

UNCLASSIFIED

AD 400 504

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-3-1

FTD-TT-62-1789

AD No. 400 504

ASTIA FILE COPY

TRANSLATION

FORGING MOLYBDENUM AND ALLOYS
ON ITS BASE

By

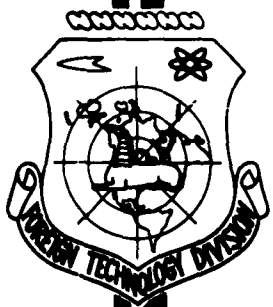
T. V. Vorontsova and N. N. Morgunova

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO



1.60

ASTIA
RECORDED
APR 10 1963
TISIA

UNEDITED ROUGH DRAFT TRANSLATION

FORGING MOLYBDENUM AND ALLOYS ON ITS BASE

BY: T. V. Vorontsova and N. N. Morgunova

English Pages: 11

SOURCE: Russian Periodical, Kuznechno-Shtampovochnoye
Proizvodstvo, Nr. 8, 1962, pp 8-11

S/182-62-0-8

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.

PREPARED BY:

TRANSLATION SERVICES BRANCH
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

FTD-TT- 62-1789/1+2

Date 14 Feb. 19 63

Forging Molybdenum and Alloys on its Base

By

T. V. Vorontsova and N. N. Morgunova

The behavior of molybdenum in hot forming is predetermined by two specific peculiarities of this metal. In the first place, molybdenum belongs to the group of refractory metals and has a very high melting point (2625°C). If it is considered that the hot forming temperature of molybdenum should constitute about 80% of melting temperature, as for other alloys, then this temperature should be approximately 2100°C for molybdenum. This requires a special heating equipment, and such a temperature is difficultly attainable in practice. In the second place, molybdenum oxidizes easily, forming a fusible and highly volatile oxide MoO_3 , whose melting point is 793°C . At the temperature upward of 1000° , the molybdenum billet surface is covered with droplets of oily liquid oxide MoO_3 , and a dense white "smoke" of evaporating oxide forms around the billet. All these factors create considerable technological difficulties.

Forming of cast molybdenum and of its alloys is complicated by the fact that ingots have the structure of large columnar crystals, whose length attains sometimes 10 - 20 mm. The coarse-grained structure of cast molybdenum creates disadvantageous conditions for distribution of detrimental impurities decreasing transcrystallite bonds. Most dangerous is the presence of fusible molybdenum oxides on boundaries of cast molybdenum grains. Deoxidizers are usually added in molybdenum casting for the purpose of changing the composition and distributional character of impurities. Carbon, titanium and zirconium are used most frequently as the deoxidizers. If gaseous oxides CO and CO_2 , or refractory oxides ZrO_2 and TiO_2 , are formed instead of fusible molybdenum oxides, cast molybdenum acquires a sufficient technological plasticity. In order to determine experimentally

the technological plasticity of cast alloys on molybdenum base, experiments were conducted on determination of critical breaking reduction ϵ_{max} at the various temperatures.

In carrying out this investigation, small cylinders with 20-mm diameter and 30-mm height were turned on lathe from ingots of molybdenum or its alloys, in such a way that the cylinder axis was parallel to the ingot axis. Testpieces were heated up to the prescribed temperature in furnace with hydrogen atmosphere. Temperature of testpiece heating in the furnace was accepted conditionally as the forming temperature (actual temperature was not measured due to considerable technical difficulties). Upsetting was performed on hammer with 500-kg weight of drop parts per one blow. Rings of a specific height were laid on the lower block, in order to delimit the prescribed deformation degree. The upsetting test was conducted on testpieces cut out from ingots of molybdenum deoxidized by carbon, alloys of molybdenum with titanium and zirconium in diverse ratios, and alloys of molybdenum with the varying content of tungsten. Apart from that, the same small cylinders cut out from the forged bar of 25 mm in diameter were subjected to upsetting.

The occurrence of a pattern of uneven upsetting, causing non-uniformities of deformation over the testpiece cross section, was established in examining the macro- and microstructure of upset testpieces. The maximum deformation occurs in central horizontal layers of the testpiece. The deformation resistance is maximal in contact sections, due to the supporting action of friction forces, as a result of which the deformation is negligible there. The change in form of grains on macrosection of the upset testpiece profile (Fig. 1) shows that the central part of the testpiece is indeed deformed more intensely than the peripheral part. Examination of the microstructure (Fig. 2) demonstrated that a fine fibrous structure was formed in the central part, and that boundaries

of cast grains (with slip lines visible inside) were preserved on the periphery.

