Silesian University of Technology

Faculty of Materials Engineering

DOCTORAL DISSERTATION

Effect of selected reactive elements on high temperature oxidation behavior of γ–γ′ Co-based superalloys

(Efekt wybranych pierwiastków reaktywnych na wysokotemperaturowe utlenianie nadstopów kobaltu typu γ–γ′)

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Katowice, 2023

Abstract

The new γ-γ′ cobalt-based alloys are an attempt to adress the limitations of commercially used nickel alloys, which no longer allow for an increase in the maximum operating temperature of gas turbines in the aircraft and power industries. The new group of alloys attracts the attention of an increasing number of scientists worldwide and is still in the research phase. Despite numerous advantages, these new materials exhibit low resistance to high temperature oxidation. One approach to improve this property is the introduction of reactive elements (RE) into the alloys, which was the subject of the research presented in the thesis.

The experimental work included the manufacturing of the Co-9Al-9W (at%) alloy and four RE-modified alloys with a composition of Co-9Al-9W-0.1RE (RE=La, Nd, Dy, Y). The microstructure, thermal properties, and resistance to high temperature oxidation under isothermal and cyclic conditions were investigated for these alloys. The oxidation mechanism of all the alloys was studied, and the oxidation kinetics were determined at 700, 800, and 900 °C. The oxidized layers were also characterized in detail by means of electron microscopy. Special attention was given to the modifications in the microstructure and the oxidation mechanism resulting from the presence of RE.

The results showed that the introduction of small amounts of RE has a significant impact on the microstructure and properties of new Co-based alloys. The increase of both isothermal and cyclic oxidation resistance was achieved, particularly at 900 °C. However, the improvement was not efficient due to the lack of formation of a protective Al_2O_3 layer. The RE such as La, Nd, Dy, and Y exhibit very low solubility in bothj γ-Co_{ss} and γ′-Co_3(Al, W) phases, but form intermetallics phases, primarily at grain boundaries. These phases undergo selective internal oxidation. During the oxidation process, it was observed that the RE-modified alloys develop substantially thicker internal oxidation zones compared to that of the reference alloy. In addition, the increased concentration of Al-rich oxides can be observed near the scale-substrate interface. Such phenomenon is lkely associated a reduced oxidation rate and a thinner oxide scale in the modified alloys. Numerous RE-rich oxides located at or near the substrate-oxide boundary may contribute to the improved oxide scale adherence, as reflected in the enhanced of cyclic oxidation resistance.