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J. Małecka

Opole University of Technology, Faculty of Mechanical Engineering, Department of Manufacturing Engineering and Automation, Poland; j.malecka@po.opole.pl

THE ANALYSIS OF THE EFFECT OF TIME AND TEMPERATURE OF AIR ON THE COLOURING OF THE SURFACE LAYER OF O-Ti_2AlNb BASED TITANIUM ALLOY

ABSTRACT

This study presents the test results of Ti-20Nb-15Al alloy isothermal oxidation in air at 700°C with the consideration of the effect of annealing time on the condition of the surface layer. It was determined that, depending on the heating time, the surface of the tested alloy was characterized by a different colouring. This phenomenon was observed only at 700°C.

Keywords: *intermetallics, high temperature corrosion, oxidation, coatings*

INTRODUCTION

In recent years intermetallic α_2-Ti_3Al and γ-TiAl titanium alloys have found a broad application as structural materials meant for operation in elevated temperature and aggressive chemical environment. These alloys are the newest type of materials and represent a very attractive structural material for operation at elevated temperatures and in aggressive chemical environments, mainly due to particularly favourable combination of mechanical properties and low density. Good creep resistance and relatively good oxidation resistance are their main assets, which add to their versatile application [1÷4]. The fields of application on these materials are space industry, aviation and automotive industry (parts of gas turbines and compressors) [5÷7]. The tendency to brittle fracture and low flow are their main shortcomings, which set the limitations for their use. The research carried out so far by national and foreign research centres have concerned the issue of high temperature oxidation resistance of γ-TiAl based alloys [8÷22].

In the late eighties of 20th century a new phase was discovered, so called orthorombic phase: O-Ti_2AlNb. Substituting α_2-Ti_3Al phase for Ti_2AlNb in Ti-Al alloys caused the increase in their density, which was, however, offset by the improvement of other properties i.e. increasing the flow [23]. Orthorhombic titanium aluminides appear to be quite promising for this application, but will only find increased attention if they offer a unique set of properties not provided by competing alloys. For demanding elevated temperature applications, e.g. jet engines, this new class of alloys competes with conventional near-titanium alloys, the almost mature γ-TiAl alloys and, as all high temperature titanium base alloys, nickel-based materials [7].

The research presented in this paper was focused on the effect of time and temperature of the isothermal oxidation in air on the changes of the surface colouring.

MATERIAL AND RESEARCH METHODOLOGY

The tests were performed on O-Ti_2AlNb based Ti-20Nb-15Al alloy chemically composed of 58.75% Ti, 14.80% Al, 19.23% Nb, 6.01% Mo, 0.94% V (%wt.). Give the source of the alloy
The samples of alloy with dimensions of 20x15x5mm were polished with an 800 grade abrasive paper and subsequently degreased in acetone. The tests of the isothermal oxidation in air were performed at the temperature of 700°C.
The material structure were performed using a scanning electron microscope Philips XL20 equipped with EDAX analyzer.

TEST RESULTS AND ANALYSIS

The structure of the tested alloy established as lamellar and the analysis of the chemical composition in the observed area is presented in Fig. 1. Fig. 2 shows a fragment of the fracture of the analyzed alloy in the lamellar section.

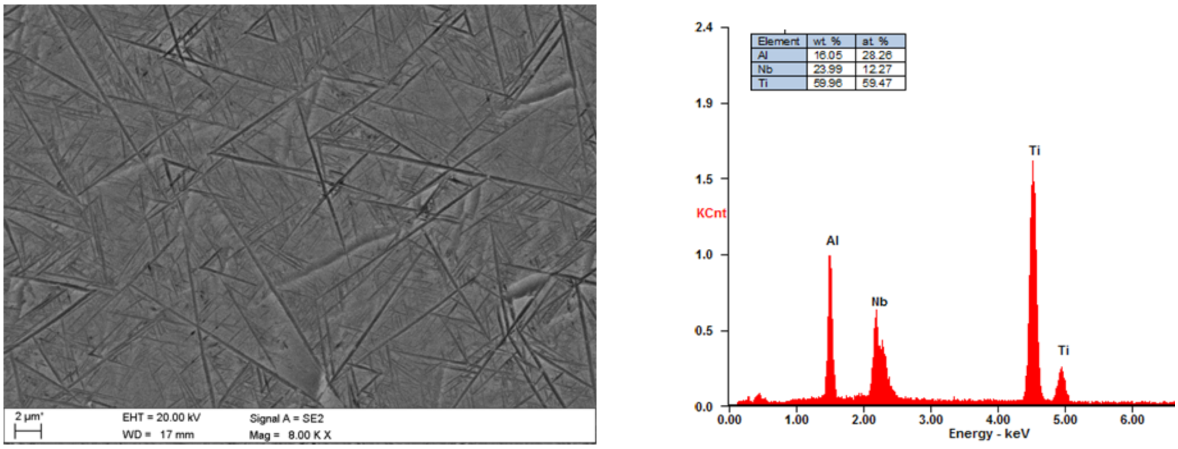

Fig. 1. Scanned images (SE) of Ti-20Nb-15Al alloy and EDX analysis results this area

