

MICROSTRUCTURE AND PROPERTIES OF DUPLEX STAINLESS STEELS

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Duplex stainless steels unite an interesting combination of mechanical properties, corrosion resistance, wear resistance and weldability, which led to the selection of these steels in numerous applications. The particular advantage of duplex steels lies in their high resistance to chlorine and hydrogen induced stress corrosion cracking together with their high resistance to pitting-, crevice- and general corrosion and their higher yield strength compared with the austenitic and ferritic stainless steels.

These steels were introduced into the market during the thirties, and there has been an accentuated development and spreading mainly for the last 15 years. Today, duplex stainless steels are in competition with single phase austenitic and ferritic steel grades. They are obtainable as forgings and castings (including centrifugal castings), cold and hot-rolled plates, tubes, wires, etc. Areas of application are chemical, petrochemical and desulphurization (pollution control) plants, off-shore techniques as well as the acetic acid, photo, pulp, dyeing and food industries.

On the other hand, these steels are subject to four types of brittleness: 475°C-embrittlement of ferrite, sigma-phase embrittlement, nitrides embrittlement and reduction of ductility which is due to a network of carbides in alloys containing a high concentration of carbon.¹

This paper reports the occurrence of these four types of brittleness, their consequences and the different types of fracture appearance.

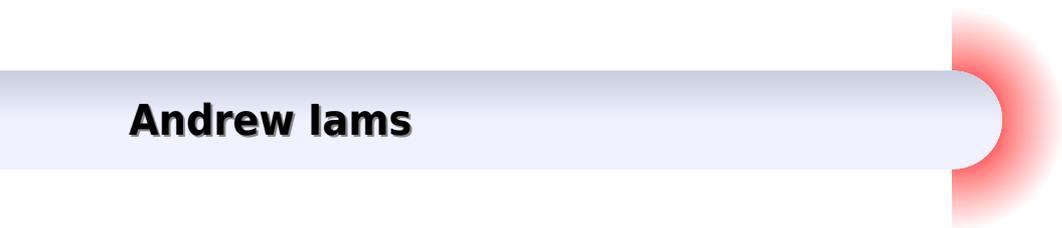
The ferritic-austenitic stainless steels with a duplex microstructure can be divided into two groups: i) low carbon wrought and cast alloys and ii) higher carbon cast alloys. In the case of the carbon-rich variants, carbides of the type $M_{23}C_6$ are also formed.²

The existence of two-phase (ferritic-austenitic) structures in corrosion-resistant CrNi-steels is mainly determined by the alloy mass portions of iron, chromium and nickel. Duplex stainless steels with ca. 20-27 wt.-% chromium and 4-8 wt.-% nickel have a ferritic-austenitic microstructure. If the carbon content is higher, they have a ferritic-austenitic-carbide microstructure. In addition to chromium and nickel they often contain 2-5 wt.-% molybdenum and up to 0.25% wt.-% nitrogen, to increase their resistance against pitting corrosion.

A completely ferritic microstructure forms during solidification. An exclusively ferritic one-phase material exists at temperatures around 1400°C. Partial transformation to austenite occurs in the solid state during cooling to produce islands of austenite in a ferritic matrix. During hot rolling and annealing, the microstructure remains within the two-phase field of the Fe-Cr-Ni phase diagram. Low carbon duplex stainless steels are processed by hot rolling or forging and cold rolling followed by suitable recrystallization annealing and quenching to equalize the proportion of the

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Andrew Iams



Duplex Stainless Steels Microstructure Properties And Applications:

