

100 YEARS



A PROVEN PARTNERSHIP

BEARING STEELS

INTO THE 21ST CENTURY

JOSEPH J. C. HOO
WILLARD B. GREEN, JR.

EDITORS

STP 1327



STP 1327

Bearing Steels: Into the 21st Century

Joseph J. C. Hoo and Willard B. Green, Jr., Editors

ASTM Stock #: STP1327



ASTM
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

Printed in the U.S.A.

Library of Congress Cataloging-in-Publication Data

Bearing steels : into the 21st century / Joseph J.C. Hoo and Willard B. Green, Jr., editors.

p. cm. -- (STP ; 1327)

Papers presented at a conference held Nov. 19-21, 1996 in New Orleans, sponsored by ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys, and its Subcommittee A01.28 on Bearing Steels.

Includes bibliographical references and index.

ISBN 0-8031-2421-X

I. Steel, Bearing--Congresses. I. Hoo, J. J. C. II. Green, Willard B., 1936. III. American Society for Testing and Materials. Committee A-1 on Steel, Stainless Steel, and Related Alloys. IV. American Society for Testing and Materials. Subcommittee A01.28 on Bearing Steels. V. Series: ASTM special technical publication ; 1327.

TA472.B34 1998

620.1'7--dc21

98-6575

CIP

Copyright © 1998 AMERICAN SOCIETY FOR TESTING AND MATERIALS, West Conshohocken, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

Photocopy Rights

Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by the American Society for Testing and Materials (ASTM) provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923; Tel: 508-750-8400; online: <http://www.copyright.com/>.

Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

To make technical information available as quickly as possible, the peer-reviewed papers in this publication were prepared "camera-ready" as submitted by the authors.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

Foreword

This publication, *Bearing Steels: Into the 21st Century*, contains papers presented at the symposium of the same name, held on 19–21 November 1996 in New Orleans, Louisiana. The symposium was sponsored by ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and its Subcommittee A01.28 on Bearing Steels. Joseph J. C. Hoo (symposium chairman) of General Bearing Corp. in West Nyack, NY and Willard B. Green, Jr. of the Torrington Co. in Torrington, CT are editors of the resulting publication.

Contents

Overview—W. B. GREEN, JR.	ix
----------------------------------	----

SUBCOMMITTEE A01.28 ON BEARING STEELS

A Brief History, Status, and Mission of ASTM Subcommittee A01.28 on Bearing Steels—W. B. GREEN, JR.	3
--	---

BEARING STEEL CLEANLINESS

Inclusion Ratings: Past, Present, and Future—G. F. VANDER VOORT	13
--	----

Quantification of Large Inclusions in Bearing Steels—T. B. LUND AND K. TORRESVOLL	27
--	----

Cleanliness Assessment: A Critical Review and a Real Need to Predict Rolling Contact Fatigue Behavior—G. AUCLAIR, F. RUBY-MEYER, R. MEILLAND, AND P. ROCABOIS	39
--	----

From Cleanliness to Rolling Fatigue Life of Bearings—A New Approach—G. LORMAND, P. MEYNAUD, A. VINCENT, G. BAUDRY, D. GIRODIN, AND G. DUDRAGNE	55
---	----

Simulation of the Behavior of Short Cracks at Inclusions Under Rolling Contact Fatigue Loading—Specially the Effect of Plasticity—A. MELANDER	70
--	----

What Happens to the Fatigue Limit of Bearing Steel Without Nonmetallic Inclusions?: Fatigue Strength of Electron Beam Remelted Super Clean Bearing Steel—Y. MURAKAMI, T. TORIYAMA, K. TSUBOTA, AND K. FURUMURA	87
---	----

BEARING LIFE/ROLLING CONTACT FATIGUE

From White Etching Areas Formed Around Inclusions to Crack Nucleation in Bearing Steels Under Rolling Contact Fatigue—A. VINCENT, G. LORMAND, P. LAMAGNERE, L. GOSSET, D. GIRODIN, G. DUDRAGNE, AND R. FOUGÈRES	109
--	-----

