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METHOD FOR PRODUCING TUBE SHELLS

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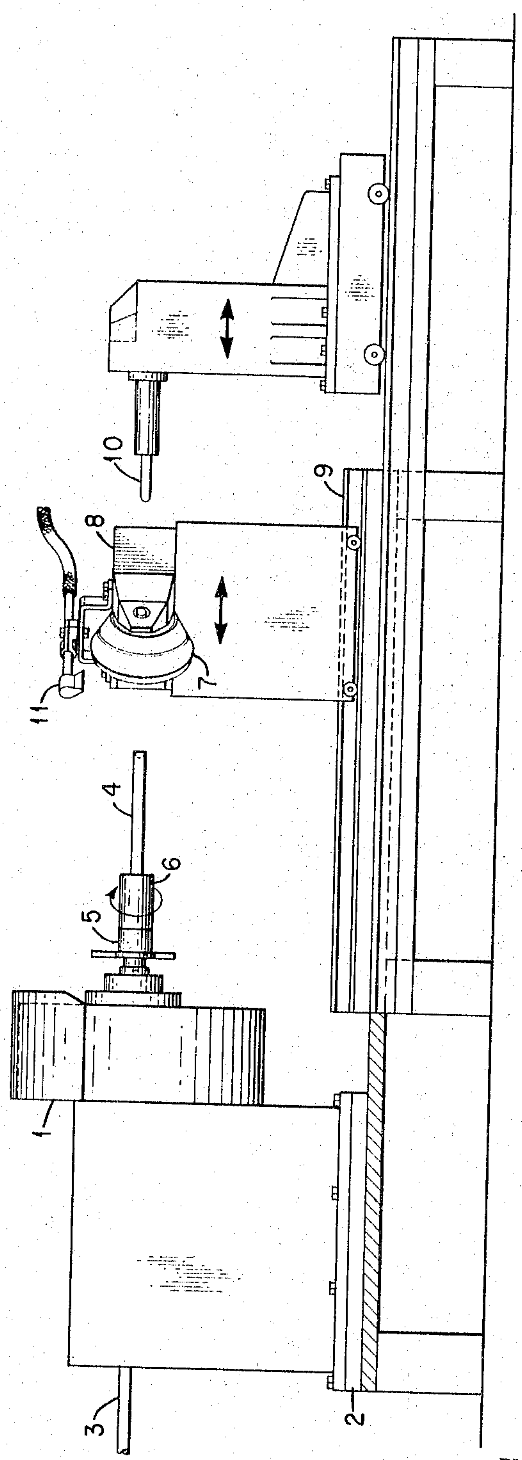

Fig. 1.