Duplex Stainless Steels R Gunn,1997-10-21 Two very successful conferences in Glasgow and Beaune were held on duplex stainless steels during the first half of the 90s This book takes keynote papers from each and develops and expands them to bring the topics right up to date There is new material to cover grades specifications and standards and the book is fully cross references and indexed The first reference book to be published on the increasingly popular duplex stainless steels it will be widely welcomed by metallurgists design and materials engineers oil and gas engineers and anyone involved in materials development and properties The first reference book on this relatively new engineering material Based on keynote papers from major international contributors Covers grades standards and specifications *Electromagnetic Nondestructive Evaluation (XVI)* J.M.A. Rebello,F. Kojima,T. Chady,2013-12-18 Electromagnetic Nondestructive Evaluation ENDE is the process of inducing electric currents magnetic fields or both within a test object to assess its condition by observing the electromagnetic response An important tool in fields as diverse as engineering medicine and art it does not permanently alter the object being tested thus proving invaluable for product evaluation troubleshooting and research This book presents the proceedings of the 17th International Workshop on Electromagnetic Nondestructive Evaluation ENDE held in Rio de Janeiro Brazil in July 2012 ENDE workshop is an important event for all scientists with interests in non destructive testing The first workshop took place in 1995 in London UK and has been followed by workshops held in various parts of the world but this is the first time this workshop series has come to a Latin American country The workshops bring together scientists and engineers active in research development and industrial applications of ENDE The book is divided into five sections advanced sensors analytical and numerical modeling systems and techniques for electromagnetic NDE characterization of materials and NDE of cracks and new developments and others Each section includes papers on a variety of subjects From the papers submitted for publication thirty six peer reviewed articles have been accepted six of which emanate from Latin American authors The book will be of interest to all those wishing to keep abreast of developments in the field or who rely on the advanced techniques based on electromagnetic principles applied to nondestructive evaluation in their work **Trends in Welding Research 2012: Proceedings of the 9th International Conference** Tarasankar DebRoy, Stan A. David, John N. DuPont, Toshihiko Koseki, Harry K. Bhadeshia,2013-03-01 The Trends conference attracts the world s leading welding researchers Topics covered in this volume include friction stir welding sensing control and automation microstructure and properties welding processes procedures and consumables weldability modeling phase transformations residual stress and distortion physical processes in welding and properties and structural integrity of weldments *Weld Cracking in Ferrous Alloys* R Singh,2008-12-12 Weld cracks are unacceptable defects that can compromise the integrity of welded structures Weld cracking can lead to structural failures which at best will require remedial action and at worst can lead to loss of life Weld cracking in ferrous alloys reviews the latest developments in the

design evaluation prevention and repair of weld cracks Part one reviews the fundamentals as well as recent advances in the areas of welding technology design and material selection for preventing weld cracking Part two analyses weld crack behaviour evaluation and repair of cracking cracked welds The book benefits from an extensive and robust chapter on the topic of NDE and quality control that was contributed by one of the most respected non destructive evaluation and development groups in the world Part three covers environment assisted weld cracking With its distinguished editor and international team of contributors Weld cracking in ferrous alloys is a valuable source of reference for all those concerned with improving the quality of welding and welded components In the planning and development of this book particular care has been taken to make the chapters suitable for people from other disciplines who need to understand weld cracking and failure Reviews the latest developments in the design evaluation prevention and repair of weld cracks Assesses recent advances in welding technology design and material selection Analyses weld crack behaviour evaluation and repair including environment assisted weld cracking

Advances in Texture, Microtexture, and Allied Techniques Satyam Suwas, David P. Field, 2025-07-02 This book presents the fundamentals of texture and microtexture with the latest developments in the field and relates the same for different materials and processes Crystallographic phase and orientation define the anisotropy of crystalline materials In polycrystalline materials the preferred crystallographic orientation of grain distributions also known as crystallographic texture controls the properties of materials The evaluation of texture has been traditionally carried out by X ray diffraction and neutron diffraction In recent times microtexture based techniques have been widely used not only to examine the crystallographic texture but also to investigate the micro mechanisms controlling the development of texture and microstructure It has therefore become almost mandatory to re visit the physical phenomenon associated with materials from the viewpoint of microtexture The individual chapters have been written by the renowned scientists working in the respective domain The book can be a valuable reference for researchers and professionals interested in fundamentals of texture and microtexture and allied fields

Terotechnology XIII Norbert Radek, Agnieszka Szczotok, 2024-11-10 The book presents recent advances in the technology of installation commissioning maintenance replacement and removal of plant machinery and equipment feedback on operation and design and related subjects and practices Keywords Fibre Prestressing Hierarchical Robotic System Environmental Pollution Casting Processes EU and US Legal Frameworks Machine Learning Models Forecasting for Supply Chain Applications Bio inspired Algorithms Resistance to the Effects of Explosions Armor Technologies Control of Aerial Drones Concentrated Energy Beams

Material Forming Anna Carla Araujo, Arthur Cantarel, France Chabert, Adrian Korycki, Philippe Olivier, Fabrice Schmidt, 2024-05-20 These ESAFORM 2024 conference proceedings cover a wide range of topics Additive manufacturing Composites forming processes Extrusion and drawing Forging and rolling Formability of metallic materials Friction and wear in metal forming Incremental and sheet metal forming Innovative joining by forming technologies Optimization and inverse analysis in forming Machining Cutting and

severe plastic deformation processes Material behavior modelling New and advanced numerical strategies for material forming Non conventional processes Polymer processing and thermomechanical properties Sustainability on material forming Keywords WAAM Technology Fused deposition Modeling FDM Fiber Composite Printers Ultrasonic Powder Atomization Finite Element Modeling FEM Laser Powder Bed Fusion L PBF Rapid Prototyping in Additive Manufacturing Directed Energy Deposition DED GTAW Droplet Deposition Deep Learning Thermoplastic Pultrusion Textile Reinforcements Thermoforming Simulation New Sustainable Materials Non Crimp Fabrics CFRP Scraps PEEK Composites Thermoplastic Sheets Flax PP Composites

