A TEXTBOOK OF PRODUCTION ENGINEERING

Dr. P.C. SHARMA

S. CHAND

A TEXTBOOK OF
PRODUCTION ENGINEERING

P.C. SHARMA
B.Sc. Engg. (Mech.) (Hons.)
M.Sc. Engg. (Mech.) (Distinction)
Ph.D., I.I.T. (Delhi), LMISME, MISTE
Visiting Professor
SUS College of Engineering and Technology
Tangori (Mohali), Punjab
Formerly of Punjab Engineering College
CHANDIGARH

S. CHAND & COMPANY LTD.
(An ISO 9001 : 2000 Company)
RAM NAGAR, NEW DELHI - 110 055

S. CHAND & COMPANY LTD.

(An ISO 9001 : 2000 Company)

Head Office: 7361, RAM NAGAR, NEW DELHI - 110 055
Phone: 23672080-81-82, 9899107446, 9911310888
Fax: 91-11-23677446
Shop at: **schandgroup.com;** e-mail: **info@schandgroup.com**

Branches :

AHMEDABAD : 1st Floor, Heritage, Near Gujarat Vidhyapeeth, Ashram Road, **Ahmedabad** - 380 014, Ph: 27541965, 27542369, ahmedabad@schandgroup.com

BANGALORE : No. 6, Ahuja Chambers, 1st Cross, Kumara Krupa Road, **Bangalore** - 560 001, Ph: 22268048, 22354008, bangalore@schandgroup.com

BHOPAL : 238-A, M.P. Nagar, Zone 1, **Bhopal** - 462 011, Ph: 4274723. bhopal@schandgroup.com

CHANDIGARH : S.C.O. 2419-20, First Floor, Sector - 22-C (Near Aroma Hotel), **Chandigarh** -160 022, Ph: 2725443, 2725446, chandigarh@schandgroup.com

CHENNAI : 152, Anna Salai, **Chennai** - 600 002, Ph: 28460026, chennai@schandgroup.com

COIMBATORE : Plot No. 5, Rajalakshmi Nagar, Peelamedu, **Coimbatore** -641 004, (M) 09444228242, coimbatore@schandgroup.com

CUTTACK : 1st Floor, Bhartia Tower, Badambadi, **Cuttack** - 753 009, Ph: 2332580; 2332581, cuttack@schandgroup.com

DEHRADUN : 1st Floor, 20, New Road, Near Dwarka Store, **Dehradun** - 248 001, Ph: 2740889, 2740861, dehradun@schandgroup.com

GUWAHATI : Pan Bazar, **Guwahati** - 781 001, Ph: 2738811, 2735640 guwahati@schandgroup.com

HYDERABAD : Sultan Bazar, **Hyderabad** - 500 195, Ph: 24651135, 24744815, hyderabad@schandgroup.com

JAIPUR : A-14, Janta Store Shopping Complex, University Marg, Bapu Nagar, **Jaipur** - 302 015, Ph: 2719126, jaipur@schandgroup.com

JALANDHAR : Mai Hiran Gate, **Jalandhar** - 144 008, Ph: 2401630, 5000630, jalandhar@schandgroup.com

JAMMU : 67/B, B-Block, Gandhi Nagar, **Jammu** - 180 004, (M) 09878651464

KOCHI : Kachapilly Square, Mullassery Canal Road, Ernakulam, **Kochi** - 682 011, Ph: 2378207, cochin@schandgroup.com

KOLKATA : 285/J, Bipin Bihari Ganguli Street, **Kolkata** - 700 012, Ph: 22367459, 22373914, kolkata@schandgroup.com

LUCKNOW : Mahabeer Market, 25 Gwynne Road, Aminabad, **Lucknow** - 226 018, Ph: 2626801, 2284815, lucknow@schandgroup.com

MUMBAI : Blackie House, 103/5, Walchand Hirachand Marg, Opp. G.P.O., **Mumbai** - 400 001, Ph: 22690881, 22610885, mumbai@schandgroup.com

