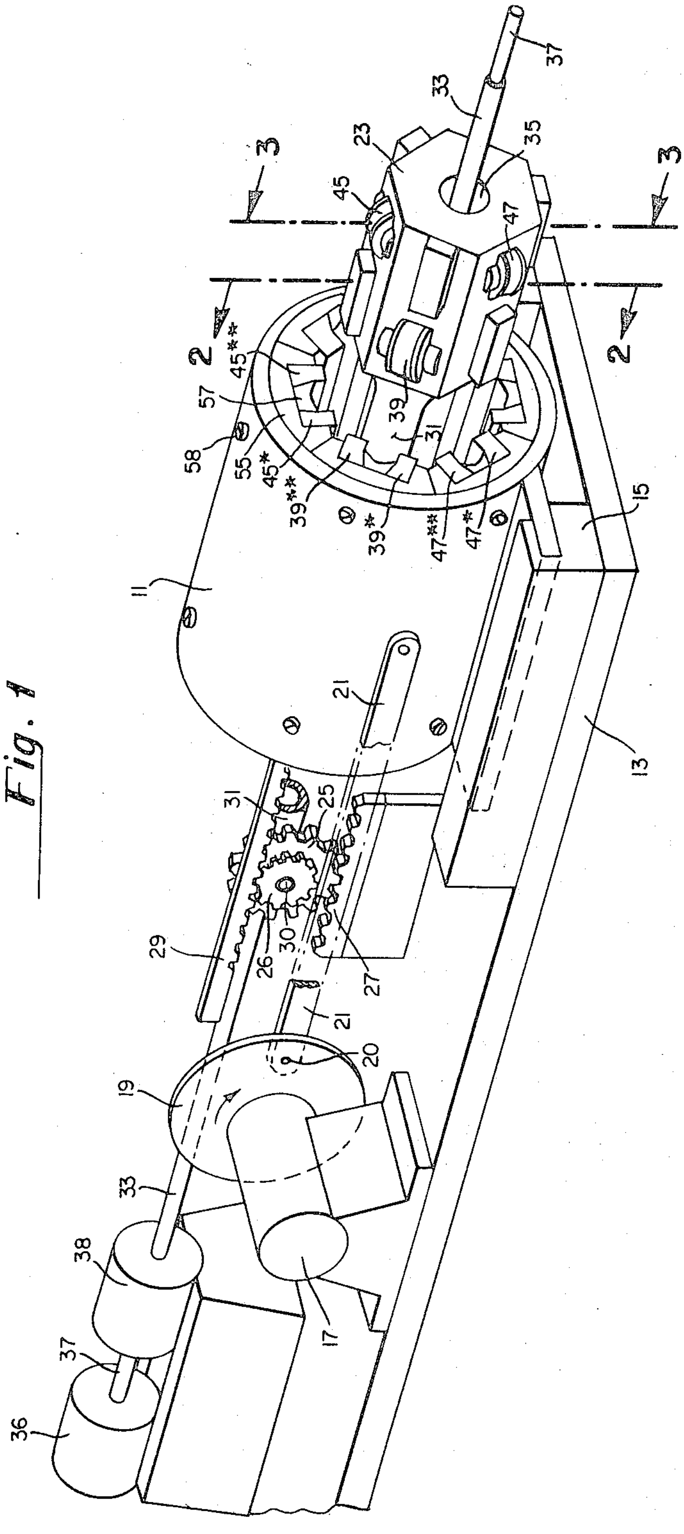
Primary Examiner—Milton S. Mehr
Attorney, Agent, or Firm—Woodcock, Washburn, Kurtz & Mackiewicz

[57] **ABSTRACT**

A tube rolling mill having two sets of three rolls each which are reciprocatingly driven along a length of a tube supported by a mandrel. Each roll is forced against the tube by individual cams that each have a surface of one or more tapers to provide controlled reduction in wall thickness of the tube. The mandrel is tapered to provide a reduction of inside tube diameter and is of a configuration to cause the inside wall of the tube to be shaped as for example in hexagonal form, simultaneously as the inside tube diameter and wall thickness are reduced. Various inside wall configurations may be produced such as clover leaf shapes, flat sided configurations, ovals, and a combination of circular and flat surfaces, each of the patterns running for the length of the finished tube.

8 Claims, 14 Drawing Figures




37
33
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23
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45**
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47*
15
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Fig. 1

Fig. 3

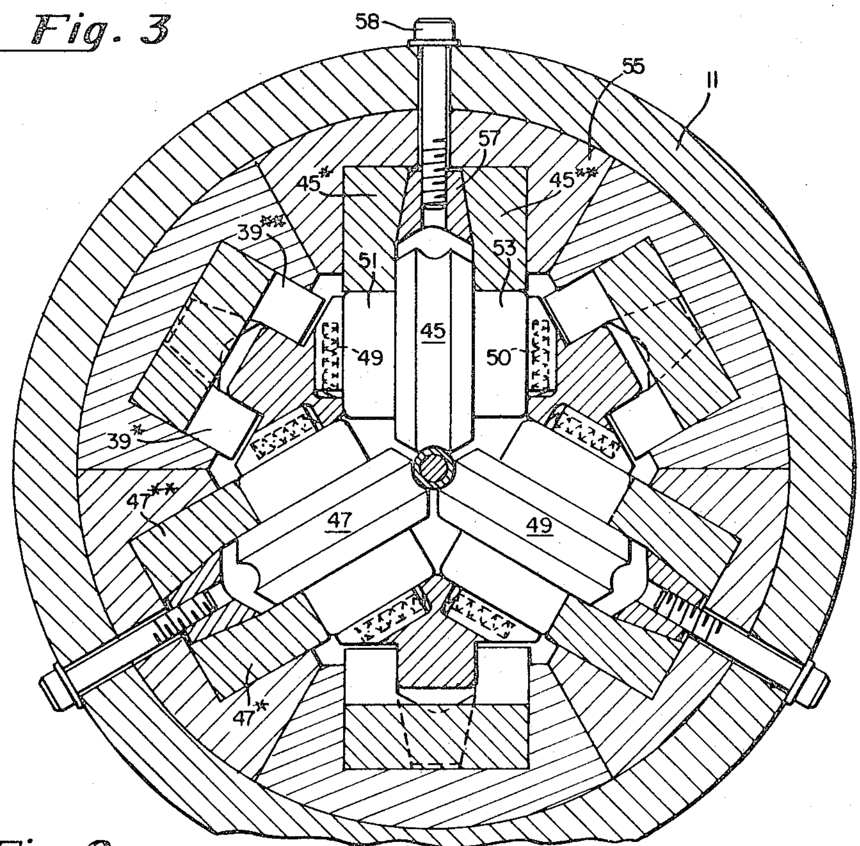
58
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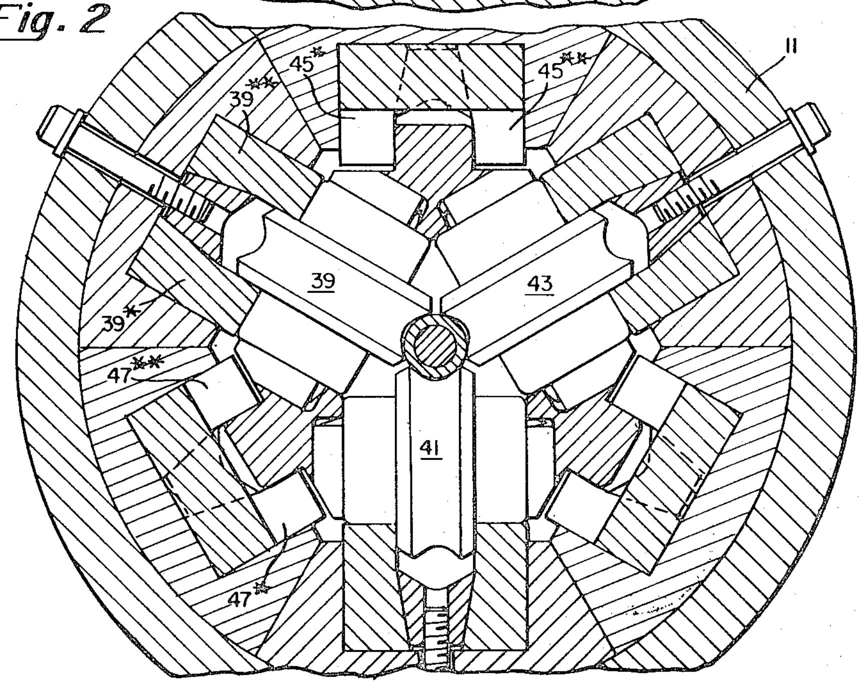
Fig. 2


