



Tool failure mechanisms and cutting performance analysis during high-feed milling of 508-III steel

Xuebing Li¹ · Xianli Liu¹ · Caibou Yue²

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Abstract

508-III steel has become one of the most viable materials for heavy nuclear reactor pressure vessels due to its excellent strength and fracture toughness. However, the poor machinability of 508-III steel requires the tool to withstand extremely high mechanical stress, thermal stress, and shock during the cutting process, thereby accelerating tool failure and affecting machining efficiency. High-feed milling (HFM) is a novel rough machining technology that ensures machining efficiency and prolongs tool life. This paper aims to reveal tool failure mechanisms during HFM of 508-III steel and to indirectly evaluate the cutting performance of the HFM cutter in the context of cutting vibration and chip morphology. Dry milling experiments of 508-III steel were carried out using an HFM cutter with arc-shaped bottom edges. Experimental results show adhesion, oxidation, and diffusion are the primary tool wear mechanisms. The wear levels between each insert present significant differences, which can be explained by cutting-edge position deviations and unexpected tool movements. With the continuous accumulation of tool wear, the insert with the weakest cutting edge strength is broken, which can be attributed to the crack propagation near the cutting edge, hard spots, and the shedding of adhesive materials. When the feed per tooth is 0.8–1.0 mm, the whole milling process shows good stability, especially in the spindle direction. The chip morphology and color variations are closely related to tool wear, which can provide an essential basis for tool failure prediction.

Keywords High-feed milling · 508-III steel · Tool wear · Tool failure mechanisms · Cutting vibration · Chip morphology

1 Introduction

508-III steel (also known as manganese-nickel-molybdenum alloy steel) is widely used as a shell material for nuclear reactor pressure vessels because of its outstanding mechanical strength and fracture toughness [1]. Taking the large water chamber head shown in Fig. 1 as an example, the manufacturing process from blank to finished product takes several months, and the material removal is up to 70%, which places even higher demands on machining efficiency. Although high-speed cutting and large cutting depth can increase machining efficiency to some extent, they are limited by the power of the machine spindle and tool life. In addition, when faced with difficult-to-machine materials such as 508-III steel, cutting tools are subjected to extremely

high mechanical stress, thermal stress, and shocks, which undoubtedly accelerate tool failure. Severe tool wear or catastrophic breakage can lead to frequent machine downtime and may even damage the surface integrity of the workpiece, resulting in unnecessary economic losses. Therefore, how to balance the contradiction between tool life and machining efficiency is an urgent technical problem to be solved in the milling process of 508-III steel.


In order to improve tool life during the 508-III steel milling process, a series of studies on tool failure mechanisms have been carried out through theoretical modeling, finite element simulation, and cutting experiments. Under high temperature and pressure, elemental diffusion between cemented carbide insert and workpiece material tends to occur, resulting in tool adhesion failure. An elemental diffusion dynamics model for the adhesion process was established based on Fick's law, which can effectively predict the diffusion concentration of Co in 508-III steel [2]. As the tool periodically cuts into and out of the workpiece, the failure modes are mainly fatigue damage and impact fracture. Fatigue damage can be attributed to crack initiation and

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Failure Mechanisms In High Performance Materials

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Failure Mechanisms in High Performance Materials Mechanical Failures Prevention Group. Meeting, J. G. Early, T. R. Shives, John Henry Smith, 1985 The focus of this meeting was the identification and interpretation of degradation and failure modes in high performance materials

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Advanced Technologies in Failure Prevention Mechanical Failures Prevention Group. Meeting, 1991-06-28 The demand for safety and reliability in complex structures and mechanical systems is increasing as performance standards are escalated The costs associated with premature or unexpected component failure require a continued need to employ the latest advances in science and engineering to assess performance throughout the life cycle A significant contributor to the escalating costs of modern complex systems is that associated with the many maintenance actions required to keep the systems operational The theme of this book is the improvement in mechanical systems through the application of advanced technology Emphasis is placed on developments in instrumentation and techniques for detection diagnosis and prognosis on the evaluation of materials durability and on mechanisms of failure in aircraft and industrial applications

Failure Modes and Mechanisms in Electronic Packages P. Singh, Puligandla Viswanadham, 2012-12-06 Those of us who grew up in the through hole age of electronic packaging are probably more amazed and appreciative than are our children at the incredible growth of electronic performance capability My son an electrical engineering student seems almost to take for granted the innovations that leave me somewhat awestruck at times Electronic circuit designers delight in packing more punch into less volume while reminding us that their job has become increasingly challenging The lay person also has learned from the media that the industry has been working wonders in shrinking the transistor and expanding the power of the chip Much attention is focussed on the silicon and on the marvelous production and entertainment tools we now see in our offices and homes Between the silicon and the end product lies the less publicized world of circuit level packaging We leave it to a cadre of technologists to take the schematics and parts lists and to develop the processes that turn the designers concepts into physical reality And while the silicon transistor is shrinking the engineering challenges of packaging multiple chips and associated components into increasingly dense subsystems are growing Further the transistor may have to function without failure through severe industrial or military environments over the lifetime of the product

