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Benteler et al.

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[54] **MULTI-PASS METHOD AND APPARATUS FOR COLD-DRAWING OF METALLIC TUBES**

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[51] **Int. Cl.**............................ **B21c 3/16,** B21c 1/12

[58] **Field of Search**......... 72/45, 279, 283, 289, 10, 72/278, 280, 282

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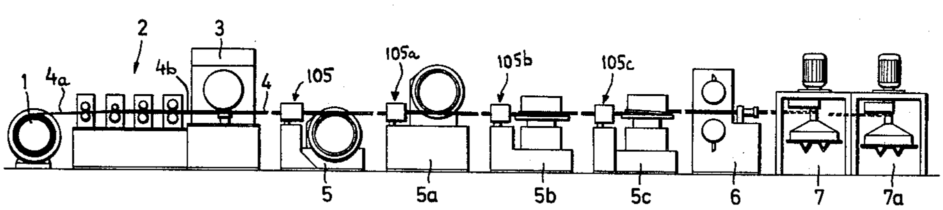
[57] **ABSTRACT**

Metallic tubes are cold-drawn by being pulled through a series of swiveling reducing dies each followed by a motor-driven wheel around which the tube forms at least one convolution. The speed of the motors is regulated to insure that the tube is subjected to tensional stresses downstream as well as upstream of each die. The tensional stressing upstream of the dies reduces the resistance which the tube offers to a reduction of its diameter and/or wall thickness during passage through the dies.

