

Preface

In today's rapidly changing product marketplace, the critical requirements for product quality, productivity, and time-to-market have been becoming the most powerful driving force behind any new product design and development (PDD) paradigm for seeking the best design solution and quality product development. This would render the design and development of products full of challenges. From design perspective, how to come out with "design right the first time" and the best design solution is crucial for reducing "time-to-market" and ensuring "quality and defect-free" product development. From product realization point of view, it would reduce trial and error and shorten product development lead time.

In net-shape or near net-shape PDD, plastic deformation process is one of the important manufacturing processes for fabrication of metal-deformed parts and components. The parts or components produced by this traditional manufacturing process are widely used in many industry clusters, ranging from computer, home appliance, medical, consumer electronics, automobile to aerospace industries. The high demand for shorter design and development lead times, good dimensional accuracy, overall quality, and rapid design changes have become the bottleneck issues in metal-forming industry. For the companies which want to maintain their competitiveness and cutting edge in this industrial cluster, there is an urgent need to shorten design and development lead times, reduce production cost, improve product quality, and enhance productivity. The simulation-enabled PDD paradigm and technologies in metal-forming arena help address the above-mentioned issues in this traditional but now revitalizing and promising industrial cluster.

With the advent of finite element method (FEM), finite element (FE)-based simulation, and their wide applications in plastic deformation processes, the traditional metal-formed products development paradigm is shifted from the heuristic know-how and trial and error to in-depth scientific calculation, analysis and simulation to support metal-formed part design, forming process determination and configuration, product quality control and assurance, and the realization of mass production of defect-free metal-formed products. The simulation-enabled metal-formed PDD paradigm provides solutions to address these issues.

In the past decades, extensive researches on simulation-enabled metal-formed PDD have been thoroughly conducted in both academia and industry. The detailed methodologies and techniques to support the above-mentioned design activities have been well explored and developed. This book aims to report the state-of-the-art advances in these areas, which include the fundamentals of rigid-plastic FEM and the FEM-based simulation of metal-forming process, simulation-aided metal-formed part design, process determination and configuration, die design, and product quality assurance and control.

In this book, Chap. 1 first introduces the basis of plastic deformation of materials, plastic deformation or forming processes, and the forming system to realize plastic deformation process. With the forming process and system, the metal-formed parts are fabricated. In addition, the challenges of this traditional manufacturing process are summarized and how to address these issues is briefly summarized. In Chap. 2, the fundamental of rigid-plastic finite element method is articulated, which is the kernel of FEM-based simulation in metal-forming processes. The simulation of plastic deformation processes by FEM is then elucidated and the detailed case studies are given to show its applicability in metal-forming arena.

In Chap. 3, how the FE simulation helps metal-formed part design is introduced. For a given designed product, there can be many design alternatives and solutions generated from metal-formed part design perspective. How good they are and how the corresponding forming systems perform are assessed by using FE simulation. In addition, the forming process determination and process parameter configuration with the aid of FE simulation are presented. By using FE simulation, different process routes and process parameter configurations can be evaluated based on the formability of materials under the given designed metal-forming parts and the quality of the deformed parts. The focus of this chapter is on the evaluation of metal-formed part design, process route, process parameter configuration, and the designed metal-forming system by using FE simulation.

In metal-forming, die is an important tool to deform the workpiece in such a way the metal-formed part is fabricated. Die works under a very severe stress condition and the working stress is not uniformly distributed in the entire die structure and thus the working stress needs to be carefully and rationally designed and controlled to ensure the good performance and long service life. In Chap. 4, the simulation-enabled die and forming system design is presented, which includes different design approaches for die design aided by FE simulation and the methodology to evaluate the entire forming system design based on the proposed evaluation criteria.

In PDD, product quality, production cost, and time-to-market are three overriding issues. Product quality is the first and most important. In metal forming, many defects can be generated in forming processes and some of them can be classified into flow-induced and stress-induced defects. The former is caused by the irrational flow pattern, while the latter is generated by the working stress exceeding the strength limit of materials. The most common defect of the latter is the ductile fracture occurring in forming process. In this book, how to identify these defects

and avoid them via FE simulation is presented in Chaps. 5 and 6. In Chap. 5, the flow-induced defects in multiscaled plastic deformation processes are introduced. The fundamental flow behaviors and formation mechanisms of defects in different scales are revealed and how to avoid the defects is also articulated. In Chap. 6, ductile fracture and stress-induced defects in multiscaled deformation are described. The defect formation mechanisms and evaluation criteria are summarized. The modeling, simulation, and prediction of the ductile fracture and stress-based defects are summarized, which provide a systematic basis for defect analysis in multiscaled, especially for microscaled plastic deformation.

Metal-forming has been becoming an important manufacturing process for long time due to its high productivity, good product quality, and low production cost. This conventional manufacturing process, however, has been traditionally linked to long years of apprenticeship and skilled craftsmanship. The traditional product design and development paradigm cannot meet more and more demanding requirements in the current competitive marketplace, and the simulation-enabled metal-formed PDD paradigm provides solutions to address these issues. This book is thus intended to give the comprehensive description and thorough articulation of the state-of-the-art simulation-enabled PDD paradigm in this arena for students, researchers, and engineers in industries, R&D organizations, and academia. In addition, this book also provides valuable information to this manufacturing field and can be used as a reference and textbook for a graduate course in learning this very useful and practical manufacturing process.

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and Products Aided by Finite Element Simulation

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