



Cold and Hot Forging: Fundamentals and Applications

Edited by T. Altan, G. Ngaile and G. Shen • 2004
• Approx. 350 pages • ISBN: 0-87170-805-1 • ASM Publication

Among all manufacturing processes, forging technology has a special place because it can be used to produce parts of superior mechanical properties with minimum waste of material. Process selection and optimization are important because of the ever-increasing costs of material, energy, and labor. This reference book reviews the fundamentals

of forging technology, the principal variables of the forging process and their interactions, and computer-aided techniques such as finite element analysis (FEA) for forging process and tooling design.

Topics addressed include the flow behavior of the forged material under processing conditions; die geometry and die materials; friction and lubrication; the mechanics of deformation (strains and stresses); the characteristics of forging equipment; the geometry, tolerances, surface finish and mechanical properties of forgings; and the effects of the process on the environment. A major emphasis is on the latest developments in the design of forging operations and dies, and process modeling using FEA is discussed in all of the relevant chapters.

Several chapters of the book have appendices that consist of computer animations showing the results of FEA simulations for various forging operations. The appendices are provided in Microsoft PowerPoint on the CD-ROM included with the book.

Contents: Metal Forming Processes in Manufacturing • Forging Process-Variables and Descriptions • Plastic Deformation: Strain and Strain Rate • Flow Stress and Forgeability • Deformation: Complex State of Stress and Flow Rules • Temperatures and Heat Transfer • Friction and Lubrication • Simultaneous Determination of Flow Stress and Friction • Methods of Analysis for Forging Operations • Principles of Forging Machines • Presses and Hammers for Forging • Special Machines for Forging • Billet Separation • Process Design in Impression Die Forging • A Simplified Method to Estimate Forging Load in Impression Die Forging • Process Modeling in Impression Die Forging using FEA • Cold and Warm Forging • Process Modeling in Cold Forging using FEA • Microstructure Modeling in Forging • Isothermal and Hot Die Forging • Die Materials and Die Manufacturing • Die Failures in Cold and Hot Forging • Near Net Shape Forging and New Developments • Index

ORDER #05104G-RPDO Price: \$165⁰⁰ / ASM Member: \$132⁰⁰



To order, contact:
Customer Service Center
ASM International
Materials Park, Ohio 44073-0002

1-800-336-5152 dial 6
Or (440) 338-5151, dial 6 (Outside U.S.)
Fax: (440) 338-4634
<http://www.asminternational.org/>
E-mail: cust-srv@asminternational.org

Cold and Hot Forging – Fundamentals and Applications

(Edited by T. Altan, G. Ngaile and G. Shen)

Preface and Table of Contents

PREFACE

Among all manufacturing processes, forging technology has a special place because it helps to produce parts of superior mechanical properties with minimum waste of material. In forging, the starting material has a relatively simple geometry; this material is plastically deformed in one or more operations into a product of relatively complex configuration. Forging to net or to net shape dimensions drastically reduces metal removal requirements, resulting in significant material and energy savings. Forging usually requires relatively expensive tooling. Thus, the process is economically attractive when a large number of parts must be produced and/or when the mechanical properties required in the finished product can be obtained only by a forging process.

The ever-increasing costs of material, energy and especially manpower require that forging processes and tooling be designed and developed with minimum amount of trial and error with shortest possible lead times. Therefore, to remain competitive, the cost-effective application of computer aided techniques, i.e. CAD, CAM, CAE and especially Finite Element Analysis (FEA) based computer simulation, is an absolute necessity. The practical use of these techniques requires a thorough knowledge of the principal variables of the forging process and their interactions. These variables include: a) the flow behavior of the forged material under processing conditions, b) die geometry and materials, c) friction and lubrication, d) the mechanics of deformation, i.e. strains and stresses, e) the characteristics of the forging equipment, f) the geometry, tolerances, surface finish and mechanical properties of the forging, and g) the effects of the process on the environment.

There are many excellent hand books and technical papers on the technology of the forging. These principles are briefly reviewed in this book, but major emphasis is on the latest developments in the design of forging operations and dies. Thus, process modeling using FEA has been discussed in all appropriate chapters. The subject is introduced in Chapter 1 with a discussion of the position of metal forming processes in manufacturing. Chapter 2 considers forging process as a system consisting of several variables that interact with one another. This chapter also includes an overall review of the forging operations. The fundamental of plastic deformation, i.e. metal flow, flow stress of materials, testing methods to determine material properties, and flow rules are discussed in Chapters 3, 4 and 5. Chapters 6 and 8 cover the significant variables of the forging process such as friction, lubrication and temperatures. Chapter 9 is devoted to approximate methods for analyzing simple forging operations. Chapters 10 thru 13 discuss forging machines, including machines for shearing and pre-forming or material distribution. Process and die design, methods for estimating forging loads, and the application of FEA based process modeling in hot forging are discussed in Chapters 14, 15 and 16.