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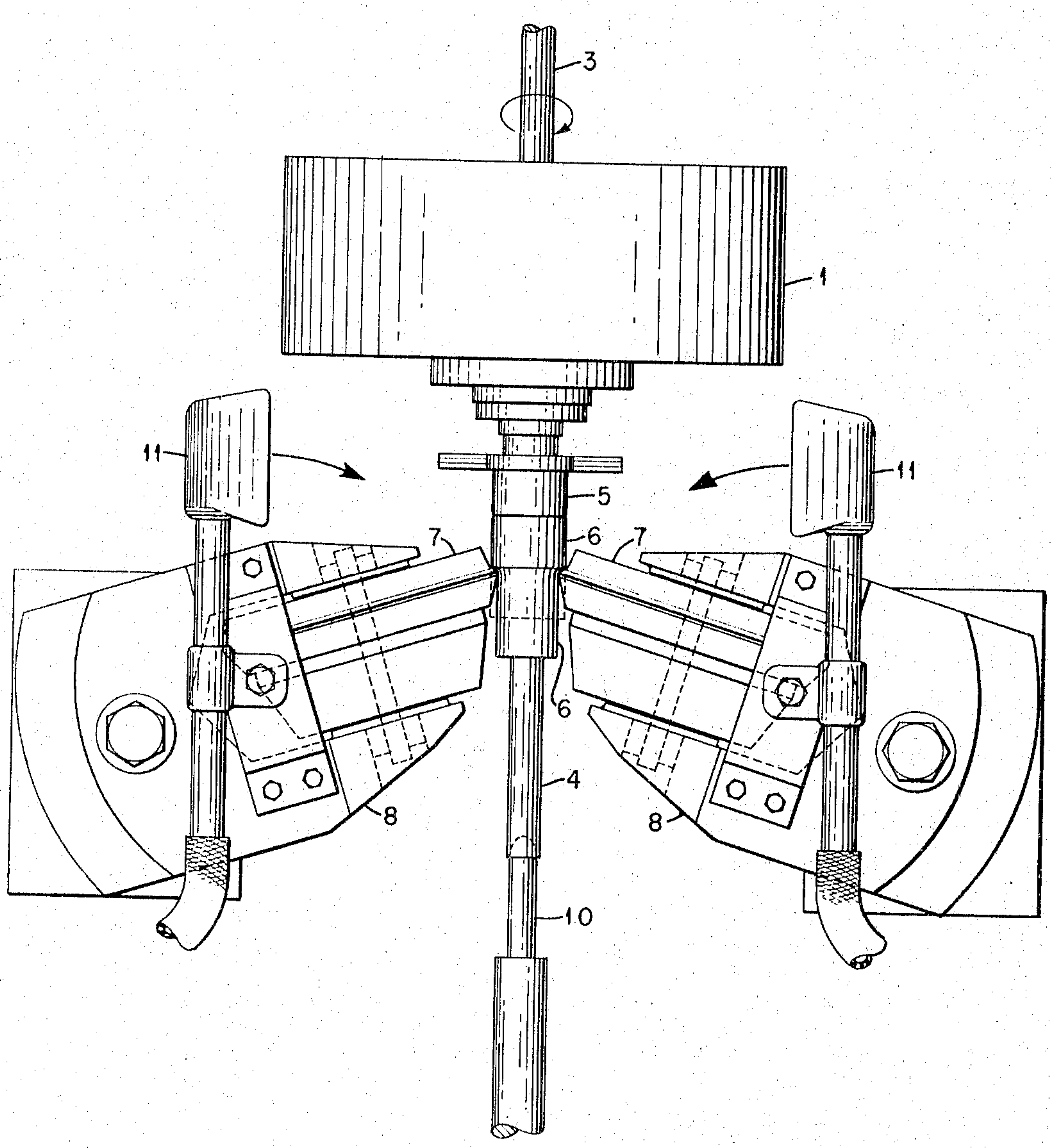

Fig. 2.

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METHOD FOR PRODUCING TUBE SHELLS
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3 Claims. (Cl. 29—528)

The present invention relates generally to processes for fabricating metal tubing and more particularly to a low temperature process for fabricating refractory metal tubing. Refractory metals and alloys thereof which possess room temperature ductility but are prone to high temperature contamination are meant to be within the scope of this process.

One method for preparing metal tubing is to extrude the metal into a tube shell or blank and then draw the resulting tube shell into finished metal tubing. While this method has been highly successful with most metals, it has not been generally satisfactory for fabricating metal tubing from such refractory metals as zirconium, columbium, tantalum, rhenium, and alloys thereof. Unlike extrusion of the more common metals, such refractory metals must be extruded at high temperature which imposes tooling, handling, and lubricating problems. Also, inasmuch as these metals readily undergo oxidation at elevated temperatures, contamination problems not attendant with most other metals become most severe when carrying out a high temperature extrusion of such metals. A more serious drawback to the use of conventional extrusion techniques is the large material losses incurred with such processes. For the refractory metals, the tube shells have to be extruded a number of times in order to obtain the desired degree of wall thickness reduction and where multiple extrusions are required the ends of the workpiece must be "squared up" after each pass. Hence, in such conventional extrusion processes only about 40–50% of the starting material is utilized in preparing finished metal tubing. It may readily be seen that when working with such expensive metals as the refractory metals it would be most advantageous to utilize a metal working process wherein essentially all of the starting material is converted into a finished product.

It is therefore an object of the present invention to provide an improved method for fabricating refractory metal tube shells which have a uniformly heavily worked structure and which can subsequently be heat treated for controlled grain size.

