Alloy oxidation based on FeAl intermetallic phase in air and water vapor

Abstract

The paper presents the results of research on oxidation in air and water vapor at 700°C of Fe40Al5Cr0.2TiB alloy after casting and plastic working. In the available literature, there is no information about studies where high-temperature oxidation was carried out, in particular at 700°C, on plastically processed material in the environment of air and water vapor. The obtained research results constitute the organization of knowledge in this field and a new, broad set of data on the structure, chemical and phase composition obtained with the use of advanced research methods and research techniques. The work has been divided into research areas, out of which five most important can be distinguished.

The first research area included the determination of the oxidation kinetics of the Fe40Al5Cr0.2TiB alloy at 700°C. It has been shown that the material after casting shows greater resistance to oxidation than after plastic working, regardless of the environment - air or water vapor. The course of oxidation kinetics for the state after casting and plastic working, both in air and in water vapor, was parabolic.

The second research area concerned the assessment of the surface condition (structure, chemical and phase composition, surface development) after oxidation of the alloy on the matrix of the Fe40Al5Cr0.2TiB intermetallic phase matrix, after casting and plastic processing, using advanced test methods (SEM, STEM, EDS, WDS, XRD, optical profilometry, confocal microscopy), in air and water vapor. The material after oxidation was covered with a layer of oxides in the form of elongated crystals with the structure of fine acicular whiskers and polygon-shaped lamellar structures.

The third research area covered the characteristics of the oxidized layer in terms of its structure (STEM, TEM). The upper part of the oxide layer of the alloy, after casting and plastic processing, to be oxidized in air, was characterized by less damage, which results from the milder course of the process of its formation, and the process was associated with a greater thermodynamic equilibrium of the process. In the case of the cast alloy and the melt oxidized in a water vapor environment, the oxide layer was more homogeneous, growing in columns. The steam oxidation process was selective, as a result of which the oxide layer showed little damage.

The fourth research area was a detailed analysis of the phase composition (XRD in situ, EBSD, electron diffraction, microdiffraction) of oxidation products, in particular the types of aluminum oxide, depending on the environment in which the oxidation was carried out. On the surface of the material after oxidation, the presence of a stable type of α-Al_2O_3 oxide and a metastable type of θ-Al_2O_3 oxide were found.

The fifth research area covered the development of a model of the Fe40Al5Cr0.2TiB alloy oxidation at 700°C in the air and water vapor environment. In particular, it was related to the analysis of all the obtained test results in terms of determining the physicochemical phenomena occurring during the formation of a layer of oxidation products, leading from the metastable phase of θ-Al_2O_3 to the stable phase of α-Al_2O_3. The summary of this stage of research is the statement that the oxidation process of the Fe40Al5Cr0.2TiB alloy is based on the dominant revival diffusion of aluminum.

Summarizing the overall research results obtained, it can be stated that the mechanism of formation of the layer of oxidation products of the Fe40Al5Cr0.2TiB alloy has been explained and their structure, chemical and phase composition have been described in detail. In practical terms, this allowed to explain the very good resistance to high-temperature oxidation of the Fe40Al5Cr0.2TiB alloy and to show that it is a material with higher heat resistance than many materials previously used to work in conditions of high-temperature corrosion in an oxidizing environment.