45*
45**
11
45**
39
39
43
39*
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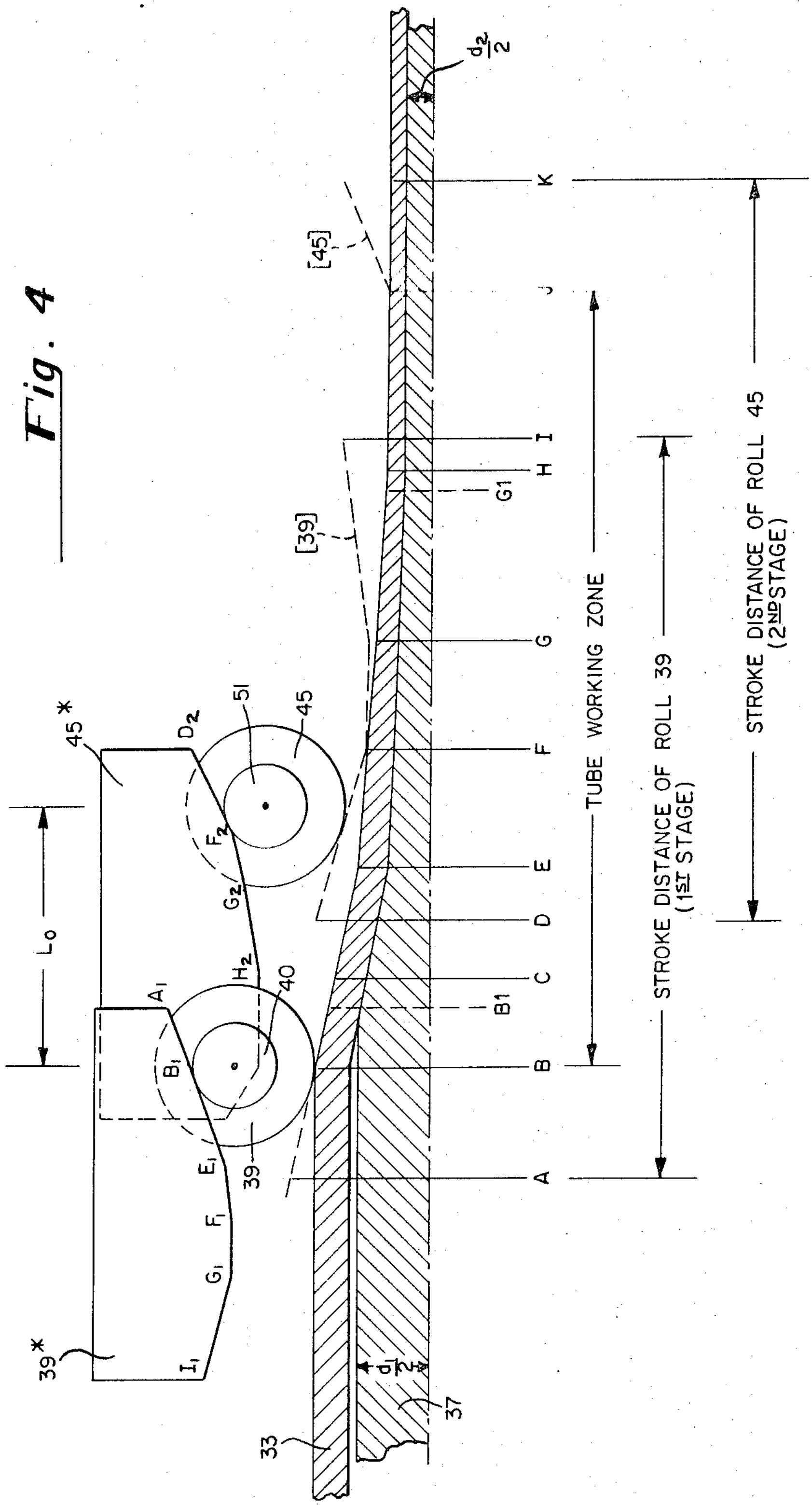
41
47*

Fig. 4


39*
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L_o
A_1
B_1
E_1
F_1
G_1
I_1
D_2
F_2
G_2
H_2
39
40
45
51
[39]
[45]
33
37
$\frac{d_1}{2}$
$\frac{d_2}{2}$
A
B
B1
C
D
E
F
G
G1
H
I
J
K
TUBE WORKING ZONE
STROKE DISTANCE OF ROLL 39
(1ST STAGE)
STROKE DISTANCE OF ROLL 45
(2ND STAGE)

