Fracture And Fatigue Of Welded Joints And Structures Woodhead Publishing Series In Welding And Other Joining Technologies

Fatigue is a mechanism of failure which involves the formation and growth of cracks under the action of repeated stresses. Ultimately, a crack may propagate to such an extent that total fracture of the member may occur. To avoid fatigue it is essential to design the structure with inherent fatigue strength. However, fatigue strength for variable amplitude loading is not a constant material property and any calculations are necessarily built on a number of assumptions. Cumulative damage of welded joints explores the wealth of research in this important field and its implications for the design and manufacture of welded components. After an Introduction, chapter two introduces the constant amplitude database, which contains results obtained in test conditions and which forms the basis of the basic S-N curves for various types of joint. Chapter three discusses the influence of residual stresses which can have a marked effect on fatigue behaviour. Chapter four explores variable amplitude loading and the problem of how information from laboratory tests, obtained under constant amplitude conditions, can be applied to the design of structures for service conditions. This problem is further investigated in the next chapter which is devoted to two and three level load testing. Chapters six, seven and eight look at the influence that the variety of variable loading spectra can have on fatigue strength, whether narrow or wide band loading or cycles of small stress range. Taking all of this knowledge, chapter nine discusses structure designs. Cumulative damage of welded joints is a comprehensive source of invaluable information for welding engineers, supervisors, inspection personnel and designers. It will also be of great interest for academics working in the fields of structural and mechanical engineering. Covers the wealth of research in the field of fatigue strength and its role in the design and manufacture of welded components Invaluable reference source for welding engineers, supervisors, inspection personnel and designers

This book presents guidelines on quantitative and qualitative measures of the geometric features and imperfections of welds to ensure that it meets the fatigue strength requirements laid out in the recommendations of the IIW (International Institute of Welding). Welds that satisfy these quality criteria can be assessed in accordance with existing IIW recommendations based on nominal stress, structural stress, notch stress or linear fracture mechanics. Further, the book defines more restrictive acceptance criteria based on weld geometry features and imperfections with increased fatigue strength. Fatigue strength for these welds is defined as S-N curves expressed in terms of nominal applied stress or hot spot stress. Where appropriate, reference is made to existing quality systems for welds.In addition to the acceptance criteria and fatigue assessment curves, the book also provides guidance on their inspection and quality control. The successful implementation of these methods depends on adequate training for operators and inspectors alike. As such, the publication of the present IIW Recommendations is intended to encourage the production of appropriate training aids and guidelines for educating, training and certifying operators and inspectors.

This volume represents a selection of papers presented at the Third International Symposium on Fatigue Design, Fatigue Design

1998, held in Espoo, Finland, 26-29 May, 1998. One objective of this symposium series was to help bridge the gap that sometimes exists between researchers and engineers responsible for designing components against fatigue failure. The 21 selected papers provide an up-to-date survey of engineering practice and a preview of design methods that are advancing toward application. Reliability was selected as a key theme for FD'98. During the design of components and structures, it is not sufficient to combine mean material properties, average usage parameters, and pre-selected safety factors. The engineer must also consider potential scatter in material properties, different end users, manufacturing tolerances and uncertainties in fatigue damage models. Judgement must also be made about the consequences of potential failure and the required degree of reliability for the structure or component during its service life. Approaches to ensuring reliability may vary greatly depending on the structure being designed. Papers in this volume intentionally provide a multidisciplinary perspective on the issue. Authors represent the ground vehicle, heavy equipment, power generation, ship building and other industries. Identical solutions cannot be used in all cases because design methods must always provide a balance between accuracy and simplicity. The point of balance will shift depending on the type of input data available and the component being considered.

Part 1 of the book provides a concise description of the fatigue behaviour of welded joints and factors which influence their fatigue lives. Part 2 concentrates on fatigue design methods, including the background and application of the design rules which have become the basis of all the modern UK, and some International, rules.

