

Ferritic Stainless Steels for High Temperature Applications in Oxidizing Environments

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Abstract: Ferritic stainless steel containing more than 7 wt. % of Al represents an interesting material for the production of components working at high temperature. To meet industrial needs of increased operating temperatures, many studies have been carried out to design FeCrAl(RE) alloys that are suitable for applications where the components have to work in oxidative environments for extended periods of operation, often at very high temperatures (>1000 °C) under cyclic operating conditions. Although a very good protectiveness against oxidation can be achieved for Al concentrations higher than 7 wt.%, mechanical properties of FeCrAl alloys are known to be poor at high temperature. High temperature strength and creep resistance can be improved by reducing grain boundary areas and by precipitating stable particles in the bulk alloy; this practice prevents grain boundary slip and dislocation movement. This paper reviews the patented progresses in the field of the production of FeCrAl alloys for high temperature applications such as heating elements and substrate of catalytic converters.

Keywords: Active elements, FeCrAl alloys, high temperature alloys, oxidation resistance.

1. INTRODUCTION

Oxidation is the most important high temperature corrosion process in oxidizing environments. Metals and alloys are oxidized when heated at high temperature in air or in highly oxidizing environments such as combustion atmospheres with excess oxygen.

A large spectrum of engineering alloys is available for applications in different temperature ranges. Aluminum is an effective alloying element in improving the resistance to high temperature oxidation. FeCrAl alloys normally require 7% Al to form a continuous Al_2O_3 layer, which is able to protect the substrate against oxidation. Figure 1 shows parabolic rate constants of some oxides against $1/T$ [1]. It can be observed that Al_2O_3 exhibits the lowest parabolic rate constant. At very high temperature ($T \geq 1200^\circ\text{C}$) Al_2O_3 provides excellent protection against oxidation, while Cr_2O_3 , which has higher growth rate and forms volatile CrO_3 , becomes non protective. On the other hand, Al_2O_3 becomes less protective at low and intermediate temperatures where it exhibits a very slow growth rate. Consequently high temperature alloys must be able to form a continuous Al_2O_3 scale at high temperature, but they must also contain enough chromium to form Cr_2O_3 at intermediate temperatures. For those reasons FeCrAl alloys appear really interesting candidates for the production of components subjected, in service, to high temperature oxidation.

The oxidation process involves nucleation, growth and finally the formation of a protective oxide layer on the surface. The alloy is protected against high temperature oxidation only when the scale formed is smooth and adherent and does not spall off. Oxide spallation often starts at the very early stages of oxidation and continues with

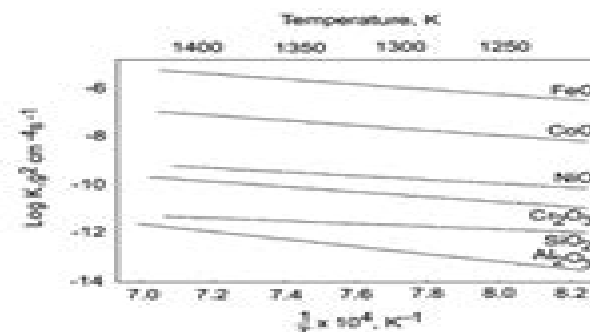


Fig. (1). Parabolic rate constant of some oxides vs. $1/T$ [1].

intermediate rebuilding of the scale. This is predominantly due to stress accumulation during the scale growth. The factors responsible for this accumulation are a considerable difference between the molar volumes of the metal and the oxide, epitaxial stresses, oxide growth mechanisms, geometry of the sample, composition of the scale and thermal expansion mismatch between the alloy and the oxide [2]. Scale spallation is a very serious problem for many high temperature components subjected to thermal variations: in fact material loss due to spallation not only creates debris, but also causes wear and erosion of the component. There are many papers available in literature that discuss effective methods to increase FeCrAl alloy component's life. Among them, the addition of the so called reactive elements seems to be the most promising one [3-6]. Reactive elements belong to the rare earth group and have a strong affinity for oxygen. Their beneficial effect is attributed, for FeCrAl and other

