

# MODELING MICROSTRUCTURE EVOLUTION DURING THERMOMECHANICAL PROCESSING AND HEAT TREATMENT OF STEELS AND PREDICTING THEIR MECHANICAL PROPERTIES

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**Abstract.** An integral computer model/program AusEvol Pro was developed to describe the evolution of steel microstructure during thermomechanical processing (hot rolling, forging), as well as subsequent heat treatment (normalization, tempering), and to evaluate the final mechanical properties (yield stress, tensile stress, elongation), hardness and impact toughness. The program implements a set of physically based models that allow quantitative description of all significant processes of steel structure formation with account of the effects of chemical composition both during thermomechanical processing and heat treatment. Calculations of the final mechanical properties are carried out using the developed models that take into account all physically meaningful contributions. The models created are verified both on the extensive database of our own experimental studies and on reliable data from literature for steels of various chemical compositions.

**Keywords:** heat treatment, mechanical property, microstructure, modeling, steel, thermo-mechanical processing

## 1. Introduction

In the last 30 years considerable attention has been paid to the development of integral quantitative models which enable describing a complex evolution of the microstructure of steels under their thermomechanical processing in industrial hot rolling and subsequent accelerated cooling, as well as predicting the final mechanical properties [1-7]. Such integral models, implemented with computer programs [6,7], are successfully used in the practice of industrial production, allowing to optimize the rolling modes of existing steel grades, as well as to quickly develop new steel grades and their production modes. However, the microstructure of thermomechanically processed steels evolves further during additional heat treatments (normalization or tempering); thus, to develop the physically based models for underlying processes is a task of great practical significance which currently receives considerable attention.

This paper briefly describes the integral computer model/program AusEvol Pro that was developed to predict the evolution of steel microstructure during both the thermomechanical processing and subsequent heat treatment, as well as to evaluate the final mechanical properties (yield stress, tensile stress, elongation), hardness and impact toughness. The resulting final properties of steels after the hot rolling and the latter in combination with subsequent heat treatment, performed in accordance with real industrial conditions, are compared with experimental data.

# Microstructure Modeling And Prediction During Thermomechanical Processing

**Remn-Min Guo, James J. M. Too**



## **Microstructure Modeling And Prediction During Thermomechanical Processing:**

**Microstructure Modeling and Prediction During Thermomechanical Processing** Raghavan Srinivasan,2001-01-01 This proceedings volume includes papers on recent developments in the modelling and prediction of microstructure during thermomechanical processing of titanium superalloys aluminium and ferrous alloys It covers both physical and computer modelling

**Proceedings of the 14th International Conference on the Technology of Plasticity - Current Trends in the Technology of Plasticity** Katia Mocellin,Pierre-Olivier Bouchard,Régis Bigot,Tudor Balan,2023-08-28 This volume highlights the latest advances innovations and applications in the field of metal forming as presented by leading international researchers and engineers at the 14th International Conference on Technology of Plasticity ICTP held in Mandelieu La Napoule France on September 24 29 2023 It covers a diverse range of topics such as manufacturing processes equipment materials behavior and characterization microstructure design by forming surfaces interfaces control optimization green sustainable metal forming technologies digitalization AI in metal forming multi material processing agile flexible metal forming processes forming of non metallic materials micro forming and luxury applications The contributions which were selected by means of a rigorous international peer review process present a wealth of exciting ideas that will open novel research directions and foster multidisciplinary collaboration among different specialists

**Simulation of Material Processing: Theory, Methods and Application** Ken-ichiro Mori,2001-01-01 This volume contains about 180 papers including seven keynotes presented at the 7th NUMIFORM Conference It reflects the state of the art of simulation of industrial forming processes such as rolling forging sheet metal forming injection moulding and casting

**Automation in Mining, Mineral and Metal Processing 2004** Dominique Sauter,D. Theilliol,2006-02-21 Approx 482 pages [Handbook of Aluminum](#) George E. Totten,D. Scott MacKenzie,2003-04-25 This reference provides thorough and in depth coverage of the latest production and processing technologies encountered in the aluminum alloy industry discussing current analytical methods for aluminum alloy characterization as well as extractive metallurgy smelting master alloy formation and recycling The Handbook of Aluminum Volume 2 examin

**THERMEC'2003** Tetsuo Sakai,Jose M. Torralba,2003 **Proceedings of the 8th International Symposium on Superalloy 718 and Derivatives** The Minerals, Metals & Materials Society (TMS),2014-12-02 [Thermomechanical Processing in Theory, Modelling and Practice \(TMP\)2](#) Bevis Hutchinson,1997 [Recent Advances in Heat Transfer and Micro-structure Modelling for Metal Processing](#) Remn-Min Guo,James J. M. Too,1995 A balance of contributors from the metal industry and academia share theoretical and practical information relevant to meeting the need for conserving energy and resources and the increasing high quality and cost effectiveness demanded by world market competition by applying newly developed modelin