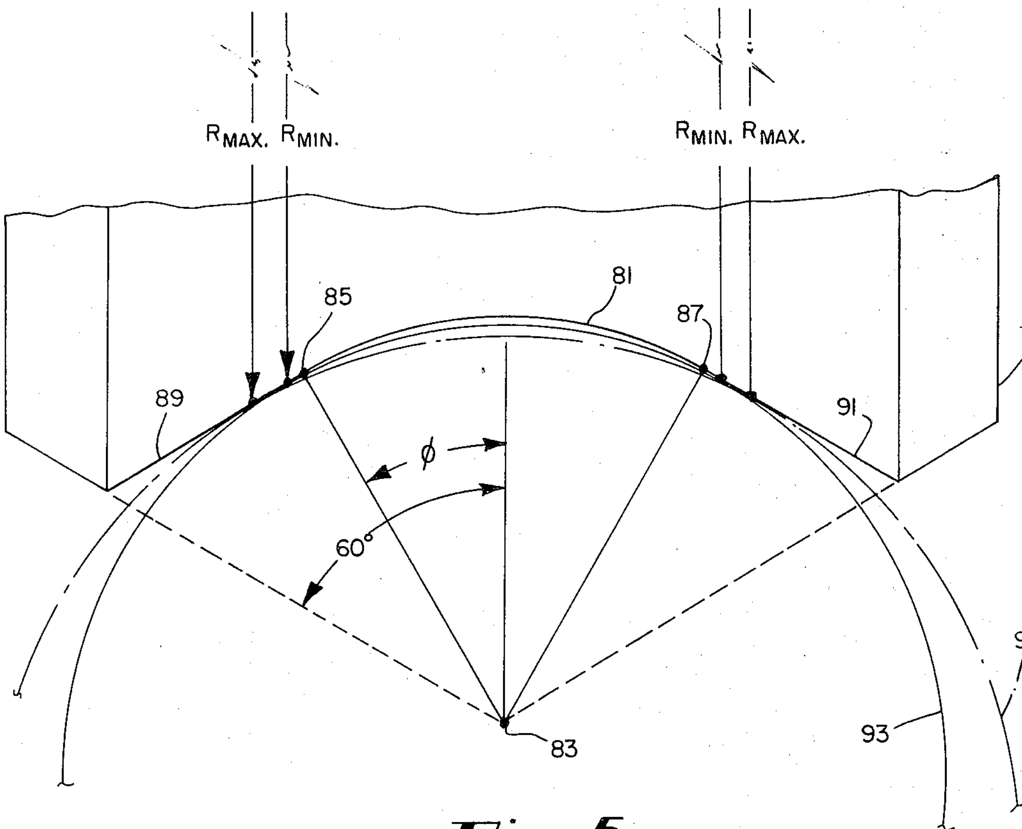

Fig. 5

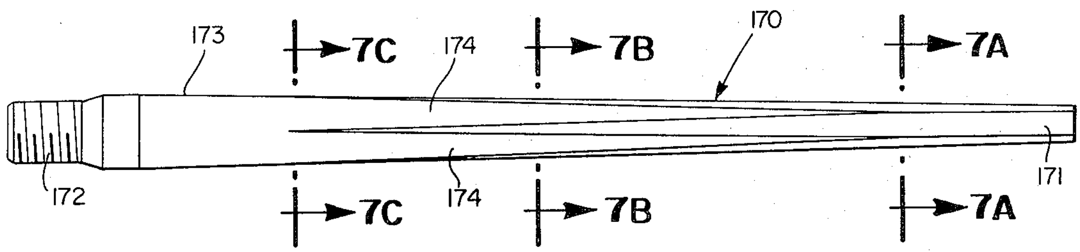

Fig. 6

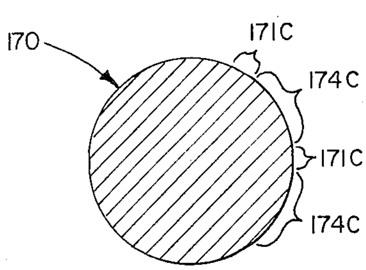

Fig. 7C

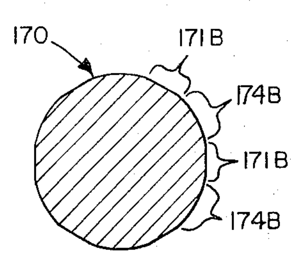

Fig. 7B

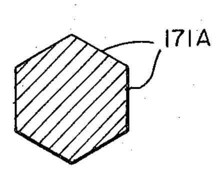

Fig. 7A

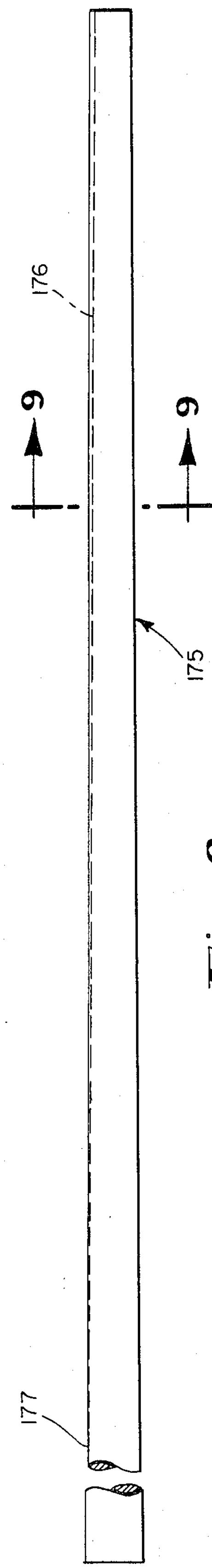

Fig. 8

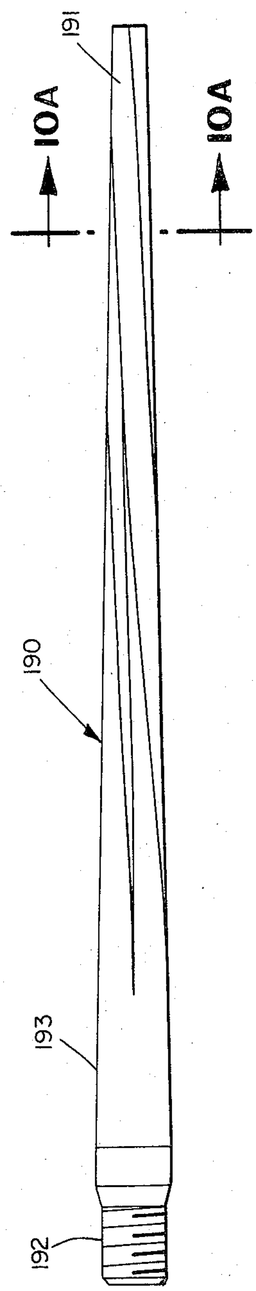

Fig. 10

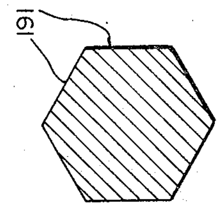

Fig. 10A

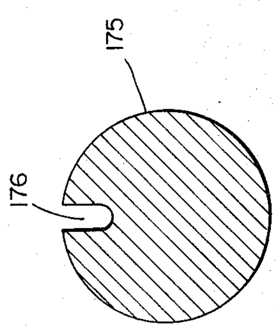

Fig. 9

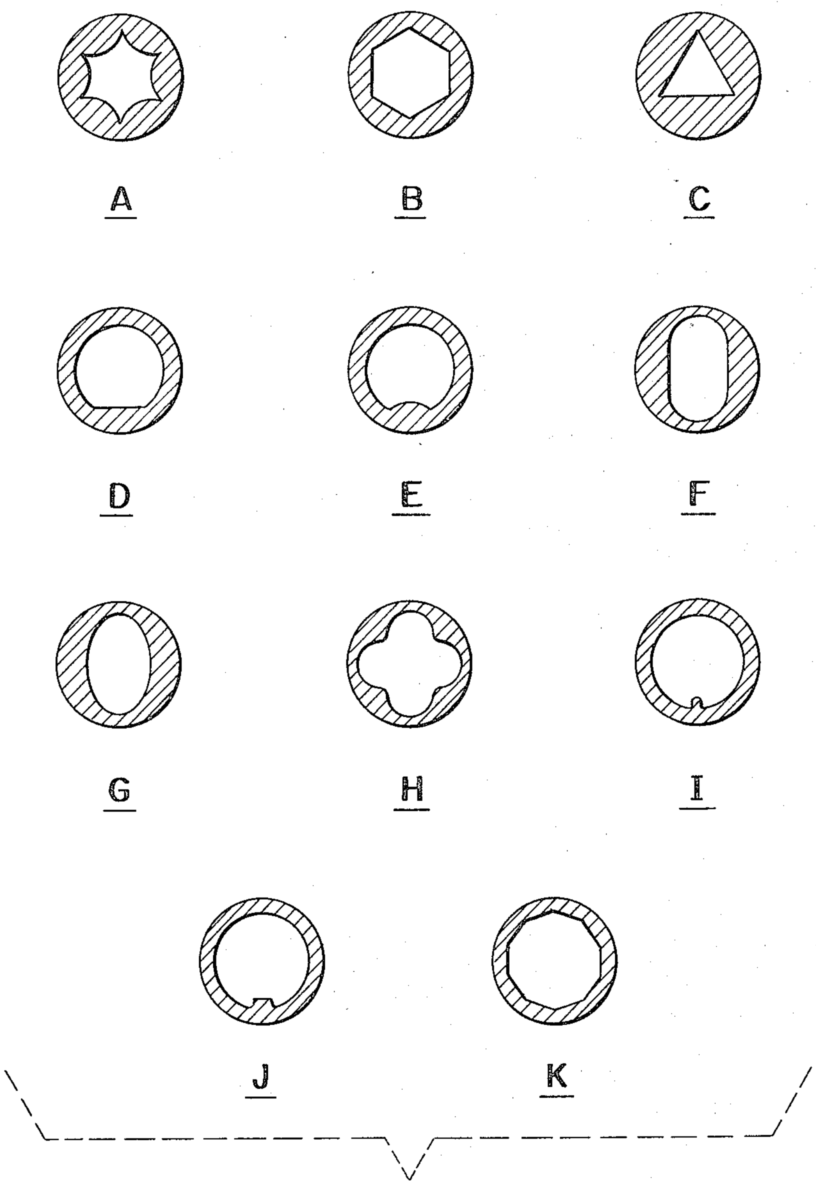

Fig. 11

TUBE ROLLING MILL FOR PRODUCING TUBING WITH VARIOUS INTERNAL CONFIGURATIONS

BACKGROUND OF THE INVENTION

The subject invention improves upon and develops further in some respects the teachings of U.S. Pat. No. 3,688,540 which issued Sept. 5, 1972; U.S. Pat. No. 3,683,661 which issued Aug. 15, 1972; and U.S. Pat. No. 3,611,775 which issued Oct. 12, 1971.

This invention relates generally to a method and apparatus for reducing and elongating metal tubing and more particularly to a method and apparatus for producing tubing which has its interior walls shaped into various configurations by a cold rolling tube reducing process.

Metal tubing is used in a wide variety of environments and for many different applications. This requires that tubing be abailable with a wide variety of inside and outside diameters and wall thicknesses. Furthermore, certain applications require that the tubing be provided with various internal configurations. In order to effectively utilize the economies of mass production, metal tubing is initially manufactured in only a few standard cylindrical sizes. This makes it necessary to modify tubing of a standard manufactured size to obtain a finished tube having an overall size that is needed for a certain application requiring less tubing that can be economically manufactured directly. When it becomes necessary to shape the tubing into various internal configurations, and this operation is in addition to the reducing and sizing operation, the overall production of such tubing becomes costly.

A machine for reducing tubing of a standard manufactured size with two rolls and a mandrel is described by Krause in the *Iron and Steel Engineer*, August, 1938, pp. 16–29, and in several patent publications such as U.S. Pat. Nos. 2,161,064, 2,161,065 and 2,223,039. In addition, there have been several disclosures by the Argonne National Laboratories relating to similar machines. Also, several publications by Russian authors have described tube rolling mills having three or six rolls. However, none of these disclosures suggest a practical way of producing tubing in which the inside walls are configurated and shaped by a cold rolling process.