NAGPUR : Karnal Bag, Model Mill Chowk**,** Umrer Road, **Nagpur** - 440 032, Ph: 2723901, 2777666 nagpur@schandgroup.com

PATNA : 104, Citicentre Ashok, Govind Mitra Road, **Patna** - 800 004, Ph: 2300489, 2302100, patna@schandgroup.com

PUNE : 291/1, Ganesh Gayatri Complex, 1st Floor, Somwarpeth, Near Jain Mandir, **Pune** - 411 011, Ph: 64017298, pune@schandgroup.com

RAIPUR : Kailash Residency, Plot No. 4B, Bottle House Road, Shankar Nagar, **Raipur -** 492 007, Ph: 09981200834, raipur@schandgroup.com

RANCHI : Flat No. 104, Sri Draupadi Smriti Apartments, East of Jaipal Singh Stadium, Neel Ratan Street, Upper Bazar, **Ranchi** - 834 001, Ph: 2208761, ranchi@schandgroup.com

VISAKHAPATNAM : Plot No. 7, 1st Floor, Allipuram Extension, Opp. Radhakrishna Towers, Seethammadhara North Extn., **Visakhapatnam** - 530 013, (M) 09347580841, visakhapatnam@schandgroup.com

First Edition 1982
Subsequent Editions and Reprints 1986, 88, 89, 90, 92 (Twice), 94, 95, 96, 97 (Twice), 99, 2000, 2002, 2003, 2005, 2006 (Twice), 2008
Reprint with Corrections 2009

ISBN : 81-219-0111-1 Code : 10A 038

printed in india

By Rajendra Ravindra Printers Pvt. Ltd., 7361, Ram Nagar, New Delhi -110 055 and published by S. Chand & Company Ltd., 7361, Ram Nagar, New Delhi -110 055.

PREFACE TO THE ELEVENTH EDITION

The author feels very happy to present the revised edition of the book to the readers. This standard treatise on "Production Engineering" was first publishing in 1982. During the last about 26 years, it has kept a close rapport with the readers. The publication of the new edition has given an opportunity to me to incorporate the latest developments in the field in the text. Additional material has been included in chapters : 1, 2, 4, 5, 9, 10, 11, 14, 15, 20, 21 and 24.

While every attempt has been made to ensure that no errors (printing or otherwise) enter the text, the possibility of these creeping into the text is always these. I shall be grateful to the readers to bring these errors to my notice so that these may be rectified in the subsequent editions.

AUTHOR

PREFACE TO THE TENTH EDITION

The author is grateful to the readers for the tremendous response to the Ninth edition of the book.

The author has done his best to remove all the errors in the text. The author shall feel grateful if the readers point out the errors in the text, which might have been overlooked.

In the present revised edition of the book, about 200 problems from various competitive examinations (GATE, IES, IAS) have been included. The author does hope that with this, the utility of the book will be further enhanced.

AUTHOR

CONTENTS

Chapters *Pages*

1. JIGS AND FIXTURES **1 – 68**

1.1 General (1); 1.2 Locating and clamping (2); 1.3 Design principles common to jigs and fixtures (17); 1.4 Drilling jigs (20); 1.5 Milling fixtures (31); 1.6 Lathe fixtures (34); 1.7 Grinding fixtures (35); 1.8 Broaching fixtures (36) 1.9 Assembly fixtures (37); 1.10 Inspection fixtures (39); 1.11 Boring fixtures (40); 1.12 Planing and Shaping fixtures (41); 1.13 Indexing jigs and fixtures (41); 1.14 Automated jigs and fixtures (43); 1.15 Fundamentals of jig and fixture design (47) 1.16 Jig and fixture construction (49); 1.17 Materials for Jigs and Fixtures (50); 1.18 Tolerance and Error analysis (53); 1.19 Analysis of Clamping Forces (61); PROBLEMS (66).