Encyclopedia of Iron, Steel, and Their Alloys (Online Version) Rafael Colás, George E. Totten, 2016-01-06 The first of many important works featured in CRC Press Metals and Alloys Encyclopedia Collection the Encyclopedia of Iron Steel and Their Alloys covers all the fundamental theoretical and application related aspects of the metallurgical science engineering and technology of iron steel and their alloys This Five Volume Set addresses topics such as extractive metallurgy powder metallurgy and processing physical metallurgy production engineering corrosion engineering thermal processing metalworking welding iron and steelmaking heat treating rolling casting hot and cold forming surface finishing and coating crystallography metallography computational metallurgy metal matrix composites intermetallics nano and micro structured metals and alloys nano and micro alloying effects special steels and mining A valuable reference for materials scientists and engineers chemists manufacturers miners researchers and students this must have encyclopedia Provides extensive coverage of properties and recommended practices Includes a wealth of helpful charts nomograms and figures Contains cross referencing for quick and easy search Each entry is written by a subject matter expert and reviewed by an international panel of renowned researchers from academia government and industry Also Available Online This Taylor E mail e reference taylorandfrancis com International Tel 44 0 20 7017 6062 E mail online sales tandf co uk

Functional and Structural Materials II Silvio Romero de Barros, Pedro Manuel Calas Lopes Pacheco, Hector Reynaldo Meneses Costa, Ricardo Alexandre Amar de Aguiar, Rodinei Medeiros Gomes, Sandro Marden Torres, 2013-06-27 Selected peer reviewed papers from the 2nd Brazilian Symposium on Functional and Structural Materials FUNCMAT 2013 April 25 26 2013 Rio de Janeiro Brazil

Duplex Stainless Steels Iris Alvarez-Armas, Suzanne Degallaix-Moreuil, 2013-01-16 Duplex Stainless Steels DSSs are chromium nickel molybdenum iron alloys that are usually in proportions optimized for equalizing the volume fractions of austenite and ferrite Due to their ferritic austenitic microstructure they possess a higher mechanical strength and a better corrosion resistance than standard austenitic steels This type of steel is now increasing its application and market field due to its very good properties and relatively low cost This book is a review of the most recent progress achieved in the last 10 years on microstructure corrosion resistance and mechanical strength properties as well as applications due to the development of new grades Special attention will be given to fatigue and fracture behavior and to proposed models to account for mechanical behavior Each subject will be developed in chapters written by experts recognized around the

international industrial and scientific communities The use of duplex stainless steels has grown rapidly in the last 10 years particularly in the oil and gas industry chemical tankers pulp and paper as well as the chemical industry In all these examples topics like welding corrosion resistance and mechanical strength properties mainly in the fatigue domain are crucial Therefore the update of welding and corrosion properties and the introduction of topics like texture effects fatigue and fracture strength properties and mechanical behavior modeling give this book specific focus and character **Study of the Pitting Corrosion Under Insulation of Duplex Stainless Steels** Khalil Masoud Alahmadi,2008 **WRC Bulletin** Welding Research Council (U.S.),1999 Recent Advances in Mechanics of Solids and Structures--2003 Young W. Kwon,Howard Chung,2003 **High Performance Structures and Materials II** C. A. Brebbia,Willy Patrick Wilde,2004 A range of topics relating to advanced types of structures particularly those based on new concepts or new types of materials Originally presented at the Second International Conference on High Performance Structures and Materials the papers contain detailed developments in design optimization manufacturing and experimentation Metals Abstracts ,1998