Therefore, it is an object of this invention to provide a tube rolling mill capable of producing various configurations on the interior wall surface of tubing.

It is also an object of this invention to provide a method of producing configurations on the interior wall surface of tubing by cold rolling.

It is a further object of this invention to provide a method and apparatus for producing configurations on the interior wall surface of a tube simultaneously and as part of a process of reducing the tube's wall thickness and/or its inside diameter.

SUMMARY OF THE INVENTION

These and additional objects are accomplished by a technique according to this invention in which a plurality of rolls are reciprocated back and forth along the length of a standard size manufactured tubing. Each of the rolls may have a uniform tube contacting groove around its outer circumference to produce cylindrical tubing or may have substantially flat surfaces to produce flat sided tubing. The plurality of rolls is held by a common roll housing which is reciprocated along the length of the tubing. Cam guide means are provided for the rolls so that they exert a substantial amount of pressure against the tube. It is this pressure against the tube which causes metal of the manufactured tubing to flow into a desired new shape. The plurality of rolls are positioned so that their tube contacting grooves or flat surfaces surround the tube being reduced.

In a preferred form of the invention, three rolls are utilized in a cluster about the tube with their axes of rotation located in a plane substantially perpendicular to the tube and displaced 120° from each other. Each roll is rotatably attached to a roll housing. The roll is urged against the tube by a pair of cam tracks on which roll trunnions ride. Within the roll housing, means are provided to insure that the rolls contact the cams at all times.

As described hereinafter, the interior walls of the tube are shaped into various desired configurations in conjunction with either wall thickness or inside diameter reduction, or both, to obtain an internally configurated tube that is dimensioned exactly as required for a particular application. In order to obtain a good quality tube with either wall thickness or inside diameter reduction, or both, it is preferred to use two sets of three roll clusters with a fixed spatial relationship within a roll housing. The axes of rotation of the rolls of one set (cluster) are displaced 60° from the axes of rotation of the rolls of the other set.