*Multi-scale Computational Techniques for Design of Polycrystalline Materials* Veeraraghavan Sundararaghyavan,2007 Microstructures play an important role in controlling distribution of properties in engineering materials It is possible to develop components with tailored distribution

of properties such as strength and stiffness by controlling microstructure evolution during the manufacturing process. When forming metallic components by imposing large deformations, mechanisms such as slip and lattice rotation drive formation of texture in the underlying polycrystalline microstructure. Such microstructural changes affect the final distribution of material properties in the component. By carefully designing the imposed deformation, one could potentially tailor the microstructure and obtain desired property distributions. This thesis focuses on development of novel computational strategies for designing deformation processes to realize materials with desired properties. The techniques presented are an interplay of several new tools developed recently such as reduced order modeling, graphical cross plots, statistical learning, microstructure homogenization, and multi scale sensitivity analysis. The primary outcomes of this thesis are listed below: Development of reduced order representations and graphical methodologies for representing process property texture relationships; Development of adaptive reduced order optimization techniques for identification of processing paths that lead to desirable microstructure sensitive properties; Development of homogenization techniques for predicting microstructure evolution in large deformation processes; Development of multi scale sensitivity analysis of polycrystalline material deformation for optimizing microstructure sensitive properties during industrial forming processes. The framework for design of polycrystalline microstructures leads to increased product yield in industrial forming processes and simultaneously allows control distribution of properties such as stiffness and strength in forged products. Multiscale design problems leading to billions of unknowns have been solved using parallel computing techniques. The computational framework can be readily used for selecting optimal processing paths for achieving desired properties. The methodology developed is a fundamental effort at providing detailed deformation process design solutions needed for controlling properties of performance critical hardware components in automotive structural and aerospace applications.

**Abstract**      **Fundamentals of Modeling for Metals Processing** David U. Furrer, ASM International. Handbook Committee, 2009. This Handbook provides an overview of the development of models of metallic materials and how the materials are affected by processing. This knowledge is central to understanding of the behaviour of existing alloys and the development of new materials that affect nearly every manufacturing industry. Background on fundamental modeling methods provides the user with a solid foundation of the underlying physics that support the mechanistic method of many industrial simulation software packages. The phenomenological method is given equal coverage.      ASM Handbook S. L. Semiatin, ASM International. Handbook Committee, 1990. These volumes cover the properties, processing and applications of metals and nonmetallic engineering materials. They are designed to provide the authoritative information and data necessary for the appropriate selection of materials to meet critical design and performance criteria.      Numerical Predictions of Deformation Processes and the Behaviour of Real Materials S. I. Andersen, 1994.      **Materials Science & Technology: AIST**, 2004.      *Microstructural Modelling in Metals Processing* Øystein Grong, 2002.      **Proceedings of the ASME Fluids Engineering Division**, 2003.

*3rd European Mechanics of Materials Conference on Mechanics and Multi-Physics Processes in Solids* E. Busso, G. Cailletaud, 1999     **Aluminum Alloys**, 1998     **Hot Deformation of Aluminum Alloys II** Thomas R. Bieler, Lawrence A. Lalli, Stuart R. MacEwen, 1998 These symposium proceedings from the 1998 TMS Fall Meeting examine the relationships between mechanical behavior and microstructural evolution that must be quantified to develop predictive models for hot deformation Issues addressed include constitutive modeling process design and modeling laboratory simulation of large scale hot working processes the evolution of microstructure texture damage dynamic precipitation recovery and recrystallization processes creep and superplastic deformation and the ability to predict phenomena such as corrosion and formability after hot deformation     **Handbook of Workability and Process Design** George E. Dieter, Howard A. Kuhn, S. L. Semiatin, 2003 If you design evaluate or produce metal parts this is an indispensable reference on the principles and practices of workability evaluation and process design Workability is a complex technological concept that is related to both material and process characteristics and this book describes the underlying concepts and practical methods for effective design evaluation and optimization of bulk working operations such as forging rolling and extrusion The Handbook of Workability and Process Design includes updated content from a previous ASTM publication Workability Testing Techniques 1984 as well as substantial new coverage in the areas of process design numerical simulation and computer based modeling of testing and processing conditions Contents Introduction Overview of workability and process design Bulk working behavior of metals Evolution of microstructure during bulk working Workability testing techniques Bulk workability testing Cold upset testing Hot compression testing Hot tension testing Torsion testing to assess bulk workability Hot working simulation by hot torsion testing Thermomechanical testing Process design and workability Design for deformation processes Workability theory and application in bulk forming processes Workability in forging Forging process design Modeling techniques in forging process design Data acquisitions and control Rolling Workability and process design in rolling Drawing Extrusion Workability and process design in extrusion and wire drawing Multidisciplinary process design and optimization Computer aided and multidisciplinary optimization of forging processes Microstructure driven computer aided process optimization Process design of gas turbine engine components using process optimization software Computer aided optimization to improve process engineering productivity for complex die and preform design and process control Index

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