Steels: Microstructure and Properties R.W.K. Honeycombe,Harshad Kumar Dharamshi Hansraj Bhadeshia,1995-03-17 Steels remain the most widely used metallic materials By examining the mechanical properties of steels in conjunction with microstructure the first edition gave a clear description of the development and behaviour of these materials the very foundation of their widespread use This new edition more explicitly links this theory with applications whilst retaining the style and purpose of the original The text is updated throughout and includes three new chapters on acicular ferrite the control of microstructures during welding and a further chapter on the modelling of steel microstructure to achieve optimum performance Extensive bibliographies are also included Steel metallurgists in both industry and academia will find this book invaluable A comprehensive introduction to the microstructure and properties of steels Clearly written and well illustrated Extensive bibliographies *Microstructural Evolution in Additively Manufactured Duplex Stainless Steel Alloys* Andrew Iams,2022 Increasing demand for high performance additively manufactured AM components is driving demand for more alloy systems beyond the rather limited number currently in wide use Duplex stainless steels which offer high strength and superior corrosion resistance at a lower cost than equivalent austenitic stainless steels are one of these emerging alloy systems Their attractive properties are achieved in the wrought condition through a series of highly controlled thermo mechanical and heat treatment steps designed to obtain a balanced ferrite austenite microstructure Although duplex stainless steels are used in petroleum marine and nuclear power applications they can fail when subjected to high temperature service environments which disrupt the balanced ferrite austenite microstructure and lead to the precipitation of deleterious secondary phases This balanced ferrite austenite microstructure is especially susceptible to disruption in fusion based AM processes such as powder bed fusion and directed energy deposition During each of these AM processing routes the layer by layer deposition methodology produces a complex series of rapid heating melting solidification

and cooling cycles. Since the duplex stainless steel compositions were originally designed for wrought processing routes, the complex thermal histories characteristic of AM processes make it difficult to obtain the balanced ferrite/austenite microstructure and impact the resulting microstructure and properties. The impact of the complex thermal histories on microstructural formation across different grades must be understood for wide implementation of duplex stainless steel components fabricated through AM processing. In order to explore the feasibility of processing these alloys in this manner, a laser-based directed energy deposition process was used to fabricate lean UNS S32101, standard UNS S32205, and super UNS S32507 duplex stainless steel structures, and their microstructural formation was investigated. The overall austenite levels were comparable to those found in wrought alloys, with austenite phase fractions ranging from 16.1% to 38.5% in the lean to standard and 58.3% to 76.0% in the super duplex stainless steel grades, respectively. Unlike the wrought condition, the austenite present in the as-built structures displayed a range of different morphologies, with intragranular austenite comprising between 55% and 76% of the austenite present within each build. This intragranular austenite primarily nucleated from oxygen-rich inclusions that originated from the powder feedstock and served as heterogeneous nucleation sites during the deposition process. Oxygen levels on the order of five times higher than that present in comparable wrought forms led to the formation of these oxide phases in the powders, as well as the as-built and hot isostatically pressed (HIP) conditions. These oxide inclusions exhibited complex structures with a combination of amorphous, metastable, and stable phases across these different conditions. In the powder particles, which experienced rapid cooling rates during the gas atomization process, amorphous inclusions that were rich in Mn, Cr, Si, and oxygen were observed and surrounded by small crystalline MnS particles. After additive manufacturing, these inclusions transformed to a combination of rhodonite (MnSiO₃) and spinel (MnCr₂O₄) with amorphous regions around the exterior. Post-process hot isostatic pressing treatments resulted in the formation of a stable spinel oxide with MnS particles around the exterior, matching the results predicted by computational thermodynamic calculations. Even with these different microstructural features, room temperature tensile properties of additively manufactured duplex stainless steels are often similar to and even exceed those observed in the wrought condition. In the AM material, the finely dispersed ferrite and austenite phases produced a ductile failure mode and appear to be unaffected by the presence of the oxide inclusions. However, these testing conditions do not capture the performance of these alloys at high strain rates and low temperatures. At these low temperatures, impact energies for the AM-fabricated materials were significantly degraded, falling well short of the wrought material requirements in both the as-deposited and HIP conditions. This loss of properties is connected to the fine distribution of austenite and the presence of the oxide inclusions in the as-deposited and post-processed microstructures. Significant changes in the fracture appearance were evident, with the largely ductile surface present under room temperature conditions becoming one with a combination of ductile and brittle features at the low temperatures. In both the standard and super grades, the brittle fracture features appeared largely in the

ferrite phase while the austenite phase retained a ductile failure appearance Materials Transactions ,2005 Properties and Processing Technologies K. Hemachandra Reddy,Vikram Kumar Chintamreddy,2021-04-15 Selected peer reviewed papers from the International Conference on Advances in Material Science and Mechanical Engineering ICAMSME 2020 February 7 9 2020 Vidyanagar India **Material Researches and Energy Engineering** Yi Jin Wu,2013-09-04 Selected peer reviewed papers from the 2013 International Conference on Future Energy Materials Research FEMR 2013 1 2 June 2013 Singapore

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