The tube is worked on a tapered mandrel which may be tapered to different degrees along its length which will cause the inside diameter of the tube to be reduced. As this reduction is taking place, shaping of the internal wall of the tube into various configurations may also be carried out by the use of a tapered mandrel with various shapes ground upon it in the following manner. Each mandrel has a portion with a diameter slightly less than the inside diameter of the tube to be reduced. From this point the mandrel tapers either fairly abruptly or in a series of tapers to a point where the final sizing diameter is obtained. The mandrel has ground into it shapes which will be transposed onto the inside wall of the tube as it is reduced, the mandrel serving as an interior mold. At the sizing portion of the mandrel, the configuration of the mandrel is exactly as will be transposed to the interior of the tube as the tube is rolled over the mandrel. From this sizing portion of the mandrel to the larger portion of the mandrel which is slightly less in diameter than the original piece of tubing that is being reduced in shape, the configuration which is ground into the mandrel becomes less and less pronounced and reaches a point where the configuration disappears and the cylindrical mandrel shape prevails. In other words, as the mandrel tapers towards its sizing position the ground configurations become more and more pronounced which effectively enables the tubing to be rolled onto the configurated mandrel and be shaped and dimensioned according to the mandrel shape at its sizing section.

Various inner diameter configurations may be produced such as hexagonal and triangular shapes, shapes having a ridged area or a grooved area and oval and clover-leaf type patterns. The hexagonal and flat sided shapes are produced by having a mandrel with flats extending lengthwise as above described along the mandrel from the sizing area gradually becoming less pronounced until the largest cross-sectional portion of the mandrel is reached where the mandrel shape becomes cylindrical.

Tubes having spiral configurations on the interior are also desired and these may be produced by using spiraled mandrels in, for example, a hexagonal or triangular pattern.

Numerous uses may be made of the configurated tubing, a few of which will be listed. The flat sided tubing as for example decagonal tubing may be used to form a suitable bore for B—B guns. Hexagonal and various shapes such as triangular and square shaped tubing may be used for socket wrenches and the like. Tubing of a clover-leaf pattern may have application in heat exchange processes which will be described later.

Internally configurated tubing may be produced by the techniques of the present invention with a wide variety of metals including those considered generally hard to work such as stainless steel, AISI types of 304 and 316.

The techniques of the present invention are described in more detail hereinafter with respect to the drawings which show a preferred embodiment utilizing two roll clusters of three rolls each and tapered mandrels of various configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified partially exploded view showing essential elements of a rolling mill in which the subject invention is utilized;

FIG. 2 is a cross-sectional view of FIG. 1 taken through the first stage (set) of rolls at 2—2;

FIG. 3 is a cross-sectional view of FIG. 1 taken through the second stage (set) of rolls 3—3;

FIG. 4 schematically illustrates the operation of the primary operating components of the rolling mill illustrated in FIGS. 1, 2 and 3;

FIG. 5 shows the shape of a preferred tube contacting groove of a roll for use in the rolling mill shown in FIGS. 1–3;

FIG. 6 is a front elevational view showing a mandrel having a hexagonal shape;

FIGS. 7*a*, 7*b*, and 7*c* are cross-sectional views of FIG. 6 taken along the lines 7*a*—7*a*, 7*b*—7*b*, and 7*c*—7*c*;

FIG. 8 depicts a mandrel having a groove which is used to produce tubing in which the inner wall has a ridge along its length;

FIG. 9 is a cross-sectional view of the mandrel of FIG. 8 taken along the lines 9—9;

FIG. 10 is a front elevational view of a spiral mandrel at the sizing section of the mandrel;

FIG. 10*a* is a cross-sectional view of FIG. 10 taken along lines 10—10; and

FIG. 11 shows cross-sectional views of tubing A through K which may be produced by mandrels within the contemplation of the subject invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a cam housing 11 is reciprocated relative to a machine frame 13 along a slide 15 in substantially a straight line. An electric motor 17, also attached to the frame 13, drives a flywheel 19. A rod 21 (partially broken away) is connected between the flywheel 19 at a crank pin 20 and the cam housing 11 to convert rotary motion of the flywheel to reciprocable motion of the cam housing. Within the cam housing 11 is a reciprocatable roll housing 23, shown removed from the cam housing for clarity of illustration. A pinion gear 25 engages a rack 27 that is rigidly attached to the frame 13. A second pinion gear 26 engages a rack 29 that is rigidly attached to the cam housing 11. The pinion gears 25 and 26 are concentric about a common axis of rotation 30 and are nonrotatable relative to each other. The reciprocable motion of the axis of rotation 30 of the pinion gear 25 is communicated to the roll housing 23 by means of a connection rod 31 (shown herein as two sections since the roll housing 23 is shown removed from the cam housing 11). The cam housing 11 has a maximum reciprocation stroke distance that is equal to the diameter of the circular path taken by the crank pin 20. From the geometry of the driving arrangement of FIG. 1, the roll housing 23 has a maximum reciprocation stroke distance that is equal to the maximum stroke of the cam housing 11 multiplied by the diameter of the pinion gear 25 and then divided by the sum of the diameters of the pinion gears 25 and 26. The use of two pinion gears having different radii as herein described has the effect of increasing the length of the working zone along the tube without increasing the stroke length of the cam housing. It should be noted that although the double pinion gear arrangement herein described is very convenient for controlling the maximum relative cam housing and roll housing stroke distances, and thereby their relative velocities, other specific mechanical arrangements, such as one employing levers, may also be employed for the same purposes.

Another aspect of the geometry of this arrangement in FIG. 1 is that the cam housing stroke distance is equal to the sum of the roll housing stroke and the working stroke length of the cams (the distance along each cam that contacts a roll trunnion) within the cam housing. It follows, then, that the cam length contacted by each roll bears the same relationship to the roll housing stroke as a ratio of the diameter of the cam housing pinion gear 26 to the diameter of the roll housing pinion gear 25.

A tube 33 to be reduced is inserted through an opening 35 of the roll housing 23, and is carried by a mandrel 37 which is held fixed relative to the machine frame 13 though rotatable by an appropriate gripping device 36, which also provides for removing the mandrel and includes the means for rotating the mandrel. An appropriate apparatus 38 is provided for positively gripping the tube 33 and linearly advancing (feeding) it over a working length of the mandrel 37. The apparatus 38 can also be designed to rotate the tube at specific positions of the reciprocating cycle in order to produce smooth tubing having a smooth external surface of reduced size. In order to produce tubing with configurated inner walls in accordance with the present invention, the mandrel is rotated as the tube is rotated.

