EXTRUDED ARC CAST MOLYBDENUM
Int. Cl. B21c 23/00; G01k 5/06
U.S. Cl. 72—253
6 Claims

ABSTRACT OF THE DISCLOSURE
Arc cast molybdenum billets are extruded at a starting temperature of about 1000°F. through a 10 to 1 reduction without excessive extrusion pressure to produce sound extruded bars with excellent surface quality and little die wear.

The present invention relates to the art of fabricating molybdenum.

BACKGROUND

In general, there are two production methods used in initially forming molybdenum for fabricated parts. The first and older method involves sintering powder compacts and reduction by hot swaging or forging followed by cold drawing or rolling. The second method involves arc casting followed by extrusion or forging and followed by hot swaging or forging and cold drawing or rolling. Despite several inherent advantages of the arc cast material including higher initial density, greater freedom form interstitial contamination, better weldability and higher ductility, its use is substantially limited to production of large parts beyond the practical size limits of powder consolidation because of cost and difficulty of present extrusion methods. The industrial extrusion of molybdenum utilizes the Ugine-Sejournet process involving high speed presses and glass lubricants (see U.S. Pat. 3,126,097, 2,907,454, 2,903,554, 2,630,220 and Deuble and Perlmutter and De Pierre, supra). As applied to molybdenum the Ugine-Sejournet process is carried out at about 2000—4000°F. with reduction ratios of up to 8:1 at these high temperatures.

It is the object of the present invention to provide a method of processing arc cast molybdenum to make its competitive in cost with sintered-power molybdenum. In general the method involves extruding molybdenum preheated to about 1000°F. The method is based on the discovery that arc cast molybdenum is amenable to such processing—a possibility which was unnoticed or even positively excluded by the experts in the art, including the above authors. In retrospect, an early clue to this possibility was set forth in my published paper, ASME, 73: 723 (1951) in which it is noted that the hot hardness of arc cast molybdenum is less than that of powder metalurgy molybdenum, the arc cast product having substantially constant hardness at 70 to 75 VPN from 1000°F. to 3000°F.

At low temperatures (800—1500°F.) conventional lubricants can be used (e.g. MoS₂ or graphite) instead of molten glass. The thermal control problems are attenuated to the point that continuous processing of billets, one after another, is feasible. Oxidation and recrystallization are avoided thus insuring more reliable processing and sound extrusions than in the high temperature process and affording desirable work hardening of the extrusion.

A further object of the invention is the production of multiple die extrusions at low temperature.

This is a further desirable aspect of the low temperature process. In the high temperature process, processing instability and unequal flow rate occurs among the several simultaneous extrusions. The present low temperature extrusion process can provide the needed stability through the extra work hardening of that one extrusion which starts to flow faster than the other simultaneous extrusions. The consequent increase in back pressure counterbalances the flow instability.

EXAMPLE 1
Molybdenum powder was pressed and sintered at 3000°F. (in vacuum) to form 18 inch long octagonal billet 2 and ¾ inch “diameter” (across the flats). The bars were secured end to end by threaded molybdenum studs to form a consumable arc melt electrode which was arc cast to form a four inch diameter by five inch long, 22 pound billet with as-cast carbon content of 0.035% and hardness of 156 Brinell. The billet was formed with a starting bevel of 45° long by 45° and heated in argon to 1200°F. The billet was placed in a 1400 ton press with a linear of 4.050 inches inner diameter and a die of 1.280 inches inner diameter lubricated with Lubr-a-Tube lubricant. The die was coated with flame sprayed zirconia as described in Perlmutter and De Pierre, supra. The extrusion (9.3:1 ratio) was carried out at 975 ton upset force and 950 tons running force with a running speed of 50 inches per minutes. The emerging extrusion was bright yellow, indicating that most of the energy was converted to heat in the molybdenum. The surface quality of the extruded bars was excellent and very little die wear occurred.

EXAMPLE 2
A similar process was carried out with the variations of heating of 1000°F. F. and upset force of 1300 tons, running force of 1275 tons and 25 inches per minute ram speed. The results were similar.

A further embodiment of the invention is to use a die with multiple orifices in a schedule of 1400°F., 10:1 reduction and (n) (d) = (d) / r where n is the number of holes and r is hole diameter (e.g. eight holes at “d” of 4/5 inch) to extrude four inch billets in a modest size press. The extruded 4/5 inch rod can be drawn to 3/16 inch spray wire.

Another variation of the invention is a continuous extrusion process with either a single orifice die or multiple orifice die. A series of molybdenum extrusions would be made starting with a copper nose block before the first billet and a copper follow block after the first billet to act as the nose block for the second billet. At the end of a billet, the extrusion would be stopped and the extruded bar
of copper in the die would be cooled down to the starting temperature of the second billet. The range of extrusion ratios obtainable on a practical basis with the present method is 8:1 and above including ratios as high as 100:1 with adequate press capacity, but preferably about 10:1 as in the above examples, for an economic production schedule.

A particular advantage of the invention is that the resultant extruded product is more workable than corresponding powder metallurgy derived structures or arc cast structures extruded through the high temperature ranges of the prior art which overlap the recrystallization temperature range for relatively long times during extrusion. An extruded product according to the invention may be further worked at the same temperature range, without first annealing.

The starting temperature range of extrusion for the present invention is 800–1500 °F, with 1000–1400 °F being preferred and 1000–1200 °F being distinctly advantageous in terms of the various benefits afforded by the present invention, as indicated above.

The method of the present invention may be applied to extrusion of other cast metals having a low work hardening exponent similar to molybdenum, e.g., tungsten. The starting temperatures for such other metals would be the homologous temperature corresponding to the molybdenum starting temperatures given above (based on the ratio of melting points of molybdenum and such other metal) where all these temperatures are in degrees Kelvin. Once the homologous temperature is so derived, it can be converted to degrees Fahrenheit.

As used herein, "essentially bare billet" means an extrusion billet free of coatings other than lubricating coatings or the like, i.e., free of the stress distributing jacket of the type described in U.S. Pat. 3,416,432 whether applied by casting as in the patent or other methods, e.g., cladding.

What is claimed is:

1. A process for fabricating arc cast molybdenum comprising the step of extruding an essentially bare billet of the molybdenum at a starting temperature of from 800 to 1500 °F, through a reduction ratio in excess of 8 to 1.

2. The process of claim 1 wherein the molybdenum is extruded through a multiple orifice die whereby stabilization and even flow rate among the several simultaneous extrusions is provided by the work hardening of molybdenum at 800–1500 °F.

3. The process of claim 2 wherein the molybdenum is extruded on a continuous basis of one billet after another.

4. The process of claim 1 wherein the molybdenum is extruded on a continuous basis of one billet after another.

5. The process of claim 1 wherein the starting temperature for extrusion is from 1000 to 1400 °F.

6. The process of claim 5 wherein the starting temperature for extrusion is from about 1000 to 1200 °F.

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U.S. Cl. X.R.