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Shoji,2011-09-22 The problem of stress corrosion cracking SCC which causes sudden failure of metals and other materials subjected to stress in corrosive environments has a significant impact on a number of sectors including the oil and gas industries and nuclear power production Stress corrosion cracking reviews the fundamentals of the phenomenon as well as examining stress corrosion behaviour in specific materials and particular industries The book is divided into four parts Part one covers the mechanisms of SCC and hydrogen embrittlement while the focus of part two is on methods of testing for SCC in metals Chapters in part three each review the phenomenon with reference to a specific material with a variety of metals alloys and composites discussed including steels titanium alloys and polymer composites In part four the effect of SCC in various industries is examined with chapters covering subjects such as aerospace engineering nuclear reactors utilities and pipelines With its distinguished editors and international team of contributors Stress corrosion cracking is an essential reference for engineers and designers working with metals alloys and polymers and will be an invaluable tool for any industries in which metallic components are exposed to tension corrosive environments at ambient and high temperatures Examines the mechanisms of stress corrosion cracking SCC presenting recognising testing methods and materials resistant to SCC Assesses the effect of SCC on particular metals featuring steel stainless steel nickel based alloys magnesium alloys copper based alloys and welds in steels Reviews the monitoring and management of SCC and the affect of SCC in different industries such as petrochemical and aerospace *Joint EPRI - 123HiMAT International Conference on Advances in High-Temperature Materials* J. Shingledecker ,M. Takeyama,2019-10-01 Proceedings from EPRI s 9th International Conference on Advances in Materials Technology for Fossil Power Plants and the 2nd International 123HiMAT Conference on High Temperature Materials Proceedings of the Institution of Mechanical Engineers ,1990 **High-Temperature Corrosion and Materials Applications** George Y. Lai,2007-01-01 George Lai s 1990 book High Temperature Corrosion of Engineering Alloys is recognized as authoritative and is frequently consulted and often cited by those in the industry His new

book almost double in size with seven more chapters addresses the new concerns new technologies and new materials available for those engaged in high temperature applications As we strive for energy efficiency the realm of high temperature environments is expanding and the need for information on high temperature materials applications was never greater In addition to extensive expansion on most of the content of the original book new topics include erosion and erosion corrosion low NO_x combustion in coal fired boilers fluidized bed combustion and the special demands of waste to energy boilers waste incinerators and black liquor recovery boilers in the pulp and paper industry The corrosion induced by liquid metals is discussed and protection options are presented

Creep-Resistant Steels Fujio Abe, Torsten-Ulf Kern, R Viswanathan, 2008-03-14 Creep resistant steels are widely used in the petroleum chemical and power generation industries Creep resistant steels must be reliable over very long periods of time at high temperatures and in severe environments Understanding and improving long term creep strength is essential for safe operation of plant and equipment This book provides an authoritative summary of key research in this important area The first part of the book describes the specifications and manufacture of creep resistant steels Part two covers the behaviour of creep resistant steels and methods for strengthening them The final group of chapters analyses applications in such areas as turbines and nuclear reactors With its distinguished editors and international team of contributors Creep resistant steels is a valuable reference for the power generation petrochemical and other industries which use high strength steels at elevated temperatures Describes the specifications and manufacture of creep resistant steels Strengthening methods are discussed in detail Different applications are analysed including turbines and nuclear reactors

Damage Mechanisms and Life Assessment of High Temperature Components Ramaswamy Viswanathan, 1989

NBSIR., 1983 *Proceedings of the 2014 Energy Materials Conference* The Minerals, Metals & Materials Society (TMS), 2015-04-15 This DVD contains a collection of papers presented at EnergyMaterials 2014 a conference organized jointly by The Chinese Society for Metals CSM and The Minerals Metals Materials Society TMS and held November 4 6 2014 in Xi an Shaanxi Province China With the rapid growth of the world s energy production and consumption the important role of energy materials has achieved worldwide acknowledgement Material producers and consumers constantly seek the possibility of increasing strength improving fabrication and service performance simplifying processes and reducing costs Energy Materials 2014 has provided a forum for academics researchers and engineers around the world to exchange state of the art development and information on issues related to energy materials The papers on the DVD are organized around the following topics Materials for Coal Based Systems Materials for Gas Turbine Systems Materials for Nuclear Systems Materials for Oil and Gas Materials for Pressure Vessels