7 Claims, 5 Drawing Figures



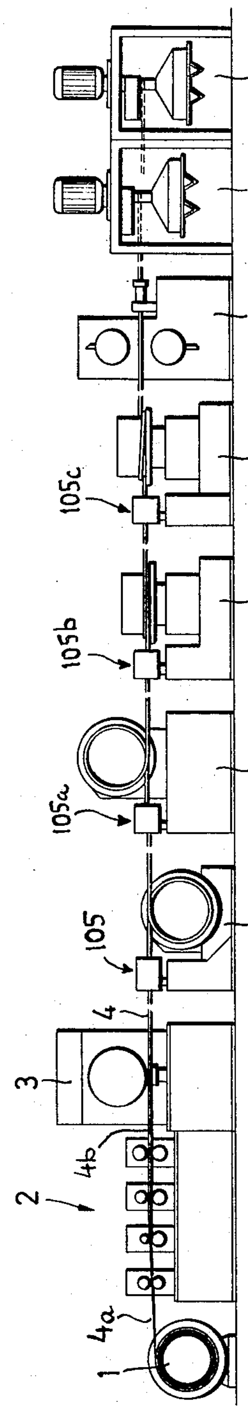

1
2
3
4
4a
4b
5
5a
5b
5c
6
7
7a
105
105a
105b
105c

FIG. 1

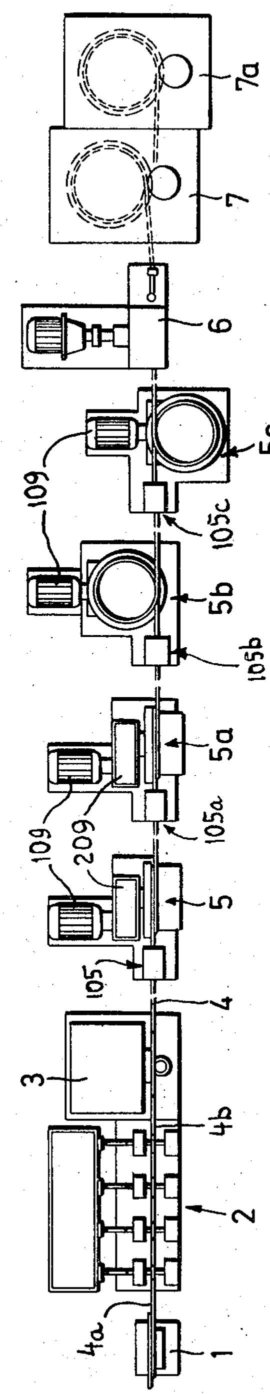

1
2
3
4
4a
4b
5
5a
5b
5c
6
7
7a
105
105a
105b
105c
109
209

FIG. 2

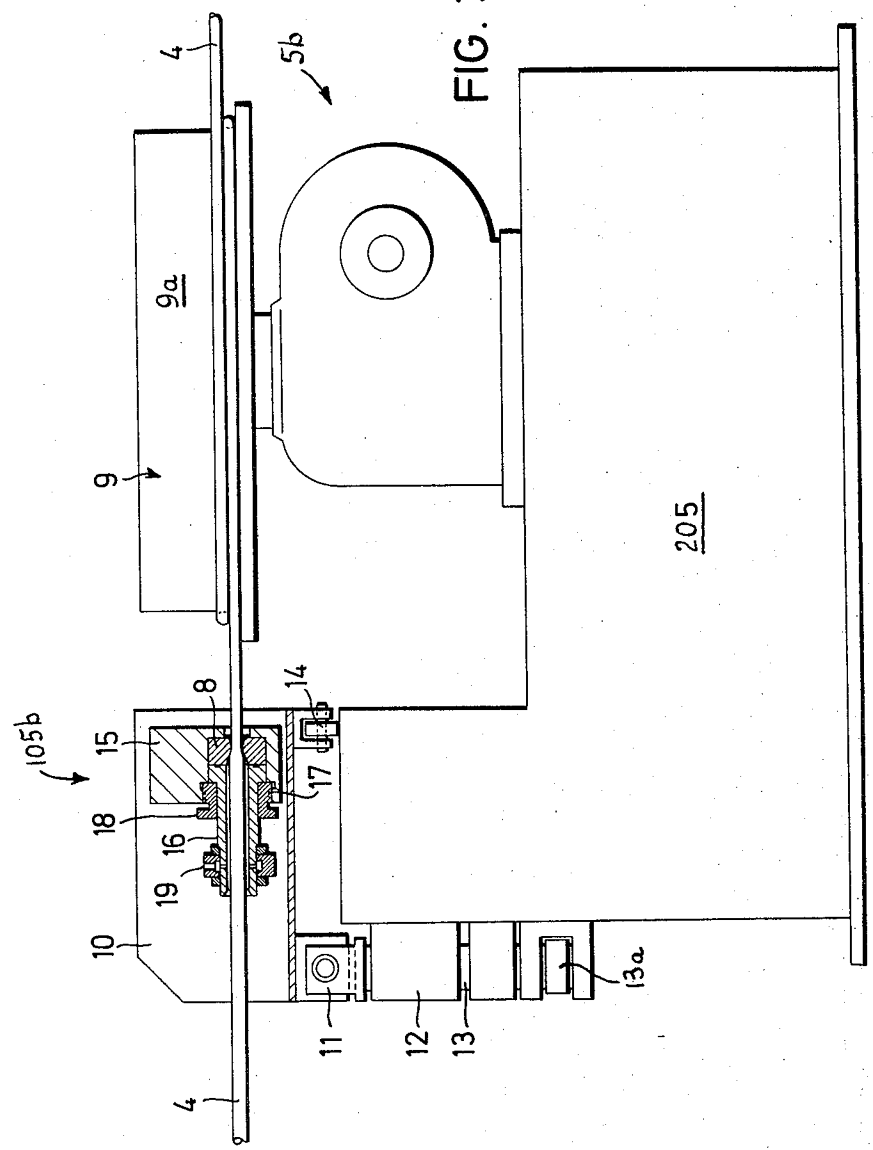


FIG. 3

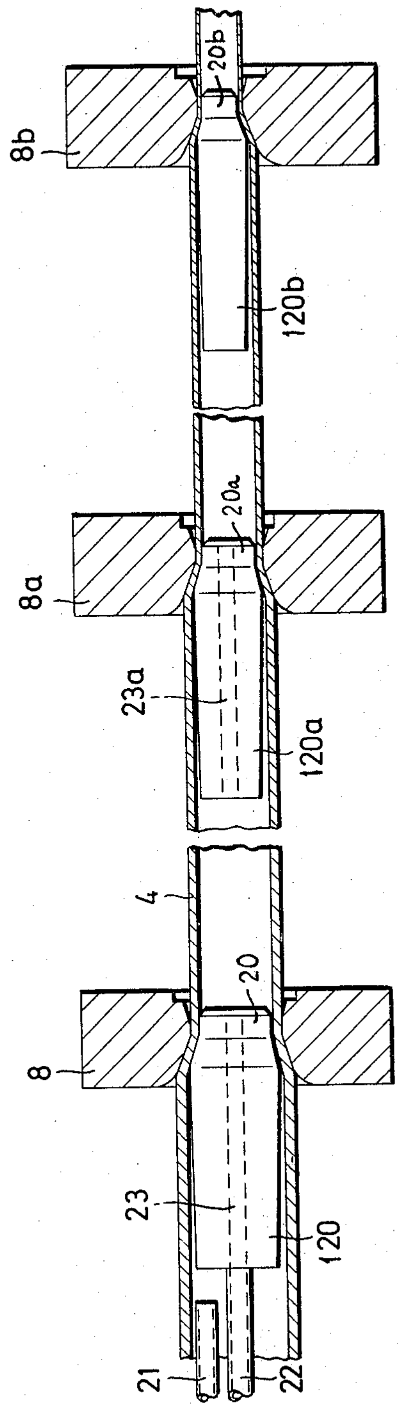


FIG. 4

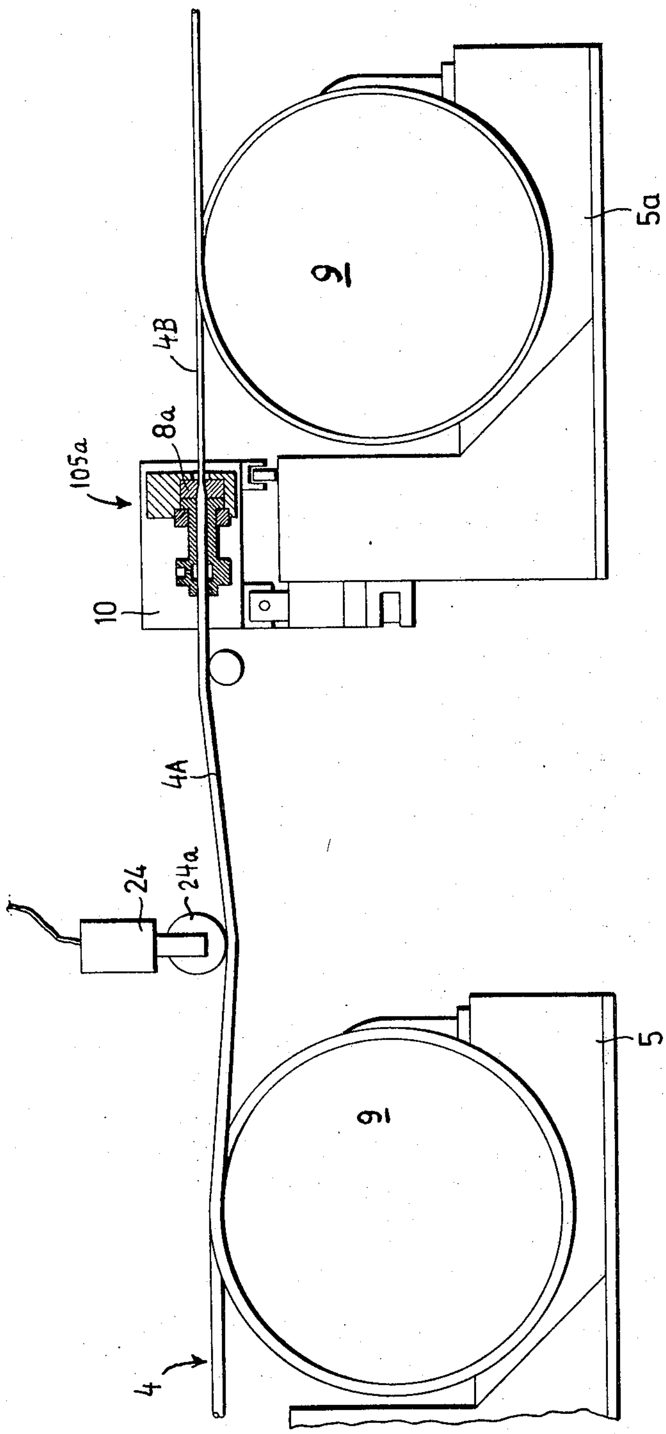


FIG. 5

MULTI-PASS METHOD AND APPARATUS FOR COLD-DRAWING OF METALLIC TUBES

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for cold-drawing metallic tubes in a series of successive passes by pulling the tubes through a succession of reducing dies.

In accordance with the presently prevailing practice, the cold-drawing of metallic tubes in a plurality of passes invariably involves extensive auxiliary treatment of tubes upon completion of each pass. Such auxiliary treatment prolongs the cold-drawing operation and contributes to complexity of the draw benches.

It is already known to treat seamless or welded metallic tubes in a rolling mill wherein the tubes are caused to advance through a series of successive roll stands. Such treatment may involve a reduction of wall thickness and/or a reduction of external diameter. The rolling of welded tubes exhibits the important advantage that, even though the external diameter of a welded tube cannot be reduced below 8–10 millimeters, a subsequent rolling of such tubes can result in a very substantial reduction to a small fraction of the minimum outer diameter of a welded tube.

