

西安交通大学学术专著丛书



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张定铨 何家文 著

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Residual Stress Analysis by X-ray Diffraction and Its Functions

Zhang Ding-Quan and He Jia-Wen

Xi'an Jiaotong University Press

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作者简介



张定铨,1942年7月生,浙江省绍兴市人。1964年毕业于西安交通大学工程物理系。毕业后留校任教。1984年至1985年作为访问学者赴德国卡尔斯鲁厄大学(Karlsruhe Uni)进修。长期从事残余应力、表面强化和金属疲劳等方面的研究。在国内外发表论文计四十余篇,并主编《钢铁热处理》一书(1982年陕西科技出版社出版)。研究课题“缺口残余应力集中及其对疲劳性能的影响”获

1995 年国家教委科技进步三等奖。



何家文, 1933 年 12 月生。1955 年毕业于北京钢铁学院。现为西安交通大学教授、博士生导师。1980 年至 1982 年在美国西北大学作为访问学者工作两年。曾任西安交通大学材料与工程系系主任和金属材料强度国家重点实验室主任。现任中国机械工程学会材料分会主任, 国际残余应力学术委员会和国际喷丸学会理事, 曾获多项国家级奖, 已发表论文

200 余篇。

A BRIEF INTRODUCTION TO THE AUTHORS

Zhang Ding-Quan was born in July, 1942 in Zhejiang Province, China. He was graduated from the Department of Engineering Physics in Xi'an Jiaotong University at 1964. Then he became an assistant professor of Xi'an Jiaotong University. He visited Karlsruhe University, Germany in 1984 ~ 1985. He has been involved in the researches on residual stresses, surface engineering and metal fatigue. A book of Heat Treatment of Iron and Steel has been published by the Press of Shaanxi Science and Technology at 1981 and more than 40 papers have been released. He achieved the Third Rank of National Award of Science and Technology at 1995 on his contribution on the research project of Residual Stress Concentration and Its Effect on Fatigue.

He Jia-Wen, born in December 1933, graduated from Beijing

Iron and Steel Institute at 1955, is now a professor of Xi'an Jiaotong University. He spent two years as a visitor in Northwestern University in US in 1980-1982. He was the head of Materials Science and Engineering Department of Xi'an Jiaotong University and the director of State Key Laboratory for Mechanical Behavior of Materials for quite a few years. He was the director of Materials Division of China Mechanical Engineering Society (CSME) in 1996-1999 and the Scientific Committee member of International Conferences of Residual Stress and Shot Peening. He achieved a few National Awards and more than 200 papers have been published.

“西安交通大学学术专著丛书”出版说明

“西安交通大学学术专著丛书”是西安交通大学学术专著出版基金委员会支持的学术著作系列书。

“西安交通大学学术专著丛书”的作者主要是我校教师和海内外校友。它对学术专著的要求是：内容的主题必须是著作者本人或与合作者一起的研究成果，具有鲜明的特色和独特的见解或方法，推进或补充了前人在某学科领域的创造，达到国内外先进水平。投来的书稿由基金委员会聘请校内外学者、教授、专家若干人认真评审，复经基金委员会（由校长聘请若干名教授组成）严肃讨论并最后采取无记名投票方式裁定。

学术著作的水平，是一个国家、一个民族科学文化水平的标志之一。它不仅代表了一定的学术文化水平和理论深度，而且其中

蕴含着丰富的潜在生产力。先进的学术思想一旦被文字或音像记载下来,出版并传播,就能在人类的历史长河中,发挥难以估量的重大作用。“西安交通大学学术专著丛书”是反映我校较高学术水平和科研水平的一个窗口。

**A PUBLICATION DESCRIPTION
OF XI'AN JIAOTONG UNIVERSITY
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“Xi'an Jiaotong University Academic Writings Series” is supported by the Academic Publication Foundation of Xi'an Jiaotong University.

The authors of “Xi'an Jiaotong University Academic Writings Series” are mainly the University's teaching staff and alumni both at home and abroad. It is required that the subjects of the writings to be published should be the research results of the author or co-partners themselves with distinguishing features, originative viewpoints or methods, which should give an impetus or supplement to predecessors' creativeness in some fields, and which have reached national or world advanced levels. Any manuscript sent to the University Press will first be conscientiously evaluated by scholars, professors and experts inside and outside the University, who are invited by the Fund Commission. Then, it will be re-examined strictly by the Fund Commission itself which is made up of a few distinguished professors appointed by the president. And finally, whether the manuscript will be published or not is decided by ballot.

