Effect of palladium diffusion in coatings deposited on the nickel based superalloy

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ABSTRACT

Purpose: In this paper the effect of palladium diffusion in coatings deposited on the surface of nickel based superalloy was evaluated.

Design/methodology/approach: The palladium coatings 3 and 7 μm thick were deposited by the electroplating process on Inconel 713 LC Ni-base superalloy. The heat treatment of electroplated coatings at the temperature 1050°C for 2 h under argon atmosphere was performed. The microstructure investigations of the heat treated coatings were conducted by the use of optical microscope (Nikon Epiphot 300) and a scanning electron microscope (Hitachi S-3400N) equipped with an Energy Dispersive Spectroscope EDS (VOYAGER of NORAN INSTRUMENTS). The phase composition was identified by X-ray (ARL X'TRAX) diffractometer. The surface roughness parameter - Ra of heat treated coatings was evaluated by Perhometer S2 MAHR equipment.

Findings: The microstructure of 3 μm thick palladium electroplated coating after diffusion treatment consists of three phases: AlPd2, Ni3Al, Ni0.52Pd0.475. The increase of palladium thickness from 3 to 7 μm does not influence the phase composition of heat treated coatings. Heat treatment of palladium electroplating coatings increases the surface roughness parameter Ra.

Research limitations/implications: The results will be used in the future investigations to explain the influence of palladium on the oxidation resistance of aluminide coatings.

Practical implications: The palladium electroplating coatings after heat treatment and aluminizing process may be used as an alternative to platinum modified aluminide coatings as coatings for turbine blades of aircraft engines.

Originality/value: The paper includes the results of microstructure and surface roughness investigations of palladium electroplating coatings 3 and 7 μm thick after diffusion treatment. Inconel 713 LC; Palladium electroplating; Diffusion treatment; Surface roughness

Keywords:

1. Introduction

Nickel-based superalloys are extensively used as gas-turbine engine components. These components need protection against high-temperature oxidation during operation. Diffusion aluminide coatings are widely used for protection of nickel-based superalloys from oxidation and hot corrosion [1-3]. Aluminide coatings have been used since the 1950s. However, aluminide coatings based on the NiAl phase deposited by the CVD method do not fulfill the requirement of the long-term oxidation resistance at high temperature. Pt-modified aluminide coatings affirm the protection of nickel-based blades from oxidative gases even at gas temperature above 1400°C [4]. Moreover, platinum causes formation of the PtAl₂ phase in the coating microstructure [5-6]. The low ductility of PtAl₂ and large difference of thermal expansion coefficients between the substrate and platinum causes the coating degradation under the cyclic thermal stress. Alperine et al. [7-8] showed that the palladium modified aluminide coating has higher oxidation and hot corrosion resistance than the conventional aluminide coating. Lehnert et al. [9] showed that palladium modified aluminide coating is a low protector due to the formation of pores by the Kirkendall effect. Monceau et al. [10] investigated the influence of oxygen partial pressure, heating rate and surface treatment on the high temperature oxidation kinetics of Pd-modified aluminide coating, used as a bond coat for partially stabilized zirconium (PSZ) thermal barrier coatings (TBC).

The important factor of palladium coatings after electroplating is the diffusion treatment. The application of diffusion treatment of palladium coatings provides their good adherence [11].

In this paper the effect of palladium diffusion in coatings obtained by means of the electroplating process (Figs. 1 a, b). The palladium electroplating process was conducted in the bath of palladium chloride PdCl₂, sulfamates acid H₂NSO₃, the hydrochloric acid and ammonium chloride NH₄Cl. The samples after electroplating were heat treated at the temperature 1050°C for 2 h under the argon atmosphere [13].

The palladium electroplating samples after diffusion treatment were cut to study the cross-section. Polished sections were etched by the use of reagent with chemical compositions as follows: 100 ml HNO₃, 4 ml HF, 11 ml H₂O. Microstructure investigations of samples after diffusion treatment were performed by the use of light microscope Nikon 300 and scanning electron microscope (SEM) HITACHI S-3400N equipped with EDS spectrometer. Evaluation of phase composition of the investigated coatings was performed by ARL X'TRA-ray diffractometer, equipped with filtered copper lamp with the voltage of 45 kV and heater current of 40 mA. Measurements were made in the range from 20 to 120°.