However, the treatment of metallic tubes in a multipass stretch-reducing mill also exhibits a number of serious drawbacks. Thus, the reduction of diameter and/or wall thickness per roll stand is relatively small so that a substantial reduction of such parameters necessitates the use of a large number of stands. Moreover, the speed of rolls in successive stands must be regulated with a very high degree of accuracy by resorting to complex and expensive regulating units. Still further, the rate of deformation of tubes in a rolling mill is much less satisfactory than in a draw bench for cold-drawing.

In the so-called stretch-reducing mills, the speed of rolls increases from stand to stand so that the stretching of a tube can exceed or can be reduced below that which corresponds to the reduction of diameter. Thus, the wall thickness can be reduced simultaneously with a reduction of external diameter whereby the extent of reduction in wall thickness depends on the magnitude of applied tensional stresses which produce a reaction force. This force is built up as a result of frictional engagement with the rolls of the foremost stands and must be reduced during passage of the tube between the rolls of the last stands. The just described treatment in stretch-reducing mills exhibits the drawback that the reduction in wall thickness is not uniform because the tensional stresses to which the moving tube is subjected during passage through the roll stands cannot be measured with the necessary degree of accuracy. Furthermore, such mills are not suited for the treatment of welded metallic tubes because the welding operation results in the formation of an internal seam which runs parallel to the axis of the welded tube and remains therein upon completion of a stretch-reducing operation. The removal of such seam presents serious problems. Also, the stretch-reducing operation invariably results in roughening of the internal surfaces of metallic tubes.

SUMMARY OF THE INVENTION

An object of the invention is to provide a novel and

improved method of reducing the diameters and/or wall thicknesses of metallic tubes in a succession of passes and in a reproducible manner.

Another object of the invention is to provide a novel and improved cold-drawing method of treating metallic tubes which allows for substantial and controlled reduction in the wall thickness and/or external diameters of such workpieces.

A further object of the invention is to provide a novel and improved apparatus for cold-drawing of metallic tubes which allows for controlled reduction of external diameters and wall thicknesses of metallic tubes and which does not necessitate any auxiliary treatment of tubes between successive cold-drawing operations.