Another object of the present invention is to provide a low temperature method for fabricating refractory metal tubing wherein essentially all of the starting refractory metal is utilized.

Still another object of the present invention is to provide a low temperature tube shell fabrication method.

A further object is to provide a low temperature method for fabricating refractory metal tube shells which have satisfactory surface finishes suitable for subsequent tube drawing operation.

Still a further object is to provide a method for preparing refractory metal tubing which requires no intermediate hot-working and/or minimal thermal treatment between extruding operations.

Another object is to provide a low temperature method for fabricating refractory metal tubing which overcomes prior art problems of contamination and high temperature oxidation of the metals during extrusion.

Other objects and advantages of the present invention, which will be apparent to those skilled in the art, are accomplished by providing a novel method for fabricating

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metal tubing comprising casting the metal into a billet and deforming the billet at room temperature on a mandrel to thereby displace the metal uniformly along the mandrel in a direction opposite to the direction of applied force to form a metal tube shell. After the metal billet is formed into a metal tube shell, it is drawn into metal tubing. Applicants have found that, with their novel back extrusion process, refractory metal tubing can be fabricated at low temperatures, i.e., around room temperatures ($\sim$20° C.) with excellent results. As used herein the term "back extrusion" means a mechanical working operation in which the material being worked is reduced in thickness by a shearing action which causes the material to flow uniformly along a mandrel in a direction opposite to the direction of applied force. With the present process applicants have been able to fabricate refractory metal tubing wherein as high as 85% of the starting material is converted into finished tubing with no intermediate hot-working and minimal thermal treatment necessary between extrusions. Furthermore, size reductions between 15 and 50 percent can be easily carried out in single or multiple operations.

In the drawings:

FIGURE 1 is a side elevation diagrammatic in character of apparatus embodying the invention;

FIGURE 2 is a plan view diagrammatic in character showing in greater detail the rollers contacting the rotating billet.

Referring to FIG. 1, a rotatable lathe **1** is mounted on a support **2** and powered by motor means (not shown) through drive shaft **3**. A cylindrical mandrel **4** is chucked in lathe **1** and adapted to receive first a follower billet **5** and then a refractory metal billet **6** which is inserted in a slip-tight fit on the mandrel **4**. A pair of rollers **7** are mounted on massive metal supports **8** which are adapted to be hydraulically driven along ways **9** into contact with the rotatable metal billet **6**. The rollers **7** which are disposed at an angle to the centerline of billet **6** and on opposite sides thereof are laterally adjustable to enable a variable size reduction of the billet for each pass. The rate of advance of the rollers **7** may be adjusted for each of the passes over the billet **6**. A tail stock **10** which is hydraulically driven is adapted to move along the centerline of billet **6** to engage the free end of the mandrel **4**. Coolant and lubricants are provided at the point where the rollers **7** contact the metal billet **6** by nozzles **11** which are rigidly mounted over the rollers **7**.

Referring more particularly to FIG. 2, which shows the rollers **7** making a first pass along the billet **6**, it may be seen that the rollers **7** have a tapered surface with a raised lip which provides a biting surface during the back extrusion. The metal billet **6** may be seen to have already been initially displaced in a direction opposite to the direction of applied force and with each pass additional displacement will occur until the billet is reduced to a tube shell of a given diameter.

In practicing the invention the metal, in either wrought or cast form, is first conditioned into billets. For this any conventional method for consolidating metals, such as by hot-working, powder metallurgical techniques, arc-casting, or by electron beam melting, may be employed. With respect to the casting operation applicants feel that an especially advantageous method for preparing the metal billets may be afforded by centrifugally casting the metal into cylindrical billets, whereby a uniform, equiaxed, fine-grain structure is obtainable. The ingot or wrought product generally will have to be machined or ground to finished billet dimensions. However, prior to carrying out the machining operation the billets should first be conditioned to a fixed hardness. With respect to this applicants have found that it is important that the metal be in a relatively soft state, i.e., an intermediate hardness state. If the metal is too hard it will not move during the extrusion operation and if it is too soft the billet will experience "roll over" during extrusion which greatly retards metal back-flow along the mandrel. It will be appreciated that, inasmuch as each of the refractory metals has a different optimum hardness range, the conditioning of each metal will vary for each one. To illustrate, applicants have found that conditioning Nb-1% Zr alloy to of hardness of between 18–24 Rockwell B is quite suitable, while conditioning tantalum metal alloy to a hardness of about 90 Rockwell B works quite well. While any conventional means may be employed in conditioning the billets, it has been found that the cast ingots or billets may conveniently be vacuum homogenized at an elevated temperature to condition the metal to a fixed hardness. For example, Nb-1% Zr alloy has been conditioned to a hardness of 21 Rockwell B by vacuum homogenizing at 980° C. for one hour.

