Article

Application of Extended Finite Element Method for Studying Crack Propagation of Welded Strip Steel in the Cold Rolling Process

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Abstract: In the cold rolling process, edge cracks, particularly those near the welded zone, can inadvertently lead to strip rupture. This study employed the extended finite element method (XFEM) to analyze the crack propagation behavior in welded strip steel during cold rolling. Various tests such as the tensile test, essential work of fracture (EWF) test, spherical indentation method, and elastoplastic finite element simulations were conducted to determine the maximum principal stress and fracture energy utilized in XFEM for the base metal and weld metal, respectively. A continuous cold rolling model was established to investigate the crack propagation behaviors in the base metal, weld metal, and the interface between the base and weld metal. In the continuous rolling process, the crack propagation and expansion speed in the base metal are much larger than that of the weld zone. In addition, the base metal at the back end of the rolled piece is more prone to fracture than the base metal at the front end.

Keywords: extended finite element method; crack propagation; welded strip steel; cold rolling; numerical simulation

1. Introduction

Cold rolling is an important production process affecting the quality and efficiency of strip steel fabrication [1]. Before the strip steel enters into the cold rolling mill, the cutting operation would be carried out to remove the edge defects to ensure the strip steel integrity. However, a cutting operation cannot eliminate all edge defects and sometimes it will introduce new edge flaws due to the inappropriate cutting parameters [2]. These initial defects may cause edge cracking or even a strip steel rupture during the cold rolling process, which will lead the halt of whole production line. Previous studies showed that the edge cracking or strip rupture easy occur near the weld zone due to the complexity of the material combination [3]. How to avoid edge cracking and strip rupture in the cold rolling process has been a crucial factor in cold rolling.

Research on the causes of cold-rolled edge cracks and corresponding protective measures has achieved some results. The main reasons for the edge cracks of cold-rolled sheet are as follows: edge defects of cold-rolled substrate, uneven structure of cold-rolled substrate and cold-rolling process control problems, cold-rolling mill load distribution and improper control of tension between stands, discordant deformation of cold rolled sheets [4], and trimming the amount of edges [5].

With the assistance of the finite element method, researchers have studied different fracture behaviors of strip steel under cold and hot rolling condition. Compared with other numerical methods, the finite element method has distinct advantages especially for arbitrary geometric shape, boundary condition, and geometric nonlinearity. Several scholars have studied the crack surface morphology based on the extended finite element method. Yu et al. [6] analyzed the deformation behavior and crack initiation when the strip

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Extended Finite Element Method Amir R. Khoei,2015-02-23 Introduces the theory and applications of the extended finite element method XFEM in the linear and nonlinear problems of continua structures and geomechanics Explores the concept of partition of unity various enrichment functions and fundamentals of XFEM formulation Covers numerous applications of XFEM including fracture mechanics large deformation plasticity multiphase flow hydraulic fracturing and contact problems Accompanied by a website hosting source code and examples   Partition of Unity Methods Stéphane P. A. Bordas,Alexander Menk,Sundararajan Natarajan,2023-10-19 PARTITION OF UNITY METHODS Master the latest tool in computational mechanics with this brand new resource from distinguished leaders in the field While it is the number one tool for computer aided design and engineering the finite element method FEM has difficulties with discontinuities singularities and moving boundaries Partition of unity methods addresses these challenges and is now increasingly implemented in commercially available software Partition of Unity Methods delivers a detailed overview of its fundamentals in particular the extended finite element method for applications in solving moving boundary problems The distinguished academics and authors introduce the XFEM as a natural extension of the traditional finite element method FEM through straightforward one dimensional examples which form the basis for the subsequent introduction of higher dimensional problems This book allows readers to fully understand and utilize XFEM just as it becomes ever more crucial to industry practice Partition of Unity Methods explores all essential topics on this key new technology including Coverage of the difficulties faced by the finite element method and the impetus behind the development of XFEM The basics of the finite element method with discussions of finite element formulation of linear elasticity and the calculation of the force vector An introduction to the fundamentals of enrichment A revisitation of the partition of unity enrichment A description of the geometry of enrichment features with discussions of level sets for stationary interfaces Application of XFEM to bio film gradient theories and three dimensional crack propagation Perfect for researchers and postdoctoral candidates working in the field of computational mechanics Partition of Unity Methods also has a place in the libraries of senior undergraduate and graduate students working in the field Finite element and CFD analysts and developers in private industry will also greatly benefit from this book

Thermo-mechanical Fatigue Using the Extended Space-time Finite Element Method Ryan T. Schlinkman,2019 Thermomechanical high cycle fatigue is a major failure mechanism for many engineering components in a diverse range of industries such as aerospace automotive and nuclear among others Engineers trying to determine the fatigue life of a component typically rely on commercial fatigue analysis software which uses traditional fatigue criteria that are limited in their applicability For instance they are poor at handling multiaxial and variable amplitude loading Furthermore adding variable amplitude thermal loading into the mix makes using these traditional fatigue criteria even less appealing In recent years there have been attempts to establish methods for simulating high cycle fatigue based on finite element calculations

