Preface

Machine tool design and manufacturing are tightly associated with innovation. They have been the key areas that support and influence a nation's economy since the eighteenth century. This is especially true for the machine tool industry. As the mother machines, machine tools form the basis for the development of many other products. In the past centuries, machine tool design and manufacturing have contributed significantly to modern civilisation and created the momentum that drives today's economy. Despite various achievements, we are still facing challenges due to the growing complexity in machine tool design and development.

The complexity comes from multiple directions. On one hand, the complex shape and geometry of new products require more sophisticated machining capability of machine tools to produce the new products to specifications. On the other hand, the ever-growing quality requirements of customers demand tight tolerance for the manufactured products. Consequently, a machine tool must perform accurately, reliably and with high repeatability over time.

It is a common practice that a machine tool is designed and analysed in static state with constraints and under assumptions. A so-designed machine may not perform consistently over time in running state. Among varying working conditions in reality, uneven temperature distribution across the machine components is most influential to machining accuracy due to thermal deformation during metal cutting operations. This thermal deformation alters the cutter–workpiece relationship dynamically, resulting in unsatisfactory machined surfaces. Although modern computer-aided techniques are helpful in addressing some of the problems in machine tool design, there still remains a big gap between the required performance and the real performance of a machine because of the static nature of problem-solving capability of current software tools and applied technology. Two significant problems remain to be solved: (1) how to effectively share information between solid modelling and engineering analysis modules, and (2) how to satisfactorily enable dynamic analysis to simulate the true behaviours of machine tools in running state.

To bridge the gap and present the state-of-the-art of machine tool design and development to a broad readership, from academic researchers to practicing engineers, is the primary motivation behind this book.

This book summarises basic concepts, fundamental considerations and problem-solving algorithms relevant to machine tool design and analysis in running state. The book is composed of six chapters, and a brief outline of each chapter is given below. Chapter 1 provides an introduction of the historical background of relevant research, and clarifies why this research is necessary to be carried out and what the objectives of the research are. Based on the literature analysis, the motivation of this book on dynamic thermal analysis for machine design is carefully laid out. Chapter 2 provides a detailed description of the techniques for representation of machine tool models. Constructive Solid Geometry (CSG) is adopted as the primary representation in this book, among contemporary solid modelling methods, for the ease of modelling of machine tool structures. A low-level data structure is documented for establishing a primitive library with the characteristics of machine tool structures. Chapter 3 presents a method to implement a product modelling system for machine tool design. Based on the design process of machine tools, considerable requirements to be met in the product modelling system are specified, together with the definition of product models. For the purpose of system development, a high-level data structure for both components and an entire machine tool is proposed. Kinematic simulations, as case studies, are carried out by using the product modelling system. The connection between the product modelling system and an integrated CAD/CAE system is emphasised.

Moving from modelling to analysis, Chap. 4 presents a new method for dynamic finite element mesh generation, called Coded Box Cell (CBC) substitution approach in this book. Hexahedrons are chosen as the mesh elements for the convenience of automatic generation and modification of FEM meshes, since machine tools are mostly composed of cuboids and box-type primitives. The extension of the CBC substitution to curved objects is introduced by using mapping and inverse mapping techniques. Full details of the CBC substitution approach are described in this chapter. A new data structure of machine tool model for its utilisation in FEM mesh generation is also given, based on which several practical case studies are carried out. Chapter 5 showcases an application of the CBC substitution approach to finite element analysis. Since thermal error is the major factor that affects the machine tool designs, the thermal analysis is taken into consideration. The table and the base of a machine tool is simplified as the model of the thermal analysis. The Emphasis is given to the interpolation of intermediate results between consecutive analytical steps for the purpose of a continuous calculation, when relative motions take place between the table and the base. The corresponding experiments under the same running conditions are conducted. Based on the analytical and experimental results, discussions and evaluations are documented. Finally, Chap. 6 draws to the conclusions of this book. After summarising each chapter and the research findings, challenges and future research directions are pointed out for interested readers working in the same field.

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