Nucleation of Fatigue in Very Low Oxygen Bearing Steels—T. B. LUND, S. A. JOHANSSON, AND L. J. PATRIK OLUND	124
Rolling Contact Fatigue Behavior of Heat Resistant Bearing Steels at High Operational Temperatures—H.-J. BOHMER, T. HIRSCH, AND E. STREIT	131
Fatigue and Material Response in Rolling Contact—A. P. VOSKAMP	152
A New Type of Flaking Failure in Bearings for Electrical Instruments of Automotive Engines—K. TAMADA, H. TANAKA, AND N. TSUSHIMA	167

BEARING STEEL PRODUCTION

Bearing Steels 20/20—A Steelmaker's Viewpoint—A Look Back 20 Years and a Look Forward 20 Years—B. M. GLASGAL	189
Bearing Steels in the 21st Century—K. TSUBOTA, T. SATO, Y. KATO, K. HIRAOKA, AND R. HAYASHI	202
Application of Continuous Casting Steel 100CR6 (SAE 52 100) for Bearing—F. STAHL, TH. HIRSCH, AND P. MAYR	216
Development of Process Capability and Testing Techniques for the Production of Bearing Steels—A. KRABIELL, H. RZEPczyk, V. SCHULER, C. H. SCHUTZ, AND D. TEMBERGEN	231

THROUGH HARDENING BEARING STEELS

Progress in Through-Hardening Bearing Steels: User's Experience— K. FURMURA, T. ABE, AND Y. MURAKAMI	249
Simulation of Heat Treatment Response and Distortion of Bearing Steels— A. THUVANDER, L. HOGLUND, A. MELANDER, A. FROM, S. JONSSON, J. AGREN, P. OLUND, J.-E. ANDERSSON, T. LUND, J. BESWICK, AND J. SLYCKE	265
New Steels Now in Use for Automotive Rolling Element Bearings— N. TSUSHIMA, K. MAEDA, H. NAKASHIMA, AND H. KASHIMURA	279

CASE HARDENING BEARING STEELS

Case Hardening Medium Carbon Steel for Tough and Long Bearing Under Severe Lubrication Conditions—K. FURUMURA, Y. MURAKAMI, AND T. ABE	293
New Steels and Methods for Induction Hardening of Bearing Rings and Rollers—B. K. OUCHAKOV AND K. Z. SHEPELJAKOVSKY	307
Study on the Limited Hardenability Steel—L. P. XU, L. LI, Y. A. MIN, M. H. XU, J. P. LE, AND R. H. LIU	321

AIRCRAFT/AEROSPACE BEARING STEELS: PART I

- The History and Future of Aircraft Turbine Engine Bearing Steels—**
P. K. PEARSON 335
- The New Low Nitrogen Steel LNS—A Material for Advanced Aircraft Engine
and Aerospace Bearing Applications—**H. BERNS, F.-J. EBERT, AND
H.-W. ZOCH 354
- Development of CSS-421TM, A High-Performance Carburizing Stainless Steel
for High Temperature Aerospace Applications—**H. I. BURRIER,
C. M. TOMASELLO, S. A. BALLIETT, J. L. MALONEY, D. L. MILAM, AND
W. P. OGDEN 374
- Metallurgical and Tribological Evaluation of 32CrMoV13 Deep Nitrided Steel
and XD15N High Nitrogen Martensitic Steel for Aerospace
Applications—**I. PICHARD, D. GIRODIN, G. DUDRAGNE, AND J.-Y. MORAUX 391

AIRCRAFT/AEROSPACE BEARING STEELS: PART II

- High Temperature Aircraft Turbine Engine Bearing and Lubrication System
Development—**D. H. GRANT, H. A. CHIN, C. KLENKE, A. T. GALBATO,
M. A. RAGEN, AND R. F. SPITZER 409

