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Oxidation of a nanostructured superalloy of high temperature

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Abstract

The oxidation kinetics of a nickel-based super alloy developed by powder metallurgy and used in the disks of turbine blades is investigated analytically, numerically and experimentally.The rate oxidation constant and the evolution of the forehead oxidation were determined analytically using Fick's diffusion equation. This equation is solved by the method of finite volumes and an iterative method.In the experimental part we have considered a material in the powder state and then in the compacted state. We have analyzed the behavior of the material by thermo gravimetric analysis for two periods: the transitional period when the temperature increases over time and the period where the temperature is maintained constant. The results showed that at a temperature equal to 700 ° C and forthe powder state the mass gain is equal to 0.09%. For the compacted material it is equal to 0.14%.

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Keywords: Nano materials;Dry corrosion;Thermogravimeter

1. INTRODUCTION

Powder metallurgy is a very well suitable technological for the mechanical characteristics and the production of complex geometries. The sectors involved in nanotechnology are energy, automotive, construction, clothing, cosmetics and food. Applications have been developed, in surgery, in the treatment of cancers, molecular imaging, medical devices and tissue engineering.The metal foam obtained by powder metallurgy has a pore microstructure

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isolated resistance superior to those interconnected pores.This type of structure is particularly suitable for applications requiring a combined weight reduction at a high energy absorption capacity.

Nomenclature

$C_i(x,t)$	solute concentration of (oxygen, chromium or iron).
D_i	diffusion coefficient of (oxygen, chrome or iron).(m^2/s)
X	diffusion distance [cm]
P_{CrOn1}	dissociation pressure of chromium oxide
P_{FeOn2}	dissociation pressure of iron oxide
P_{O2}	oxygen pressure
ξ_1	the front of oxidation of chromium oxide
ξ_2	the front of oxidation of iron oxide
α	Oxygen Concentration Ratio
β	Basic Metal Concentration Ratio
γ	Concentration ratio in first addition element
Ki	Parabolic kinetic oxidation constant ($m / s^{1/2}$), i represents a set of parameters (α, β and γ)

These alloys are very commonly used in combustion systems such as municipal waste incinerators.The study of high temperature corrosion is a highly interdisciplinary subject at the interface of the physical chemistry of ceramic-metallic materials and mechanical, and operates in areas where failures often have a financial cost, environmental or human high. Knowledge and understanding of corrosion, aging and damage are essential to predict the lifes pan of a material or a technological device. The high temperature oxidation designates the corrosive reaction between the metal and oxygen. Experimental studies exist to explain the behavior of nickel alloys at high temperatures. There are few studies that investigated on the high temperature corrosion phenomenon in the world of nanomaterial. A number of researcher have been interested to the high temperature corrosion of nickel-based alloys, the characterization of degradation, to an inter diffusion and local electronic properties of passive films which can be formed during the oxidation, to the development of new alloys and finally to the numerical modelling of corrosion at high temperature. Delabrouille [1] has worked on the characterization by transmission electron microscopy and the stress corrosion cracking of nickel-based alloys: Trials traction showed that the sensitivity decreases as the chromium content of the alloy increases. Trindade and al. [2] have studied numerically the high-temperature corrosion of Nickel based alloy. The modelling, based on the concept of local thermodynamic equilibrium was designed for predicting the life time of the components. The agreement between experimental and numerical results revealed the potential of the numerical modelling for application to complex corrosion process. Vialas [3] has devoted his work on deterioration by high temperature oxidation and interdiffusion coating systems nickel based superalloy. The oxidation kinetics of three superalloys were determined by thermo gravimetric analysis at 900 ° C and 1150 ° C. Lecallier, [4] worked on a nickel base superalloy obtained by powder metallurgy. Its objective was the modernization of the M88 engine SNECMA using new materials in the field of aeronautics including high pressure turbine disks. The study focused mainly on microstructures nuances prepared. Andrew et al, [5] were interested in analysing the consequences of oxidation at 950 ° C in alloys based on Nickel, near the alloy-oxide interface. The study was done by comparing the analytical model of Wagner with the numerical model Feulvarch. In this work, we were interested to an analytical, numerical and experimental study of the oxidation kinetic at high temperature of a porous nanomaterial based with nickel. The diffusion phenomenon is modeled by the second law of Fick.

2. **Analysis and modelling.**

The kinetic constants and the changes in the oxidation front are based on the second law of Fick.

2.1. Analytical analysis

The speed of propagation of the oxidation front is determined by solving the equations of the second law of Fick: