Preface to the Second Edition

*Hot Working Guide: A Compendium of Processing Maps* is a unique source book with flow stress data for hot working, processing maps with metallurgical interpretation and optimum processing conditions for metals, alloys, intermetallics and metal matrix composites. The use of this book replaces the expensive and time consuming trial and error methods in process design and product development. In the first edition, which was published by ASM International in 1997, processing maps for 162 materials were presented. Since that time, processing maps for another 130 materials with different initial conditions have been published in the literature which motivated updating of the first edition. In the second edition, significant additions of maps on stainless steels, magnesium alloys, titanium alloys and nickel alloys have been made. In compiling the second edition, stress-strain curves were not included since their shapes do not lead to clear conclusions on the mechanisms. However, the flow stress data are included since they are valuable in formulating constitutive equations required for finite element simulation. In this book, the available information is compiled in such a way that the processing industry will find it easy to use.

In the first chapter, information on typical microstructures that help in interpreting the processing maps have been presented along with literature updates on the review articles on processing maps. In Chapters 2-9, processing maps developed on the basis of data extracted from published papers have been given along with interpretations. It may not be considered as an exhaustive coverage of literature since some of the data may not have been included when the test matrix was found to be insufficient. The compilation will help researchers get started on this topic.

Information on many commercial alloys has been included in this reference book. It is believed that this will cater to the needs of the bulk metal working industry in improving the yield by process optimization and in achieving better product quality. Researchers in this area will find the compilation as a ready reference in pursuing further work in correlating the material chemistry and processing history with the hot workability. The complications in processing intermetallics and metal-matrix composite are clearly revealed and the advantage of using processing maps for these materials is easily recognizable. In materials like titanium alloys and magnesium Alloys, the importance of texture in processing is clearly seen in the maps.

Historically, the foundation to processing maps was laid in 1984 in the Materials Laboratory of Wright-Patterson Air Force Base, OH, USA. This was further pursued at the Department of Metallurgy, Indian Institute of Science, Bangalore, India, with the support of the Department of Science and Technology, Government of India, and contributions from several national laboratories. After the year 2000, research efforts on processing maps were taken up at the City University of Hong Kong, and to a large extent the effort was focused on magnesium materials. Many commercial magnesium alloys as well as new experimental alloys have been characterized and the hot workability was correlated with microstructural mechanisms including texture. This edition reflects these important contributions to hot working research.

The help and contributions to the second edition of Dr. K. Suresh, Senior Research Associate at the City University of Hong Kong, is gratefully acknowledged. His hard work and commitment to perfection is truly exemplary.

Y.V.R.K. Prasad

K.P. Rao

S. Sasidhara
Preface to the First Edition

Hot Working Guide: A Compendium of Processing Maps is a unique source book with flow stress data for hot working, processing maps with metallurgical interpretation and recommendation of optimum processing conditions. The use of this book replaces the expensive and time consuming trial and error methods in process design and product development.

In the first chapter, the issues involved in the design and manufacturing are discussed in relation to hot working. Hot workability is defined and the concept of processing maps for optimising material workability and control of microstructure are explained along with the details of the method of generating processing maps. Guidelines are given for its interpretation and application to industrial hot working process with the help of typical examples. In Chapters 2–10, processing maps and flow stress data are compiled for over 160 materials which include metals of different purity, conventional alloys used in industry like aluminum alloys, copper alloys and steels, advanced materials like superalloys, titanium and zirconium alloys, and never materials like titanium aluminides and metal matrix composites.

The contents of this book will benefit bulk metal working (rolling, forging, and extrusion) industry in improving the yield by process optimization and in achieving better quality by avoiding defects. Practicing engineers and R & D specialists may use the data base for FEM simulations and process design, and undergraduate students may utilize the material for understanding the science of processing.