The level of academic writings signifies one of the scientific and cultural levels of a country and of a nation. It is not only the sign of

a certain academic and cultural level but also theory in depth, and it embodies abundant potentialities of the productive forces as well. Once the advanced academic thinking is recorded in script and publications or by using audio-visual aids for wide spreading, the result will play an important role in the long process of human history, the value of which is difficult to estimate. “Xi’an Jiaotong University Academic Writings Series” reflects, as a window, the higher academic and scientific research level of our University.

内容简介

本书比较全面地阐述了残余应力的基本概念、产生原因、稳定性及测试方法;系统地介绍了 X 射线衍射应力分析技术,并对影响测试结果的各种因素进行了探讨;最后从理论和实验两方面着重论述了残余应力对材料疲劳性能的影响。

本书可供材料科学与工程、机械制造工程及力学等专业的科研人员、工程技术人员、教师、研究生及高年级学生参考。

A brief introduction to this book

This book introduces the basic concept of internal stresses and the reasons it produces and relaxes. Among different testing methods, it is emphasized on x-ray diffraction analysis. The diffraction geometry, setting parameters, data processing and experimental de-

viation and error are discussed. As the testing material is in a state of coarse grain size, preferred orientation, thin film or curved surface, special care should be taken in testings. Also the ways to examine tri-axial stress state, sharp stress gradient and the state that second kind of internal stress being involved are discussed.

The effects of residual stresses on mechanical properties are separated into two parts of static property and fatigue. Fatigue fracture without any macro-plastic deformation is important to take account of residual stress, since it does not relax under loading. Intensive discussions have been made in this book on the topic of the influence of compressive residual stresses on fatigue limit as well as fatigue crack propagation for both smooth and notched samples.

This book is expected to provide a better understanding of residual stress analysis and its functions for the scientists, technicians, professors and graduated students in the departments of materials science and engineering and mechanical engineering as well as engineering mechanics.

序 言

得知何家文教授与张定铨副教授将出版有关残余应力专著的消息,甚感欣喜。二十多年前,我与他们两位为推广残余应力分析技术,曾经有过非常愉快的合作,并结下了深厚的友情。他们勤奋工作的精神与严谨的治学作风给我留下深刻的印象。那时,国内从事残余应力分析技术的工作者们渴望有一本系统论述残余应力对材料性能影响及有关测试分析的书。但限于国内刚开展此项工作,只得依赖国外的文献资料和有关书籍。经过二十多年的研究工作积累,他们两位将国内外对残余应力研究的最新成果凝集于此书中,并把他们的学识、见解、工作经验和成果注入其中,无疑将成为从事这方面工作的人们不可缺少的工具。

残余应力对材料和工件性能的影响,既有不利一面,也有有利一面。但存在于材料和工件中的残余应力,是人们无法用其感官

直接感知的,因而往往不为人们所重视,由此而引起的事故不乏其例。快速、无损地测知材料和工件中的残余应力,始终为很多研究人员所重视,并为之作出了很多不懈的努力。迄今为止,X射线衍射分析是唯一能无损和较便捷地测试残余应力的技术。随着微电子技术和计算机技术的发展,X射线衍射分析,无论测试方法或测试仪器都将日臻完善,测试数据更加准确可靠,从而为人们更深刻地认识残余应力提供更完备的手段,促进残余应力分析技术的发展。

如同残余应力对材料和工件性能的影响不易引起人们的重视一样,残余应力分析技术的应用和研究也还未得到有关方面的足够重视。国内对残余应力分析技术的研究和应用,经历了起伏和曲折。本书集各家所长、撷自家所研,不失为该领域的一本系统而有分析的专著。相信本书的出版,将为我国残余应力分析技术的研究和应用起到再一次推动的作用。

机械部总工程师 朱森第

1997年10月3日

前 言

实际机件中的残余应力对其疲劳强度、抗应力腐蚀能力、尺寸稳定性和使用寿命有着十分重要的影响。正因为如此,关于残余应力测定及其对材料性能影响的研究日益为工程技术界所重视,成为材料科学和力学中相当活跃的一个分支。为满足工程技术发展的需要,随着测试手段的不断改进,近年来该领域的研究取得了很大的进展。自第一届国际残余应力会议 1986 年在联邦德国召开以来,又在法、日、美和瑞典等国连续召开了四届会议。仅在联邦德国,80 年代后出版的德文版和英文版有关残余应力的专著达十几种之多。

著者长期从事材料中残余应力的研究。鉴于该领域的研究正面临着“长江后浪推前浪”的发展局面和国内此类专著十分稀少的状况,作者渴望将多年来有关残余应力的研究工作加以总结,写成