United States Patent Office 2,767,112 Patented Oct. 16, 1956

2,767,112

METHODS OF ROLLING MOLYBDENUM AND MOLYBDENUM ALLOYS

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No Drawing. Application June 24, 1953, Serial No. 363,918

4 Claims. (Cl. 148—11.5)

This invention relates to a new method for rolling molybdenum and molybdenum alloys.

The successful rolling of molybdenum and its alloys is dependent upon a number of controlling factors attendant to the process. Such factors as rolling at maximum plasticity, the rolling-annealing schedule, temperatures, times, etc., are controlling for the production of a product of satisfactory hardness, strength and bending yield. For example, it has been found that if molybdenum and its alloy containing 0.10% cobalt are rolled above the maximum plasticity temperature range (about 1300–1500° C.) they tend to become "hot short." As another example, the anneal time in the rolling schedule is highly controlling as is evident from the fact that if the metal is overheated or underheated in the process the ingot will break during rolling, so that the problem becomes one of heating sufficiently to relieve the stresses so that overstressing the material in the succeeding passes is avoided and yet not heating to such an extent that the yield strength and tensile strength developed in the preceding passes is undesirably lowered. Other factors are equally important.

In addition to the production of a product having maximum hardness, strength and bending yield, the process should give consistent and reproducible results and yield products having uniform properties so that the process will be adaptable for large scale production.

It is therefore an object of the present invention to provide a process for rolling molybdenum and its alloys which gives maximum reduction in cross-sectional area with the production of a product having acceptable hardness, strength and bending yield.

It is another object of the invention to provide a process as stated above which gives consistent and reproducible results and provides finished products having uniform properties.

The following examples are illustrative of the invention but are not limiting. The anneal times in all schedules appear to be critical. The elapsed time between successive passes taken without reheating should be held to a minimum. Ingots are rotated 90° between successive passes.

Example I

In the following example a 21 inch diameter mill and a rolling speed of 52 R. P. M. was used to reduce the cross-sectional area of the ingot approximately 56%. A $1\frac{21}{32}$" x $1\frac{21}{32}$" ingot of molybdenum containing 0.10% cobalt was heated to between 1420 and 1480° C. and rolled to reduce the cross-sectional area to 2.40 square inches in the first pass (approximately 88% of the original cross-sectional area). Without reheating the ingot was rerolled to a cross-sectional area of 2.16 square inches in the second pass (approximately 79% of the original cross-sectional area). Annealing was accomplished by heating for 5 minutes above 1350° C., preferably between 1350 and 1400° C. In the third pass the ingot was rolled to an area of 1.89 square inches at 1370–1420° C. (approximately 69% of the original cross-sectional area). In the fourth pass it was rerolled without reheating to an area of 1.62 square inches (approximately 59% of the original cross-sectional area). The ingot was then annealed by heating for 2½ minutes above 1300° C., preferably between 1300–1350° C. In the fifth pass the ingot was rolled to an area of 1.39 square inches at 1340–1370° C. (approximately 51% of the original cross-sectional area) and in the sixth and final pass it was rolled without reheating to an area of 1.25 square inches (approximately 44% of the original cross-sectional area).

Rods of molybdenum containing 0.10% cobalt, 1⅛ inch square by 30–35 inches long were produced using the above schedule. They had the following properties: Hardness—230–250 V. P. N. (Vickers pyramid number); strength—120–148% of an arbitrary standard; yield in bending—22–38 mils. By way of comparison it is noted that heat-treated or sintered material has a strength value of approximately 80% of an arbitrary standard.

Example II

Ingots of pure molybdenum of an area of $1\frac{21}{32}$" x $1\frac{21}{32}$" were reduced approximately 56% in area by using the following schedule. On the first pass, taken at 1420–1480° C. the cross-sectional area was reduced to 2.40 square inches (a reduction to approximately 88% of the original cross-sectional area). Without reheating the ingot was given four more passes reducing the area to 2.02, 1.72, 1.49 and 1.23 square inches, respectively (a reduction to approximately 74%, 63%, 54% and 44%, respectively, of the original cross-sectional area). Pure molybdenum ingots were rolled in this manner to finish bars 1⅛" square by 30–35 inches in length with the following properties: hardness—215–230 V. P. N.; strength —170–200% of an arbitrary standard, and yield in bending—46–60 mils.