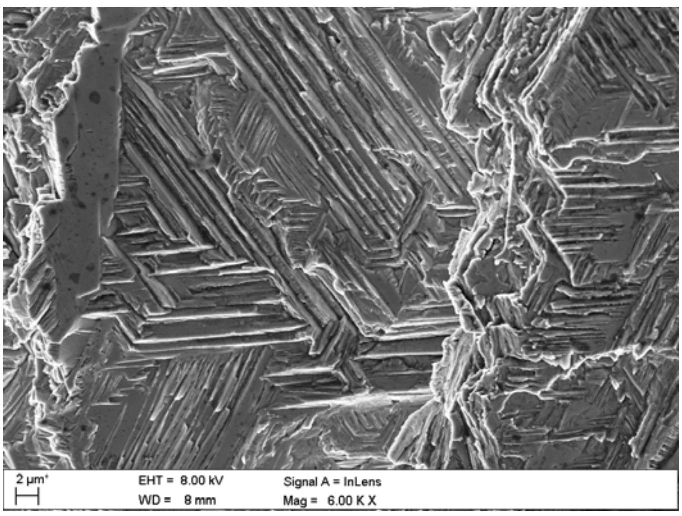

Fig. 2. Fracture of Ti-20Nb-15Al alloy in lamellar area

During the oxidation of Ti-Al titanium alloys in air TiO_2+Al_2O_3 oxide layer forms on their surface. TiO_2 - rutile is always the first oxide, which forms on the surface at the initial stages of oxidation as the titanium's activity is much higher than the aluminum's activity. The content of Al_2O_3 in the scale is much lower [19]. However, the thickness of the forming oxide layer strongly depends on the time and temperature of holding in the air atmosphere. In oxidation trials the material destruction process includes the formation of oxides in heating cycles, chipping during cooling and holding in room temperature. The mass changes during isothermal oxidation of the tested alloy were presented in Fig. 3. And thus the oxidation in air at 700°C during 500 hours caused the mass gain only. The mass gain of the alloy samples was respectively 0,046 mg/cm^2 after 50 hours of oxidation, around 0,17 mg/cm^2 after 100 hours, 0,18 mg/cm^2 after 300 hours and 0,19 mg/cm^2 after 500 hours of annealing at 700°C. The scale forming on the surface of samples was tightly attached to the substrate and did not chip either immediately after the test nor later.

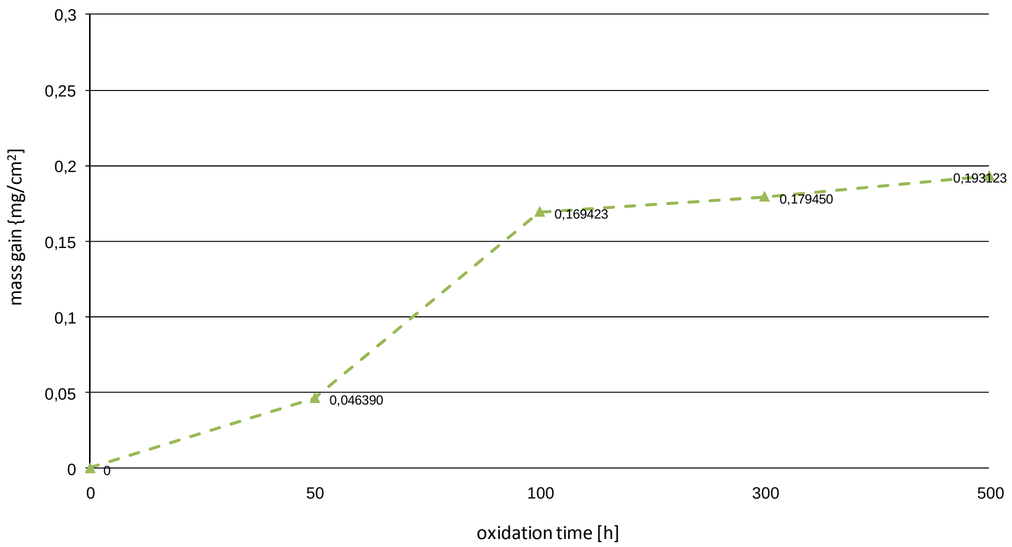

Fig. 3. The mass change of Ti-20Nb-15Al oxidized isothermally at 700°C

The thickness of the scale determines the occurrence of the particular colouring and the colours which appear on the surface may carry important information. Figs. 4 show the obtained colouring of the surface of Ti-20Nb-15Al alloy during the trials, after 50, 100, 300, and 500 hours respectively. The content of oxygen and nitrogen in the metallic substrate is the outcome of the atmosphere, the temperature and the time of exposure to annealing. Along with the increase of temperature and time, the content of nitrogen and oxygen rises. Nitrogen is characterized by a high chemical affinity to titanium, higher than the oxygen. The formed nitrides are easily recognizable by the golden colouring of the surface.