FIGS. 2 and 3 better show the relationship of tube deforming rolls and the cam housing as sectional views of FIG. 1. A first set of rolls 39, 41 and 43, shown in FIG. 2, are held in the roll housing 23 with their axes of rotation lying substantially in a plane perpendicular to the mandrel 37 and making an angle of 120° with each other. Similarly, a second set of rolls 45, 47 and 49, shown in FIG. 3, are held by the roll housing 23 in the position that their axes of rotation lies substantially in a plane perpendicular to the mandrel 37 and at a spatially fixed distance along the length of the mandrel from the plane in which the axes of rotation of the first set of rolls 39, 41 and 43 lie. Furthermore, the axes of rotation of the two sets of rolls are angularly displaced from each other by 60°.

Although held by the roll housing 23 against movement relative thereto in the direction of its reciprocation, each roll is free to move in a direction normal to the mandrel. Each roll is resiliently urged by a set or springs (such as springs 49 and 50, each held within a roll guide) out of the roll housing 23 and against its associated cam surfaces. Alternatively, the rolls may be hydraulically urged against their associated cams. Each roll has a trunnion formed on either side thereof, such as trunnions 51 and 53 on either side of the coil 45. Each roll is associated with a pair of cam tracks upon which its pair of trunnions ride. The two cams associated with each roll are designated herein with the same number as the roll but with an asterisk placed after the reference number of one of the cam tracks and a double asterisk placed after the number referring to the other of the cam tracks. The cams are long metal bars shaped in a manner discussed hereinafter and rigidly attached to the cam housing 11. This attachment is accomplished through a recessed member for each pair of cams, such as a recessed member 55 which is shaped to support the cams 45* and 45**. Notice that the cams 45* and 45** each have a sloped side surface which allows fastening them to the recessed member 55 by a wedge 57 which is attached to the recessed member by a threaded fastener 58.

It should be noted with reference to FIGS. 1, 2 and 3, the ease with which the cam surfaces may be replaced in the cam housing 11 and also the ease with which the rolls may be replaced in the roll housing 23. A given pair of cams are removed by removing their associated wedge. The rolls are merely lifted out of the roll housing 23 when the roll housing is removed to a position as illustrated which is out of the cam housing 11. The mandrel 37 is also easily removed. These features allow quick conversion of the tube rolling mill to receive raw tubes of various sizes and also to produce finished tubes with various wall thicknesses and inside diameters.

The schematic diagram of FIG. 4 illustrates operation of the rolling mill illustrated in FIGS. 1, 2 and 3. A mandrel 37 which is not shaped for the purpose of producing configurated tubing walls in accordance with the subject invention but which may be used for illustrative purposes is shown in cross-section along its length which includes a tube working zone B–J wherein at all points therealong the tube 33 is contacted by one or both sets of rolls to accomplish reduction either in wall thickness or inside diameter or both. The mandrel has a diameter d_1 at its large end which is something slightly less than the inside diameter of the starting tube 33, thereby allowing the tube to be slid easily over the mandrel. The small end of the mandrel has a diameter d_2 which is substantially equal to the desired inside diameter of the reduced tube. The mandrel 37 is gradually tapered within the tube working zone from one of these diameters to the other. This taper is significantly in excess of that required for tube relief. The diameters d_1 and d_2 may differ by 20% or 30% or more, depending on the tube inside diameter reduction desired.

In order to demonstrate the cooperation between the cams and the mandrel, one roll from each of the two sets of rolls is shown in FIG. 4 as if they operated in the same plane so that the relationship between them and their cooperation in reducing the tube are illustrated. Rolls 39 and 45 are illustrated in FIG. 4 along with their associated cams 39* and 45*, respectively. The axis of the first stage roll 39 reciprocates along the tube between positions A and I with a distance therebetween equal to the stroke distance of the roll housing 23 (not shown in FIG. 4) in which the roll 39 is journaled. Similarly, the axis of the second stage roll 45 reciprocates along the tube between positions D and K. The cams 39* and 45* are attached to the cam housing 11 (not shown in FIG. 4) and thereby are reciprocatably driven at a greater velocity than the axis of the rolls, as described hereinabove. The cam 39* contacts a trunnion 40 attached to the roll 39 and the cam 45* contacts the trunnion 51 of the roll 45. The shape of the cams and of the mandrel determine the displacements of rolls downward against the tube to bring about a desired deformation of the tube.

Consider a single working stroke wherein the rolls and cams of FIG. 4 move from their far left hand position to the far right and back again. This represents the extent of movement brought about by a single revolution of the flywheel 19 of FIG. 1. The roll 39 begins at the position A and the roll 45 begins at the position D. As shown by the dashed lines, the roll 39 contacts the tube 33 for the first time at about the position B and the roll 45 contacts the tube 33 for the first time at approximately the position F. Proceeding further to the right, the cooperative shapes of the cams and the mandrel allow the roll 39 to be lifted from the tube 33 at about the position F, as shown by the path [39] of the roll, away from the tube. Similarly, the roll 45 is caused to be lifted from the tube 33 at about the position J, as shown by the path [45] of the roll, away from the tube. The roll 39 arrives at the position I at the same time the roll 45 arrives at the position K to complete the first one-half of the working stroke. The rolls 39 and 45 then move back to their beginning positions A and D, respectively, to complete one working stroke cycle. It may be noted that the "cam working length" as used herein is a horizontal projection of the length of a cam surface contacted by the trunnion. With reference to the cam 39*, the cam working length thereof is the horizontal distance between points A_1 and I_1.

The tube 33 is advanced (fed) by the apparatus 38 an increment to the right while the rolls are drawn away from contact with the tube, either at one or both ends of the working stroke. As a variation in the system shown in FIG. 4, the cams 39* and 45* may be altered so that the rolls 39 and 45 are not drawn away from the tube at positions I and K, respectively, and the tube is fed only at the beginning of the working stroke. The shape of the tube 33 shown in FIG. 4 within the working zone represents the finished shape thereof after working stroke and before the tube is fed an increment in preparation for the next working stroke.

There are many specific cam and mandrel shapes that may be utilized depending upon the specific tube reduction desired. FIG. 4 illustrates a preferred arrangement for major inside diameter reduction. The following tabulation describes the work done by the roll 39 within the working zone between lettered positions along the length of the tube;

Between B–C: The tube is reduced to intimate contact with the mandrel.

Between C–E: Primarily tube diameter reduction is accomplished by the roll 39.

Between E–F: Primarily wall reduction is accomplished by the roll 39.

The following tabulation describes the work concurrently performed by the roll 45 within the working zone between letter positions along the length of the tube:

Between F–G: Primarily wall reduction performed by the roll 45.

Between G–H: Primarily wall reduction performed by the roll 45 but with a lesser bit into the tube than between F–G.

Between H–J: This is a finishing zone where there is substantially no taper to the mandrel 37 and with very little bite of the roll into the tube.