Example III

In working larger bars of pure molybdenum a slight modification of the above schedule was used. An overall reduction of approximately 73% was obtained in a 21 inch diameter mill. An ingot, 2⅛" x 2⅛" in cross-section was rolled as follows: On the first pass at 1470–1520° C. the area was reduced to 3.95 square inches (a reduction to approximately 92% of the original cross-sectional area). Without reheating the ingot was rerolled on the second pass to an area of 3.24 square inches (a reduction to approximately 72% of the original cross-sectional area). Both of the above passes were made at a roll speed of 40 R. P. M. After the second pass the ingot was annealed by heating for 5 minutes above 1350° C., preferably between 1350 and 1400° C. With the roll speed increased to 52 R. P. M. the ingot was reduced in the third pass to an area of 2.60 square inches at a temperature of 1420–1480° C. (a reduction to approximately 58% of the original cross-sectional area). At the same roll speed and without reheating, the ingot was given five more passes reducing the area to 2.22, 1.89, 1.62, 1.39 and 1.25 square inches, respectively (a reduction in cross-sectional area to approximately 49%, 42%, 36%, 31% and 27%, respectively, of the original cross-sectional area).

Using the above schedule, rods of pure molybdenum 1⅛" square by 66–72 inches in length were produced having the following properties: hardness—200–220 V. P. N., strength—120–145% of an arbitrary standard, and yield in bending—20–30 mils.

It is thus seen that the invention provides a process for rolling molybdenum and its alloys by which a maximum of reduction in cross-sectional area is obtained and which gives a product meeting acceptable standards of hardness, strength and yield in bending. It is an advan-

tage of the invention that the results are consistent and therefore reproducible, thus making the process adaptable for large scale production.

What is claimed is:

1. The process of working ingots of molybdenum and molybdenum-cobalt alloys containing a major proportion of molybdenum which comprises reducing the cross-sectional area of the ingot by approximately 56% according to the following schedule: (1) rolling between 1420–1480° C. to reduce the cross-sectional area to approximately 88% of the original cross-sectional area, (2) rerolling without reheating to reduce the cross-sectional area to approximately 79% of the original cross-sectional area, (3) annealing by heating for five minutes at a temperature between about 1350° C. and 1400° C., (4) rolling between 1370–1420° C. to reduce the cross-sectional area to approximately 69% of the original cross-sectional area, (5) rerolling without reheating to reduce the cross-sectional area to approximately 59% of the original cross-sectional area, (6) annealing by heating for 2½ minutes at a temperature of between about 1300° C. and 1350° C., (7) rolling between 1340–1370° C. to reduce the cross-sectional area to approximately 51% of the original cross-sectional area and (8) rerolling without reheating to reduce the cross-sectional area to approximately 44% of the original cross-sectional area.

2. The process of claim 1 in which the ingot is turned 90° between successive passes.

3. The process of working ingots of molybdenum which comprises reducing the cross-sectional area of the bar approximately 73% according to the following schedule: (1) rolling at 1470–1520° C. to reduce the cross-sectional area to approximately 92% of the original cross-sectional area, (2) rerolling without reheating to reduce the cross-sectional area to approximately 72% of the original cross-sectional area, (3) annealing by heating for five minutes at a temperature between about 1350° and 1400° C., (4) rolling at 1420–1480° C. to reduce the cross-sectional area to approximately 58% of the original cross-sectional area, (5) and rerolling without reheating in five successive passes to reduce the cross-sectional area to approximately 50%, 42%, 36% and 27% respectively, of the original cross-sectional area.

4. The process of claim 3 in which the ingot is turned 90° between successive passes.

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