The Shock and Vibration Digest, 1983

Applied Mechanics Reviews, 1986

Opportunities in Protection Materials Science and Technology for Future Army Applications National Research Council, Division on Engineering and Physical Sciences, Board on Army Science and Technology, National Materials Advisory Board, Committee on Opportunities in Protection Materials Science and Technology for Future Army Applications, 2011-08-27 Armor plays a significant role in the protection of warriors During the course of history the introduction of new materials and improvements in the materials

already used to construct armor has led to better protection and a reduction in the weight of the armor. But even with such advances in materials the weight of the armor required to manage threats of ever increasing destructive capability presents a huge challenge. Opportunities in Protection Materials Science and Technology for Future Army Applications explores the current theoretical and experimental understanding of the key issues surrounding protection materials, identifies the major challenges and technical gaps for developing the future generation of lightweight protection materials and recommends a path forward for their development. It examines multiscale shockwave energy transfer mechanisms and experimental approaches for their characterization over short timescales as well as multiscale modeling techniques to predict mechanisms for dissipating energy. The report also considers exemplary threats and design philosophy for the three key applications of armor systems: 1. personnel protection including body armor and helmets; 2. vehicle armor; and 3. transparent armor. Opportunities in Protection Materials Science and Technology for Future Army Applications recommends that the Department of Defense (DoD) establish a defense initiative for protection materials by design (PMD) with associated funding lines for basic and applied research. The PMD initiative should include a combination of computational, experimental, and materials testing, characterization, and processing research conducted by government, industry, and academia. Review, 1988. *NRL Review*, 1988. High Performance Materials in Aerospace. Harvey M. Flower, 2012-12-06. Aerospace presents an extremely challenging environment for structural materials and the development of new or improved materials. Processes for material and for component production are the subject of continuous research activity. It is in the nature of high performance materials that the steps of material and of component production should not be considered in isolation from one another. Indeed, in some cases, the very process of material production may also incorporate part or all of the component production itself and at the very least will influence the choice of material component production method to be employed. However, the developments currently taking place are to be discovered largely within the confines of specialist conferences or books each dedicated to perhaps a single element of the overall process. In this book, contributors, experts drawn from both academia and the aerospace industry, have joined together to combine their individual knowledge to examine high performance aerospace materials in terms of their production, structure, properties, and applications. The central interrelationships between the development of structure through the production route and between structure and the properties exhibited in the final component are considered. It is hoped that the book will be of interest to students of aeronautical engineering and of materials science together with those working within the aerospace industry. Harvey M. Flower, Imperial College. 1. Design requirements for aerospace structural materials. C. J. Peel and P. J. Gregson. 1. **Carbon Fibers, Filaments, and Composites**. J. L. Figueiredo, Carlos A. Bernardo, R. T. K. Baker, K. J. Hüttinger, 2013-03-14. Conventional synthetic materials like metals, ceramics, or glass are usually isotropic substances, and their suitability for structural applications is achieved by morphological design and combination in the macroscopic scale. However, in modern engineering

this is often not acceptable As an alternative the use of non homogeneous anisotropic materials with significant stiffness and strength only in the directions these mechanical properties are really needed can lead to enormous material and weight savings This is the case of multiphase systems called composite materials In these composites different material parts are added and arranged geometrically under clearly designed and controlled conditions Usually a structure of fibers provides strength and stiffness and a matrix holds them together whilst providing the geometric form Carbon fibers are among the high performance fibers employed in these advanced structural composites which are profoundly changing many of today s high technology industries New research and development challenges in this area include upgrading the manufacturing process of fibers and composites in order to improve characteristics and reduce costs and modifying the interfacial properties between fibers and matrix to guarantee better mechanical properties The interdisciplinary nature of this new frontier is obvious involving chemistry materials science chemical and mechanical engineering Other topics which more often are treated separately are also important for the understanding of the processes of fiber production Carbon filaments is one such topic as the study of their mechanisms of nucleation and growth is clearly quite relevant to the production of vapour grown carbon fibers Railway Engineering Technology V. M. Ravindra Kumar,K. P. Vineesh,Sunil Kumar

Sharma,2025-09-30 This book presents advances in railway engineering including railway wheels wheel failure mechanisms innovations in railway track designs and axle failures It covers rail wheel traction characteristics under various environmental conditions for full scale test conditions including braking systems It provides an understanding of the applications of digital twin technology in railway systems predictive maintenance performance optimization and overall system efficiency It also emphasizes sustainable practices energy efficient technologies and environmental impact assessments Features Comprehensively reviews various aspects of railway engineering technology Discusses major failure mechanisms and various types of braking systems Covers the modernization of railways and high speed trains Explores emerging topics such as digital twin technology sustainable practices and autonomous technologies Includes case studies of railway component failures and accidents This book is aimed at researchers and professionals in railway and mechanical engineering as well as transportation systems Ultra-High Performance Concrete and High Performance Construction Materials Ekkehard Fehling,Bernhard Middendorf,Jenny Thiemicke,2016-03-01

