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2016

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Mantyi, Hadio Caprice (2016) High temperature oxidation and corrosion behaviour of Titanium Aluminide alloy Ti-52.5Al-10.0Ni-0.2Ru (at.%), University of the Witwatersrand, Johannesburg, <http://hdl.handle.net/10539/22671>

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High Temperature Oxidation and Corrosion Behaviour of Titanium Aluminide Alloy Ti-52.5Al-10.0Ni-0.2Ru (at.%)

by

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A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Engineering

15 October 2016

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted for the degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Signature: H.C. Mantyi

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October 2016

ABSTRACT

The alloys Ti-52.5Al-10.0Ni (at.%) and Ti-52.5Al-10.0Ni-0.2Ru (at.%) were made by mixing, and melting their powders in a button arc furnace under an argon atmosphere. The high temperature oxidation and room temperature corrosion of behaviour of the alloys was investigated. Isothermal oxidation in air at 950°C for 120 hours and 720 hours was done. Cyclic oxidation behaviour of the alloys was also investigated in air and in a hot salt (Na_2SO_4) environment. The corrosion tests were conducted in 5 wt% and 25 wt% HCl. All the samples were characterised using scanning electron microscopy with energy dispersive X-ray spectroscopy, X-ray diffraction and hardness measurements.

On solidification, the Ti-52.5Al-10.0Ni (at.%) alloy formed dendrites of γ-TiAl (~55 at.% Al) surrounded by a eutectic of γ-TiAl + Ti_2NiAl_3 (τ_3) phases. Most of the nickel was found in the Ti_2NiAl_3 (τ_3) phase (~12 at.%) with trace amounts in the dendrites (~0.5 at.%).

The Ti-52.5Al-10.0Ni-0.2Ru (at.%) alloy formed dendrites of γ-TiAl (~53 at.% Al) surrounded by a eutectic of γ-TiAl + Ti_2NiAl_3 (τ_3). Most of the nickel (~15 at.%) and ruthenium (~0.3 at.%) were in solid solution in the Ti_2NiAl_3 (τ_3) phase, although small amounts of both metals were present in the dendrites (~1 at.% Ni and 0.1 at.% Ru).

Under isothermal oxidation conditions, both alloys showed good oxidation resistance with a low mass gain (< 2%). The alloys formed a continuous scale of TiO_2 and Al_2O_3 with good adherence to the substrate, but as exposure time increased, the scale was severely degraded and exfoliated from the surface. Cyclic oxidation conditions were more aggressive for both alloys. The Ti-52.5Al-10.0Ni-0.2Ru (at.%) alloy was more resistant and formed a nickel-rich sub-surface zone between the substrate and intermixed oxide layer.

Both alloys had a fairly good corrosion resistance in HCl due to the presence of nickel. They formed a thin and non-continuous Al_2O_3 oxide scale on the surface of the γ-TiAl dendrites, with Ti_3NiAl_2O on the γ-TiAl + Ti_2NiAl_3 (τ_3) eutectic regions. The acid mainly corroded the τ_3 phase, thus attacking the eutectic and leaving the γ-TiAl dendrites exposed.