The foundation for the Dynamic Materials Model leading to the concept of processing maps was laid in 1984 in the Materials Laboratory of Wright-Patterson Air Force Base (WPAFB), OH, USA. Subsequently, work in this area took two directions: WPAFB along with Ohio University and Universal Energy Systems Inc., integrated the concept with the FEM simulation model and developed process design and control concepts for use in industrial processes. Simultaneously, at Department of Metallurgy, Indian Institute of Science, Bangalore, India, the metallurgical interpretation of the processing map leading to science of mechanical processing was pursued. With the support of Department of Science and Technology, Government of India, hot compression testing (custom built by DARTEC, UK) and computational facilities were established. Several research laboratories and educational institutions in India participated in this effort, and major contributors are Defense Metallurgical Research Laboratory at Hyderabad, Bhabha Atomic Research Center at Bombay, Indira Gandhi Center for Atomic Research at Kalpakkam. Several of the processing maps developed in this effort are also industrially validated both in terms of optimizing the existing process to improve productivity and in designing newer processes. In this book, the available information is compiled in such a way that processing industry will find it easy to use. The reference material was not meant to be a complete review of the work on the topic but to help the reader to get introduced.

Y.V.R.K. Prasad
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About the Editors ....

Y.V.R.K. Prasad obtained his Ph.D. degree in Mechanical Metallurgy from the Indian Institute of Science, Bangalore, India in 1971, where he taught and conducted research for four decades in dislocation dynamics, microstructure-mechanical property correlations, and mechanical processing of materials. In the early seventies, he was a post-doctoral fellow at the University of Maryland, College Park, and Drexel University, Philadelphia, USA. In the early eighties and late nineties, he was a Senior Research Associate of the U.S. National Research Council at the Materials Laboratory of Wright-Patterson Air Force Base, Dayton, Ohio, USA, where he was part of the team that developed the Dynamic Materials Model that uses processing maps to optimize hot working processes. Two U.S. Patents have been awarded for this invention. He developed the processing science laboratory at the Indian Institute of Science where he retired as Professor in 2003. Later, he continued his research at the City University of Hong Kong where he is an Academic Visitor and a consultant on processing maps. He is a Fellow of the Indian National Science Academy, Indian Academy of Sciences and Indian National Academy of Engineering.

K.P. Rao obtained his Ph.D. degree in Metal Forming from the Indian Institute of Technology, Madras (Chennai), India in 1983 and an MBA in Technology Management from LaTrobe University, Australia in 2003. After post-doctoral assignments at the University of New Brunswick, Fredericton, and the University of British Columbia, Vancouver, Canada, he joined the faculty of the City University of Hong Kong in 1990, firstly in the Department of Manufacturing Engineering and Engineering Management, and then in the Department of Mechanical and Biomedical Engineering, where he is now a Professor and Associate Head of the Department. He has extensive experience in the simulation, design, and development of metal forming processes and his recent research interests encompass the formability and processing maps for hot working of new magnesium alloys, thermo-mechanical processing of magnesium alloys for bioimplants, and processing of bulk magnesium alloy composites with nano-dispersions. His earlier research included the evaluation of hot working mechanisms in aluminum alloys, pure copper and titanium aluminide, and its in-situ composite produced by powder metallurgy.

S. Sasidhara obtained his B.E. degree in Mechanical Engineering from Bangalore University in 1972 after getting his B.Sc. degree from Mysore University. He joined the Department of Metallurgy of the Indian Institute of Science in 1973 to head up several universal mechanical testing and processing equipment areas. He specialized in designing tooling for specialized testing requirements, most importantly the constant true strain rate high temperature compression. He is credited with conducting more than 10,000 hot compression tests on a wide range of materials including metals, alloys, intermetallics, and metal-matrix composites, the data on which formed the basis for developing the processing maps presented in this volume. He has visited the works of Instron Limited, Dartec Limited, England, and British Alcan, and the laboratories of Imperial College, University of Sheffield, and University of Cambridge, U.K. He has been the mentor for many students that graduated from IISc with Doctoral and Masters Degrees over four decades. At present, he is a technical consultant in the Department of Materials Engineering at the Indian Institute of Science, Bangalore, India.
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