

Effect of TiC Content on Oxidation Behavior of Sintered WC-TiC-TaC Alloys

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Abstract

The effect of TiC content on oxidation behavior of the sintered WC-TiC-TaC alloys with 2 mass% TaC and different TiC amounts of 3-45 mass% was investigated through oxidation tests in air at 973K. As a result of the tests, it was revealed that with increasing TiC content in the alloys, mass changes caused by oxidation and thickness of the scale decreased. Thus, it is considered that the main component of the scales changed gradually from WO₃ to TiO₂ with increasing TiC content in the alloys, and oxygen diffusion through the scale to the alloys was inhibited gradually.

Keywords : oxidation, WC-TiC-TaC alloys, TiC content, scale

1. Introduction

The sintered WC-TiC-TaC alloys have been used as high temperature molds in N₂ or inert gas. According to our previous study, however, WC phase in the WC-TiC-TaC alloys started to be oxidized even by trace oxygen in N₂ gas. Generally, oxidation resistance, namely resistance to surface roughening due to formation of scale, is required in high temperature applications. It has been reported that oxidation resistance can be improved by adding TiC in WC-Co alloys¹⁾, and this effect can be further increased by increasing TiC or TiN phase, because the oxidation of TiC or TiN results in the formation of the adherent layer of TiO₂ that enhances the oxidation resistance of alloys²⁾. However, there is no detailed study on the oxidation properties of the sintered WC-TiC-TaC alloys. Therefore, in this study, we conducted oxidation tests on the sintered WC-TiC-TaC alloys with different TiC amounts, and investigated the effect of TiC amount on oxidation behavior of the alloys.

2. Experimental and Results

Samples were fabricated according to the composition shown in Table 1. As raw powders, commercially available WC powder (mean diameter 0.6 μm), TiC powder (mean diameter 0.9 μm) and WC-TiC-TaC (5:3:2 [mass ratio]) solid solution (β phase: which has crystal structure of TiC, but the crystal lattice was distorted by W and Ta) powder

(mean diameter 1.0 μm) were used.

Table 1. Composition of samples

sample	TiC	TaC	WC
	/ mol%		
A0	9.1	1.9	bal.
A1	22.0	1.7	bal.
A2	38.2	1.5	bal.
A3	53.3	1.3	bal.
A4	72.6	1.0	bal.

Oxidation test was conducted in air and the temperature was raised from room temperature to 973K with a heating rate of 4 K/min and then held for 600 s with a heating furnace. After that, the oxidized samples were cooled off to room temperature in the furnace.

Fig. 1 shows the relation between TiC content in the samples and mass change after the oxidation. It was found that the mass gains decreased with increasing TiC content in the samples.

Fig. 2 shows the cross-sectional microstructure of the samples after the oxidation test, respectively. In this figure, the upper parts of microstructures show scales formed by the oxidation and the lower parts show substrates. It was confirmed that the scales different from substrates formed on the samples after the oxidation, except the A4 sample as shown in Fig. 2(d), and thickness of the scales decrease with increasing TiC content in the samples.

Fig. 3 shows X-ray diffraction patterns of the samples after the oxidation. It was found that WO_3 peaks were observed from the A0 sample and the intensity of WO_3 peaks became weaker and TiO_2 peak became stronger with increasing Ti content in the samples. Therefore, it is considered that main component of the scales changed gradually from WO_3 to TiO_2 with increasing TiC content in samples.

Generally, it is known that TiO_2 layer protects substrate from oxidation or protects oxygen diffusion into substrate. Although the oxidation behavior of the β phase is not clear, it is considered that the β phase with crystal structure of TiC shows a *passive oxidation* behavior due to formation of TiO_2 .

From the microstructure of the samples, the volume fraction of the WC phase decreases with increasing TiC content due to formation of β phase. Furthermore, the WC shows *active oxidation* behavior with a fairly large volume gain of about 160 vol% during formation of WO_3 . From these facts, the formation of the oxide scales can be controlled by decreasing the volume fraction of the WC phase in the alloys.

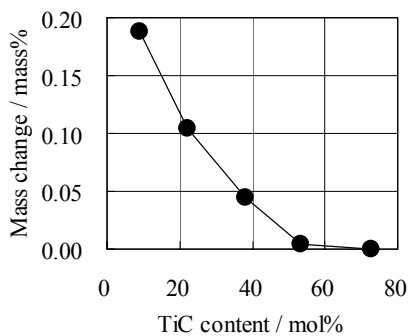


Fig. 1. Mass change of WC-TiC-TaC alloys after oxidation.

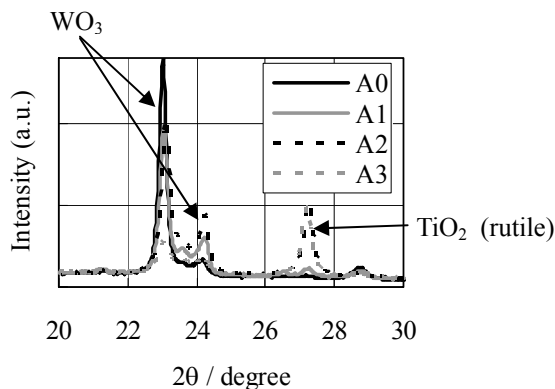


Fig. 3. X-ray diffraction patterns of A0 sample to A3 sample after oxidation.

3. Summary

Based on the findings obtained from the experimental results, the following conclusions were drawn;

- (1) With increasing TiC content in the alloys, mass changes resulting from oxidation and the thickness of oxidation scales decreased. It is considered that the main component of the scales changed gradually from WO_3 to TiO_2 with increasing TiC content in the alloys, and oxygen diffusion into the alloys was inhibited gradually.
- (2) As β phase with crystal structure of TiC has an anti-oxidation function compared to WC phase, the formation of the oxide scales can be controlled by decreasing the volume fraction of the WC phase in the alloys.

4. References

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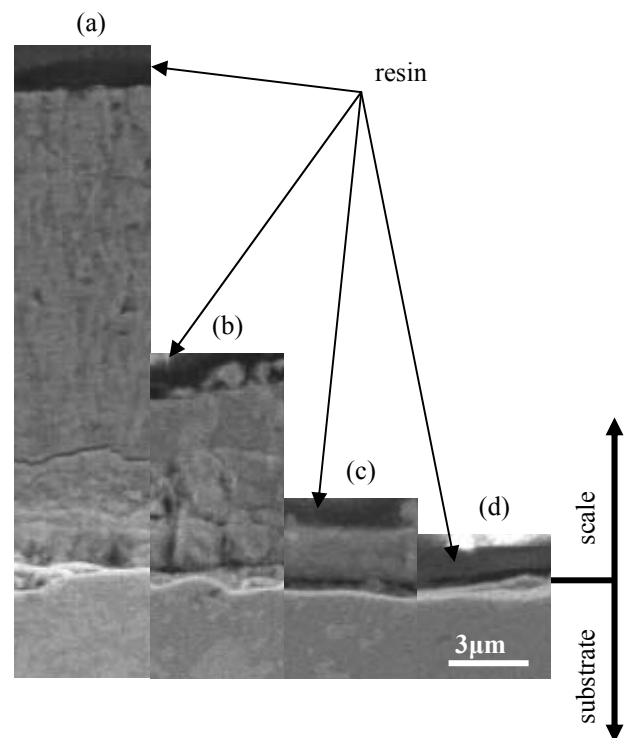


Fig. 2. Cross-sectional microstructures of (a) A1 sample, (b) A2 sample, (c) A3 sample and (d) A4 sample after oxidation.