An additional object of the invention is to provide the cold-drawing apparatus with novel and improved means for moving metallic tubes lengthwise through a series of successive reducing dies.

Still another object of the invention is to provide an apparatus for economical cold-drawing of metallic tubes which can be utilized to effect a substantial reduction in the diameters and/or wall thicknesses of metallic tubes.

Another object of the invention is to provide an improved multi-stage cold-drawing apparatus for seamless or welded metallic tubes.

The method of the present invention is utilized for cold-drawing of metallic tubes in a plurality of successive passes while a tube travels within a series of longitudinally spaced diameter-reducing surfaces each of which surrounds a space whose cross-sectional area exceeds the cross-sectional area of the space surrounded by the next-following surface. The method comprises the steps of subjecting the tube to be cold-drawn to the action of discrete pulling forces acting on the tube downstream of the reducing surfaces so that the tube advances lengthwise through successive spaces, and regulating the magnitude of such forces so as to subject the tube to oppositely directed variable tensional stresses acting on the tube upstream and downstream of each reducing surface whereby the tensional stresses which act on the tube upstream of the reducing surfaces reduce the resistance which the tube offers to a reduction of its diameter during travel through the respective spaces.

The method may further comprise the step of subjecting the tube to the action of at least one wall-thickness reducing surface which is spacedly surrounded by one of the diameter-reducing surfaces. The diameter-reducing surfaces are the internal surfaces of discrete reducing dies and the wall-thickness reducing surface or surfaces are the external surfaces of mandrels which are inserted into the tube in the region of one or more dies.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved cold-drawing apparatus itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic side elevational view of a multipass cold-drawing apparatus which embodies the invention;

FIG. 2 is a schematic plan view of the cold-drawing apparatus;

FIG. 3 is an enlarged longitudinal vertical sectional view of a draw bench and of a tube advancing unit in the apparatus of FIGS. 1 and 2;

FIG. 4 is an enlarged sectional view of three successive reducing dies in the apparatus of FIGS. 1 and 2; and

FIG. 5 is an enlarged partly longitudinal vertical sectional view of a detail in the apparatus of FIGS. 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIGS. 1 and 2, there is shown a cold-drawing apparatus which includes a reel 1 storing a supply of convoluted steel tape or band 4*a* and a tube forming unit 2 which converts the band 4*a* into a continuous tube 4*b*. Such tube is thereupon caused to pass through a welding unit 3 to be converted into a welded tube 4 which is ready to enter the first of a series of four successive draw benches 105, 105*a*, 105*b*, 105*c*. The welding unit 3 provides the tube 4 with an axially parallel welded seam, not shown.

Each of the draw benches 105–105*c* is assembled with one of four advancing devices 5, 5*a*, 5*b*, 5*c* to form therewith a compact combined cold-drawing and advancing or pulling unit.

The reference character 6 denotes a conventional calibrating device for cold-drawn tubes, and such calibrating device is followed by collecting or winding devices 7, 7*a* for calibrated tubes.

Each of the advancing devices 5, 5*a*, 5*b*, 5*c* comprises a rotary wheel or drum 9 having a cylindrical external surface 9*a* (FIG. 3) around which the tube 4 forms at least one convolution, and a discrete variable-speed electric motor 109 (FIG. 2) which drives the respective wheel 9 at a selected speed through the intermediary of a suitable transmission 209.

FIGS. 1 and 2 further show that the wheels 9 of the advancing devices 5, 5*a* are angularly offset relative to each other by 180°, as considered in the circumferential direction of the path for the tube 4. The relative positions of wheels 9 in the advancing devices 5*b*, 5*c* are similar but the plane of the wheels 9 in the devices 5*b*, 5*c* makes an angle of 90 degrees with the plane of the wheels 9 in the devices 5 and 5*a*. Such distribution of the wheels 9 is particularly desirable when the diameters of the peripheral surfaces 9*a* are relatively small.

