METHOD OF HEAT-TREATING TUNGSTEN-BASE ALLOYS

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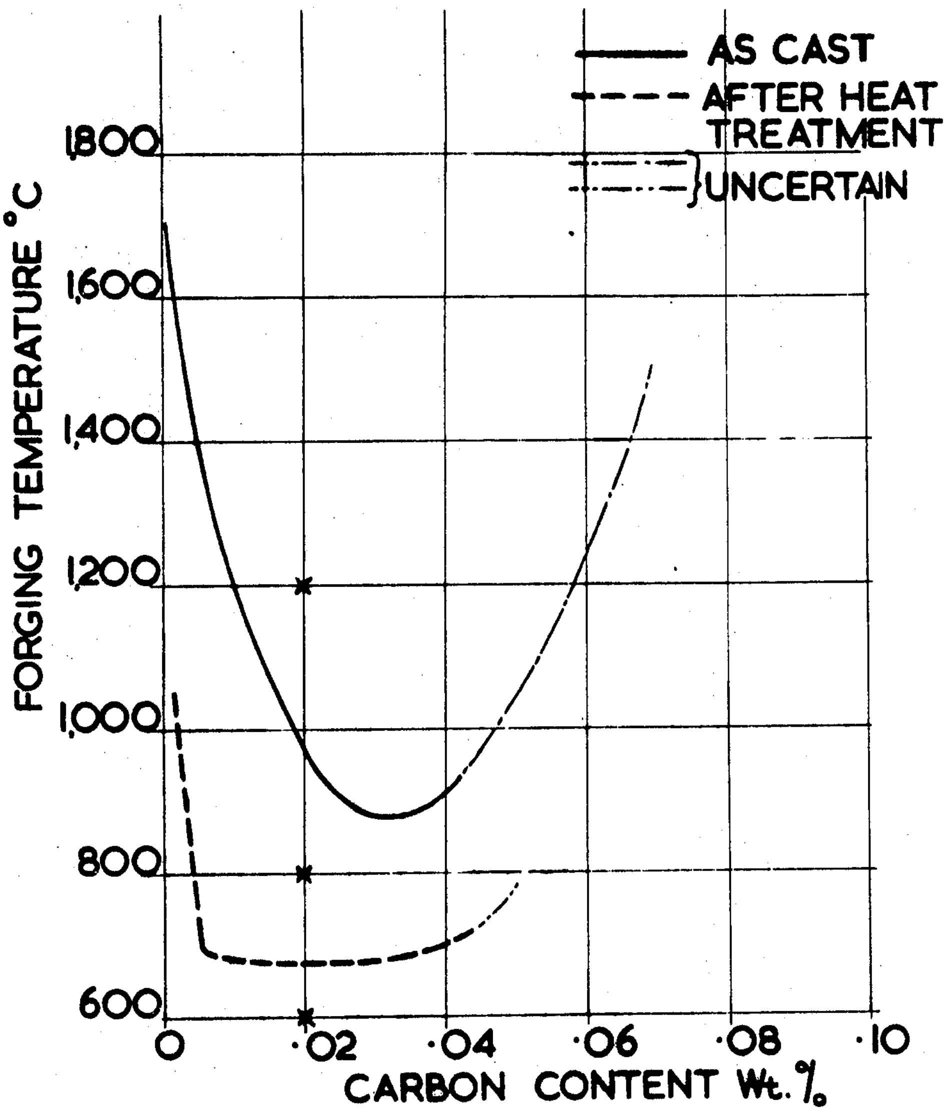

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METHOD OF HEAT-TREATING TUNGSTEN-BASE ALLOYS

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ABSTRACT OF THE DISCLOSURE

A method of heat-treating tungsten-base alloys containing about 0.005 to about 0.0490 carbon and optionally molybdenum, tantalum, niobium and zirconium to render the alloy forgeable below 1100° C., in which the alloy is heated between 1700 and 1900° C. and cooled at a constant rate over a period of one hour to a temperature of 900° C.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to a method of heat-treating tungsten-base alloys containing carbon and is particularly applicable to cast material.

(2) Description of prior art

Tungsten-base alloys have been used in applications involving the very high melting point of tungsten. Components made of this metal, for example rocket nozzles, have hitherto been fabricated by methods which are not very satisfactory. Machining of nozzles directly from cast material is a difficult and wasteful method. Furthermore, cast tungsten is very brittle and difficult to work.

Ductility is improved by breaking down the cast structure of tungsten and extrusion has hitherto been the only reliable method of so doing. The products of extrusion are, however, long thin bars which are unsuitable for rolling to sheet or for shape-forging.

Forging is the most suitable primary working process for producing sheet-bar for rolling and for producing more complex shapes, such as, for example, rocket nozzles. As-cast, pure tungsten cannot be forged satisfactorily below 1700° C., but the addition of small amounts of carbon improves the forgeability of tungsten, so much so, that forging can be carried out at much lower temperatures. At the optimum composition, 0.03 wt. percent carbon, tungsten can be forged at 900° C.

Although this is a notable improvement, there are two drawbacks associated with it:

(a) The addition of 0.03% carbon to tungsten lowers the melting point from 3400° C. to about 2800° C. Thus for very high temperature applications such as in rockets using the "hottest" propellants, melting may occur.

(b) The range of carbon content over which alloys are forgeable at the typical forging temperature (1100° C.) is rather narrow 0.015–0.04%. Because of the variability of carbon losses during melting, it may not be possible to maintain the composition of ingots on a production basis within this narrow range, and consequently the forgeability may be adversely affected.

