This text-book explains the fundamentals of NC/CNC machine tools, operations and part programming which form essential portion of course on Computer Aided Manufacturing (CAM). This book also covers advanced topics such as Macro programming, DNC and Computer Aided Part Programming (CAPP) in detail.

In this second revised and enlarged edition, all the chapters are reviewed and relevant topics, examples, part programs, sketches, review questions and exercises have been added to enhance the utility of the book.

This book is divided into 6 major areas.

Chapter 1 to 4 cover the history, fundamentals and structure of NC/CNC machine tools.

Chapter 5, 6 and 7 cover turning center programming in detail. Various turning canned cycles are discussed in depth with the help of illustrative examples.

Chapter 8 and 9 are devoted to machining center programming. Drilling canned cycles are discussed in detail with relevant examples.

Chapter 10 and 11 cover advanced topics of subprogramming and macro programming.

Chapter 12 deals with the communications and networking of NC/CNC machine tools.

Chapter 13 and 14 explain the advanced programming using APT and CAD/CAM based programming respectively.

The book contains:

* 258 Self explanatory and neatly drawn drawings
* 62 Solved part programming examples
* 37 Part programming exercises
* 173 Review questions at the end of all the chapters
* 101 Multiple choice questions.

It is the fervent hope of the authors that book will satisfy the needs of the Mechanical, Production, Mechatronics and Automobile Engineering students preparing for the B.Tech/B.E. examinations of all the Indian Universities, Diploma examinations conducted by various Boards of Technical Education, Certificate course as well as for the A.M.I.E., U.P.S.C., G.A.T.E., I.E.S. and other similar competitive and professional examinations. It should also be of an immense help to the practising Mechanical Engineers.
Chapter 1 INTRODUCTION TO NC/CNC MACHINE TOOLS

1-1. History of NC machines

1-2. Introduction to numerical control (NC) machine tools

1-3. CNC (Computer Numerical Control)

1-4. Differences between NC and conventional machine tools

(a) Spindle drives
(b) Guideways
(c) Motion transmission
(d) Feed drives
(e) Machine tool structure
(f) Control unit
(g) Feedback unit
(h) Automatic tool changer (ATC)
(i) Automatic pallet changer (APC)

1-5. Advantages of CNC over NC

(a) Controller
(b) Memory
(c) Part program editing
(d) Cutter compensation
(e) Multimass canned cycles
(f) Advance part programming
(g) Tool path simulation
(h) Conversational programming
(i) Diagnostic

1-6. Advantages of NC and CNC over Conventional machine tools

(a) Increased flexibility
(b) More complex geometry
(c) Higher production rate
(i) Reduced set-ups
(ii) Reduced lead time
(iii) Reduced non-machining time
(iv) Higher accuracy and repeatability
(v) Reduced inspection
(vi) Reduced operator skill
(vii) Reduced scrap
(viii) Reduced work-in-process inventory
(ix) Elimination of profile tools
(x) Simpler fixtures
(xi) Optimum cutting conditions

1-7. Limitations of NC/CNC machine tools

(a) Cost
(b) High maintenance costs
(c) Not cost effective for low production levels
(d) Programming skill

1-8. Specifications of a typical turning center

(a) Axes system
(b) Main spindle
(c) Tool turret
(d) Tail stock (with hydraulic quill)
(e) Other Features

1-9. Specifications of a typical vertical machining center (VMC)

(a) Axes system
(b) Table
(c) Headstock
(d) ATC system
(e) Special features

1-10. Role of NC/CNC technology in modern manufacturing

(a) Machining
(b) Unconventional machining
(c) Fabrication and welding
(d) Press work
(e) Material handling and assembly
(f) Inspection and measurement
(g) Wood working

1-11. Multi-tasking machine tools

Review questions 1

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Follow us:

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2-1. Axes designation

2-1-1. Coordinate system

2-1-2. Designating the axes

2-2. Axes system of different machine tools

2-2-1. Turning center

2-2-2. Vertical machining center (VMC)

