

# Engineering Metrology

Third Edition

**Dr. K. L. Narayana**

Former Principal  
S.V.U. College of Engineering  
Tirupati



Publishing for future

**SCITECH PUBLICATIONS (INDIA) PVT. LTD.**

[www.scitechpublications.com](http://www.scitechpublications.com)

# Contents

<b>Chapter 1</b>	<b>System of Limits and Fits</b>	<b>1.1 - 1.84</b>
1.1	Introduction . . . . .	1.1
1.2	Need for Inspection . . . . .	1.2
1.3	Precision and Accuracy . . . . .	1.2
1.4	Errors in Measurement . . . . .	1.3
1.5	Limit System . . . . .	1.5
1.5.1	Limits . . . . .	1.6
1.5.2	Tolerance . . . . .	1.6
1.5.3	Deviation . . . . .	1.10
1.5.4	Maximum Material Condition / limit (MMC) . . . . .	1.11
1.5.5	Least Material Condition/ limit (LMC) . . . . .	1.11
1.5.6	Allowance . . . . .	1.12
1.5.7	Nominal size and Basic size . . . . .	1.13
1.5.8	Limits and fits . . . . .	1.13
1.5.9	Standardized tolerances . . . . .	1.18
1.5.10	Role of an engineer . . . . .	1.19
1.6	Basic Systems of Fit . . . . .	1.20
1.6.1	Hole basis system . . . . .	1.20
1.6.2	Shaft basis system . . . . .	1.21
1.6.3	Basic shaft fits from basic hole ones . . . . .	1.2
1.6.4	General Vs specific tolerances . . . . .	1.25
1.6.5	Cumulative tolerances . . . . .	1.26
1.7	Systems of Assembly . . . . .	1.28
1.7.1	Interchangeable assembly . . . . .	1.28
1.7.2	Selective assembly . . . . .	1.29
1.8	Aspects of Tolerance System . . . . .	1.32
1.8.1	Principles of tolerance system . . . . .	1.34
1.8.2	Selecting tolerances . . . . .	1.34
1.8.3	Indian standard system of limits and fits (IS: 919 and 2709) . . . . .	1.36
1.8.4	Standard tolerances . . . . .	1.36
1.8.5	Fundamental deviation . . . . .	1.40
1.8.6	British standard 1916 . . . . .	1.45
1.8.7	ISO System of limits and fits . . . . .	1.45
1.8.8	Geometric tolerances . . . . .	1.47
1.8.9	Application of suitable limits and tolerances . . . . .	1.56

1.8.10	Condition for economic manufacturing . . . . .	1.56
1.9	Tolerances for ISO Metric Threads . . . . .	1.62
1.9.1	Class of fit for ISO threads . . . . .	1.63
1.9.2	Tolerance grades . . . . .	1.64
1.10	Tolerances for Screw Threads . . . . .	1.65
1.10.1	Tolerance for major diameter of bolt (Td) . . . . .	1.65
1.10.2	Tolerance for minor diameter of nut (TD) . . . . .	1.66
1.10.3	Tolerance for pitch diameter of bolt thread (Te) . . . . .	1.66
1.10.4	Tolerance for pitch (effective) diameter of nut (TE) . . . . .	1.66
1.10.5	Designation of ISO metric threads . . . . .	1.68
1.10.6	ISO Coarse thread series . . . . .	1.68
1.10.7	Fine thread series . . . . .	1.69
1.10.8	Constant pitch series . . . . .	1.69
1.10.9	Example . . . . .	1.69
1.11	Statistical Analysis . . . . .	1.71
1.11.1	Design and natural tolerances . . . . .	1.71
1.11.2	Natural spread of dimensions . . . . .	1.71
	<b>Review Questions</b> . . . . .	<b>1.74</b>
	<b>University Questions</b> . . . . .	<b>1.75</b>
	<b>Short Answers Questions</b> . . . . .	<b>1.79</b>
	<b>Objective Questions</b> . . . . .	<b>1.79</b>
	<b>Answers</b> . . . . .	<b>1.83</b>

**Chapter 2 Linear Measurement 2.1 - 2.61**

2.1	Introduction . . . . .	2.1
2.2	Standards of Measurement . . . . .	2.1
2.2.1	Line/ Length standard - yard . . . . .	2.2
2.2.2	The International Standard meter . . . . .	2.2
2.2.3	End standards . . . . .	2.3
2.2.4	Wave length standard . . . . .	2.6
2.2.5	Slip gauges . . . . .	2.7
2.3	Dial Indicator . . . . .	2.13
2.3.1	Principle of a dial indicator . . . . .	2.13
2.3.2	Dial indicator mechanism . . . . .	2.14
2.3.3	Uses of dial indicators . . . . .	2.14
2.3.4	Requirements of dial indicator . . . . .	2.16
2.3.5	Advantages of dial indicator . . . . .	2.17
2.3.6	Drawbacks of dial indicator . . . . .	2.17
2.4	Micrometer . . . . .	2.17

