

# Fundamentals Of Hydrogen Embrittlement

Fundamentals of Hydrogen Embrittlement Hydrogen Embrittlement in Metals and Alloys Gaseous Hydrogen Embrittlement of Materials in Energy Technologies Hydrogen Embrittlement and Stress Corrosion Cracking Hydrogen Embrittlement Advances in Hydrogen Embrittlement Study Hydrogen Embrittlement of Steel Gaseous Hydrogen Embrittlement of Materials in Energy Technologies Hydrogen Embrittlement of Structural Alloys. A Technology Survey Inhibition of Hydrogen Embrittlement in High Strength Steels Hydrogen Embrittlement of Steel Gaseous Hydrogen Embrittlement of Materials in Energy Technologies A Study of Hydrogen Embrittlement in Lath Martensitic Steels Solutions to Hydrogen Attack in Steels Hydrogen Embrittlement and Stress Corrosion Cracking A New Concept of Hydrogen Embrittlement in Steel Hydrogen Embrittlement of Steel Resulting from Corrosion Hydrogen Embrittlement Testing Advances in Hydrogen Embrittlement Study HYDROGEN EMBRITTLEMENT OF METALS Michihiko Nagumo Pasquale Cavaliere Richard P Gangloff Alexander Robert Troiano Louis Raymond Vladimir A. Polyanskiy Robert Walton Buzzard Richard P Gangloff Barbara Ann Heydorn Robert Walton Buzzard R P Gangloff Young Ho Kim P. F. Timmins R. Gibala H.H. Johnson J.G. Morlet (A.R. Troiano) Robert Edward Wicen L Raymond Vladimir A. Polyanskiy Fundamentals of Hydrogen Embrittlement Hydrogen Embrittlement in Metals and Alloys Gaseous Hydrogen Embrittlement of Materials in Energy Technologies Hydrogen Embrittlement and Stress Corrosion Cracking Hydrogen Embrittlement Advances in Hydrogen Embrittlement Study Hydrogen Embrittlement of Steel Gaseous Hydrogen Embrittlement of Materials in Energy Technologies Hydrogen Embrittlement of Structural Alloys. A Technology Survey Inhibition of Hydrogen Embrittlement in High Strength Steels Hydrogen Embrittlement of Steel Gaseous Hydrogen Embrittlement of Materials in Energy Technologies A Study of Hydrogen Embrittlement in Lath Martensitic Steels Solutions to Hydrogen Attack in Steels Hydrogen Embrittlement and Stress Corrosion Cracking A New Concept of Hydrogen Embrittlement in Steel Hydrogen Embrittlement of Steel Resulting from Corrosion Hydrogen Embrittlement Testing Advances in Hydrogen Embrittlement Study HYDROGEN EMBRITTLEMENT OF METALS *Michihiko Nagumo* *Pasquale Cavaliere Richard P Gangloff Alexander Robert Troiano Louis Raymond Vladimir A. Polyanskiy Robert Walton Buzzard Richard P Gangloff Barbara Ann Heydorn Robert Walton Buzzard R P Gangloff Young Ho Kim P. F. Timmins R. Gibala H.H. Johnson J.G. Morlet (A.R. Troiano) Robert Edward Wicen L Raymond Vladimir A. Polyanskiy*

this book is the second edition of the one originally published in 2016 as the first comprehensive treatment on the fundamentals of hydrogen embrittlement of metallic materials mainly steel the book provides students and researchers engaging in hydrogen problems with a unified view of the subject establishing reliable principles for materials design against hydrogen embrittlement and assessing their performance are recent urgent industrial needs in developing high strength steel for hydrogen energy equipment and weight reducing vehicles the interdisciplinary nature of the subject covering metal physics materials science and mechanics of fracture has disturbed a profound understanding of the problem in this book previous studies are critically reviewed and supplemental

descriptions of fundamental ideas are presented when necessary emphasis is placed on experimental facts with particular attention to their implication rather than phenomenological appearance the adopted experimental conditions are also noted since the operating mechanism of hydrogen might differ by material and environment for theories employed assumptions and premises are noted to examine their versatility progress in the past decade in experimental and theoretical tools is remarkable and has nearly unveiled characteristic features of hydrogen embrittlement proposed models have almost covered feasible aspects of the function of hydrogen this second edition has enriched the contents with recent crucial findings chapters on the manifestation of embrittlement in the deterioration of mechanical properties and microscopic features are reorganized and the description is revised for the convenience of readers systematic understanding a new chapter is created for delayed fracture in atmospheric environments as a conclusive subject of critical ideas presented in this book