An elastic-plastic fracture mechanics solution for fatigue cracks initiating from weld toes is introduced that admits plasticity by replacing the conventional stress term with a strain term. It accounts for the propagation of very short cracks by the introduction of an effective crack length equal to the actual length increased by an amount l0, where l0 is a constant characteristic of the material and material condition. Consideration is also given to the effect of mean stress and crack front shape on an intensity factor derived from this solution. Crack growth results for cracks in both elastic and plastic strain fields of welded specimens, when interpreted in terms of the intensity factor, show excellent agreement with elastic long crack data. This intensity factor, when combined with a propagation model that includes all stages of crack growth, also successfully predicts the entire life of butt- and fillet-welded specimens for two steels. The threshold stress corresponding to the failure of butt-welded specimens is equal to the smooth specimen fatigue limit stress divided by the elastic stress concentration factor. However, for fillet welds, the stress level corresponding to failure is higher than the fatigue limit stress divided by the elastic stress concentration factor. At stresses between these two stress levels, cracks start at fillet-weld toes but do not propagate to failure.

This report is the result of a major study on the influence of both main plate thickness and of attachment size on the fatigue strength of joints with transverse non-load-carrying fillet welds. In particular, it defines the extent to which the size of the attachment might influence the thickness effect in such joints. Through a whole range of different tests, the study confirms that the present thickness effect correction for certain types of joint is too severe.

The failure of any welded joint is at best inconvenient and at worst can lead to catastrophic accidents. Fracture and fatigue of welded joints and structures analyses the processes and causes of fracture and fatigue, focusing on how the failure of welded joints and structures can be predicted and minimised in the design process. Part one concentrates on analysing fracture of welded joints and structures, with chapters on constraint-based fracture mechanics for predicting joint failure, fracture assessment methods and the use of fracture mechanics in the fatigue analysis of welded joints. In part two, the emphasis shifts to fatigue, and chapters focus on a variety of aspects of fatigue analysis including assessment of local stresses in welded joints, fatigue design rules for welded structures, k-nodes for offshore structures and modelling residual stresses in predicting the service life of structures. With its distinguished editor and international team of contributors, Fracture and fatigue of welded joints and structures is an essential reference for mechanical, structural and welding engineers, as well as those in the academic sector with a research interest in the field. Analyses the processes and causes of fracture and fatigue, focusing predicting and minimising the failure of welded joints in the design process Assesses the fracture of welded joints and structure featuring constraint-based fracture mechanics for predicting joint failure Explores specific considerations in fatigue analysis including the assessment of local stresses in welded joints and fatigue design rules for welded structures

This book provides a basis for the design and analysis of welded components that are subjected to fluctuating forces, to avoid failure by fatigue. It is also a valuable resource for those on boards or commissions who are establishing fatigue design codes. For maximum benefit, readers should already have a working knowledge of the basics of fatigue and fracture mechanics. The purpose of designing a structure taking into consideration the limit state for fatigue damage is to ensure that the performance is satisfactory during the design life and that the survival probability is acceptable. The latter is achieved by the use of appropriate partial safety factors. This document has been prepared as the result of an initiative by Commissions XIII and XV of the International Institute of Welding (IIW).

This book reviews the available knowledge on local approaches to fatigue assessment of welded joints, gathers the data necessary for their practical application and demonstrates the power of the local concept by way of demonstration examples from research and industry. It covers the hot spot structural stress approach to fatigue in general, the notch stress and notch strain approach to crack initiation and the fracture mechanics approach to crack propagation. Seam-welded and spot-welded joints in structural steels and aluminium alloys are considered. The book is intended for designers, structural analysts and testing engineers who are responsible for the fatigue-resistant in-service behaviour of welded structures. It should become a reference work for researchers in the field and should support activities directed to standardisation of local approaches.

This book provides a comprehensive and thorough guide to those readers who are lost in the often-confusing context of weld fatigue. It presents straightforward information on the fracture mechanics and material background of weld fatigue, starting with fatigue crack initiation and short cracks, before moving on to long cracks, crack closure, crack growth and threshold, residual stress, stress concentration, the stress intensity factor, J-integral, multiple cracks, weld geometries and defects, microstructural parameters including HAZ, and cyclic stress-strain behavior. The book treats all of these essential and mutually interacting parameters using a unique form of analysis.