The mass gain resulting from bonding oxygen and nitrogen and the resolving of these elements in the metallic substrate is rather moderate for this temperature.

After 50 hours of isothermal heating in air, the surface of the alloy took a straw-yellow colour (Fig. 4a) Doubling the oxidation time causes the alloy surface to take a purple shade (Fig. 4b) while the oxide layer growth during 250 hours results in the blue surface with minor inclusions of purple (Fig. 4c). After 500 hours of oxidation where the formed layer is the thickest - the scale is of brown colour (Fig. 4d).

It is however worth noticing that such colouring was obtained only at heating at 700°C. The rise of the temperature up to 800°C does not promote a distinct colouring of the surface.

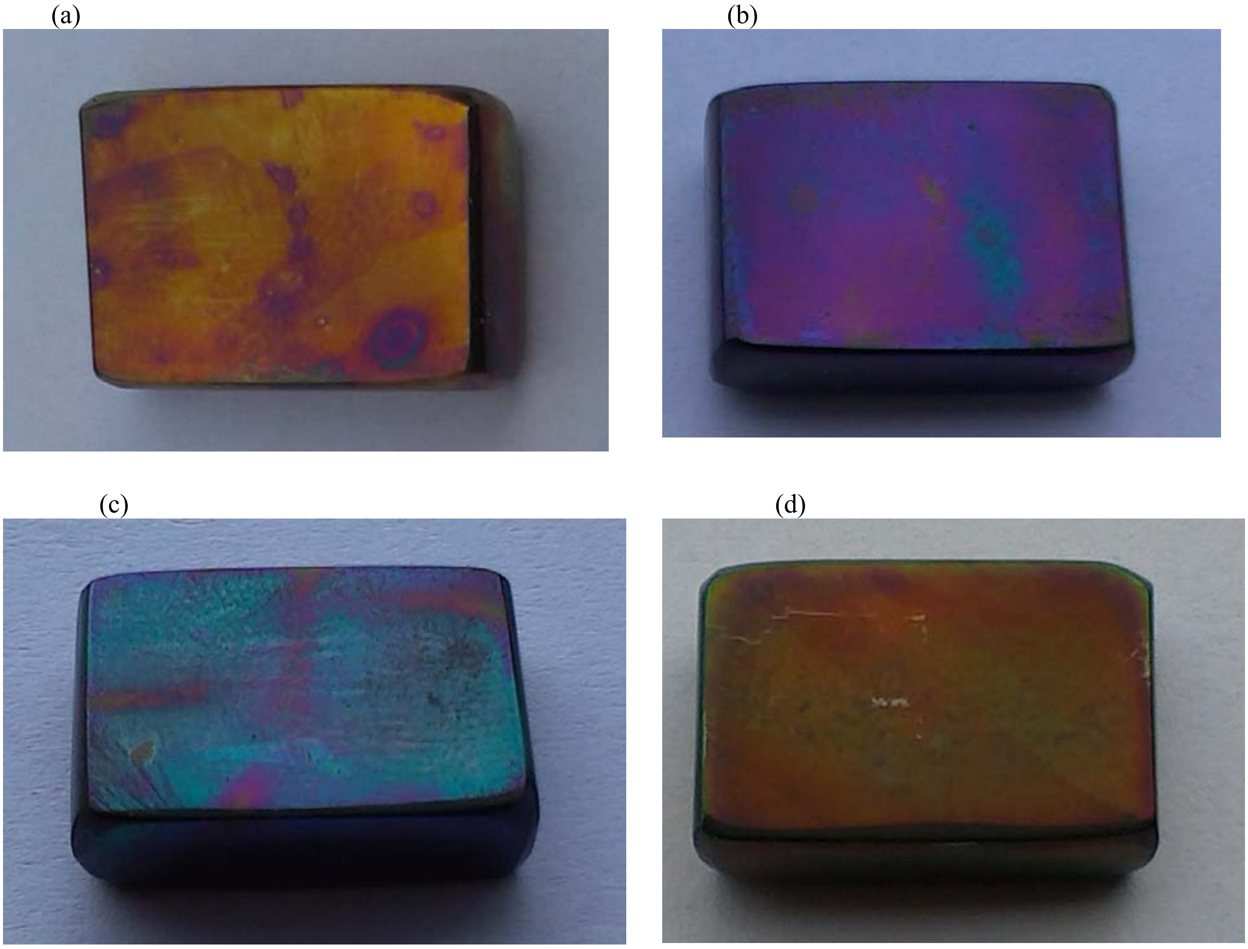

Fig. 4. Surface of Ti-20Nb-15Al alloy after isothermal heating in air
(a) after 50 hours, (b) after 100 hours, (c) after 250 hours, (d) after 500 hours

CONCLUSIONS

1. The oxidation of Ti-20Nb-15Al at 700°C in air causes mass gain exclusively, which intensifies along with extending the test time,
2. In the tested temperature the alloy shows relatively constant and slight mass gain,
3. A satisfying resistance to high-temperature oxidation of Ti-20Nb-15Al allows its potential application in power industry devices working in the temperature on the order of 700°C.

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