METALS FABRICATION

UNDERSTANDING THE BASICS

Edited by F.C. Campbell

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Dedicated to the memory of

F.C. (Flake) Campbell

Flake Campbell passed away shortly after completing his work on this volume. His 38-year career at The Boeing Co. was split equally between engineering and manufacturing. He worked in the engineering laboratories, manufacturing R&D, engineering on four production aircraft programs, and in production operations. He was a 2001 recipient of Boeing's Senior Technical Fellow award for accomplishments in his field. At retirement, Campbell was a director and senior technical fellow in the field of manufacturing technology within Boeing's Phantom Works service. Campbell received an M.B.A. from Maryville University in St. Louis, 1994, and an M.S. in metallurgical engineering, from the University of Missouri at Rolla, 1972.

Flake loved metallurgical engineering, a lifelong vocation that culminated in the authorship and publication of numerous educational and reference books. He wrote or edited ten books including these ASM International titles: *Elements of Metallurgy and Engineering Alloys*, 2008; *Structural Composite Materials*, 2010; *Joining—Understanding the Basics*, 2011; *Phase Diagrams—Understanding the Basics*, 2011; *Lightweight Materials—Understanding the Basics*, 2012; *Fatigue and Fracture—Understanding the Basics*, 2012; *Inspection of Metals—Understanding the Basics (2013). Metals Fabrication—Understanding the Basics* was the final book he authored before his death in 2013.

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Preface

This book deals with the fabrication processes used to produce metallic products. It is intended primarily for technical personnel who want to learn more about metallic fabrication processes. This book is useful to designers, structural engineers, materials and process engineers, manufacturing engineers, technicians, production personnel, management, faculty, and students.

The first chapter gives an introduction to the processes used at the mill to produce metals and their alloys. Procedures for the primary melting, casting, and hot rolling of steel, aluminum, and titanium are covered. The importance of ladle metallurgy and secondary melting operations, such as vacuum induction melting, vacuum arc remelting, electroslag remelting, and stainless steel refining by argon oxidation decarburization, are emphasized. Both ingot casting and continuous casting are included. Rolling methods covered include hot and cold rolling, along with annealing procedures (batch and continuous).

The second chapter on casting discusses the basics of solidification, casting imperfections, and the important casting methods—sand casting, plaster and shell casting, evaporative pattern casting, investment casting, permanent mold casting, cold and hot chamber die casting, squeeze casting, semisolid metal processing, and centrifugal casting.

The third chapter is on the bulk deformation processes—forging, extrusion, and drawing. The differences between hot and cold working are initially covered. This is followed by a discussion of forging including hammers and presses, die design and materials, lubrication, forging defects, and forging processes. Forging process descriptions are given for open-die forging, closed-die impression forging, hot upset forging, roll forging, high-energy-rate forging, ring rolling, radial forging, isothermal and hot-die forging, precision forging, and cold forging. The chapter concludes with cold and hot extrusion and the various drawing operations.

Sheet metal forming processes (fourth chapter) usually employ hot or cold rolled sheet or strip material that is formed into a desired shape. Topics covered include cutting of plate and flat sheet, die materials for forming,

forming lubricants, and the forming processes of blanking, piercing, fine-edge blanking and piercing, press bending and press-brake forming, deep drawing, stretch forming, spinning, rubber-pad forming, fluid-cell forming, drop hammer forming, electromagnetic forming, and superplastic forming.

The fifth chapter covers traditional, abrasive, and nontraditional machining processes with an emphasis on conventional machining. Topics include workpiece machinability, dimensional and surface finish requirements, surface integrity, the mechanics of chip formation, tool wear and cutting tool materials, cutting and grinding fluids, machining equipment, machining parameters, and machining forces and power requirements.

The sixth chapter discusses the various heat treatments used to thermally alter the property of the metal. Included are steel heat treatments—annealing, stress relieving, normalizing, spheroidizing, and hardening by quenching and tempering. Direct and interrupted quenching processes are explained. The second section of the chapter discusses the various surface-hardening processes, such as flame hardening, induction hardening, case hardening by carburization, nitriding, and carbonitriding. The third part of the chapter covers precipitation hardening with an emphasis of aluminum alloys. However, precipitation hardening is also used extensively to strengthen magnesium alloys, nickel-base superalloys, beryllium-copper alloys, and precipitation-hardening (PH) stainless steels.

The seventh chapter covers the rather wide topic of surface finishing and coatings. Areas included are cleaning methods, abrasive finishing, polishing and buffing, eletropolishing, mass finishing methods such as barrel and vibratory finishing, phosphate and chromate conversion coatings, electroplating (e.g., copper plating, chromium plating, and cadmium plating), electroless plating, weld overlay coatings, thermal spray coatings, high-temperature ceramic coatings, and chemical vapor deposition (CVD) and physical vapor deposition (PVD).

Powder metallurgy (eighth chapter) is the process of blending fine powdered materials, pressing them into a desired shape or form (compacting), and then heating the compressed material in a controlled atmosphere to bond the material together (sintering). The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending, compacting, and sintering. Compacting is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducted at atmospheric pressure. Full-density processes are also included. Optional secondary processing is often used to obtain special properties or enhanced precision.

I would like to acknowledge the help and guidance of Karen Marken, ASM International, and the staff at ASM for their valuable contributions.

F.C. Campbell
St. Louis, Missouri
October 2012

Metal fabrication is the process of building machines and structures from raw metal materials. The process includes cutting, burning, welding, machining, forming, and assembly to create the final product. Metal fabrication projects include everything from hand railings to heavy equipment and machinery. Specific subsectors include cutlery and hand tools; architectural and structural metals; hardware manufacturing; spring and wire manufacturing; screw, nut, and bolt manufacturing; and forging and stamping. Metal fabrication is the process of manufacturing sheet metal and other flat metals to make them conform to specific shapes. The process starts with sheet metal around a quarter of an inch thick or less. At this thickness, the metal is pliable enough to assume different shapes. Different metals are prized in metal fabrication for different reasons. For example, stainless steel is preferred for its lustrous appearance while galvanized steel (steel that is coated with zinc) is popular due to low costs. Like stainless steel, copper is also prized for its luster.Â The intermediate step of metal fabrication suffers from a level of terminology confusion. For our purposes, it is sufficient to simply label this stage of metal fabrication as shaping.