Referring again to FIG. 3, there is shown that cold-drawing and advancing unit which includes the draw bench 105*b* and the next-following advancing device 5*b*. This unit comprises a single base 205 which supports all components of the draw bench 105*b* and all components of the advancing device 5*b*. The draw bench 105*b* comprises a reducing die 8 which is fixedly but removably mounted in a holder 15 and abuts against a flange at the forward end of a lubricant-confining sleeve 16. A nut 18 meshes with the holder 15, as at 17, to prevent axial movement of the die 8 and/or sleeve 16. The inlet for admission of lubricant into a tubular confining space between the external surface of the welded tube 4 and the forwardly tapering conical internal surface of the sleeve 16 is shown at 19. The purpose of the confining sleeve 16 is described in our copending application Ser. No. 265,970 filed June 26, 1972 and owned by the assignee of the present application.

The holder 15 is mounted in a frame 10 which is pivotable about a horizontal pin 11. The latter extends at right angles to the path of the tube 4 and across the space between the prongs of the bifurcated upper end portion of a vertical shaft 13 which is rotatable in a bearing sleeve 12 of the base 205. The shaft 13 is movable up and down by an adjusting device 13*a*, e.g., a feed screw. It will be seen that the parts 11 and 13 allow for movement of the die 8 in a plurality of directions so that the axis of the die coincides with the axis of the tube 4 when the latter is moved lengthwise in response to rotation of the wheel or drum 9 in the advancing device 5*b*. A roller 14 at the lower front end of the frame 10 abuts against a platform at the top of the base 205 to reduce friction when the frame 10 is caused to turn about the axis of the shaft 13. It will be seen that the portion of the tube 4 shown in FIG. 3 forms a single convolution around the surface 9*a* of the wheel 9. The construction of the other three combined cold-drawing and advancing units is preferably identical with that of the unit shown in FIG. 3. Of course, the cross-sectional areas of spaces surrounded by the reducing internal surfaces of the dies 8 in draw benches 105, 105*a*, 105*b* respectively exceed the cross-sectional areas of spaces surrounded by the dies 8 in the draw benches 105*a*, 105*b*, 105*c* and the wheels 9 of successive advancing devices 5, 5*a*, 5*b*, 5*c* are angularly offset relative to each other in a manner as described in connection with FIGS. 1 and 2.

Referring to FIG. 4, the dies of the draw benches 105, 105*a*, 105*b* are respectively denoted by reference characters 8, 8*a* and 8*b*. The draw benches 105, 105*a*, 105*b* further respectively comprise floating mandrels 20, 20*a*, 20*b* which respectively cooperate with the dies 8, 8*a*, 8*b* to reduce the wall thickness of the tube 4 simultaneously with a reduction in external and internal diameters of the tube. The mandrels 20, 20*a*, 20*b* are respectively provided with rearwardly extending confining members 120, 120*a*, 120*b* which define with surrounding portions of the internal surface of the tube 4 a series of forwardly tapering tubular confining spaces for pressurized lubricant. The space around the confining member 120 receives pressurized lubricant from a supply pipe 21. A conduit 22 delivers pressurized lubricant to an axial bore 23 extending through the parts 20, 120 whereby such lubricant fills the confining space around the member 120*a*. An axial bore 23*a* of the member 120*a* and mandrel 20*a* admits pressurized lubricant into the space surrounding the confining member 120*b*. The conduit 22 and supply pipe 21 are introduced into the interior of the tube 4 at the station accommodating the tube forming unit 2 or welding unit 3 of FIGS. 1 and 2. The purpose of the lubricant which is fed by way of the pipe 21 and conduit 22 is disclosed in our aforementioned copending application Ser. No. 265,970 to which reference may be had if necessary. Such lubricant insures that the tube 4 remains separated from the mandrels 20–20*b* and confining members 120–120*b* by continuous films of lubricant whose pressure preferably exceeds 600 atmospheres and may rise to 3,000 atmospheres superatmospheric pressure.