CORROSION RESISTANT BEARING STEELS

- A New Corrosion Resistant, Martensitic Stainless Steel for Improved
Performance in Miniature Bearings—**C. M. TOMASELLO, J. L. MALONEY,
P. C. WARD, AND J. P. MATERKOWSKI 437
- Progress in Bearing Performance of Advanced Nitrogen Alloyed Stainless
Steel, Cronidur 30—**W. TROJAHN, E. STREIT, H. A. CHIN, AND D. EHLERT 447
- The Evaluation of Corrosion Resistant Rod End Rolling Element Bearings—**
J. BRAZA, K. GIUNTOLI, AND J. R. IMUNDO 460
- Laser Glazed Bearings—**D. W. HETZNER 471

BEARINGS WITH SURFACE MODIFICATION

- Rolling Contact Fatigue Properties of TIN/NBN Superlattice Coatings on
M-50 Steel—**M. A. LISTON 499
- The Application of Resonance Ultrasound Spectroscopy to Bearing Rollers—**
G. W. RHODES 511
- Author Index 519**
- Subject Index 521**

Overview

The anti-friction bearing industry is once again indebted to Joseph J. C. Hoo for his leadership in organizing and chairing an international symposium on Bearing Steels and related subjects. His efforts have brought together experts from around the world to present their work. This symposium, Joe's fifth, was entitled "Bearing Steels into the 21st Century", and was sponsored by the American Society for Testing and Materials Committee A01 and its subcommittee A01.28 on Bearing Steels. It was held in New Orleans, Louisiana, November 19-21, 1996. Special Technical Publications (STPs) for the four previous symposia have been published and are listed here for quick reference:

1974	STP 575	<i>Bearing Steels: The Rating of Nonmetallic Inclusions</i>
1981	STP 771	<i>Rolling Contact Fatigue Testing of Bearing Steels</i>
1986	STP 987	<i>Effect of Steel Manufacturing Processes on the Quality of Bearing Steels</i>
1991	STP 1195	<i>Creative Use of Bearing Steels</i>

The symposia titles and subject matter have been carefully chosen to follow the evolution of bearing and bearing steel technology over the last quarter century. It is certainly fitting that this symposium focused on where the industry is headed in the 21st century. The collection of work reported in these five STPs provides a unique focus on the international thinking in the bearing industry from the materials and materials processing point of view.

The symposium was organized in 9 separate categories, some sessions updating information previously presented, and some presenting brand new materials and processing to advance bearing technology. Subjects covered include steel cleanliness and measuring methods, bearing fatigue life, and advanced steel processing. Also covered are advances in both thru-hardening and carburizing heat treatments, progress in aerospace and corrosion resistant materials, and surface modifying processes, such as induction hardening and coating methods. Details of the sessions and the papers are covered in the index to this STP.

With each symposium, the international participation is increasing. 175 to 200 engineers and scientists from around the world attended this symposium, some coming to these gatherings for the first time. The organizers are grateful for the wide interest and participation. This book is a collection of 33 papers presented in New Orleans. It is the work of researchers from (alphabetically) Austria, Belgium, China, France, Germany, Greece, Japan, Netherlands, Russia, Sweden, UK, and USA. Some of these countries participated for the first time in an ASTM sponsored event. They represented 10 bearing companies, 15 steel producing companies, 8 universities and research institutes, and 4 miscellaneous bearing users.

We are sure that the work contained in this and previous STPs has advanced that world's knowledge of those simple, yet complicated, devices known as anti-friction bearings, be they ball, roller, or needle. We also hope that some of these papers will form the foundation for future research to further advance our industry. While we have come a long way in the past 25 years, we do not know all the answers yet. The challenge of the future is, of course, to make bearings that last longer, are smaller, more corrosion resistant, and more cost effective. The researchers of the future have work to do. We hope that ASTM symposia will continue to provide forums to report advances toward these goals.

Joe Hoo, because of his international stature, has been successful in bringing together world leaders in bearing technology to present their research. We hope that the spirit of sharing information continues as the world gets smaller, and probably more competitive. On behalf of the ASTM Subcommittee A01.28 on Bearing Steels, and the world bearing industry - thanks, Joe.

Willard B. Green, Jr.
Chief Materials Engineer
The Torrington Company
Torrington, CT 06790
Chairman, A01.28, Bearing Steels

ISBN 0-8031-2421-X