The Welding Engineer's Guide to Fracture and Fatigue provides an essential introduction to fracture and fatigue and the assessment of these failure modes, through to the level of knowledge that would be expected of a qualified welding engineer. Part one covers the basic principles of weld fracture and fatigue. It begins with a review of the design of engineered structures, provides descriptions of typical welding defects and how these defects behave in structures undergoing static and cyclical loading, and explains the range of failure modes. Part two then explains how to detect and assess defects using fitness for service assessment procedures. Throughout, the book assumes no prior knowledge and explains concepts from first principles. Covers the basic principles of weld fracture and fatigue. Reviews the design of engineered structures, provides descriptions of typical welding defects and how these defects behave in structures undergoing static and cyclical loading, and explains the range of failure modes. Explains how to detect and assess defects using fitness for service assessment procedures.

Avoiding or controlling fatigue damage is a major issue in thedesign and inspection of welded structures subjected to dynamicloading. Life predictions are usually used for safe life analysis,i.e. for verifying that it is very unlikely that fatigue damagewill occur during the target service life of a structure. Damagetolerance analysis is used for predicting the behavior of a fatiguecrack and for planning of in-service scheduled inspections. Itshould be a high probability that any cracks appearing are detectedand repaired before they become critical. In both safe lifeanalysis and the damage tolerance analysis there may be largeuncertainties involved that have to be treated in a logical andconsistent manner by stochastic modeling. This book focuses on fatigue life predictions and damage toleranceanalysis of welded joints and is divided into three parts. Thefirst part outlines the common practice used for safe life anddamage tolerance analysis with reference to rules and regulations.The second part emphasises stochastic modeling and decision-makingunder uncertainty, while the final part is devoted to recentadvances within fatigue research on welded joints. Industrialexamples that are included are mainly dealing with offshore steelstructures. Spreadsheets which accompany the book give the readerthe possibility for hands-on experience of fatigue lifepredictions, crack growth analysis and inspection planning. Assuch, these different areas will be of use to engineers andresearchers.

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A vast majority of failures emanate from stress concentrators such as geometrical discontinuities. The role of stress concentration was first highlighted by Inglis (1912) who gives a stress concentration factor for an elliptical defect, and later by Neuber (1936). With the progress in computing, it is now possible to compute the real stress distribution at a notch tip. This distribution is not simple, but looks like pseudo-singularity as in principle the power dependence with distance remains. This distribution is governed by the notch stress intensity factor which is the basis of Notch Fracture Mechanics. Notch Fracture Mechanics is associated with the volumetric method which postulates that fracture requires a physical volume. Since fatigue also needs a physical process volume, Notch Fracture Mechanics can easily be extended to fatigue emanating from a stress concentration.

Local approaches to fatigue assessment are used to predict the structural durability of welded joints, to optimise their design and to evaluate unforeseen joint failures. This standard work provides a systematic survey of the principles and practical applications of the various methods. It covers the hot spot structural stress approach to fatigue in general, the notch stress and notch strain approach to crack initiation and the fracture mechanics approach to crack propagation. Seam-welded and spot-welded joints in structural steels and aluminium alloys are also considered. This completely reworked second edition takes into account the tremendous progress in understanding and applying local approaches which has been achieved in the last decade. It is a standard reference for designers, structural analysts and testing engineers who are responsible for the fatigue-resistant in-service behaviour of welded structures. Completely reworked second edition of a standard work providing a systematic survey of the principles and practical applications of the various methods Covers the hot spot structural stress approach to fatigue in general, the notch stress and notch strain approach to crack initiation and the fracture mechanics approach to crack propagation. Written by a distinguished team of authors

Fracture mechanics-based fatigue crack growth prediction methods based on the line spring technique are presented. Developments in the line spring method are described that make it possible to apply the method to realistic welded structures for fatigue design studies. The line spring finite element described in the paper has been formulated to fit between isoparametric brick elements in order to allow shell-to-shell junctions to be represented more accurately. The effect of stress concentrations at weld toes has been also introduced. The accuracy of the line spring approach for the calculation of stress-intensity factors is demonstrated by comparison with three-dimensional finite element fracture mechanics results and empirically estimated values. Prediction of fatigue crack growth in girth welds and tubular connections is compared with observations of cracking in large-scale test specimens. An example of how the fatigue crack growth prediction methods could be applied to the design of welded joints is presented.

