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TITANIUM-TANTALUM HIGH-SPEED STEEL

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This application is a continuation-in-part of prior application Ser. No. 234,233 filed on October 30, 1962, now abandoned, in the same of Masao Kondo et al., and entitled "Titanium-Tantalum High-Speed Steel."

This invention relates to high-speed steels, and more particularly it relates to new high-speed steels containing carbide with titanium and tantalum as its principal constituents.

High-speed steels of conventional type, quenched and tempered, have heretofore contained almost entirely only two kinds of carbide. One is the M_6C type carbide with tungsten and molybdenum as its principal components and another is an MC type carbide with vanadium as its principal component, these carbides participating effectively in the cutting performance.

It is an essential object of the present invention to provide a group of new titanium-tantalum high-speed steels which have, in addition to good heat-withstanding property, good chipping-resistant property and excellent cutting characteristic.

The present invention relates to a titanium-tantulum high speed steel consisting essentially of up to 25% tungsten, up to 20% molybdenum, up to 10% chromium, up to 10% vanadium, 0.2 to 6% titanium, 0.3 to 6% tantulum, the total percentage of the titanium and tantulum contents being about 0.5 to 10% and the ratio of the titanium content to the tantulum content being 1:0.5 to 1:2, said the percentages being weight percentages and the remainder component being iron.

The above-mentioned high speed steel according to this invention has been proposed as a result of various experiments of the inventors of this invention. The amounts of various constituents of the steel according to this invention are based on the following reasons. That is, when Ta/Ti is below 0.5, toughness of the high speed steel becomes inferior and when Ta/Ti is above 2, high speed cutting ability of the high speed steel become low.

On the other hand:

When amount of tungsten is above 25%, toughness of the product becomes low, when amount of molybdenum is above 20%, cutting ability of the product becomes low; when quantity of chromium is above 10%, heat treated hardness of the product decreases, and when quantity of vanadium is above 10%, hard carbide becomes large, thus causing difficulty of the working and decrease of toughness of the product.

In the production of the high speed steel according to this invention, carbon content should be an excess quantity sufficient to form carbides of W, Mo, Cr and V as

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well as to form carbides of Ti and Ta. However, the carbon content should be varied in accordance with amounts of Ti and Ta. Even when the quantity of Ti+Ta is equal to 0.5%, at least 0.6% is necessary from heat-treatment point of view. In the case wherein quantity of Ti+Ta is equal to 10%, when the carbon content is above 5%, their carbides become coarse and brittle, so that quantity of carbon should be 0.6 to 5%. For example, the necessary carbon content is selected to be 0.4% with respect to 1% of Ti and 1% with respect to 1% of Ta.

The nature and details of the invention will be more clearly apparent by reference to the following description of a few representative embodiments of the invention.

The compositions of steels containing both titanium and tantalum, that is, the steels of this invention Mo, Ti, Ta (A) and Mo, Ti, Ta (B) and the compositions of molybdenum-titanium high-speed steel Mo, Ti, molybdenum-cobalt high-speeed steel M_{36}, and molybdenum high-speed steel M_2, which are considered here for the purpose of comparison and reference, are as shown in the Table 1.

When the steels (A) and (B) of this invention were subjected to heat treatment under exactly the same conditions as those employed for ordinary high-speed steels, hardnesses after quenching and tempering of HRC 65 or higher were obtained, and better results than M_{36} steel in the property of withstanding tempering were obtained.

Cutting tests were carried out on 10-mm. square cutting tools made of the steels of this invention and prepared by heating for 3 minutes at 1,250 degrees C. and oil quenching and tempering twice in one hour at 550 degrees C. to produce a hardness of HRC 66.4—66.6 and on other cutting tools made of steels to be compared with the steels of this invention, the said other cutting tools being subjected to their respectively optimum heat treatment, and comparison of test cutting performances of these cutting tools was made.

The method of these tests in all cases was the cutting operation commonly called facing, and the test conditions were as follows:

Condition 1 was high-speed cutting of a hard material (chromium-molybdenum steel, Japan Industrial Standard Designation SCM 5, containing 0.43–0.48%, C, 0.15–0.35% Si, 0.60–0.85% Mn, 0.030% max. P, 0.030% max. S, 0.90–1.20% Cr, and 0.15–0.35% Mo, and having a Brinell hardness of 302–363) with heat resistance considered as the principal measure for comparison.

Condition 2 was low-speed cutting, similarly of a hard material, with wear resistance considered as the principal measure for comparison.

Condition 3 was high-speed cutting of a workpiece which was provided with a groove on a diameter so as to impart impact to the cutting edge of the cutting tool, and which was made of relatively soft material (carbon steel for machine construction, Japanese Industrial Standards Designation S 45 C, containing 0.40–0.50% carbon and having a Brinell hardness of 167 to 229), resistance against chipping being considered as the principal measure for comparison.