2.4.1	External micrometer . . . . .	2.18
2.4.2	Depth micrometer . . . . .	2.19
2.4.3	Inside micrometer . . . . .	2.20
2.5	Measurement of Angles and Tapers . . . . .	2.21
2.5.1	Vernier bevel protractor . . . . .	2.21
2.5.2	Spirit level . . . . .	2.23
2.5.3	Circular division . . . . .	2.25
2.5.4	Angle gauges . . . . .	2.25
2.5.5	Sine bars . . . . .	2.27
2.5.6	Use of rollers and spheres in measuring tapers . . . . .	2.29
2.6	Limit Gauging . . . . .	2.32
2.6.1	Taylor's principle . . . . .	2.33
2.6.2	Classification of gauges . . . . .	2.35
2.6.3	Design of gauges . . . . .	2.41
2.6.4	Gauge materials . . . . .	2.46
	<b>Review Questions</b> . . . . .	<b>2.48</b>
	<b>University Questions</b> . . . . .	<b>2.49</b>
	<b>Objective Questions</b> . . . . .	<b>2.58</b>
	<b>Answers</b> . . . . .	<b>2.61</b>

**Chapter 3      Optical Measuring Instruments & Flat Surface Measurement      3.1 - 3.32**

3.1	Introduction . . . . .	3.1
3.2	Tool Makers' Microscope . . . . .	3.2
3.2.1	Working principle . . . . .	3.2
3.2.2	Use of tool makers' microscope . . . . .	3.3
3.2.3	Typical applications of tool makers' microscope . . . . .	3.4
3.3	Optical Projectors . . . . .	3.5
3.3.1	Nikon optical profile projector . . . . .	3.5
3.4	Principle of Interference . . . . .	3.7
3.5	Optical Flat . . . . .	3.7
3.6	Interferometers . . . . .	3.8
3.6.1	Flatness interferometer . . . . .	3.9
3.6.2	Pitter gauge length interferometer . . . . .	3.10
3.7	Flatness . . . . .	3.12
3.7.1	Rubbing two surfaces-use of prussian blue . . . . .	3.13
3.7.2	Knife edge . . . . .	3.14
3.7.3	Parallel bridge . . . . .	3.15
3.7.4	Dial gauge . . . . .	3.16

3.7.5	Beam comparator . . . . .	3.17
3.7.6	Determining the flatness . . . . .	3.18
3.7.7	Use of optical flat . . . . .	3.18
3.8	Auto Collimator . . . . .	3.19
3.8.1	Principle of auto collimator . . . . .	3.19
3.8.2	Construction of an auto-collimator . . . . .	3.21
3.8.3	Angle dekkor . . . . .	3.22
3.8.4	Application of auto collimator . . . . .	3.23
3.9	Constant Deviation Prism . . . . .	3.25
3.10	Dowell Prism . . . . .	3.26
	<b>Review Questions</b> . . . . .	<b>3.27</b>
	<b>University Questions</b> . . . . .	<b>3.27</b>
	<b>Objective Questions</b> . . . . .	<b>3.30</b>
	<b>Answers</b> . . . . .	<b>3.32</b>

**Chapter 4 Surface Roughness Measurement 4.1 - 4.29**

4.1	Introduction . . . . .	4.1
4.2	Geometric irregularities . . . . .	4.2
4.2.1	Surface roughness . . . . .	4.5
4.2.2	Assessment of surface roughness . . . . .	4.10
4.3	Roughness from Common Manufacturing Process . . . . .	4.12
4.3.1	Machining symbols . . . . .	4.14
4.3.2	Indication of surface roughness . . . . .	4.14
4.3.3	Indication of special surface roughness characteristics . . . . .	4.16
4.4	Surface finish measuring instruments . . . . .	4.17
4.4.1	Profilo graph . . . . .	4.17
4.4.2	Double microscope . . . . .	4.18
4.4.3	Tomlinson surface meter . . . . .	4.19
4.4.4	Talysurf instrument . . . . .	4.20
4.4.5	Moving coil instrument (Current generating type) . . . . .	4.21
4.4.6	Piezo electric instrument (Voltage generating type) . . . . .	4.21
4.4.7	Surface inspection by comparison methods . . . . .	4.22
	<b>Review Questions</b> . . . . .	<b>4.24</b>
	<b>University Questions</b> . . . . .	<b>4.24</b>
	<b>Objective Questions</b> . . . . .	<b>4.27</b>
	<b>Answers</b> . . . . .	<b>4.29</b>

