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Influence of molibdenium under the hightemperature friction of titatium materials on wear

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The addition of molybdenum into the titanium material Ti—Cr—TiC significantly changes the composition and properties of nanostructural film, which is generated from the friction on air and under high temperatures. Predominant contents of brittle oxide TiO_2 (rutile) within the films in the process of friction determines the high wear of materials. There is no titanium oxide TiO_2 within the newly generated film of titanium material containing molybdenum whereas hydroxides and molybdenum oxides prevail in terms of quantity and ensure high protective and lubricate properties of the film as well.

Keywords: *titanium material, molybdenum, hightemperature friction, nanostructural film.*

Introduction

The mechanism of wear of titanium material Ti—Cr—TiC was already studied before [1, 2]. The influence of chromium as an alloying element on the mechanism of wear of titanium material Ti—Cr—TiC was previously examined. It is shown, that nanostructural films are being generated in the process of wear of the material on air and under the room temperature, and act as the solid-film lubricants. These films consist of chromium and titanium oxides, hydroxides, nitrides, and hydrides. The additional alloying of titanium material allowed a significant raise of its strength and wear resistance within the temperature range of 250—750 °C [3].

This paper is aimed at the examination of influence of molybdenum on nanostructural film formation at the high-temperature friction of titanium material Ti—Cr—Mo—TiC on air.

The investigation was carried out on such compositions as Ti, Ti—Cr—TiC, Ti—Cr—Mo—TiC, which were obtained by the pressing and the subsequent sintering in vacuum 0.13 Pa from powder mixture of electrolytic titanium of the fraction −180+40 μm, Cr_3C_2 and Mo of the fraction −10 μm. The porosity of sintered materials made up 10—12%. It was sought to obtain a partial dissolution of molybdenum in titanium base within the Ti—Cr—Mo—TiC material. The presence of free molybdenum was supposed to ensure its full participation in oxide films formation process. The molybdenum trioxide formation is known to occur at the temperature of 250 °C and to intensify at 500 °C [4].

It was studied the wear-resistance of sintered materials Ti, Ti—Cr—TiC, Ti—Cr—Mo—TiC. The friction test was carried out according to the scheme of 3 specimens — disc on air under the temperature of 550 °C, loading of 3,0 MPa, test time of 1 h and slip velocity of 1,0 m/sec. Disc was produced from nitrated titanium alloy VT-14. The area of samples section amounted to 0,35 cm^2. The wear-resistance of friction pair was estimated according to intensity of samples and disc wear, which is measured accurately to 25.

The structure of friction surface was studied by section perpendicularly to the surface of titanium material friction as well as to the surface of samples oxidized on air under the temperature of 550 °C in course of 1,0 h. The studying process was carried out on X-ray unit URS-50I under the iron radiation.

Results and discussion

The structure of Ti—Cr—Mo—TiC material is a titanium base, alloyed with chromium and molybdenum, which contains uniformly distributed inclusions of titanium carbide and not fully dissolved inclusions of molybdenum (fig. 1).

The wear testing (see the table) showed high wear intensity of the friction pair titanium–nitrated titanium, which amounts to 1360 μm/km. But there's no pair adhesion as at the friction under the room temperature. The wear of Ti—Cr—TiC material is twice as lower as of titanium, but still high enough and amounts to 700 μm/km. The addition of molybdenum reduced the wear of pair up to 20 μm/km. The friction coefficient remains the same irrespective of the composition of titanium material and equals to 0,23—0,26. Visual inspection of friction surfaces has showed that there were tears along the friction direction in samples from Ti and Ti—Cr—TiC. That is an evidence of significant plastic flow of surface layer of materials within the friction area. Due to its influence as a part of titanium base while formation of Ti—Cr—Mo solid solution no tears were seen on the samples of materials that contain molybdenum. In paper [2] it was already mentioned that molybdenum essentially increases the strength of titanium base of material under the given temperature of 550 °C. As a result the plastic strain of friction surface layer also goes down.

The metallographic research (fig. 2) reveals the formation of white films on the surface of friction. The character of its destruction is reflected by thesoftening of surface layer. The destruction of the film by tracks (fig. 2, *a*, *b*) is seen at significant plastic strain (Ti, Ti—Cr—TiC). If no plastic flow is evident, the film is destructed as a spot (Ti—Cr—Mo—TiC), its damage probability is significantly reduced as well (fig. 2, *c*).

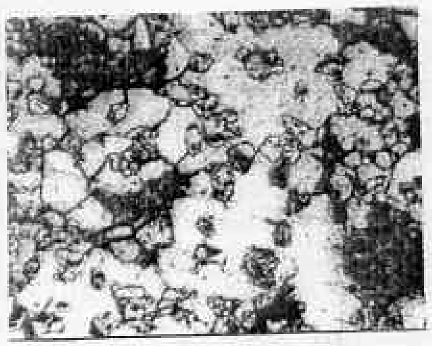
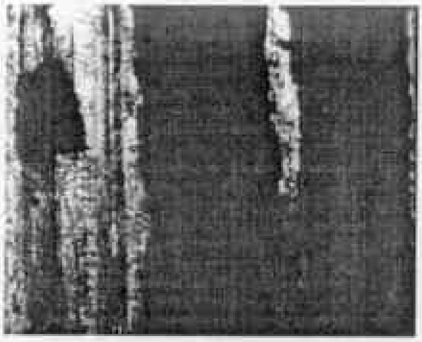


Fig. 1. Structure of Ti—Cr—Mo—TiC material (x500).