After the billet is cooled to room temperature it is machined to billet dimensions, as for example 3" O.D. x 1½" I.D. x 5" cylinder, and placed on the mandrel. It will be appreciated that the billet dimensions are not critical, but are selected to insure compatibility with subsequent tube shell processing. From FIG. 1 it may be seen that the mandrel is chucked in the lathe and the metal billet is mounted on the mandrel independent of the lathe. Thus, it may be seen that the billet must be tightly fitted to the mandrel. This may be accomplished by any convenient means wherein an interference fit between the billet and the mandrel is provided to afford a slip-tight fit. A thin sleeve of a ductile metal, such as copper, may be employed over the mandrel to improve the I.D. surface of the extruded tube; however, it should be recognized that where such a sleeve interferes with the friction fit between the mandrel and the billet it might be preferred to omit the sleeve. As a special point it has been found that, in the case of tantalum metal alloys, the billet cannot readily be removed from the mandrel after extrusion and it is preferred to apply a thin layer of material, such as Teflon, on the mandrel prior to mounting the billet thereon to aid in removal of the metal billet after extrusion.

After the billet is fitted on the mandrel, it is back-extruded into a tube shell. In carrying out this extrusion a pair of rollers, which are disposed at an angle to the centerline of the billet, are advanced along the centerline of the billet into contact with the rotating billet. The rollers may be driven by any suitable power means, such as by a hydraulically actuated drive system. These rollers, which are friction-driven by the rotating workpiece, effect a size reduction in the billet by a shearing action of the metal billet, causing the metal to flow in a direction opposite to the direction of applied force. It will be appreciated that, while such process parameters as the rotational speed of the lathe and the feed rate of the rollers affect the physical characteristics of the finished tube shell, they are not critical and may be varied widely. For example, rotational speeds of 300–400 r.p.m. with a feed rate of 1–3 inches/minute have been employed with such metal billets as Nb-1% Zr alloy billet. While the angle to which the rollers are disposed from the centerline of the billet is not critical, applicants have found that it is preferred that the rollers form such an angle with the billet that the leading edge of the rollers is in close proximity or in actual contact with the trailing edge of the metal billet. Applicants feel that this, along with the metal which has not become pliable, restrains the metal from flowing in the direction of applied force and effects a back-flow along the mandrel.

It will be apparent to those skilled in the art that the size reduction for each pass will vary for each refractory metal, depending upon its respective mechanical properties. This may conveniently be shown by the rate of work hardening of the metal, i.e., the greater the rate of work hardening the smaller the size reduction per pass. By rate of work hardening it is meant the speed at which the metal becomes hardened, thereby requiring annealing before any further size reduction may be effected. Although size reductions as great as 50% (¼" off radius of billet per pass) may be effected, it has been found that size reductions of ⅛" to $\frac{1}{16}$" off the radius per pass have been quite suitable and are preferred. With a size reduction of ⅛" off the radius per pass applicants have been able to extrude an 18"-long tube shell from a 3" O.D. x 1½" I.D. x 5" Nb-1% Zr metal billet in 6 passes without having to anneal the billet between extrusions.