Testpieces of examined alloys were subjected to upsetting at temperatures of 1050, 1300, 1400, and 1600°. The magnitude of critical destructive reduction \max was determined by formula

$$\max = \frac{H_1 - H_2}{H_1} \cdot 100\%$$

where H_1 is the initial height of cylinder (30 mm), and H_2 is its height upon setting.



Fig. 1. Macrostructure of Axial Section of upset Testpieces (Alloy with Small Additives of Titanium and Zirconium; Upsetting Temperature - 1600°; Deformation Degree - 73%)



Fig. 2. Microstructure of Axial Section of Upset Testpiece (Alloy with Small Additives of Titanium and Zirconium; Upsetting Temperature - 1600°; Deformation Degree - 73%)

a - central part of testpiece; b - peripheral part.

The dependence of critical destructive reduction on upsetting temperature (Fig. 3) permits to establish certain regularities. Cast alloys of molybdenum with tungsten, and then alloys with titanium and zirconium, have the lowest plasticity up to 1300 - 1400°. The alloy with small additives of titanium and zirconium has the highest plasticity up to 1300 - 1400°; at the same time, its plasticity increases strongly in the deformed state.

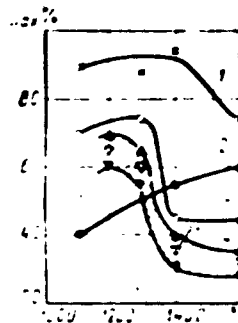


Fig. 3. Critical Reduction as a Function of Upsetting Temperature.

1 - pre-formed alloy with small additives of titanium and zirconium; 2 - alloys of molybdenum with tungsten; 3 - cast alloy with small additives of titanium and zirconium; 4 - alloys of molybdenum with titanium and zirconium.

The plasticity of molybdenum alloys with titanium and zirconium decreases abruptly at temperatures upward of 1300 - 1400°. The decrease in plasticity was confirmed also during the experiment on testpieces with 60-mm diameter and 90-mm height. However, this does not correspond to the behavior of metal in forging, where the technological plasticity improves and the forming process becomes easier upon the increase in forming temperature up to 1600 - 1700°. This non-correspondence can be explained in the following manner. As was already noted, that degree of deformation at which the first crack appeared was the plasticity measure in experiments conducted. Cracks of the following two types were observed.

1. At low temperatures and in low-plasticity alloys of molybdenum with tungsten,

cracks are of the shift type (Fig. 4); they are oriented at 45° with respect to the testpiece axis and penetrate deeply into the body of metal. The microstructure of such a crack is shown in Fig. 5.



Fig. 4. Cracks of Deformation Origin (Alloy of Molybdenum with Tungsten; Upsetting Temperature - 1600°)

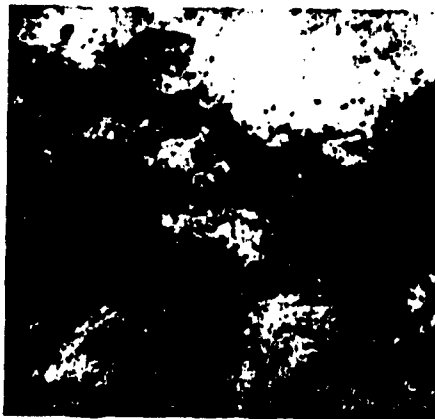


Fig. 5. Microstructure of Cracks of Deformation Origin (Alloy of Molybdenum with Tungsten; Temperature of Upsetting - 1600°)

2. At high temperatures, cracks are located on the side surface of the testpiece, "outlining" the boundaries of the initial cast grain (Fig. 6). This character of "hot" cracks bears witness to the fact that they are produced as a result of deformation of intergranular interlayers. The microstructural analysis of the edge of upset testpieces shows that these cracks have a somewhat peculiar form; they have a negligible depth (from 0.5 to 2.0 mm) and circular bottom, and the boundary of grain behind the crack is not damaged. Such cracks can be observed under microscope also on testpieces that were upset with a small reduction, when the depth

of disturbances is still very shallow (Fig. 7a). When the degree of deformation increases, these cracks become deeper and their intergranular location is more obvious (Fig. 7b). The analysis of the shape of cracks permitted to assume that they are caused by oxidation of molybdenum in air and evaporation of its oxide. This process has a more intensive course on boundaries of grains, as a result of a higher intensity and activity of atoms in these zones. Such "slightly torn" boundaries of grains open during the deformation. In molybdenum-tungsten alloys, as well as in forged alloy with small additives of titanium and zirconium, cracks of this kind are formed at higher temperatures, which can be explained -- in all probability -- by a smaller grain of the initial structure of the given alloys.