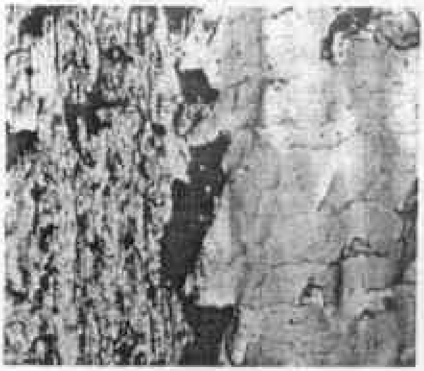
Wear and friction coefficient of titanium materials under the temperature of 550 °C and sliding rate of 1,0 m/sec

Material composition	Wear intensity, μm/km	Friction coefficient
Ti	1360	0,23
Ti—Cr—TiC	700	0,25
Ti—Cr—Mo—TiC	20	0,26



a

b



c

Fig. 2. Surface of material friction Ti (*a*), Ti—Cr—TiC (*b*), Ti—Cr—Mo—TiC (*c*) (x63).

Phase composition of the film on the surface of friction differs from the one on oxidized surface of material. Simple oxides as well as titanium, chromium and molybdenum nitrides are generated on the surface of speci-mens oxidized on air while on the surface of friction mostly oxides of complex composition — hydroxides — are being formed. The film on the friction surface of titanium consisted of oxides TiO_2 (rutile), Ti_3O_5, Ti_9O_{17} and nitrides TiN that ensured the sliding of pair in friction without adhesion but with the disastrous wear. As opposed to friction under the room temperature the high temperature friction of titanium ensured more intensive oxidation and subsequent recovery of destructed oxide films. The main constituent of film of Ti—Cr—TiC material was oxide TiO_2 (rutile) as in case of pure titanium. This material has a little bit lower but still high wear. Among the other constituents of the film were also chromium oxides Cr_5O_{12} and CrO_2 as well as compounds like spinel Cr_3Ti_3O. In comparison to titanium these constituents contributed to reduction of wear of the Ti—Cr—TiC material. There is no oxide TiO_2 on the friction surface of Ti—Cr—Mo—TiC specimen and newly generated film contains the following compounds (in order of intensity reduction of the lines on X-ray pattern): $Mo_5O_8(OH)_8$, $Mo_5O_7(OH)_8$, Mo_9O_{26}, Cr_3O_4, Mo_2N, Cr_3Ti_3O. Hydroxides and molybdenum oxides prevailed in terms of quantity. Titanium was to some extent engaged in formation of wear-resistant film, which contains mainly oxidation products of alloying elements of molybdenum and chromium. It also acted as a constituent of complex compound like spinel Cr_3Ti_3O. Brittle oxide was the main constituent of the film on the surface of Ti—Cr—Mo—TiC sample oxidized on air, but no evidence of it was found within the film generated at friction of this material. The reduction of level of titanium part and increase of activity of alloying elements in the process of films formation at friction is accompanied by the reduction of wear intensity of titanium material and subsequent improvement of lubricate and protective properties of newly generated films.

Conclusions

The presence of molybdenum in the titanium material Ti—Cr—Mo—TiC contributes to the formation of solid films with high lubricate and protective properties under the conditions of high temperatures. These films contain mainly hydroxides and molybdenum oxides.

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Вплив молібдену при високотемпературному терті на знос титанових матеріалів

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Введення молібдену в титановий матеріал Ti—Cr—TiC значно змінює склад та властивості наноструктурних плівок, які утворюються при терті на повітрі при підвищених температурах. Домінуючий вміст у плівках при терті Ti, Ti—Cr—TiC крихкого оксиду TiO_2 (рутіл) визначає високий знос матеріалів. У плівки, яка утворюється у титановому матеріалі, що містить молібден, оксид титану TiO_2 відсутній і переважають гидроксиди та оксиди молібдену, які забезпечують високі захисні та мастильні властивості плівок.

Ключові слова: *титановий матеріал, молібден, високотемпературне тертя, наноструктурні плівки.*

Влияние молибдена при высокотемпературном трении на износ титановых материалов

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Введение молибдена в титановый материал Ti—Cr—TiC существенно изменяет состав и свойства наноструктурных пленок, образующихся при трении на воздухе и повышенных температурах. Превалирующее содержание в пленке при трении Ti, Ti—Cr—TiC хрупкого оксида TiO_2 (рутил) определяет высокий износ материалов. В образующейся пленке титанового материала, содержащего молибден, оксид титана TiO_2 отсутствует и в количественном отношении преобладают гидроксиды, оксиды молибдена, которые обеспечивают высокие защитные и смазывающие свойства пленки.

Ключевые слова: *титановый материал, молибден, высокотемпературное трение, наноструктурные пленки.*