Referring finally to FIG. **5**, there are shown two successive advancing devices (e.g., **5** and **5***a*) and the draw bench (**105***a*) therebetween. The speed of the motors **109** which drive the wheels **9** of the advancing devices **5** and **5***a* is regulated by a control circuit including a gauge **24** having a dancer roll **24***a* which rides on the tube **4** upstream of the die **8***a*. The tension of the tube **4** is selected in such a way that the tube portion **4B** downstream of the die **8***a* is pulled forwardly by the device **5***a* and that the tube portion **4A** upstream of the die **8***a* is pulled rearwardly by the advancing device **5**. Thus, the tube **4** is subjected to oppositely directed tensional stresses upstream and downstream of the die **8***a* whereby the tensional stresses which are produced by the device **5** reduce the resistance which the tube portion **4A** offers to a reduction of its diameter and wall thickness during travel through the die **8***a*. The gauge **24** furnishes signals whose intensity is proportional to tensional stressing of the tube portion **4A** whereby the control circuit which includes the gauge **24** changes the speed of the motor **109** for the wheel **9** in the advancing device **5***a* and/or **5** when the magnitude of the detected tensional stress deviates from a desired value. The exact construction of the regulating means including the circuit which receives signals from the gauge **24** and controls the speed of the motors **109** forms no part of the present invention. The tensional stressing of tube portions **4A** upstream of each of the dies is preferably maintained within a desired range. The arrangement is such that the forces acting upon the tube **4** counter to the direction of its movement through the dies are balanced by the forces which must be applied to deform the tube during passage through the dies. The determining factor is the magnitude of tensional stresses which are measured by the gauges **24** and are regulated in response to signals from the gauges to remain at an optimum value. Such tensional stresses oppose the pulling forces furnished by the advancing devices **5**, **5***a*, **5***b*, **5***c* downstream of the respective dies. The pulling forces are selected by the regulating means automatically as a function of tensional stresses acting on the tube upstream of the dies and as a function of the magnitude of necessary deforming forces which are needed to effect the reduction in diameter and/or wall thickness during travel through the dies.

For the sake of simplicity, FIG. **5** shows the wheels **9** of the advancing devices **5** and **5***a* at the same side of the path for the tube **4**.

EXAMPLE

The apparatus is assumed to comprise four draw benches and four advancing units. Each draw bench includes a die and a floating mandrel. Such apparatus allows for a reduction in the cross-section of a metallic tube by 82.3% . Thus, and assuming that the outer diameter of a freshly welded tube **4** is 15 millimeters and that the wall thickness of such tube is 1.15 millimeters, the wall thickness and outer diameter can be respectively reduced to 1 and 4 millimeters.

The reductions of diameter and wall thickness during each of four successive passes are given in the following table:

	Dimensions in millimeters	Reduction of cross section in percent
after the 1st pass:	11.7×1.10	26.8
after the 2nd pass:	8.9×1.05	29.4
after the 3rd pass:	6.3×1.02	34.7
after the 4th pass:	4.0×1.00	44.2

The speed of the motor **109** in each next-following advancing device **5***a*, **5***b*, **5***c* exceeds the speed of the motor **109** in the respective preceding advancing device **5**, **5***a*, **5***b*. This compensates for automatic elongation of the tube **4** during cold-drawing. In addition, and as mentioned above, the speed of the motors **109** is regulated with a view to subjecting the tube **4** to desirable tensional stresses upstream of each reducing die. These tensional stresses reduce the resistance of the material of the tube to deformation during passage between the dies and the associated mandrels. Such mode of operation allows for a substantial reduction of the cross section of tubular workpieces in a relatively small number of passes. The reduction of cross section is much greater than in rolling mills; as indicated in the preceding table, such reduction may be in the range of 30–50 percent per die whereas the reduction per stand of a rolling mill normally approximates 5 percent. In addition, the dies exert a beneficial influence on the material of the tubes and render it possible to reduce the dimensions of tubes in an accurately reproducible manner, i.e., within very close tolerances. Still further, the apparatus of the present invention does not cause a one-sided reduction of diameter and/or wall thickness, even when the dies and the mandrels are called upon to effect a very substantial reduction in the cross-sectional area of a tubular workpiece. This constitutes another important advantage over the rolling mills.