Chapters 17 and 18 cover cold and warm forging, including the application of FEA simulation in these processes. Microstructure modeling, using forging of high temperature alloys as example, is covered in Chapter 19, while Chapter 20 is devoted to isothermal and hot die forging of aerospace

alloys. Die materials, die manufacturing and die wear in hot and cold forging are discussed in Chapters 21 and 22.

Finally, Chapter 23 reviews the near net shape forging technology, including enclosed die forging, multiple-action tooling and the most recent developments in forging presses. This chapter also discusses briefly the future of forging technology in the global economy, the importance of information technology in the forge shop and finally, the need to continuously acquire knowledge on new methods and techniques to remain competitive.

Several chapters of the book (Chapters 4, 6, 7, 14, 15 and 17) have Appendices that consist of computer animations. These animations represent the results of FEA simulations for various forging operations. They are given in a CD that is included with this book. The reader is encouraged to utilize the CD and these Appendices in order to understand better and easier some of the fundamental issues discussed in corresponding chapters.

The preparation of this book has been partially supported by Jacob Wallenberg Foundation Prize, awarded to Dr. Taylan Altan by the Royal Swedish Academy of Engineering Sciences. The staff and the students of the Engineering Research Center for Net Shape Manufacturing (ERC/NSM) of The Ohio State University contributed significantly to the preparation of the book. Specifically, Mr. Pinak Barve, Graduate Research Associate, provided valuable assistance in preparing the text and the figures. Considerable information has been supplied by a large number of companies that support the forging research and development at the ERC/NSM. On behalf of the authors and the editors, I would like to thank all who made our work so much easier. Finally, I would like to thank my wife, Susan Altan, who has offered me enormous support and encouragement throughout the preparation of this book.

Taylan Altan
March 2004

Scroll down for the table of contents

TABLE OF CONTENTS

Chapter 1 Metal Forming Processes in Manufacturing - Manas Shirgaokar

Classification of Manufacturing Processes
Characteristics of Manufacturing Processes
Metal Forming Processes In Manufacturing

Chapter 2 Forging Process-Variables and Descriptions - Manas Shirgaokar

Introduction
Forging Operation as a System
Types of Forging Processes

Chapter 3 Plastic Deformation - Strain and Strain Rate - Manas Shirgaokar & Gracious Ngaile

Introduction
The Stress Tensor
Properties of the Stress Tensor
Plane Stress or Biaxial Stress Condition
Local Deformations and the Velocity Field
Strains
Velocities and Strain Rates
Homogeneous Deformation
Plastic (True) Strain and Engineering Strain

Chapter 4 Flow Stress and Forgeability - Manas Shirgaokar

Introduction
Tensile Test
Compression Test
Ring Test
Torsion Test
Representation of Flow Stress Data
 Appendice 4.1 Determination of Flow Stress by Compression Test at Room Temperature
 Appendice 4.2 Determination of Flow Stress at High Temperature
 Appendice 4.3 Forgeability and Damage Factor in Cold Forging

Chapter 5 Deformation – Complex State of Stress and Flow Rules - Gracious Ngaile

State of Stress
Yield Criteria
Flow Rules
Power and Energy of Deformation
Effective Strain and Effective Strain Rate

Chapter 6 Temperatures and Heat Transfer - Gangshu Shen

Introduction
Heat generation and Heat Transfer in Metal Forming Processes
Temperatures in Forging Operations
Measurement of Temperatures at the Die/Material Interface
Measurement of Interface Heat Transfer Coefficient
Influence of Press Speed and Contact Time on Heat Transfer
 Appendice 6.1 Upset Forging of Cylinders

Chapter 7 Friction and Lubrication - Mark Gariety & Gracious Ngaile

Introduction

Lubrication Mechanisms in Metal Forming
Friction Laws and Their Validity in Forging
Parameters Influencing Friction and Lubrication
Characteristics of Lubricants Used
Lubrication Systems for Cold Forging
Lubrication Systems for Warm and Hot Forging
Methods for Evaluation of Lubricants
 Appendice 7.1 Ring Compression Test
 Appendice 7.2 Double Cup Extrusion Test

Chapter 8 Simultaneous Determination of Flow Stress and Friction - Hyunjoong Cho

Introduction
Inverse Analysis in Metal Forming
Flow Stress Determination in Forging by Inverse Analysis
Inverse Analysis for Simultaneous Determination of Flow Stress and Friction
Example of Inverse Analysis