To accomplish the above-noted specific tube reductions at various points within the tube working zone, the mandrel has one or more straight line tapers. The cams are shaped cooperatively therewith, each having a plurality of straight line tapers. The cams of FIG. 4 have their roll contacting surfaces marked with subscripted letters corresponding to the lettered positions along the tube. For example, when the roll 39 us positioned at E along the tube, the cam 39* is contacting the trunnion at position E_1. Straight line-tapers are preferred for the cams and the mandrel since they are easy to machine, although continuous curves may also be employed.

The description herein with respect to FIG. 4 is exemplary only with various changes in the specifics thereof being possible. For example, if major inside tube diameter reduction is not required, the portion $B_1 - F_1$ of the cam 39* may be shaped differently relative to the portion B–F of the mandrel than as shown to effect tube wall reduction between B–F instead of the tube diameter reduction. Also, the elements may be designed so that the rolls 39 and 45 overlap in their work zones along a portion of the tube, preferably with dissimilar cam tapers acting on the two rolls in this common length of the tube. Also, certain applications may require only a single taper along a working length of each of one set of cams.

Along any of the portions of the tube length wherein substantial wall thickness reduction is desired, the controlling cam and mandrel tapers are designed for a bite of the rolls into the tube at each point within this portion that is approximately the same percentage of the wall thickness at that point before the roll. Multiple straight line tapers on the cams may be employed to approximate this constant percentage although continuous curved cam surfaces are more exact. The amount of tube feed for each stroke is then adjusted to a maximum for a given tube material just short of that which ruptures the tube, thereby maximizing productivity of the machine.

A preferred tube contacting groove is illustrated in FIG. 5 for the rolls of a rolling mill illustrated with respect to FIGS. 1–3. The groove shape is uniform in cross-section at any radial plane thereof. The groove cross-section is shown on a roll 79 which represents relative roll groove dimensions for any roll shown in FIGS. 1–3 for the purpose of describing roll groove design. In the center of the groove is an arcuate portion 81 having a center of curvature at a point 83. Joining either side of the arcuate center portion 81 as tangents thereto at its end points 85 and 87 are straight line segments 89 and 91 which extend to the groove outside edges 97 and 99, respectively. The arcuate portion 81 extends for an angular distance ϕ on either side of a center line.

The radius of curvature of the arcuate portion 81 is made substantially equal to or slightly less than the smallest outside tube radius the roll is designed to contact, such outside tube radius being represented by a solid circle 93. This represents a desired radius of the finished tube for the roll 45 shown in FIG. 4 and the radius of the tube at location F for the roll 39. A circle 95 (FIG. 5) represents the largest outside tube radius which the roll groove is designed to contact, that of the beginning tube for the roll 39 of FIG. 4 and that of the tube at position F for roll 45.

This roll groove design provides two zones of contact for each roll against the outside of the tube between the tube's larger portion (95) and substantially until its smallest portion (93). Such "two-zone rolling" accomplishes more reduction in a given working zone of a tube when compared to a roll groove providing only one zone of contact with the tube. Non-uniform tube wall strain is reduced as well as resulting degradation of tube quality. Also, required rolling forces, and thus machine wear, are reduced. To optimize these advantages, the radius of the arcuate center portion 81 of the roll groove may be made 1 or 2 percent less than the smallest outside tube radius to be contracted by the roll groove, thereby extending two zone rolling over the entire length of the tube contacted by the roll, whereby roll life is extended. FIG. 5 illustrates such a preferred roll that is designed to contact the tube at two zones throughout the stroke. A rolling radius r of the roll 79 along the tube varies between R_{max} (contacting tube portion 95) and R_{min} (contacting tube portion 93) during each tube reducing stroke. An arcuate center portion 81 with a radius significantly smaller than the finished tube outside radius (in the extreme the groove becomes V-shaped) results in a finished reduced tube surface that is irregular and rough.

For a given tube material, there is an optimum angle ϕ which allows the roll to take the most efficient maximum bite into the tube, thereby resulting in the most rapid feed rate of the tube through the machine. An angle ϕ of from 30°–38° is satisfactory for most common tube materials and specific types of reduction.

The tangential portions 89 and 91 of the roll groove are shown in FIG. 5 as straight lines. However, these portions of the groove may, alternatively, be given a curvature with one or more finite radii of curvature.

The rolling mill described with respect to FIG. 4 is used for producing a smooth surface finished tube by rotating the tube at least once each working stroke at a position thereof where the rolls do not contact the tube.

In accordance with the subject invention, in place of the tapered cylindrical-in-cross-section mandrel described above there is substituted a configurated mandrel which is tapered and has ground into it, a shape which suitably forms an internal mold for the tube being processed, the mold being transitional in nature so that the internal shape of the tube is gradually transformed as it is rolled from cylindrical-in-shape to its desired shape. As the tube is rotated after each working stroke (the amount of rotation being variable) the mandrel is also rotated in like manner as the tube to permit the continual forming of the internally shaped tube through successive working strokes.

With reference to FIG. 6, a mandrel is shown for producing tubing having hexagonal inner walls. The mandrel 170 has six flats 171 or flat sides which produce a mandrel which is hexagonal in cross-section at the sizing portion as shown by the cross-sectional view in FIG. 7*a*. To the right of this sizing section, the mandrel continues to taper in slight diminution of size to provide the relief area to enable easy removal of the tube when the rolling process has been completed for the particular section of tubing which had been rolled. The hexagonal configuration is maintained and the relief area consists of the six flat sides or relief flats.

The diameter of size of the mandrel 170 increases to the left side of the sizing portion to the far left where the greatest diameter of the mandrel is located. It will be noted that the flat sides 171 gradually taper to zero along this portion. As configuration 7*a* shows, the cross-sectional area at the sizing section is a hexagon formed by six flat sides 171A while FIG. 7*b* taken midway between the sizing section and the left end of the mandrel shows a figure which is characterized by six flat portions 171B and six rounded portions 174B as the gradual reduction of the flat sides occurs. As FIG. 7*c* shows, the cross-sectional area of the mandrel 170 at the point where the flats disappear almost completely comprises small flat portions 171C and increased rounded portions 174. The tube working zone as described in relation to FIG. 4 extends from the left of section line 7*c* in FIG. 6 to the tube sizing section represented by section line 7*a*. Thus, the initial rolling commences at a point where the mandrel is at its greatest diameter and perfectly cylindrical in cross-section. The mandrel 170 is secured by means 172 in the manner of a cylindrical mandrel 37 as described in the general description.

With reference to FIG. 8, a mandrel 175 is shown which may be used for producing tubing having a ridge on its inner wall. The mandrel 175 has a groove 176 which extends from the relief end of the mandrel at the right side and gradually decreases in depth as the diameter of the mandrel increases to a point where the groove disappears completely on the left side of the mandrel near where the mandrel is at its largest diameter as shown by reference numeral 177. This is at the approximate location of the beginning of the working zone as described with respect to FIG. 4. As shown in FIG. 9, the sizing section of the mandrel is circular and has the one groove into which the metal tubing flows as it is cooled rolled on the mandrel.