TABLE 1

Kind of Steel	Designation Symbol	C	W	Mo	Cr	V	Co	Ti	Ta
Steel of this invention containing 0.6% Ti, 0.7% Ta.	MoTiTa (A)	1.33	10.40	4.53	4.28	2.11	----------	0.60	0.74
Steel of this invention containing 1.2% Ti, 1.4% Ta.	MoTiTa (B)	1.55	13.00	4.13	3.82	1.87	----------	1.18	1.44
Molybdenum-titanium high-speed steel	MoTi	1.72	8.78	5.26	4.20	2.01	----------	2.00	----------
Molybdenum-cobalt high-speed steel	M_{36}	0.80	6	5	4	2	8	----------	----------
Molybdenum high-speed steel	M_2	0.85	6	5	4	2	----------	----------	----------

As a criterion of performance, the width of wear of the flank surface after cutting or the cutting speed at the time of termination of the life of the tool was measured.

The test results obtained were as shown in Table 2.

TABLE 2

Steel Designation	Condition 1 (meters/min.)	Condition 2 (mm.)	Condition 3 (meters/min.)
MoTiTa (A)	26.2	0.21	82.6
MoTiTa (B)	27.8	0.21	81.1
MoTi	28.2	0.23	78.9
M_2	25.2	0.37	78.9
M_{35}	26.5	0.27	83.2

As indicaed in Table 2, the steel alloy MoTi containing the carbide which has Ti as its principal constituent has the greatest heat resistance, but exhibits somewhat low resistance against chipping.

The steel alloy MoTiTa containing the carbide which has Ti and Ta as its principal constituents has heat resistance of a magnitude which depends on the quantity of the said carbide and is equal to or greater than that of the steel M_{36}; but in resistance against chipping, the steel MoTiTa is superior to the steel MoTi and almost equal to M_{36}. The steel MoTiTa is definitely superior to the steel M_{36} in wear resistance.

The high speed steel, the carbide containing Ti and Ta as its principal constituents prepared by adding Ti and Ta and a quantity of carbon sufficient for forming carbide with the said Ti and Ta, has greater chipping resistance than a steel containing a carbide having Ti as its principal constituent, has heat resistance and chipping resistance which are equal or superior to those of cobalt high-speed steel, and is superior to cobalt high-speed steel in wear resistance.

Accordingly, if a high-speed steel containing carbide which has Ti and Ta as its principal constituents is used as a tool material for high-speed cutting and cutting of hard work materials, the cutting tools made of such a material will exhibit excellent cutting performance.

This excellent cutting performance exhibited by the steel according to this invention may be thought to be due to the extreme hardness of the carbide having Ti and Ta as its principal constituents and due to its superior toughness as compared to that of a carbide having Ti as its principal constituent.

High-speed steels in which small quantities of Ti and Ta were added with the aim of effecting deoxidation, denitrification, or refinement of structure have heretofore been used on a trial basis. In contrast, however, the high-speed steel of the present invention contains, in addition to M_6C carbide and VC carbide, carbide having Ti and Ta as its principal constituents, wherefore the significance of these additives is exhibited for the first time, and it is absolutely necessary for the steel of this invention to contain, together with Ti and Ta, a quantity of carbon which is sufficient for combining with Ti and Ta. Therefore, the high-speed steel of the present invention differs in essence from the above-mentioned steels used heretofore.

The high-speed steel of this invention may be made by adding titanium, tantalum, and other metallic elements and carbon as separate mother alloys and casting the same, but when it is made by a quick heating and cooling method such as build-up welding with a solid solution power consisting of TiC and Tac, or these carbides together with other kinds of carbides, as the starting material, the carbide with Ti and Ta as its principal constituents is finely distributed, and a high-speed steel having excellent mechanical properties and cutting performance is easily produced.

It is a requisite of the steel of the present invention that it contain both titanium and tantulum, the lack of either, of these alloying elements causing the steel to have inadequate properties.

As a result of experimental research, it has been found that the chemical compositions stated in the appended claims are suitable for the high-speed steel according to the invention.

What we claim is:

1. A titanium-tantulum high speed steel consisting essentially of up to 25% tungsten, up to 20% molybdenum, up to 10% chromium, up to 10% vanadium, 0.2 to 6% titanium, 0.3 to 6% tantulum, 0.6 to 5% carbon and the balance essentially iron, the total percentage of the titanium and tantulum contents being about 0.5 to 10% and the ratio of the titanium content to the tantulum content being 1:0.5 to 1:2, all said percenages being by weight.

2. A titanium-tantulum high speed steel according to claim 1, in which the carbon content of the high speed steel is a quantity sufficient to form carbides of said tungsten, molybdenum, chromium and vanadium and includes an excess beyond an amount required to form said carbides, said excess being sufficient to form carbides of said titanium and said tantalum.

3. A titanium-tantulum high-speed steel according to claim 2, in which the titanium content is about 0.6 to 1.18% and the tantulum content is about 0.74 to 1.44%.

4. A titanium-tantulum high-speed steel according to claim 3, in which the tungsten content is about 10.4 to 13%, the molybdenum content is about 4.13 to 4.53%, the vanadium content is about 1.87 to 2.11%, and the carbon content is about 1.33 to 1.55%.

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