Preface

About the Book

The first edition of the book was published in 1984 under the title, *Machine Tool Design*, when the subject was gaining popularity as a specialised course in engineering institutions in the country. The motivation for writing the book is to provide a basic text for undergraduate students that would also serve as a useful reference for postgraduate students and practicing engineers.

The revision of the book for the second edition published in 1996 was undertaken with the limited objective of incorporating the advances in numerical control in the intervening years. Therefore, the chapter on 'Numerical Control of Machine Tools' was substantially modified and a new chapter on Extensions of Numerical Control – CNC, DNC, Machining Centers' was added. To adequately, reflect the updated content, the title of the book was changed to *Machine Tool Design and Numerical Control*.

In today's 'user-friendly age', the revision for the third edition has been undertaken primarily to make the book more reader friendly and the changes are mostly based on the feedback from the reviewers and a survey carried out by the publisher.

The important new features of this edition are summarised below:

- A subsection on 'Calculation of Machining Time' has been added in Chapter 1. The highlight of this section is the inclusion of calculation of machining time of grinding operations which is usually not covered in text books.
- A major section on 'Kinematics of Machines Tools' has been added in Chapter 2, wherein the gearing diagrams of lathe, drilling machine and milling machine have been discussed to give the reader a better understanding of the finer practical aspects of gear box design. A new attractive feature of this section is the discussion on thread cutting operation on lathe and operations using indexing head on milling machine based on fundamental principles, as distinct from the usual thumb rule type approach in most of the existing books. It is felt that this section will serve as useful base material for formulating design projects and independent assignments for final year students of mechanical and production engineering disciplines
- In the second edition the design procedure of machine tool gear boxes was terminating with the calculation of gear teeth. This has been extended in the present edition, to its logical conclusion by adding a subsection on 'Determination of Shaft and Gear Dimensions' in Chapter 2.
- A subsection on 'Design of Lathe Bed' has been added in Chapter 3 giving the detailed procedure supported with a solved example to provide practical illustration of the theoretical aspects for one specific case. This material will be helpful in formulating design projects and assignments not only for beds of various machine tools but also for other structural elements of machine tools such as bases, columns, tables etc.
- A large number of solved examples have been added, especially in Chapters 1–3 in support of the elaboration of the new topics added in these chapters. In addition, new review questions have also been added in almost all the chapters.

- A major curtailment has been undertaken in Chapter 8 on 'Numerical Control of Machine Tools'. Previous edition contained a detailed description of the hardware of NC technology spread over seven subsections. Most of this technology has now become obsolete. It has, therefore, been thoroughly condensed and retained in one subsection only to the extent necessary for understanding the functioning/operation of NC machine tools.
- Enhanced pedagogy includes

  ***Solved Examples*: 25**
  ***Review* Questions: 130**
  ***Computer Programs for NC, CNC and* DNC: 12**

Structure of the Book

The book is organised into 9 chapters. **Chapter 1** is an introductory chapter that provides a review of the concepts of working and auxiliary motions in machine tools and calculation of machining time of various operations. It also gives an overview of the elements of hydraulic and mechanical transmissions employed in machine tools. A section on layout of machine tools is unique to this book and is extremely relevant in the context of increasing emphasis on modularity and reconfigurability in CNC machines.

Chapter 2 deals with the description of the laws of stepped regulation of speed and feed in machine tools and goes on to provide in rigorous detail the procedures for the design of gear boxes for stepped control of speed and feed, covering the whole gamut of issues from selecting the optimum structural diagram and speed chart to the finalisation of gearing diagram and determination of shaft and gear dimensions. A separate section is devoted to design of gear boxes with multiple speed motors and special gear boxes with overlapping speeds, broken geometric progression, etc., which have been supported with multiple diagrams. Steeples regulation of speed and feed rates by electrical, hydraulic and mechanical methods is discussed in great detail. To strengthen the understanding of kinematics of machining operations, thread cutting on lathe and operations using indexing head on milling machine are described from first principles, as distinct from the thumb rule approach presented in most of the existing books.

