MICROSTRUCTURE EVOLUTION OF THE AS-RECEIVED AND ALUMINIZED INCONEL 740 AFTER EXPOSURE AT 1000°C

Izabela MIERZEJEWSKA[1,2], Mateusz KOPEC[1], Dominik KUKLA[1], Magdalena ŁAZIŃSKA[2], Ryszard SITEK[3], Zbigniew L. KOWALEWSKI[1]

[1] Department of Experimental Mechanics, Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland, E-mail: ibarw@ippt.pan.pl, mkopec@ippt.pan.pl, dkukla@ippt.pan.pl, zkowalew@ippt.pan.pl

[2] Faculty of Advanced Technologies and Chemistry, Military University of Technology, 00-908, Warsaw, Poland, E-mail: izabela.mierzejewska@student.wat.edu.pl, magdalena.lazinska@wat.edu.pl

[3] Faculty of Materials Science and Engineering, Warsaw University of Technology, Wołoska 141, 02-507 Warsaw, Poland, E-mail: ryszard.sitek@pw.edu.pl

1. Introduction

Materials for the power engineering industry are exposed to high temperature and increased pressure. The continuous development of this industry is aiming to reduce CO2 emissions; however, it simultaneously leads to an increase of the temperature and pressure during power plant operation. The current operating temperature in power plants reaches up to 760°C, while the pressure generated could be as high as 35 MPa. Such extreme conditions reduce significantly the number of materials that can be use. Among the possible materials to be used in this sector one can indicate an austenitic nickel–chromium-based superalloy Inconel 740 [1,2]. It well suits for a service under extreme conditions (high pressure and heat) due to its superior oxidation corrosion-resistance related to its microstructure strengthened by γ’ phase and alloying elements such as cobalt and molybdenum. However, oxidation of the Inconel 740 alloy leads to the formation of hard internal oxide particles and simultaneous reduction in the extent of the ductile γ’ phase, which consequently contributes to a decrease in creep strength and crack resistance.

Components operating at high temperature are particularly exposed to oxidation and degradation under corrosive environmental conditions. Hence, the aluminide coatings are commonly used to protect them from damage development during operation. The protective coating against corrosion at 700–950°C is applied primarily by the CVD method. It offers high repeatability, coating uniformity and excellent adhesion strength [3, 4].

Therefore, the main aim of this research is to assess a suitability of the aluminized Inconel 740 by the CVD method during a long-time annealing for 100 h at 1000°C. In addition, the results obtained for the aluminized Inconel 740 are compared to those captured for the same material in the as-received state.

2. Materials and methods

Inconel 740, with the chemical composition presented in Table 1, was investigated in this research. The prepared specimens were subjected to the aluminizing process performed by means of an IonBond apparatus and CVD process, with the participation of $AlCl_3$ vapors in the hydrogen atmosphere (carrier gas), at temperature of 1040°C for 8 h, and pressure of 150 hPa.

Table 1. Chemical composition of Inconel 740 in the as-received state

Element	Al	Nb	Ti	Fe	C	Mn	Si	Cr	Co	Ni
Wt.%	0.90	2.00	1.80	0.60	0.03	0.25	0.40	24.66	20.12	bal

High-temperature oxidation was performed on five aluminized and five as-received specimens at 1000°C in the air atmosphere. Each specific specimen was removed from the furnace after 1 h, 5 h, 25 h, 50 h, and 100 h in order to measure its weight and dimensions by applying a precise micrometer screw gauge and laboratory scale, respectively. Oxidation kinetics was determined by mass gain and measurements of the scale after specific time of the heat treatment. In addition, the microstructural analysis was performed by using a Quanta 3D FEG field emission scanning electron microscope (SEM) operated at 20 kV with EDS detector. Such detector was also used to carry out a qualitative chemical composition analysis. Applying SEM an effect of the heat treatment scale of the specimen surface for modified and unmodified specimen areas was analyzed on their grounded and mechanically polished cross-sections.

3. Results

The aluminizing process enabled a deposition of the uniform coating of approximately 25 ± 2 µm thickness on the Inconel 740 substrate. The cross-sectional micrograph of the aluminide coating revealed the presence of three zones introduced by the CVD process: outer NiAl coating, interdiffusion zone (IDZ), and substrate material.