Chapter 9 Methods of Analysis for Forging Operations - Manas Shirgaokar

Introduction
Slab Method of Analysis
The Upper Bound Method and its Application to Axisymmetric Upsetting
Finite Element Method in Metal Forming

Chapter 10 Principles of Forging Machines - Manas Shirgaokar

Introduction
Interaction Between Process Requirements and Forming Machines
Load and Energy Requirements in Forging
Classification and Characteristics of Forming Machines
Characteristic Data for Load and Energy
Time-Dependent Characteristic Data
Characteristic Data for Accuracy

Chapter 11 Presses and Hammers for Forging - Manas Shirgaokar

Introduction
Hydraulic Presses
Screw Presses
Hammers

Chapter 12 Special Machines for Forging - Pinak Barve

Forging Rolls
Transverse or Cross Rolling Machines
Electric Upsetters
Ring-Rolling Mills
Horizontal Forging Machines or Upsetters
Rotary or Orbital Forging Machines
Radial Forging Machines

Chapter 13 Billet Separation - Serdar Isbir & Pinak Barve

Introduction
Billet And Sheared Surface Quality
Shearing Force, Work And Power
Shearing Equipment

Chapter 14 Process Design in Impression Die Forging - Manas Shirgaokar

Introduction

Forging Process Variables

Shape Complexity in Forging

Design of Finisher Dies

Prediction of Forging Stresses and Loads

Design of Blocker (Preform) Dies

Appendice 14.1 Preform Design in Closed Die Forging

Appendice 14.2 Flash Design in Closed Die Forging

Chapter 15 A Simplified Method to Estimate Forging Load in Impression Die Forging – Hyunjoong Cho

Introduction

Effect Of Process Parameters On Forging Load

Methods For Load Estimation

A Simplified Method for Load Estimation

Example Of Load Estimation

Appendice 15.1 FORGE-PAL – A Computer Program for Estimating Forces in Hot Forging with Flash

Chapter 16 Process Modeling in Impression Die Forging using Finite Element Analysis - Manas Shirgaokar & Gracious Ngaile

Introduction

Information Flow in Process Modeling

Process Modeling Input

Characteristics of the Simulation Code

Process Modeling Output

Examples of Modeling Applications

Chapter 17 Cold and Warm Forging - Prashant Mangukia

Introduction

Cold Forging as a System

Materials for Cold Forging

Billet Preparation and Lubrication in Cold Forging of Steel and Aluminum

Upsetting

Load Estimation for Flashless Closed Die Upsetting

Extrusion

Estimation of Friction and Flow Stress

Prediction of Extrusion Loads From Selected Formulas

Prediction of Extrusion Loads From Model Test

Tooling for Cold Forging

Punch Design for Cold Forging

Die Design and Shrink fit

Process Sequence Design

Parameters Affecting Tool Life

Warm Forging

Appendice 17.1 Examples of Forging Sequences

Appendice 17.2 Forward Rod Extrusion

Appendice 17.3 Backward Cup Extrusion

Chapter 18 Process Modeling in Cold Forging using Finite Element Analysis - Prashant Mangukia

Introduction

Process Modeling Input

Process Modeling Output

Process Modeling Examples

Chapter 19 Microstructure Modeling in Forging - Gangshu Shen

Experiments for Microstructure Model Development

Microstructure Model Formulation

Prediction of Microstructure in Superalloy Forging

Chapter 20 Isothermal and Hot Die Forging - Manas Shirgaokar & Gangshu Shen

Introduction

Isothermal Forging

Hot Die Forging

Benefits of Isothermal and Hot-die Forging

High Temperature Materials for Isothermal and Hot-Die Forging

Equipment and Tooling

Post Forging Heat Treatment

Production Isothermal/Hot-Die Forgings

Economic Benefits of Isothermal and Hot-Die Forging

Chapter 21 Die Materials and Die Manufacturing - Prashant Mangukia

Introduction

Die and Tool Materials for Hot Forging

Heat Treatment

Die and Tool materials for Cold Forging

Die Manufacture

Surface Treatments

Chapter 22 Die Failures in Cold and Hot Forging - Mark Gariety

Introduction

Classification of Die Failures

Fracture Mechanisms

Wear Mechanisms

Analytical Wear Models

Parameters Influencing Die Failure

Prediction of Die Fatigue Fracture and Enhancement of Die Life in Cold Forging Using FEM

Prediction of Die Wear and Enhancement of Die Life in Hot Forging Using FEM

Chapter 23 Near Net Shape Forging and New Developments - Manas Shirgaokar & Gracious Ngaile

Introduction

Tolerances in Precision Forging

Advances in Tool Design

Advances in Forging Machines

Innovative Forging Processes

Future of Forging Technology in the Global Marketplace

The Appendices are power point slides and animations. They are on the CD distributed with this book.