2. PRESS TOOL DESIGN **69 – 146**

2.1 General (69); 2.2 Press operations (69); 2.3 Press working equipment (72); 2.4 Press selection (76); 2.5 Press working terminology (76); 2.6 Types of dies (78); 2.7 Principle of metal cutting (80); 2.8 Clearance (81); 2.9 Cutting forces (83); 2.10 Methods of reducing cutting forces (84); 2.11 Minimum diameter of piercing (87); 2.12 Blanking die design (88); 2.13 Piercing die design (108); 2.14 Pilots (110); 2.15 Drawing dies (111); 2.16 Bending dies (116); 2.17 Design procedure for progressive dies (127); 2.18 Dimensions of Back-post die-sets (128); 2.19 Materials and manufacture of sheet metal working dies (129); 2.20 Solved examples (132); PROBLEMS (144).

3. FORGING DIE DESIGN **147 – 193**

3.1 General (147); 3.2 Forging equipment (149); 3.3 Design of a forging (156); 3.4 Die-design for Drop forging and Press forging (163); 3.5 Die-Design for Machine forging (171); 3.6 Determination of stock size (174); 3.7 Selection of forging equipment (176); 3.8 Selection of sizes of forging equipment (177); 3.9 Die-inserts (179); 3.10 Solved examples (180); 3.11 Tools for flash trimming and hole piercing (181); 3.12 Materials and manufacture of forging dies (183); 3.13 Die-Manufacture (183); 3.14 Electro-removal processes (189); 3.15 Cast dies (190); 3.16 Resinking of dies (190); 3.17 Size of Die Blocks (192); 3.18 I.S. Code (192); PROBLEMS (192).

4. COST ESTIMATION **194 – 235**

4.1 Definition (194); 4.2 Cost accounting or costing (194); 4.3 Elements of cost (195); 4.4 Estimation of cost elements (198); 4.5 Methods of cost estimating (204); 4.6 Data requirement for cost estimating (205); 4.7 Steps in making a cost estimate (205); 4.8 Chief factors in cost estimating (206); 4.9 Numerical examples (206); 4.10 Calculation of machining Times (211); 4.11 Estimation of total unit time (231) PROBLEMS (234).

5 ECONOMICS OF TOOLING **236 – 297**

5.1 Introduction (236); 5.2 Machine tool replacement (244); 5.3 Mathematical analysis (265); 5.4 Economics of small tool selection (269); 5.5 Break even point analysis (273); 5.6 Economic lot size (286); PROBLEMS (292).

6. PROCESS PLANNING **298 – 320**

6.1 General (298); 6.2 Contents of a process plan (299); 6.3 Process operations (299); 6.4 Steps of process planning (301); 6.5 How process plans are expressed (307); 6.6 Planning and tooling for low cost processing (308); 6.7 Solved examples (314); Problems (319).

7. TOOL LAYOUT FOR CAPSTANS AND TURRETS **321 – 339**
7.1 General (321); 7.2 Types of turret lathes (322); 7.3 Main parts (323); 7.4 Work-holding equipment (326); 7.5 Standard equipment and tools (328); 7.6 Machine operations (330); 7.7 Advantages of turret lathe (331); 7.8 Tool layout (331); 7.9 Bar stock feeding mechanism (332); 7.10 Solved examples (334); 7.11 Programme controlled turret lathes (338); PROBLEMS (338).

8. TOOL LAYOUT FOR AUTOMATICS **340 – 358**
8.1 Automatic lathes (340); 8.2 Classification of Automatic machines (340); 8.3 Classification of semi-automatics (348); 8.4 Setting up of automatics and semi-automatics (348); 8.5 Tooling layout and operation sheet (348); 8.6 Cam design (350); 8.7 Tool layout for automatic screw machine (351); 8.8 Programmed automatic lathes (356); 8.9 Bar stock feeding (356); PROBLEMS (357).

9. LIMITS, TOLERANCES AND FITS **359 – 385**
9.1 General (359); 9.2 Terminology for limits and fits (359); 9.3 Meaning of limits (364); 9.4 General limits of tolerance (364); 9.5 Limit systems (368); 9.6 Selective assembly (376); 9.7 Solved examples (376); PROBLEMS (383).