Still further, the generation of tensional stresses in those portions of a moving tubular workpiece which are located upstream of the dies results in a reduction of transverse (radial) stresses and in less pronounced elastic expansion of the dies. Also, such tensional stresses reduce frictional losses with less pronounced heating of and less pronounced wear upon the workpieces and component parts of the draw benches. The tensioning of tubes upstream of the dies facilitates the deforming operation and reduces the peaks of stresses upon the dies.

It is clear that the advancing devices **5**, **5***a*, **5***b*, **5***c* constitute but one form of means for moving the tubular workpieces lengthwise through a series of reducing dies. For example, such advancing devices can be replaced with worms, plyers or the like. However, the illustrated advancing devices exhibit a number of important advantages. The angular spacing of wheels **9** as shown in FIGS. **1** and **2** reduces the likelihood of unequal distribution of material in the tubular workpieces and/or peripheral incrustation of certain strands of the metallic material.

It is further clear that the apparatus and method of the present invention can be resorted to for the cold-drawing of continuous or finite lengths of seamless metallic tubes. In the cold-drawing of seamless or welded tubes of finite length, successive tubes are preferably connected to each other end-to-end by means of plugs or the like.

The admission of pressurized lubricant between the internal surfaces of dies and the external surface of a moving tube on the one hand and the internal surface of the tube and external surfaces of floating mandrels on the other hand renders it possible to transport the tube at a very high speed in the range of up to and in excess of 300 meters per minute.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of our contribution to the art and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. In an apparatus for cold-drawing metallic tubes, a combination comprising a series of discrete draw benches each having a diameter-reducing die surrounding a space whose cross-sectional area exceeds the cross-sectional area of the space surrounded by the next-following die, each of said draw benches further having means for admitting a pressurized lubricant between the respective die and the portion of a tube within the respective die, at least two successive draw benches including floating mandrels spacedly surrounded by the respective dies and defining therewith annular reducing passages for successive increments of a tube, the floating mandrel in the preceding one of said two successive draw benches being provided with a channel for admission of a pressurized lubricant into a tube between said mandrels; a plurality of discrete tube advancing means each disposed downstream of a different one of said dies and each comprising a rotary element having an endless surface engaging with at least one convolution of the tube to be cold-drawn and motor means for driving the respective rotary element in a direction to pull the tube through the preceding die; means for regulating the speed of said motors so as to subject the tube to oppositely directed tensional stresses acting on the tube upstream and downstream of each die whereby the tensional stresses acting on the tube upstream of said dies reduce the resistance which the tube offers to a reduction of its diameter during travel through the respective dies; a source of metallic band material; and tube forming means disposed between said source and the foremost draw bench to convert the band material of said source into a tube which is caused to pass through the dies of successive draw benches.

2. A combination as defined in claim **1**, wherein the rotary elements of successive advancing means are offset relative to each other in the circumferential direction of the path for the tube.

3. A combination as defined in claim **2**, wherein the number of said advancing means exceeds three and said rotary elements include a first pair of elements angularly offset relative to each other by about 180° and a second pair of elements angularly offset relative to each other by about 180° and angularly offset relative to the elements of said first pair by about 90°.

4. A combination as defined in claim **1**, wherein said regulating means includes at least one gauge arranged to measure the tension of the tube.

5. A combination as defined in claim **4**, wherein said gauge includes a tube-engaging dancer roll.

6. A combination as defined in claim **1**, further comprising a common frame for each of said dies and the next-following advancing means.

7. A combination as defined in claim **1**, further comprising a frame for each of said dies and mounting means coupling said dies to the respective frames for pivotal movement in a plurality of different directions so that the axes of the dies coincide with the axes of the tube portions therewithin.

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