The fatigue behavior of aluminum-zinc-magnesium (Al-Zn-Mg) alloy fillet-welded joints was analyzed in fracture mechanics terms.

Basic crack propagation data were obtained with -2 ? R ? + 0.5 and correlated using formulas in the literature and, more successfully, in terms of ?Keff, based on the results of crack closure experiments. The form of the da/dN versus ?K relationship was influenced by the specimen geometry. A fracture mechanics analysis of the fatigue life of Al-Zn-Mg alloy fillet welds based on the da/dN versus ?Keff relationship indicated that the weld toe was less severe from the fatigue viewpoint than the same region in a steel fillet weld. This was compatible with the fact that metallurgical examination of Al-Zn-Mg alloy fillet welds has failed to reveal toe defects similar in magnitude to those which act as fatigue crack initiators at the toes of steel fillet welds. The analysis showed that the fatigue life obtained from the Al-Zn-Mg alloy weld could be predicted on the basis that defects only one tenth the size of those observed in steel were present. Fatigue failure from the weld root in a cruciform joint was also analyzed and the optimum weld design, which gives an equal chance of failure from the root and toe, was determined. The analysis was supported by fatigue test results. Comparison with results obtained for steel added confirmation to the finding that if toe defects are present in Al-Zn-Mg alloy welds, they are smaller than those in steel.

In this report two methods of fracture analysis of welds will be emphasized, one addressing fatigue life testing and analysis of notches at welds, and the other addressing the final fracture of the welded component and the fracture toughness tests used to characterize final fracture. These fatigue and fracture methods will be described by referring to recent work from the technical literature and from the U.S. Army Armament Research, Development, and Engineering Center, primarily fracture case study and fracture test method development investigations. A brief general summary will be given of fatigue and fracture methods and concepts that have application to welded structures. Specific fatigue crack initiation tests and analysis methods will be presented, using example results from a welded stainless steel box beam of a cannon carriage. Recent improvements and simplifications in J.integral fracture toughness tests will be described, particularly those related to welds. Fracture toughness measurements for various stainless steel weld metals and heat treatments will also be described. (MM).