10. GAUGES AND GAUGE DESIGN **386 – 413**
10.1 Introduction (386); 10.2 Plain gauges (386); 10.3 Design of limit gauges (390); 10.4 Manufacture of limit gauges (398); 10.5 Choice of limit gauges (399) 10.6 Thread or screw gauges (401); 10.7 Advantages of limit gauges (402); 10.8 Limits of limit gauges (402); 10.9 Care of gauges (403); 10.10 Other types of gauges (404); 10.11 Solved examples (407); PROBLEMS (411).

11. SURFACE FINISH **414 – 439**
11.1 Introduction (414); 11.2 Elements of surface roughness (415); 11.3 Evaluation of surface roughness (417); 11.4 Representation of surface roughness (422); 11.5 Relationship of surface roughness to production methods (423); 11.6 Effect of surface roughness on the performance of machine parts (425); 11.7 Measurement of surface roughness (426); 11.8 Surface finishing processes (428); 11.9 Superfinishing (435); 11.10 Polishing (435); 11.11 Numerical Examples (436); PROBLEMS (437).

12. MEASUREMENT **440 – 476**
12.1 General (440); 12.2 Calipers (441); 12.3 Vernier calipers (442); 12.4 Vernier height gauge (444); 12.5 Vernier depth gauge (445); 12.6 Micro-meter caliper (445); 12.7 Slip gauges (448); 12.8 Checking straightness and flatness (449); 12.9 Checking squareness (453); 12.10 Dial gauge Indicator (453); 12.11 Surface gauge (455); 12.12 Checking of parallelism (455); 12.13 Measurement of angles (456); 12.14 Telescopic gauge (462); 12.15 Small hole gauges (462); 12.16 Feeler gauges (462); 12.17 Radius gauges (463); 12.18 Comparators (463); 12.19 Optical measuring instruments (470); PROBLEMS (475).

13. ANALYSIS OF METAL FORMING PROCESSES **477 – 528**
13.1 Theoretical basis for metal forming (477); 13.2 Classification of metal forming processes (483); 13.3 Effect of variables on metal forming processes (486); 13.4 Methods of analysis of manufacturing processes (487); 13.5 Open die forging (488); Closed die forging; 13.6 Rolling (496); 13.7 Drawing (Wire, Rod, Tube) (505); 13.8 Extrusion (512); 13.9 Solved examples (515); PROBLEMS (527).

14. THEORY OF METAL CUTTING **529 – 585**
14.1 Introduction (529); 14.2 The mechanics of chip formation (529); 14.3 Single point cutting tool (530); 14.4 Methods of machining (537); 14.5 Types of chips (537); 14.6 Determination of shear angle (539); 14.7 Determination of undeformed chip thickness

(541); 14.8 Force relations (543); 14.9 Energy considerations is metal cutting (548); 14.10 Oblique cutting (549); 14.11 Tool wear and tool life (550); 14.12 Economics of metal cutting (556); 14.13 Machineability (559); 14.14 Surface roughness (561); 14.15 Solved examples (563); PROBLEMS (577).

15 DESIGN AND MANUFACTURE OF CUTTING TOOLS 586 – 633

15.1 Types of cutting tools (586); 15.2 General problems of cutting tool design (589); 15.3 Single point cutting tools (589); 15.4 Milling cutters (592); 15.5 Broach design (598); 15.6 Drills (604); 15.7 Reamers (611); 15.8 Form tools (618); 15.9 Combination tools (620); 15.10 Manufacture of cutting tools (622); PROBLEMS (631).

16 GEAR MANUFACTURING 634 – 655

16.1 Introduction (634); 16.2 Materials (634); 16.3 Methods of manufacture (635); 16.4 Gear cutting by milling (636); 16.5 Gear cutting by single point formed tool on shaper/planer (638); 16.6 Broaching (638); 16.7 Shear speed process (638); 16.8 Gear planing (638); 16.9 Gear shapers (640); 16.10 Gear hobbing (641); 16.11 Bevel gear generating (643); 16.12 Miscellaneous gear manufacturing methods (645); 16.13 Gear finishing operations (645); 16.14 Gear inspection (646); 16.15 Design of gear hob (651); PROBLEMS (654).