this book provides a complete description of hydrogen technologies from the basic theoretical underpinnings to the different production routes for various applications it summarizes the most recent research findings with respect to theory and the broad array of industrial technologies currently in place as well as those under development with high potential special attention is given to the hydrogen embrittlement mechanisms at room and high temperatures as well as problems related to hydrogen in liquid and high pressure compressed states the author further describes the hydrogen diffusion embrittlement issues related to different types of metallic materials from steel to light alloys to nikel based superalloys

many modern energy systems are reliant on the production transportation storage and use of gaseous hydrogen the safety durability performance and economic operation of these systems is challenged by operating cycle dependent degradation by hydrogen of otherwise high performance materials this important two volume work provides a comprehensive and authoritative overview of the latest research into managing hydrogen embrittlement in energy technologies volume 2 is divided into three parts part one looks at the mechanisms of hydrogen interactions with metals including chapters on the adsorption and trap sensitive diffusion of hydrogen and its impact on deformation and fracture processes part two investigates modern methods of modelling hydrogen damage so as to predict material cracking properties the book ends with suggested future directions in science and engineering to manage the hydrogen embrittlement of high performance metals in energy systems with its distinguished editors and international team of expert contributors volume 2 of gaseous hydrogen embrittlement of materials in energy technologies is an invaluable reference tool for engineers designers materials scientists and solid mechanicians working with safety critical components fabricated from high performance materials required to operate in severe environments based on hydrogen impacted technologies include aerospace petrochemical refining gas transmission power generation and transportation summarises the wealth of recent research on understanding and dealing with the safety durability performance and economic operation of using gaseous hydrogen at high pressure chapters review mechanisms of hydrogen embrittlement including absorption diffusion and trapping of hydrogen in metals analyses ways of modelling hydrogen induced damage and assessing service life

the book presents a collection of chapters on the current problems associated with

hydrogen damage it discusses the effect of hydrogen on material properties and its interaction with the material microstructure physical features of hydrogen transport in metals and alloys as well as applicable methods of measuring concentration of hydrogen in solid media

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this important two volume book reviews the problem of degradation of metals and other materials exposed to hydrogen the first part of volume one begins by discussing how the problem of gaseous hydrogen embrittlement affects such sectors as the petrochemicals automotive nuclear and other energy industries part two reviews ways of characterising and testing for hydrogen assisted fatigue and fracture a final group of chapters analyse the ways gaseous hydrogen embrittlement affects high performance steels superalloys titanium and aluminium alloys the first part of volume two reviews the mechanism of hydrogen embrittlement including absorption diffusion and trapping of hydrogen in metals part two discusses ways of modelling hydrogen induced damage and assessing service life the final section in the book assesses future trends in research summarises the wealth of recent research on understanding and dealing with the safety durability performance and economic operation of using gaseous hydrogen at high pressure reviews how hydrogen embrittlement affects particular sectors such as the petrochemicals automotive and nuclear industries chapters review mechanisms of hydrogen embrittlement including absorption diffusion and trapping of hydrogen in metals

this book is designed to help metallurgical chemical mechanical and reliability engineers responsible for the safe operation and maintenance of equipment made of steel

nineteen papers cover internal hydrogen embrittlement testing for relative susceptibility

testing for hydrogen pickup during processing mechanical delay time test hydrogen deflection methods hydrogen environment embrittlement

the book presents a collection of chapters on the current problems associated with hydrogen damage it discusses the effect of hydrogen on material properties and its interaction with the material microstructure physical features of hydrogen transport in metals and alloys as well as applicable methods of measuring concentration of hydrogen in solid media

hydrogen reduces the service life of many metallic components such reductions may be manifested as blisters as a decrease in fatigue resistance as enhanced creep as the precipitation of a hydride phase and most commonly as unexpected macroscopically brittle failure this unexpected brittle fracture is commonly termed hydrogen embrittlement frequently hydrogen embrittlement occurs after the component has been in service for a period of time and much of the resulting fracture surface is distinctly intergranular many failures particularly of high strength steels are attributed to hydrogen embrittlement simply because the failure analyst sees intergranular fracture in a component that served adequately for a significant period of time unfortunately simply determining that a failure is due to hydrogen embrittlement or some other form of hydrogen induced damage is of no particular help to the customer unless that determination is coupled with recommendations that provide pathways to avoid such damage in future applications this paper presents qualitative and phenomenological descriptions of the hydrogen damage processes and outlines several metallurgical recommendations that may help reduce the susceptibility of a particular component or system to the various forms of hydrogen damage

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