Transportation Strategic Research Plan National Science and Technology Council (U.S.). Subcommittee on Transportation Research and Development,1999 The NSTC s National Transportation Science and Technology Strategy issued in April 1997 has four key elements Strategic Planning and Assessment Partnership Initiatives Enabling Research and Education and Training This Transportation Strategic Research Plan addresses the Enabling Research element It incorporates R D activities with clear potential relevance to one or more transportation modes or functions regardless of the objectives for which it is conducted or the performing agency Enabling research includes activities described under three Federal budget categories For civil agencies

these are Basic Research Applied Research and Development The comparable Defense Department terms are 6 1 Basic Research 6 2 Applied Research and 6 3 Advanced Technology Demonstration **Scientific and Technical Aerospace Reports** ,1994 **Proceedings of the Tenth International Conference on Composite Materials** Anoush Poursartip,Ken Street,1995 **Micro- and Macromechanical Properties of Materials** Yichun Zhou,Li Yang,Yongli Huang,2013-09-26 This is an English translation of a Chinese textbook that has been designated a national planned university textbook the highest award given to scientific textbooks in China The book provides a complete overview of mechanical properties and fracture mechanics in materials science mechanics and physics It details the macro and micro mechanical properties of metal structural materials nonmetal structural materials and various functional materials It also discusses the macro and micro failure mechanism under different loadings and contains research results on thin film mechanics smart material mechanics and more **New Materials for Next-Generation Commercial Transports** Committee on New Materials for Advanced Civil Aircraft,Commission on Engineering and Technical Systems,National Materials Advisory Board,Division on Engineering and Physical Sciences,National Research Council,1996-03-29 The major objective of this book was to identify issues related to the introduction of new materials and the effects that advanced materials will have on the durability and technical risk of future civil aircraft throughout their service life The committee investigated the new materials and structural concepts that are likely to be incorporated into next generation commercial aircraft and the factors influencing application decisions Based on these predictions the committee attempted to identify the design characterization monitoring and maintenance issues that are critical for the introduction of advanced materials and structural concepts into future aircraft

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Table of Contents Failure Mechanisms In High Performance Materials

1. Understanding the eBook Failure Mechanisms In High Performance Materials
 - The Rise of Digital Reading Failure Mechanisms In High Performance Materials
 - Advantages of eBooks Over Traditional Books
2. Identifying Failure Mechanisms In High Performance Materials
 - 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 Failure Mechanisms In High Performance Materials
 - User-Friendly Interface
4. Exploring eBook Recommendations from Failure Mechanisms In High Performance Materials
 - Personalized Recommendations

- Failure Mechanisms In High Performance Materials User Reviews and Ratings
- Failure Mechanisms In High Performance Materials and Bestseller Lists
- 5. Accessing Failure Mechanisms In High Performance Materials Free and Paid eBooks
 - Failure Mechanisms In High Performance Materials Public Domain eBooks
 - Failure Mechanisms In High Performance Materials eBook Subscription Services
 - Failure Mechanisms In High Performance Materials Budget-Friendly Options
- 6. Navigating Failure Mechanisms In High Performance Materials eBook Formats
 - ePub, PDF, MOBI, and More
 - Failure Mechanisms In High Performance Materials Compatibility with Devices
 - Failure Mechanisms In High Performance Materials Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Failure Mechanisms In High Performance Materials
 - Highlighting and Note-Taking Failure Mechanisms In High Performance Materials
 - Interactive Elements Failure Mechanisms In High Performance Materials
- 8. Staying Engaged with Failure Mechanisms In High Performance Materials
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Failure Mechanisms In High Performance Materials
- 9. Balancing eBooks and Physical Books Failure Mechanisms In High Performance Materials
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Failure Mechanisms In High Performance Materials
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Failure Mechanisms In High Performance Materials
 - Setting Reading Goals Failure Mechanisms In High Performance Materials
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Failure Mechanisms In High Performance Materials
 - Fact-Checking eBook Content of Failure Mechanisms In High Performance Materials

- 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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web prep 30 min cook 5 min yield 6 servings raclette is a traditional swiss dish that dates back to the time when cowherds would pasture their animals high in the alps and camp alongside them

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web sep 23 2019 raclette is both the name of a cheese and the name of a quintessential après ski sharing dish which is made from that same cheese it has swiss origins although you ll also find it the region of france that shares a border with switzerland it gets its name from the french racler which means to scrape

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web feb 24 2022 a traditional raclette the type of cheese traditionally used is actually called raclette a semi soft creamy textured rind cheese made of cow s milk that melts well raclette is a centuries old swiss food likely originated by shepherds and farmers who d take a block of cheese to melt and eat by a campfire while herding

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raclette they can expect to joyfully scrape gooey melted cheese onto their plate

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