Of especal benefit is the fact that the back extrusion may be carried out at room temperature (20° C.). Thus, applicants' process alleviates the prior art problems of having to heat the refractory metal to extremely high temperatures prior to inserting the billet in the billet chamber in order to carry out a hot extrusion. It will be apparent that during the actual back extrusion of applicants' process the metal is heated to its softening point and is thus displaced along the mandrel. However, it is not required that the metal billet be heated prior to the extrusion operation. During extrusion applicants have found it desirable to provide a coolant and a lubricant such as a sulfonated oil and water mixture, to the metal during actual extrusion. This may be provided by any convenient means such as by nozzles which may be rigidly mounted above the rollers so as to direct a stream of the coolant and lubricant onto the metal billet at the point of contact between the rollers and the billet.

Further illustration of the quantitative aspects and procedures of the present invention is provided in the following examples. Example I demonstrates the applicability of back extrusion to producing a tube shell directly from a cast Nb-1% Zr ingot, and Example II shows extrusion of a tantalum metal alloy.

Example I

An ingot of cast Nb-1% Zr was vacuum homogenized at 980° C. for one hour to an intermediate hardness of 21 Rockwell B. After cooling to room temperature in vacuum, a cylinder (3" O.D. x 1½" I.D. x 5" long) was machined from the ingot. The machined billet was shrink-fitted onto a 1½" O.D. H–12 hardened steel mandrel which was chucked in a rotatable lathe. The metal billet was back-extruded by advancing a pair of rollers, which were mounted at an angle to the centerline of the billet, into contact with the rotating billet. The rotational speed of the billet was 325 r.p.m. and the feed advance of the rollers was 1 inch/minute. A size reduction of ⅛" off the radius of the billet was used and the billet was reduced by approximately 50% in 6 passes.

No intermediate hot-working and/or thermal treatment was necessary between extrusion passes. The resulting tube shell (2" O.D. x 18" long) was visually examined, ultrasonically checked, and found to have a satisfactory surface finish which was amenable to a subsequent tube drawing operation.

After the tube shell was inspected for defects and tube reduced, it was placed on a warm-draw bench and drawn to ¾" O.D. metal tubing having a wall thickness of .035 inch by conventional warm-drawing techniques. Better than 81% of the starting metal was converted into tubing.

It should be noted that the 15% loss of metal was due to the drawing operation with essentially all of the starting metal converted into tube shell during the back extrusion.

Example II

An ingot of cast tantalum metal alloy was vacuum homogenized at 1200° C. for one hour to an intermediate hardness of 93 Rockwell B and machined to a cylinder (3" O.D. x 1½" I.D. x 5" long) billet. The machined billet was extruded as in Example I. The rotational speed of the billet was 250 r.p.m. and the feed advance of the rollers was 2.75 inches/minute. A size reduction of 1/16" off the radius of the billet was used. The metal billet had to be annealed at a temperature of ~1200° C. four times between extrusions due to the work hardening of the metal billet during extrusion and it required 8 passes to reduce the billet by approximately 50%. The resulting tube shell (2" O.D. x 18" long) was visually examined, ultrasonically inspected, and found to have a satisfactory surface finish which was amenable to a subsequent tube-drawing operation. The tube shell was warm-drawn as in Example I into a 3/4" O.D. metal tubing having a wall thickness of .035 inch. Better than 85% of the starting metal was converted into tubing with the loss of starting metal occurring in the tube-drawing operation.

It should be noted that even with tantalum metal alloy, which has a high work hardening rate, applicants were able to go from a cast structure to a finished tube shell with only four annealings, whereas prior art methods would require many times more the number of anneals between extrusions.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

What is claimed is:

1. A method for fabricating metal tubing comprising

the steps of casting said metal into a hollow billet, shrink fitting said billet onto a mandrel, deforming said billet on said mandrel to thereby displace said metal uniformly along said mandrel in a direction opposite to the direction of applied force, said deforming step being carried out at room temperature, and thereafter drawing the resulting tube shell into metal tubing.

2. The method of claim 1 wherein said metal is selected from the group consisting of zirconium, tantalum, columbium, rhenium, and alloys thereof.

3. The method of claim 1 wherein said metal is Nb-1% Zr metal alloy, said casting step is accomplished by centrifugally casting said metal into billets and said deforming step is carried out by a shearing process at 20° C.

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