17 THREAD MANUFACTURING 656 – 672

17.1 Introduction (656); 17.2 Casting (656); 17.3 Thread chasing (656); 17.4 Thread rolling (658); 17.5 Die-threading and tapping (660); 17.6 Thread milling (666); 17.7 Thread grinding (668); 17.8 Thread measurement and inspection (668); PROBLEMS (672).

18 DESIGN OF MACHINE TOOL ELEMENTS AND MACHINE TOOL TESTING 673 – 692

18.1 Design of machine tool elements (673); 18.2 Machine tool testing (683); PROBLEMS (691).

19 MACHINE TOOL INSTALLATION AND MAINTENANCE 693 – 709

19.1 Machine tool installation (693); 19.2 Machine tool maintenance (698); 19.3 Machine tool lubrication (701); 19.4 Reconditioning of machine tools (703); 19.5 Safety in machine tools (703); PROBLEMS (708).

20 DESIGN OF PRODUCT FOR ECONOMICAL PRODUCTION 710 – 727

20.1 Introduction (710); 20.2 Suggestions for designing for production (710); 20.3 Design for Manufacturability (725); PROBLEMS (727).

21 STATISTICAL QUALITY CONTROL 728 – 765

21.1 Introduction (728); 21.2 Statistical tools for quality control (729); 21.3 Frequency distribution (729); 21.4 Control charts (732); 21.5 Sampling inspection (739); 21.6 Average outgoing quality limit (AOQL) (748); 21.7 Total Quality Management (TQM) (754); PROBLEMS (763).

22 KINEMATICS OF MACHINE TOOLS 766 – 804

22.1 Introduction (766); 22.2 Drives in machine tools (767); 22.3 Stepless mechanical drives (795); 22.4 Hydraulic Drives (797); 22.5 Electrical drives (801); PROBLEMS (803).

23 PRODUCTION PLANNING AND CONTROL 805 – 847

23.1 Introduction (805); 23.2 Types of Productio (808); 23.3 Sales forecasting (810); 23.4 Economical batch quantity (815); 23.5 Production planning and control functions (818); 23.6 Production planning and control for different types of production (828); 23.7 Inventory control (830); 23.8 Network techniques (835); PROBLEMS (844).

24 MANUFACTURING SYSTEMS AND AUTOMATION **848 – 867**

24.1 Introduction (848); 24.2 Material movement (848); 24.3 Classification of manufacturing systems (855); 24.4 Characteristics of manufacturing systems (863); 24.5 Production systems (863); 24.6 Automation (864); PROBLEMS (866).

25 COMPUTER INTEGRATED MANUFACTURING **868 – 888**

25.1 Introduction (868); 25.2 Computer-Aided Design (CAD) (868); 25.3 Computer-Aided Manufacturing (CAM) (873); 25.4 Computer-Integrated manufacturing (CIM) (879); 25.5 Computerized Information System (880); 25.6 The Automatic factory (882); 25.7 Simultaneous engineering (883); 25.8 Rapid prototyping technique (883); 25.9 Enterprise Resource Planning (886); PROBLEMS (887).

26 PLANT LAYOUT **889 – 909**

26.1 Introduction (889); 26.2 Definition (889); 26.3 Necessity of plant layout (889); 26.4 Importance of plant layout planning (890); 26.5 Objectives of plant layout (890); 26.6 Advantages of Good Plant Layout (891) 26.7 Factors influencing plant layout (892); 26.8 Types of plant layout (893); 26.9 Types of flow patterns (890); 26.10 Principles of plant layout (898); 26.11 Steps in plant layout planning (898); 26.12 Visualisation aids of the layout engineer (906); 26.13 Single storey versus Multi-storey buidling (906) 26.14 Computerized techniques for planning a plant layout (907) 26.15 Effect of "Push" or "Pull" type of Repetitive manufacturing system on plant layout (908); PROBLEMS (908).

27 PRODUCTION AND PRODUCTIVITY **910 – 918**

27.1 Definition (910); 27.2 Difference between production and productivity (911); 27.3 Importance of productivity (911); 27.4 Measurement of productivity (911); 27.5 Factors affecting productivity (913) 27.6 Techniques for improving productivity (914); PROBLEMS (918).