In **Chapter 3**, the functions and requirements of the machine tool structures are discussed along with the design criteria and their application to individual structural elements such as beds, bases, columns etc. Aspects of design related to selection of the shape of structural elements and their strengthening with ribs and stiffeners are discussed in detail with lot of supporting data. In view of the complexity of their configuration and force system, it is seldom possible to analytically arrive at an exact design solution for structural elements of machine tools. Model techniques are therefore an essential part of the validation of their design and the fundamentals of these techniques are discussed at the end of the chapter.

The description of the functions and classification of guide ways are dealt in **Chapter 4**. The design criteria of slideways are discussed and the detailed procedure of slideways design for stiffness and wear resistance based on average and maximum pressure is presented. Selection of slideway profiles and techniques of clearance adjustment and protection are presented and explained with the help of simple sketches. The design of hydrodynamic guideways, hydrostatic guideways, aerostatic guideways and anti-friction guideways is described in detail, supported with analysis as well as the relevant design data and curves. Design of sliding friction and rolling friction power screws is also included in this chapter.

Chapter 5 discusses the functions and requirements of machine tool spindles and an analyses the effect of the compliance of spindles and their supports on machining accuracy. A major portion of this chapter is devoted to the design of sliding bearings, hydrodynamic and hydrostatic journal bearings and aerodynamic

and aerostatic bearings, supported with analysis and the relevant design data and curves. Issues specific to machine tools such as functional requirements, appropriate combinations of bearings for different machine tools and pre loading of bearing are discussed in detail.

The initial thrust of **Chapter 6** is on establishing the study of the dynamic behaviour of a machine system. The latter can be looked upon as a closed loop system in which the machine tool elastic system (MTES) and cutting process (CP) are the interacting elements. The dynamic cutting force models of Tlusty, Tobias and Kudinov are discussed and compared. Stability analysis of single and multiple degree of freedom systems with and without mode coupling is described. Regenerative chatter and the response of MTES-CP system under forced vibrations are also discussed. Dynamics of machine tools is a difficult topic, but by adopting a logical approach based on fundamental principles of control theory, it has been made easy to understand.

Chapter 7 discusses the functions, requirements and classification of machine tool controls and goes on to describe the speed and feed changing mechanisms with simple centralised control, preselective control and selective control. For manual control systems, anthropometric and functional anatomy data has been systematically compiled for ergonomic design of control members such as push buttons, knobs, toggles, cranks, levers, hand wheels, etc., and also for the location of displays and control members. The highlight of this chapter is the detailed compilation of data for ergonomics design of control members which is not only unique to this book but also sets it apart from any other text book on machine tool design.

Chapter 8 elaborates on the fundamental concepts of numerical control and classification of numerically controlled machine tools. It provides an overview of the NC hardware technology to the extent necessary for understanding the functioning and operation of NC machine tools. A major portion of this chapter is devoted to manual part programming for point-to-point, positioning- cum-straight cut and continuous path systems. The concept of computer aided part programming has been discussed and the APT programming system has been covered in reasonable detail. Both the manual and APT part programming systems have been illustrated with sample problems with step-by-step explanation of the part programs.

The concluding chapter, i.e., **Chapter 9** deals with the extensions of numerical control, namely computer numerically controlled (CNC) machine tools, machining centres and direct numerical control (DNC). A major portion of this chapter is devoted to CNC part programming for machining centres as well as turning centres. The programming concepts of tool diameter compensation, tool length off set, etc., are taken one at-a-time and illustrated with suitable programming examples. Advanced programming features such as mirror imaging and canned cycles are discussed and illustrated with complete programs for sample parts.

In addition, the present edition also contains new and improved solved examples, computer programs and chapter-end review questions to help students understand the concepts in a better way.

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In the end, I must confess that the response received from the readers for the earlier editions is both humbling and gratifying. I am grateful to them for their continuous support of my modest contribution to the teaching and practise of machine tool design and numerical control. I sincerely hope that the changes incorporated in the current edition will add more value to the book and will continue to provide useful service to students, teachers and practising engineers for many more years to come.

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