**Chapter 5 Measurement through Comparators & Gear Measurement 5.1 - 5.70**

5.1	Introduction . . . . .	5.1
5.2	Comparator . . . . .	5.2
5.3	Mechanical Comparators . . . . .	5.2
5.3.1	Dial indicators . . . . .	5.3
5.3.2	Microkator . . . . .	5.4
5.3.3	Hirth mini-meter . . . . .	5.5
5.3.4	Sigma comparator . . . . .	5.6
5.4	Optical Comparators . . . . .	5.7
5.4.1	Mechanical (Cooke's) optical comparator . . . . .	5.8
5.4.2	Omtimeter-OMT meter . . . . .	5.9
5.5	Electrical Comparators . . . . .	5.10
5.5.1	Electro limit gauge . . . . .	5.11
5.5.2	Linear variable differential transformer (LVDT) . . . . .	5.12
5.5.3	Electronic comparator . . . . .	5.13
5.6	Pneumatic Comparators . . . . .	5.13
5.6.1	Pressure sensitive air gauging . . . . .	5.14
5.7	Gear Measurement . . . . .	5.18
5.7.1	Elements of gear tooth . . . . .	5.19
5.7.2	Rolling gear tester . . . . .	5.21
5.7.3	Examination of tooth profile . . . . .	5.22
5.7.4	Measurement of tooth thickness . . . . .	5.23
5.7.5	Measurement of pitch . . . . .	5.25
5.8	Test Plug Method for Checking Pitch Diameter and Tooth Spacing . . . . .	5.27
5.9	Screw Thread Measurement . . . . .	5.30
5.10	Elements of Screw Threads . . . . .	5.30
5.10.1	Measurement of major diameter, D . . . . .	5.31
5.10.2	Measurement of minor diameter, d . . . . .	5.32
5.10.3	Measurement of effective diameter, E . . . . .	5.33
5.10.4	Pitch . . . . .	5.37
5.11	Errors in Screw Threads . . . . .	5.38
5.11.1	The pitch errors . . . . .	5.38
5.11.2	Errors in flank angle with reference to mean diameter . . . . .	5.40
5.12	Machine Tool Alignment Tests . . . . .	5.40
5.12.1	Geometrical tests . . . . .	5.41
5.12.2	Performance tests . . . . .	5.41
5.12.3	Measuring tools used in machine tool alignment tests . . . . .	5.41
5.12.4	Alignment tests on lathe . . . . .	5.42

5.12.5	Alignment tests on radial drilling machine . . . . .	5.48
5.12.6	Alignment tests on pillar drilling machine . . . . .	5.51
5.12.7	Alignment tests on milling machine . . . . .	5.54
	<b>Review Questions . . . . .</b>	<b>5.59</b>
	<b>University Questions . . . . .</b>	<b>5.60</b>
	<b>Objective Questions . . . . .</b>	<b>5.66</b>
	<b>Answers . . . . .</b>	<b>5.69</b>

**Chapter 6 Co-ordinate Measuring Machines 6.1 - 6.8**

6.1	Introduction . . . . .	6.1
6.2	Configuration of CMMs . . . . .	6.1
6.2.1	Cantilever . . . . .	6.2
6.2.2	Bridge type . . . . .	6.2
6.2.3	Column type . . . . .	6.2
6.2.4	Gantry . . . . .	6.3
6.2.5	Horizontal arm . . . . .	6.3
6.2.6	Data processing . . . . .	6.3
6.2.7	Applications . . . . .	6.5
6.2.8	Advantages . . . . .	6.5
	<b>Review Questions . . . . .</b>	<b>6.8</b>
	<b>Objective Questions . . . . .</b>	<b>6.8</b>
	<b>Answers . . . . .</b>	<b>6.8</b>

**Chapter 7 Surface Treatment 7.1 - 7.13**

7.1	Introduction . . . . .	7.1
7.2	Treatments that Cover the Surfaces . . . . .	7.2
7.2.1	Conversion coatings . . . . .	7.2
7.2.2	Electroplating . . . . .	7.2
7.2.3	Electro less plating . . . . .	7.3
7.2.4	Hard facing processes . . . . .	7.4
7.2.5	Thermal spraying . . . . .	7.5
7.2.6	Thin-film coatings . . . . .	7.6
7.2.7	Anodizing . . . . .	7.8
7.2.8	Hot dipping . . . . .	7.8
7.2.9	Enameling . . . . .	7.8
7.3	Diffusion Coatings . . . . .	7.8
7.3.1	Carburizing . . . . .	7.9
7.3.2	Carbo-nitriding . . . . .	7.9

7.3.3	Cyaniding . . . . .	7.9
7.3.4	Nitriding . . . . .	7.9
7.4	Altering Surfaces . . . . .	7.10
7.4.1	Hardening processes . . . . .	7.10
7.4.2	High energy processes . . . . .	7.11
7.4.3	Special treatments . . . . .	7.11
	<b>Objective Questions</b> . . . . .	<b>7.12</b>
	<b>Answers</b> . . . . .	<b>7.13</b>

SCITECH