Proceedings American Petroleum Institute. Refining Department, 1985

Effects of Radiation on Materials Roger E. Stoller, 1992 Symposium held in Nashville Tennessee June 1990 Almost two thirds of these 91 papers are authored by researchers outside of the US including information on research in the former USSR Japan and Europe Topics include current commercial power

reactor systems microstructural characterization **Paper** ,1990 Comprehensive Nuclear Materials ,2020-07-22

Materials in a nuclear environment are exposed to extreme conditions of radiation temperature and or corrosion and in many cases the combination of these makes the material behavior very different from conventional materials This is evident for the four major technological challenges the nuclear technology domain is facing currently i long term operation of existing Generation II nuclear power plants ii the design of the next generation reactors Generation IV iii the construction of the ITER fusion reactor in Cadarache France iv and the intermediate and final disposal of nuclear waste In order to address these challenges engineers and designers need to know the properties of a wide variety of materials under these conditions and to understand the underlying processes affecting changes in their behavior in order to assess their performance and to determine the limits of operation Comprehensive Nuclear Materials Second Edition Seven Volume Set provides broad ranging validated summaries of all the major topics in the field of nuclear material research for fission as well as fusion reactor systems Attention is given to the fundamental scientific aspects of nuclear materials fuel and structural materials for fission reactors waste materials and materials for fusion reactors The articles are written at a level that allows undergraduate students to understand the material while providing active researchers with a ready reference resource of information Most of the chapters from the first Edition have been revised and updated and a significant number of new topics are covered in completely new material During the ten years between the two editions the challenge for applications of nuclear materials has been significantly impacted by world events public awareness and technological innovation Materials play a key role as enablers of new technologies and we trust that this new edition of Comprehensive Nuclear Materials has captured the key recent developments Critically reviews the major classes and functions of materials supporting the selection assessment validation and engineering of materials in extreme nuclear environments Comprehensive resource for up to date and authoritative information which is not always available elsewhere even in journals Provides an in depth treatment of materials modeling and simulation with a specific focus on nuclear issues Serves as an excellent entry point for students and researchers new to the field **Frontiers in Materials Processing, Applications, Research and Technology** M. Muruganant,Ali Chirazi,Baldev Raj,2017-11-13 This volume comprises the select proceedings of FiMPART 2015 The volume covers advances in major areas of materials research under one umbrella This volume covers all aspects of materials research processing fabrication structure property evaluation applications of ferrous non ferrous ceramic polymeric materials and composites including biomaterials materials for energy fuel cells hydrogen storage technologies batteries super capacitors nano materials for energy and structural applications aerospace structural metallic materials bulk metallic glasses and other advanced materials The book will be useful to researchers students and professional working in areas related to materials innovation and applications

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Table of Contents Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference

1. Understanding the eBook Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - The Rise of Digital Reading Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Advantages of eBooks Over Traditional Books
2. Identifying Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - User-Friendly Interface
4. Exploring eBook Recommendations from Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference

- Personalized Recommendations
 - Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference User Reviews and Ratings
 - Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference and Bestseller Lists
5. Accessing Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference Free and Paid eBooks
- Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference Public Domain eBooks
 - Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference eBook Subscription Services
 - Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference Budget-Friendly Options
6. Navigating Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference eBook Formats
- ePub, PDF, MOBI, and More
 - Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference Compatibility with Devices
 - Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference Enhanced eBook Features
7. Enhancing Your Reading Experience
- Adjustable Fonts and Text Sizes of Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Highlighting and Note-Taking Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Interactive Elements Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
8. Staying Engaged with Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
- Joining Online Reading Communities

- Participating in Virtual Book Clubs
- Following Authors and Publishers Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
- 9. Balancing eBooks and Physical Books Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Setting Reading Goals Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Fact-Checking eBook Content of Ferritic Steels For High Temperature Applications Proceedings Of An Asm International Conference
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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