2-2-3. Horizontal machining center

2-2-4. Turn mill center

2-2-5. Three axes planer

2-2-6. Four axes machining center

2-2-7. Five axes horizontal boring machine

2-2-8. Five axes vertical machining center

2-3. Reference points

2-3-1. The grid system

2-3-2. Machine origin or machine zero

2-3-3. Part origin or part zero

2-3-4. Tool reference point

2-4. CNC control systems

2-4-1. Point-to-Point control (P-type)

(i) Axial path

(ii) 45° path

(iii) Linear Path

2-4-2. Line control/straight cut control (L-type)

2-4-3. Continuous path control (C-type)

(i) 2-D contouring control

(ii) 2½-D contouring control

(iii) 3-D contouring control

(iv) 4-D contouring control

2-4-4. Example of P, L and C type controls

2-5. Automatic tool changer (ATC)

2-6. Automatic pallet changer

Review questions 2

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3-1. Machine tool structure

3-2. Machine tool spindle

(i) Belt driven spindle

(ii) Integral motor-spindle

3-3. Spindle bearings

3-4. Guideways

3-5. Transmission system

3-5-1. Recirculating ballscrews

(i) Double nut preloading

(ii) Single nut preloading

3-5-2. Roller screw

3-6. Drives

3-6-1. Stepper motor

3-6-2. AC/DC rotary servo motor

3-6-3. Linear motor

3-7. Open loop and closed loop control systems

3-7-1. Open loop control system

3-7-2. Closed loop control system

3-8. Feedback devices

3-8-1. Incremental optical encoders

3-8-2. Absolute optical encoders

(i) Pure binary code

(ii) Gray code

(iii) Gray excess code

3-9. CNC Tooling

3-9-1. Qualified tool

3-9-2. Preset tools/semi-qualified tools

3-9-3. Tool preseters

3-9-4. Tool holders

Review questions 3

Exercise 3
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### 4-1. Coding systems
- (1) Fixed sequential format
- (2) Tab sequential format
- (3) Word address format
  - (i) Alphabet
  - (ii) Digits
  - (iii) Operators
  - (iv) Special characters

### 4-2. Punched paper tapes
- (1) ISO code
- (2) EIA code

### 4-3. Punched tape readers
- (1) Electromechanical tape reader
- (2) Photoelectric tape reader
- (3) Pneumatic tape reader
- (4) Magnetic tapes

### 4-4. Types of codes
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- (2) Preparatory code
- (3) Miscellaneous code
- (4) Axis words
- (5) Feed word
- (6) Speed word
- (7) Tool number

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### 4-4-2. Miscellaneous codes

### 4-4-3. Modal and Non-modal codes

### 4-5. Decimal point programming

### 4-6. Absolute and incremental positioning

### 4-6-1. Absolute programming or positioning

### 4-6-2. Incremental/relative programming or positioning

### 4-7. Diameter and radius programming

### 4-8. Programming functions

### 4-8-1. Data input units

### 4-8-2. Spindle speed control
- (1) Direction
- (2) Spindle speed

### 4-8-3. Feedrate control

### 4-8-4. Coordinate system preset

### 4-8-5. Tool and tool offset

### 4-8-6. Program control
- (1) M00: Program stop
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- (4) M30: Program stop and rewind

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### 5-1. Rapid Traverse (G00)

### 5-2. Linear Interpolation (G01)

### 5-3. Circular Interpolation (G02/G03)
- (1) Cutting direction (G02 or G03)
- (2) Arc end point coordinates
- (3) Radius of arc or center of arc

### 5-4. Tool Compensations
- (1) Geometry offsets
- (2) Wear offsets
- (3) Tool nose radius compensation

### 5-4-1. Geometry Offsets

### 5-4-2. Wear Offset

### 5-4-3. Tool Nose Radius Compensation

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