APPENDIX-I **919 – 923**

APPENDIX-II : Process Planning Sheets for Some Mechanical Components **924 – 932**

APPENDIX-III : Cutting Force Measurement : Dynamometery **933 – 938**

APPENDIX-IV : Gear Manufacturing **939 – 944**

APPENDIX-V : Problems from Competitive Examinations (GATE, IES, IAS) **945 – 979**

INDEX **980 – 983**

1

JIGS AND FIXTURES

1.1. GENERAL

Jigs and fixtures are special purpose tools which are used to facilitate production (machining, assembling and inspection operations) when workpieces are to be produced on a mass scale. The mass production of workpieces is based on the concept of interchangeability according to which every part will be produced within an established tolerance. Jigs and fixtures provide a means of manufacturing interchangeable parts since they establish a relation, with predetermined tolerances, between the work and the cutting tool. They eliminate the necessity of a special set up for each individual part. Once a jig or fixture is properly set up, any number of duplicate parts may be readily produced without additional set up. Hence jigs and fixtures are used :

1. To reduce the cost of production, as their use eliminates the laying out of work and setting up of tools.

2. To increase the production.

3. To assure high accuracy of the parts.

4. To provide for interchangeability.

5. To enable heavy and complex-shaped parts to be machined by being held rigidly to a machine.

6. Reduced quality control expenses.

7. Increased versatility of machine tool.

8. Less skilled labour.

9. Saving labour.

10. Their use partially automates the machine tool.

11. Their use improves the safety at work, thereby lowering the rate of accidents.

A jig may be defined as a device which holds and positions the work, locates or guides the cutting tool relative to the workpiece and usually is not fixed to the machine table. It is usually lighter in construction.

A fixture is a work holding device which only holds and positions the work, but does not in itself guide, locate or position the cutting tool. The setting of the tool is done by machine adjustment and a setting block or by using slip gauges. A fixture is bolted or clamped to the machine table. It is usually heavy in construction.

Jigs are used on drilling, reaming, tapping and counterboring operations, while fixtures are used in connection with turning, milling, grinding, shaping, planning and boring operations.

Jigs and fixtures, because of their functions and advantages are also called “Production Devices”. To facilitate interchangeability, we need “Inspection Devices, *i.e.*, the different types of Gauges (Refer to Chapter 9 and 10)”.

To fulfil their basic functions, both jigs and fixtures should possess the following components or elements:

1. A sufficiently rigid body (plate, box or frame structure) into which the workpieces are loaded.

2. Locating elements.

3. Clamping elements.

4. Tool guiding elements (for jigs) or tool setting elements (for fixtures).

5. Elements for positioning or fastening the jig or fixture on the machine on which it is used.

Locating pins are stops or pins which are inserted in the body of jig or fixture, against which the workpiece is pushed to establish the desired relationship between the workpiece and the jig or fixture. To assure interchangeability, the locating elements are made from hardened steel. The purpose of clamping elements is to exert a force to press a workpiece against the locating elements and hold it there in opposition to the action of the cutting forces. In the case of a jig, a hardened bushing is fastened on one or more sides of the jig, to guide the tool to its proper location in the work. However, in the case of a fixture, a target or set block is used to set the location of the tool with respect to the workpiece within the fixture. Most jigs use standard parts such as drill bushings, screws, jig bodies and many other parts. Fixutres are made from grey cast iron or steel by welding or bolting. Fixtures are usually massive bodies because they have to withstand large dynamic forces. Because the fixtures are in between the machine and the workpiece, their rigidity and the rigidity of their fastening to the machine table are most important. Jigs are positioned or supported on the machine table with the help of feet which slide or rest on the machine table. If the drill size is quite large, either stops are provided or the jig is clamped to the machine table to withstand the high drilling torque. Fixtures are clamped or bolted to the machine table. A simple jig and a fixture are shown in Fig. 1.1.