The surface roughness parameter - Ra was evaluated by Perthermometer S2 MAHR. The average value of surface roughness parameter and a standard deviation were calculated.

2. Experimental procedure

The superalloy used in this study was Inconel 713 LC. Chemical composition of the used superalloy in Table 1.

<table>
<thead>
<tr>
<th>Elements content, % mas</th>
<th>Ni</th>
<th>Cr</th>
<th>C</th>
<th>Mo</th>
<th>Nb</th>
<th>Al</th>
<th>Ti</th>
<th>Co</th>
<th>Fe</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>74.7</td>
<td>12</td>
<td>0.05</td>
<td>4.6</td>
<td>1.96</td>
<td>5.7</td>
<td>0.7</td>
<td>0.08</td>
<td>0.19</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Sandblasting process is an usual surface pretreatment before a palladium electroplating process. As analysis of the grit-blasted surface by secondary ion mass spectrometry (SIMS) reveals this pretreatment leads to contamination of the coatings by various impurities, in particular, the alkali and alkaline-earth metals and titanium [12]. These impurities become incorporated into the growing alumina scale during oxidation of palladium-aluminide coatings and adversely affect the oxidation behavior of the aluminide coatings [12]. In this paper surface treatment before palladium electroplating process was grinding.

Process of palladium electroplating was performed in Warsaw Institute of Precision Mechanics. The palladium coatings 3 and 7 μm thick were deposited by electroplating process. The material surface preparation for palladium electroplating includes: degreasing by means of ultrasound, electrolytic etching and surface activation.

The palladium electroplating process was conducted in the bath of palladium chloride PdCl₂, sulfamates acid H₂NSO₃, the hydrochloric acid and ammonium chloride NH₄Cl. The samples after electroplating were heat treated at the temperature 1050°C for 2 h under the argon atmosphere [13].

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3. Results and discussion

The good quality palladium coatings 3 and 7 μm thick were obtained by means of the electroplating process (Figs. 1 a, b).

![Image](image-url)
Effect of palladium diffusion in coatings deposited on the nickel based superalloy

The surface roughness parameter of specimens decreases with the increase of palladium deposition thickness (Table 5). Heat treatment of palladium electroplating causes the increase of...
4. Conclusions

Palladium coatings 3 and 7 μm thick were produced by electroplating method. Electroplated samples were heat treated at the temperature 1050 °C during 2 h under argon atmosphere. After the heat treatment the 3 μm palladium coating diffused for 10 μm whereas 7 μm coating diffused for 14 μm. It was found, that palladium coatings consist of three phases - AlPd2, Ni0.52Pd0.475 and Ni3Al. The chemical composition on the cross-section of palladium coating after diffusion treatment showed outward diffusion of nickel, chromium and aluminum and inward diffusion of palladium. Heat treatment of palladium coatings causes the increase of surface roughness parameter Ra with the increase of palladium thickness as a result of unequal mass flow of palladium and nickel.

Fig. 5. Cross-section of palladium electroplating coating 7 μm thick after heat treatment process

Table 4.
The results of EDS analysis from area presented in Fig. 5

<table>
<thead>
<tr>
<th>Point</th>
<th>Elements content, % at</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al</td>
</tr>
<tr>
<td>1</td>
<td>4.37</td>
</tr>
<tr>
<td>2</td>
<td>4.21</td>
</tr>
<tr>
<td>3</td>
<td>7.47</td>
</tr>
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</table>

Fig. 6. Diffraction results of palladium coating 3 and 7 μm thick after heat treatment process

Table 5.
Values of surface roughness parameter after palladium electroplating and diffusion treatment

<table>
<thead>
<tr>
<th>Nickel alloy</th>
<th>Ra</th>
</tr>
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<tbody>
<tr>
<td>Inconel 713 LC</td>
<td>0 μm Palladium electroplating</td>
</tr>
<tr>
<td></td>
<td>3 μm</td>
</tr>
<tr>
<td>Average value</td>
<td>1.080</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.0144</td>
</tr>
</tbody>
</table>

Fig. 7. Microstructure (a) and EDS analysis results (b) of the surface of palladium coating 7 μm thick after heat treatment process: showing a fine grain structure
Acknowledgements

The present work was supported by the Polish Ministry of Education and Science under the research project Nr 5146/B/T02/2010/39.

References