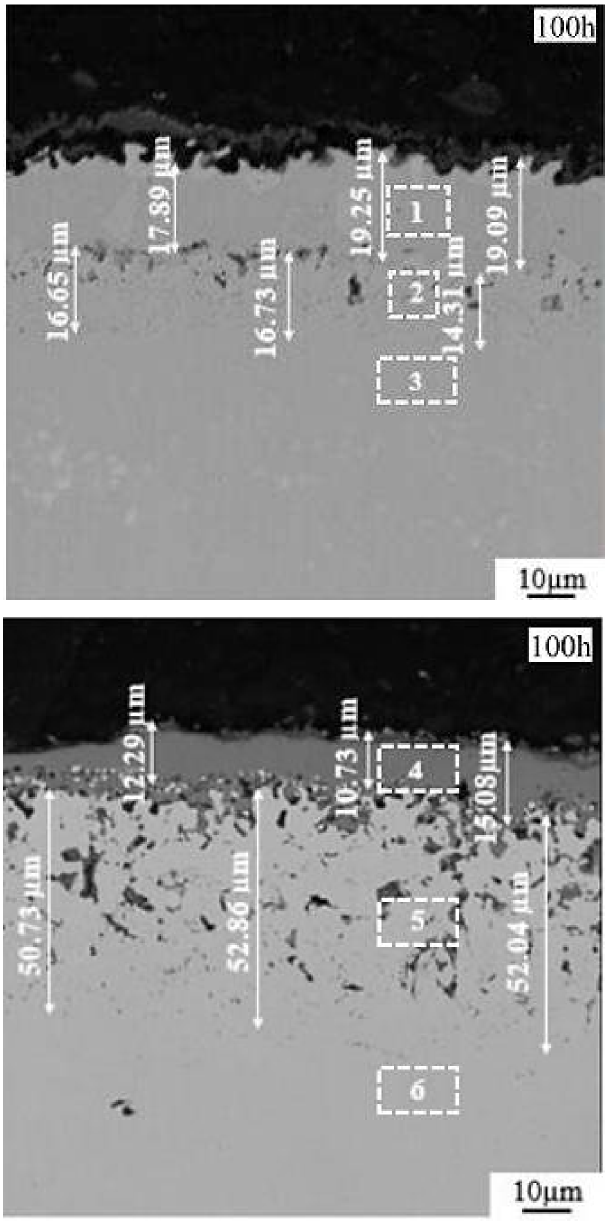

Fig. 1. The cross-section micrographs of (a) aluminized Inconel 740 and (b) as-received Inconel 740 after 100 h exposure at 1000C.

The microscopic observation (Fig.1) exhibited a significant improvement in terms of oxidation resistance for the coated Inconel 740 after 100h at 1000°C. The value of the oxidation scale thickness was almost 2 times higher for the as-received specimen. This proves that the optimized CVD process enabled the application of a tight and well-adhered AlNi coating, which reduces the intensity of pitting corrosion. In addition, the results showed that the aluminum content was the highest on the top of coating, while elements including niobium, titanium and chromium enriched the IDZ. However, the uncoated specimen was covered by the chromium-enriched scale. The high temperature led to the formation of a diffusion zone where an increased content of cobalt could be observed. Moreover, aluminum and niobium-rich areas were found to be close to the specimen surface.

4. Conclusions

Application of the aluminizing process improved the corrosion resistance of Inconel 740 significantly, since the effective protection of its surface against high temperature oxidation was successfully achieved. The thickness stability of the oxidation scale for the aluminized Inconel 740 corresponded to the stabilization of the aluminum oxide during the high-temperature annealing at 1000°C either for 50 h or 100 h. Hence, it seems to be reasonable to conclude, that the aluminizing process improves the heat resistance of Inconel 740 remarkably, and therefore, it can be treated as a promising tool for protecting selected materials against the hot-temperature corrosion.

References

[1] Xie, X., Wu, Y., Chi, C., Zhang, M. Superalloys for Advanced Ultra-Super-Critical Fossil Power Plant Application. In *Superalloys*, Aliofkhazraei M., IntechOpen, London, 2015.

[2] Barwińska, I., Kopec, M., Kukla, D., Łazińska, M., Sitek, R., Kowalewski, Z. Effect of Aluminizing on the Fatigue and High-Temperature Corrosion Resistance of Inconel 740 Nickel Alloy, JOM, 2023, 75(2), 1-13.

[3] Barwińska, I., Kopec, M., Kukla, D., Senderowski, C., Kowalewski, Z.L., Thermal Barrier Coatings for High-Temperature Performance of Nickel-Based Superalloys: A Synthetic Review, Coati., 2023, 13(4), 1-21.

[4] Kukla, D., Kopec, M., Sitek, R., Olejnik, A., Kachel, S., Kiszkowiak, Ł. A Novel Method for High Temperature Fatigue Testing of Nickel Superalloy Turbine Blades with Additional NDT Diagnostics. Mater., 2021, 14 (6), 1392.