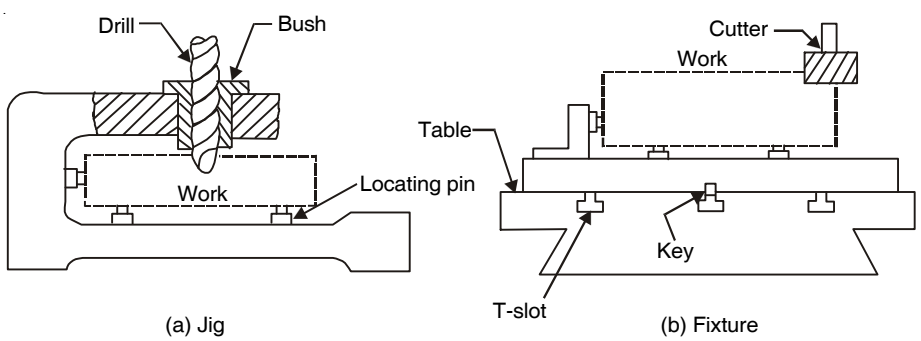


Fig. 1.1. A Simple Jig and a Fixture.

According to the degree of mechanization and automation, jigs and fixtures are classified as : (*a*) hand operated (*b*) power (*c*) semi-automatic (*d*) automatic.

1.2. LOCATING AND CLAMPING

The question of properly locating, supporting, and clamping the work is important since the overall accuracy is dependent primarily on the accuracy with which the workpiece is consistently located within the jig or fixture. There must be no movement of the work during machining. Locating refers to the establishment of a proper relationship between the workpiece and the jig or fixture. The function of clamping is to exert a force to press the workpiece against the locating surfaces and hold it there against the action of cutting forces.

1.2.1. Principle of Location. In order to study the complete location of a workpiece within a jig or fixture, let us consider a workpiece in space (Fig. 1.2). The workpiece is assumed to have true and flat faces. In a state of freedom, it may move in either of the two opposed directions along three mutually perpendicular axes, *XX*, *YY* and

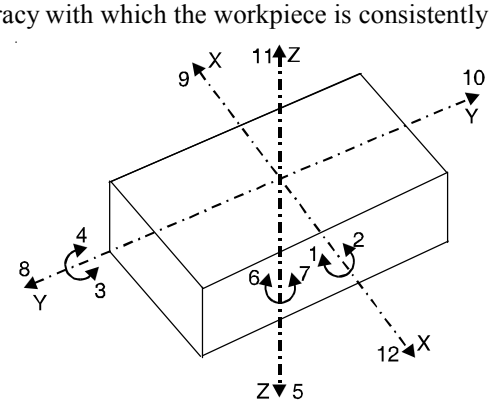
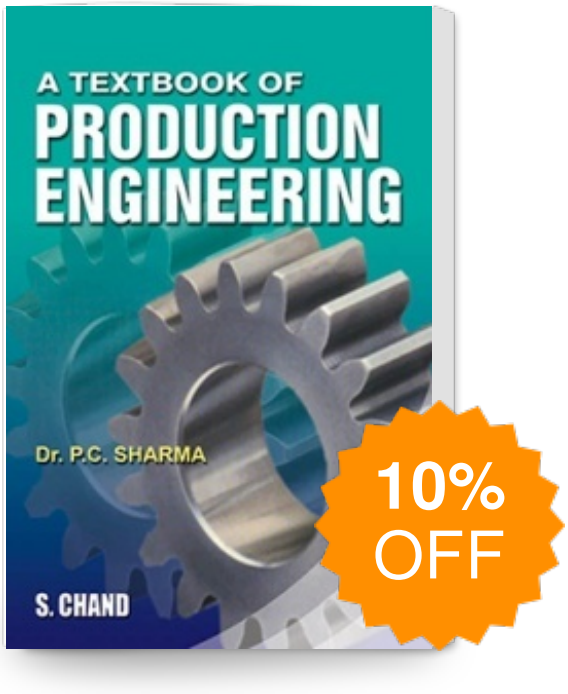


Fig. 1.2. Workpiece in Space.

A Textbook of Production Engineering



Publisher : SChand Publications ISBN : 9788121901116 Author : Dr P C Sharma