Welded joints are considered to be one of the most critical locations in structural components from a fatigue perspective because of high stress concentrations near the weld toe region, the presence of tensile residual stresses, and defects from the welding process. New welding techniques like friction stir welding (FSW) and post-weld treatment technologies like high-frequency mechanical impact (HFMI) treatment have a strong potential to improve the fatigue performance of welded joints. However, it is essential to carefully examine the effectiveness and limitations of these new welding techniques and treatment technologies to ensure their reliable fatigue performance in service. Often, new technology is not employed until it has been proven to be reliable through years of performance under real-life service conditions. The design of welded joints fabricated using new technologies poses another challenge for structural engineers, which is, how to design a component for which there are no design codes or code-specified quality control criteria. In the absence of such design codes, designers often refer to non-compulsory guidelines, which may only be applicable to components fabricated with older technologies. This can result in overly conservative designs. In the absence of specific quality control criteria for components fabricated with new welding technologies like FSW, existing design codes usually recommend quality control criteria based on "best practice" rather than relating defect size to fatigue performance. Against this background, this thesis aims to study FSW joints and HFMI treated joints, from a fracture mechanics perspective, which will contribute to the development of performance-based design provisions and quality control criteria for welds employing these technologies. FSW joints have been found to have better fatigue performance than arc welded joints. While the tolerance window for the FSW process is wide, there is a possibility of having defects in these joints, which can severely affect the fatigue performance. In this study, a comprehensive testing program was carried out to study the fatigue performance of FSW joints with intentionally introduced defects including angular misalignment, toe flash, lack of penetration or "kissing bond", and wormhole defects. As fatigue testing becomes time-consuming and expensive, numerical modelling and simulation provide complementary ways to assess the effects of parameter variations on fatigue performance. With this in mind, a previously-developed strain-based fracture mechanics (SBFM) model is improved and extended in this thesis to study the fatigue behavior of FSW aluminum joints. In its previous form, the employed SBFM model was capable of performing a one-dimensional (1D) crack propagation analysis. For each crack size, the crack shape was allowed to evolve using a pre-defined crack shape evolution function. In the current work, the existing 1D model was first programmed in MATLAB and then improvements in the existing model related to failure criteria were made. Subsequently, the model was extended to perform 2D fracture mechanics analysis. This improved 2D SBFM model is applied to assess the fatigue behaviour of HFMI treated A514 steel and 5083 aluminum welds (welded using metal inert gas welding process). Fatigue tests of as-welded and HFMI treated specimens were carried out to validate the prediction capability of the 2D SBFM model. A comprehensive material testing program was also carried out to estimate the input parameters required by the 2D model. With inputs obtained from material tests, the 2D model shows a reasonably good agreement between the fatigue life obtained from the model and the experiments. A sensitivity analysis is performed with the 2D model to identify the most important parameters, which affect the behaviour of HFMI treated welds. Following the deterministic SBFM analysis of FSW and HFMI treated joints, the 2D SBFM model is extended to a probabilistic framework to obtain probabilistic stress-life curves (i.e. curves associated with a specific survival probability). To do this, statistical distributions of the input parameters are first defined. The resulting probabilistic stress-life curves are then compared with the available design curves and the differences are highlighted. The presented probabilistic analysis demonstrates how the 2D SBFM model can serve as a useful analytical tool for developing quality control guidelines and reliability-based design curves for the HFMI treatment technology, which is applicable to a broad range of materials (e.g. various grades of steel and aluminum), scales, and cyclic loading conditions, beyond what can be practically investigated in a purely experimental program.

This report provides background and guidance on the use of the structural hot spot stress approach to the fatigue design of welded components and structures. It complements the IIW recommendations for 'Fatigue Design of Welded Joints and Components' and extends the information provided in the IIW recommendations on 'Stress Determination for Fatigue Analysis of Welded Components'. This approach is applicable to cases of potential fatigue cracking from the weld toe. It has been in use for many years in the context of tubular joints. The present report concentrates on its extension to structures fabricated from plates and non-tubular sections. Following an explanation of the structural hot spot stress, its definition and its relevance to fatigue, the authors describe methods for its determination. Stress determination from both finite element analysis and strain gauge measurements is considered. Parametric formulae for calculating stress increases due to misalignment and structural discontinuities are also presented. Special attention is paid to the use of finite element stress analysis and guidance is given on the choice of element type and size for use with either solid or shell elements. Design S-N curves for use with the structural hot spot stress are presented for a range of weld details. Finally, practical application of the recommendations is illustrated in two case studies involving the fatigue assessment of welded structures using the structural hot spot stress approach. Provides practical guidance on the application of the structural hot-spot stress approach Discusses stress determination from both finite element analysis and strain gauge measurements Practical application of the recommendations is illustrated in two case studies

Based on the European Welding Engineer (EWF) syllabus Part 3 – Construction and Design, this book provides a clear, highly illustrated and concise explanation of how welded joints and structures are designed and of the constraints which welding may impose on the design. It is therefore of value both to the welding engineer and the design engineer Many engineers coming into the profession of welding engineering lack a background in design and construction of welded structures and plant. This book has been written with such engineers very much in mind. The safe performance of a structure relies on materials and methods of fabrication which can respond to the explicit or implicit design requirements. It is essential that the welding engineer has the opportunity of making his specialist input to the design process, and an understanding of the basis of the design will help that contribution to be most effective. It is also important that the practising design engineer acquires a basic knowledge of the relevant aspects of welding to be able to execute satisfactory designs and, equally important, to know when to seek the input of a qualified welding engineer. Designed for both students and practising engineers in welding and design, the book will also be of great value to civil, structural, mechanical and plant engineers. There is also much that will interest test houses, welding equipment and consumable manufacturers, classification societies and steel companies.