Fig. 6. Cracks Formed through Oxidation of Molybdenum (Alloy with Small Additives of Titanium and Zirconium; Upsetting Temperature - 1600°)



Fig. 7. Microstructure of Cracks Formed through Oxidation of Molybdenum (Alloy with Small Additives of Titanium and Zirconium; Temperature of Upsetting - 1600°)

a - shrinkage 33%; b - shrinkage 73%.

In view of the negligible depth of "hot" cracks and specificity of their formation, they cannot characterize the total plasticity of metal. The practice shows that the attempt to forge molybdenum ingots at 1300° complicates extremely the forging operation because of a high resistance of metal to plastic deformation. At the same time, forging with heating-up temperature of 1600° permits to form the ingots quite successfully. Surface cracks, produced therein, necessitate large allowances for machining (up to 3 mm per side) and make it difficult to obtain billets of small cross sections.

Particular attention must be paid to the fact that the technological plasticity of alloy with small additives of titanium and zirconium increases abruptly at high

temperatures upon pre-working of cast structure. Testpieces made of forged bar with 25-mm diameter can be upset to 90% (Fig. 8) without visible cracks at a temperature as low as 1100 - 1200°. This makes it possible to reduce the temperature of molybdenum forging in proportion to the increase in metal deformation degree.



Fig. 8. Outer View of Testpieces Made from Preformed Alloy (Alloy with Small Additives of Titanium and Zirconium; Upsetting Temperature - 1600°)

One can assume, on the basis of investigation performed and working experience accumulated, that two phases must be envisaged in the technology of molybdenum ingot forming. The main purpose in the first phase of forging is crushing the ingot structure and imparting the necessary technological plasticity to the ingot. The heating of ingots is accomplished in the resistance furnace with hydrogen atmosphere up to 1600 - 1700°. Ingots are formed by drop forging on hammers with 500-kg or 750-kg weight of drop parts on flat blocks. Crushing of the coarse-grained structure is achieved by ingot deformation in all directions with repeated turning and 2 - 3 heatings (at a temperature that should not be lower than 1200°).

As a result of such a treatment, the metal becomes plastic; this is noticeable through a strong heat effect.

The ingot surface is sprinkled during the forging with fine river sand, in order to increase the friction between the metal and the surface of blocks. It is necessary in drop forging, inasmuch as the surface of hot ingot is covered with oily liquid oxide MoO_3 , and the ingot may easily slip out from under the blocks. Apart from that, a strong exhaust system near the hammer is necessary in forging molybdenum ingots to eliminate molybdenum oxide vapors. Otherwise, the dense white "smoke" of oxides around the billet makes it difficult to see the billet being formed, which also impedes the operation.

The purpose of forming in the second phase of forging is imparting specific dimensions and shape to the billet, as well as improving mechanical properties of the metal. The heating preparatory to forging can be conducted at lower temperatures ($1200 - 1400^\circ$) in gaseous or hydrogen medium. The behavior of metal in drop forging according to the technology described is determined, to a considerable extent, by the metallurgical quality of molybdenum ingots. In the case of a good, dense structure without pores and gas holes, the forming of ingots weighing up to 16 - 18 kg is satisfactory.

When ingots have flaws, and the deoxidation of metal in smelting is not sufficiently complete, the drop forging causes the failure of ingots.

Molybdenum alloys with a very high strength at high temperatures (alloys with a high content of tungsten, two-phase alloys of molybdenum with carbide phase) submit with difficulty to the drop forging; in these cases, it is recommended to use flashless die extrusion.

Bibliography

1. N. I. Korneyev, I. G. Skuzarev and S. B. Revzner. Technology of Drop Forging and Extruding Molybdenum and Alloys on Its Base. Symposium: "Pressure Treatment of Alloys", 1958.
2. N. N. Morgunova. Heat Resistant Alloys on Molybdenum Base, 1959.
3. Molybdenum. Symposium (Translation from English).
4. Dzhaffi. Properties of Refractory Metals. "Problems in Modern Metallurgy", 1960, No 6.
5. Dzhaffi and Kharris. Manufacture of Sheets from Refractory Metals in USA. "Problems in Modern Metallurgy", 1961, No 3.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies	MAJOR AIR COMMANDS	Nr. Copies
		AFSC	
		SCFDD	1
		ASTIA	25
HEADQUARTERS USAF		TDETL	5
		TDBDP	5
AFCIN-3D2	1	AEDC (AEY)	1
ARL (ARB)	1		
OTHER AGENCIES			
CIA	1		
NSA	6		
DIA	9		
AID	2		
OTS	2		
AEC	2		
PWS	1		
NASA	1		
ARMY	3		
NAVY	3		
RAND	1		