With reference to FIG. 10, a further embodiment of a hexagonal type of mandrel 190 is illuatrated. In this embodiment the flats 191 which make up the hexagonal sides are spiraled or rifled to produce a spiraling effect in the rolled tubes. The spiraling may be such that there is one 360° turn in 20 inches of length. As in the embodiment of FIG. 6, the flats 191 begin to emerge from the cylindrical position of the mandrel 190 slightly to the right of the beginning of the tube working zone as shown in FIG. 4. The flats 191 increase in size as they extend to the right causing more and more of the cross-sectional surface of the mandrel to be covered by flat portions, and prior to the time where the flats 191 reach the sizing section a hexagon is formed, thus producing the hexagonal sizing section as is shown in FIG. 10A. The spiraled mandrel 190 of FIG. 10 is similar to the mandrel 170 of FIG. 6 except for the spiraling and if the sizing end of mandrel 170 could be twisted, mandrel 190 could be produced. As in the case of the previously described mandrels, the area to the right of the sizing section is a relief area with a reduced size to enable the tube to be removed from the mandrel once it has been rolled to the size and shape of the mandrel at the sizing section.

As shown in FIG. 11, cross-sectional views of various tubes which can be produced by shaped mandrels are shown. The present invention should not be considered as limited to the configurations shown in FIG. 11 since mandrels may as well be ground to produce various other internal configurations. Numerous applications may be made of the shaped tubing shown in FIG. 11 including the following uses. The tubing of FIG. 11*h* has particular utility in heat exchange applications. A round tube may be placed inside of the center portion of the clover-leaf while the outlying areas effectively form separate conduits which can be used to advantage where heat exchange principles are involved. For example, fluid may be supplied in the inner round tube while other fluid or a gas may be supplied in the outer conduits for the purpose of exchanging heat from one to the other.

The tubing of FIG. 11*k* which is in the shape of a decagon may be used advantageously as to produce barrels for B—B guns and air rifles, and the like, the flat sides or flats being necessary to impart spin in the B—B.

The tubing of FIG. 11*d* is internally configurated into the shape of a hexagon and such tubing finds utility when cut and manufactured into various size socket wrenches and the like. Other of the configurations such as the tube of FIG. 11*a* have electronic applications and present the user of the tubing with a wide range of products to meet varied needs.

Thus, tubing having various internal configurations may be produced by cold rolling a cylindrical tube on a tapered mandrel which has been ground to provide the desired shape to be molded into the tube. The mandrel may be made of a Vasco 350_{max} steel which is an 18% nickel, chrome steel. Flats, grooves, and the like may be ground into the mandrel so that they begin to emerge near the end of the mandrel where the diameter is the greatest and gradually increase in size until they reach the desired size for molding near the sizing point of the mandrel. Grinding, for example, flats, may be done by grinding the flat at the sizing end and continuing to grind back along the mandrel on a taper until the flat disappears.

By the use of a tapered mandrel which has various shapes ground into it as described above, tubing having various internal configurations may be produced during a rolling process in which the inner diameter of the tube is sumultaneously reduced as the shaping is being done. The tubing will assume the shape of the mandrel and the interior of the tube will thus be converted to have a configurated inner wall with grooves, flats, ridges or the like running the length of the tubing. Since both the tube reduction and the tube shaping as described above can be performed simultaneously as distinguished from previously known processes in which two distinct operations were necessary, higher production may be achieved and operational expenses accordingly reduced.

It shall be understood that the invention is not limited to the specific arrangements described herein and the preferred embodiments, but that changes and modifications may be made within the scope of the appended claims.

What is claimed is:

1. A mandrel for use in a cold rolling process in which cylindrical tubes are simultaneously reduced and shaped to assume various internal configurations, said mandrel comprising:

a first length where said mandrel is cylindrical and of a diameter slightly less than the inner diameter of the tube to be shaped,

a second length where said mandrel is of a size and shape to serve as an interior mold about which the tube is rolled to assume its finished size and shape,

a continuously tapered transitional length joining said first and second lengths along which said mandrel shape gradually is developed from said first length to said second length so that the tube may be rolled over a working zone of said mandrel extending from said first length to said second length whereby during the time of rolling the tube will gradually be reduced and shaped as it is rolled over said transitional length until the tube assumes the shape and sizing of the second length of said mandrel, and

a relief length at its end adjacent to said second length, said relief length tapering slightly but otherwise conforming to the shape of the second length to permit removal of said tube once it has been rolled to assume the configuration of the second length of said mandrel.

2. The mandrel of claim 1 wherein the shape of the second length comprises longitudinal flat portions which extend into the transitional length where they gradually become less and less in width to a point where they taper to zero in the proximity of the first length of said mandrel which is cylindrical.

3. The mandrel of claim 2 wherein the second length comprises six longitudinal flat portions which cover the entire outer surface of said second length of said mandrel to provide an interior mold for forming a hexagonal tube, said six longitudinal flat portions gradually tapering to zero through said transitional length of said mandrel, the total cross-sectional area of said transitional length tapering in the opposite direction to said flat portions to provide the transitional length with a combination of rounded and flat portions running longitudinally throughout said transitional length said rounded portions tapering toward said second length while said flat portions taper towards said first length.

4. The mandrel of claim 3 wherein said longitudinal flat portions are spiraled through at least said transitional length to provide a tube of spiraled hexagonal configuration.

5. The mandrel of claim 2 wherein the second length comprises three longitudinal flat portions which cover the entire outer surface of said second length of said mandrel to provide an interior mold for forming a triangular tube, said three longitudinal flat portions gradually tapering to zero through said transitional length of said mandrel, the total cross-sectional area of said transitional length tapering in the opposite direction to said flat portions to provide the transitional length with a combination of rounded and flat portions running longitudinally throughout said transitional length said rounded portions tapering toward said second length while said flat portions taper towards said first length.

6. The mandrel of claim 5 wherein said flat portions are spiraled to provide a tube which is of spiraled triangular configuration.

7. The mandrel of claim 1 wherein said mandrel has a groove in its second length which gradually diminishes in depth through said transitional length of said mandrel to a point where said groove reaches zero depth in the proximity of said first length of said mandrel, said groove causing the formation of a ridge on the inner wall of said tube as it is rolled over the working zone of said mandrel.

8. A mandrel for use in cold rolling processes to produce tubing with various internal configurations comprising:

an elongated member adapted for insertion within a hollow circular tube, said member being tapered and shaped for at least portions of its length, said shaping being for the purpose of imparting to the interior walls of the hollow circular tube the shape of said mandrel, said shaping comprising surfacing of said mandrel so that said mandrel is effectively divided into longitudinal portions, each portion being of the same configuration, although gradually increasing in size and pronouncement from the end of the mandrel of greatest diameter to the opposite end near the portion of the mandrel where the size and shape of said mandrel are used to mold the interior walls of said tube.

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