rather than using it as a post processing step These include cohesive zone and continuum damage mechanics models However all of these methods employ cycle jumping strategies to cut down on the enormous computational time required However cycle jumping is not applicable for a random loading history or with random or out of phase temperature variation Motivated by these current developments this thesis proposes the use of the extended space time finite element method XTFEM in combination with a two scale progressive fatigue damage model for the direct numerical simulation of thermomechanical high cycle fatigue Instead of using the conventional explicit or implicit finite difference time integration methods temporal approximations are introduced with FEM mesh and enriched based on the extended finite element method After outlining the basic theory for XTFEM with thermomechanical coupling the effectiveness of the computational framework is demonstrated in numerical examples including a coupled thermomechanical fatigue simulation of a plate and hat stiffener model representative of a hypersonic aircraft s structure   Book of Abstracts Presented at the 7th International Conference on Numerical Modelling in Engineering (NME 2024) Magd Abdel Wahab,2024-08-29 This book contains the abstracts presented at the 7th International Conference on Numerical Modelling in Engineering NME 2024 It is the 7th NME meeting and was held at Xi an China during the period 28 31 July 2024 Previous NME conferences were celebrated in Ghent Belgium 2018 Beijing China 2019 and Ghent Belgium 2020 2023 The overall objective of the conference is to bring together international scientists and engineers in academia and industry in fields related to advanced numerical techniques such as FEM BEM IGA etc and their applications to a wide range of engineering disciplines The conference covers industrial engineering applications of numerical simulations to civil engineering aerospace engineering materials engineering mechanical engineering biomedical engineering etc   **Applied Mechanics and Materials I** Guang Fan Li,Chao He Chen,2013-01-11 Selected peer reviewed papers from the 2012 International Conference on Applied Mechanics and Materials ICAMM 2012 November 24 25 2012 Sanya China   **Extended Finite Element Method** Soheil Mohammadi,2008-03-31 Provides an introduction to the concepts of extended finite element method XFEM for fracture analysis of structures as well as for other related engineering applications The book is self contained with summaries of both classical and modern computational techniques It also includes numerical examples describing various features of XFEM
      10th ESAFORM Conference on Material Forming Elías Cueto,Francisco Chinesta,2007-05-10 This book contains papers presented at the 10th Annual ESAFORM Conference which covers the multitude of disciplines related to material forming This year s conference features for the first time an ECCOMAS Thematic conference devoted to new advanced numerical strategies in forming simulation which has been traditionally one of the mini symposia of the conference   **Advances in Fracture and Damage Mechanics VI** Jorge Alfaiate,M.H. Aliabadi,Mario Guagliano,Luca Susmel,2007-09-15 International Conference on Fracture and Damage Mechanics VI 17 19 July 2007 Madeira Portugal   *Advances in Computational Modeling and Simulation* Ran Guo,Yun Zeng,Jian Ming Zhang,Yang Yang,Ze Li,Tao Guo,2013-10-15 Selected peer reviewed

papers from the 2nd International Conference on Advances in Computational Modeling and Simulation ACMS 2013 July 17 19 2013 Kunming China *Extended Finite Element Method for Crack Propagation* Sylvie Pommier,Anthony Gravouil,Nicolas Moes,Alain Combescure,2013-03-04 Novel techniques for modeling 3D cracks and their evolution in solids are presented Cracks are modeled in terms of signed distance functions level sets Stress strain and displacement field are determined using the extended finite elements method X FEM Non linear constitutive behavior for the crack tip region are developed within this framework to account for non linear effect in crack propagation Applications for static or dynamics case are provided **Advanced Materials and Engineering Structural Technology II** Iman Mansouri,Mohaned Eldessouki,Wasim M.K. Helal,2018-03-20 3rd International Conference on Advanced Material and Engineering Structural Technology 3rd ICAMEST 2017 Selected peer reviewed papers from the 3rd International Conference on Advanced Material and Engineering Structural Technology ICAMEST 2017 Nanjing China November 17 19 2017 **Proceedings of the 6th ESAFORM Conference on Material Forming** V. Brucato,2003 *Engineering Innovations Vol. 11* Afrooz Barnoush,Elena Gordo Odériz,Femiana Gapsari,2024-06-26 This volume of the journal Engineering Innovations collected articles that accent the reader s attention on the latest advances and results of research in the engineering design of power equipment parts of vehicles and a multicriteria scheduling problem in the machinery industry The presented articles will be helpful to many mechanical engineers Proceedings of the World Tribology Congress III--2005 ,2005 **Proceedings of the 12th International Modal Analysis Conference** Dominick J. DeMichele,Society for Experimental Mechanics (U.S.),1994 **Extended Finite Element Analysis of Fatigue Crack Growth for Cold Expanded Holes** Daniel Stockton,2015 *SIAM Journal on Scientific Computing* ,2005 **The Engineering Index Annual** ,1992 Since its creation in 1884 Engineering Index has covered virtually every major engineering innovation from around the world It serves as the historical record of virtually every major engineering innovation of the 20th century Recent content is a vital resource for current awareness new production information technological forecasting and competitive intelligence The world s most comprehensive interdisciplinary engineering database Engineering Index contains over 10 7 million records Each year over 500 000 new abstracts are added from over 5 000 scholarly journals trade magazines and conference proceedings Coverage spans over 175 engineering disciplines from over 80 countries Updated weekly Dissertation Abstracts International ,2008 DGLR/AIAA 14th Aeroacoustics Conference Hanno Heller,1992

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