SUMMARY OF THE INVENTION

We have found that the forgeability of tungsten carbon alloys may be improved by heat-treatment.

According to the present invention, a method of heat-treating an alloy of tungsten containing 0.006–0.07% carbon comprises heating the alloy to a temperature of

1700–1900° C. for at least 10 minutes and cooling to 900° C. at a constant rate over a period of at least 1 hour, said treatment being carried out in a non-oxidising environment.

A useful commercial range of composition includes a carbon content of 0.01–0.05%. The binary tungsten carbon alloy may be further strengthened at high operating temperatures by the addition of one or more alloying constituents, up to 10% in total, as follows: up to 10% molybdenum, up to 2% tantalum, up to 1% niobium or up to 0.5% zirconium. These elements strengthen the alloy at very high temperatures and ternary alloys may be used in preference to the binary alloy where conditions of service are particularly arduous, for example, in rocket nozzles where the "hottest" propellants are used.

Treatment is preferably carried out in a vacuum and this includes heating and cooling. At the temperature of treatment oxidation is very rapid and oxygen must be excluded. Slight oxidation, however, is tolerable.

The preferred solution treatment is 30 minutes at 1800° C. and the preferred cooling rate is 8° C. minute. Below 900° C. the cooling rate is unimportant, as carbon does not readily diffuse below that temperature.

The success of the treatment depends largely upon the rate of cooling since, as will be described later, it is believed that the particle size of carbides plays an important part in the forgeability of the alloy. If the cooling rate is too high, a large number of fine particles is precipitated and this is undesirable, whilst a very slow rate of cooling is uneconomic. We have found that a period of about 1 hour is the highest rate of cooling which will produce the desired improvement.

The improvement in forgeabilty brought about by the treatment is believed to be due to the presence of a dispersion of carbides of a particle size conducive to a favourable dislocation pattern. Relatively large particles of W_2C (1–2 microns) which have many dislocations associated with them, possibly produced by differences in thermal contraction between tungsten and W_2C are belived to be responsible for improved forgeability. Small particles less than 0.1 micron in size often form on dislocations, and are likely to hinder their movement and thereby increase the resistance to deformation.

The effect of the heat-treatment in accordance with the invention is believed to eliminate the fine particles by taking them into solution and reprecipitating the carbon on the large particles. Then the dislocations are no longer pinned, and can move more freely.

DESCRIPTION OF DRAWING

The invention is further illustrated by reference to the accompanying drawing which is a graph showing curves corresponding to forgeability at various temperatures and carbon contents.

The influence of the heat-treatment on the forgeability of tungsten-carbon alloys is shown in the drawing in which the curves mark the lower limits of temperature relative to carbon content at which sound forgings can be made. The upper curve shows the forgeability of as-cast alloys and the lower curve that of alloys heat-treated in accordance with the invention. Alloys forged at temperatures above the appropriate curve are sound and those forged below are cracked.

As can be seen from the drawing, an alloy containing 0.02% carbon would crack on forging at 600° C. whether heat-treated or as-cast. If heat-treated, this alloy would forge without cracking at 800° C., but if it were as-cast it would crack at 800° C. Even in the as-cast condition this alloy would forge satisfactorily at 1200° C.

It will be seen that the lower curve has an almost linear portion extending from about 0.005–0.04% carbon which has a minimum forging temperature of about 700° C. Beyond 0.04% the curve rises and whilst the exact path is not shown, there is reason to believe that the limit of forgeability at 0.07% carbon is about 1100° C. At low carbon contents, the curve rises very steeply and below 0.005% carbon, the alloy rapidly becomes forgeable only at very high temperatures. The range of carbon content over which the alloys treated in accordance with the invention may be forged at temperatures below 1100° C. is about 0.006–0.07% which extends the previously known range of 0.015–0.04% without heat-treatment by a factor of about 2.6. Variations in carbon content are thus less serious.

Carbon contents above 0.04% are not required in high temperature applications such as rocket nozzles as the effect of increased carbon content is to decrease the melting point. The heat-treatment of the invention enables alloys of very low carbon content, and hence very high melting point, to be forged at about 800° C.

The heating-treatment makes it possible to produce articles in a tungsten-base alloy containing 0.006–0.07% of carbon, such as rocket nozzles, by heating a cast ingot to 1700–1900° C., cooling to 900° C. at a constant rate over a period of at least one hour, forging to the required shape at a temperature in the region of 1100° C.

I claim:

1. A method of improving the forgeability of a tungsten-base alloy containing about 0.005 to about 0.04% carbon to render said alloy forgeable at a minimum temperature of about 700° C. without cracking, comprising heating the alloy to a temperature of 1700–1900° C. for at least 10 minutes and cooling to 900° C. at a constant rate over a period of at least one hour, said treatment being carried out in a non-oxidizing environment.

2. A method as claimed in claim 1 in which the alloy contains one or more of the following alloying constituents up to 10% in total: 0–10% molybdenum, 0–2% tantalum, 0–1% niobium, 0–0.5% zirconium.

3. A method as claimed in claim 1 in which the alloy is cooled at a rate of 8° C. per minute.

4. A method as claimed in claim 1 in which the alloy is heated to a temperature of 1800° C.

5. A method of producing a rocket nozzle from a cast ingot of a tungsten-base alloy containing about 0.005 to about 0.04% carbon comprising heating the cast ingot to a temperature of 1700–1900° C. for at least 10 minutes, and cooling to 900° C. at a constant rate over a period of at least one hour in a vacuum, and forging to the required shape.

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