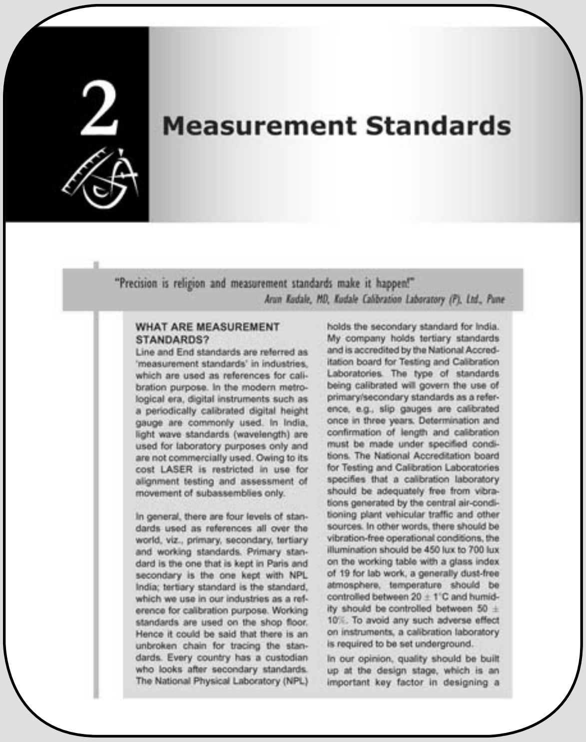
VISUAL WALKTHROUGH

Introductory Quotation

Each chapter begins with an introductory quotation (by an eminent personality in the respective field) that is not only motivating but also gives the importance of the subject matter of the chapter.



2

Measurement Standards

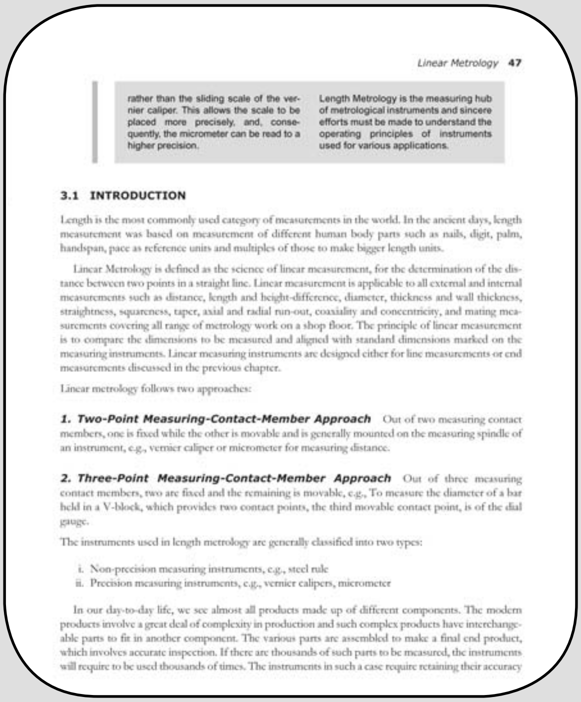
> "Precision is religion and measurement standards make it happen!"
>
> *Arun Kudale, MD, Kudale Calibration Laboratory (P), Ltd., Pune*

WHAT ARE MEASUREMENT STANDARDS?

Line and End standards are referred as 'measurement standards' in industries, which are used as references for calibration purpose. In the modern metrological era, digital instruments such as a periodically calibrated digital height gauge are commonly used. In India, light wave standards (wavelength) are used for laboratory purposes only and are not commercially used. Owing to its cost LASER is restricted in use for alignment testing and assessment of movement of subassemblies only.

In general, there are four levels of standards used as references all over the world, viz., primary, secondary, tertiary and working standards. Primary standard is the one that is kept in Paris and secondary is the one kept with NPL India; tertiary standard is the standard, which we use in our industries as a reference for calibration purpose. Working standards are used on the shop floor. Hence it could be said that there is an unbroken chain for tracing the standards. Every country has a custodian who looks after secondary standards. The National Physical Laboratory (NPL) holds the secondary standard for India. My company holds tertiary standards and is accredited by the National Accreditation board for Testing and Calibration Laboratories. The type of standards being calibrated will govern the use of primary/secondary standards as a reference, e.g., slip gauges are calibrated once in three years. Determination and confirmation of length and calibration must be made under specified conditions. The National Accreditation board for Testing and Calibration Laboratories specifies that a calibration laboratory should be adequately free from vibrations generated by the central air-conditioning plant vehicular traffic and other sources. In other words, there should be vibration-free operational conditions, the illumination should be 450 lux to 700 lux on the working table with a glass index of 19 for lab work, a generally dust-free atmosphere, temperature should be controlled between 20 ± 1°C and humidity should be controlled between 50 ± 10%. To avoid any such adverse effect on instruments, a calibration laboratory is required to be set underground.

In our opinion, quality should be built up at the design stage, which is an important key factor in designing a



Linear Metrology **47**

rather than the sliding scale of the vernier caliper. This allows the scale to be placed more precisely, and, consequently, the micrometer can be read to a higher precision.

Length Metrology is the measuring hub of metrological instruments and sincere efforts must be made to understand the operating principles of instruments used for various applications.

3.1 INTRODUCTION

Length is the most commonly used category of measurements in the world. In the ancient days, length measurement was based on measurement of different human body parts such as nails, digit, palm, handspan, pace as reference units and multiples of those to make bigger length units.

Linear Metrology is defined as the science of linear measurement, for the determination of the distance between two points in a straight line. Linear measurement is applicable to all external and internal measurements such as distance, length and height-difference, diameter, thickness and wall thickness, straightness, squareness, taper, axial and radial run-out, coaxiality and concentricity, and mating measurements covering all range of metrology work on a shop floor. The principle of linear measurement is to compare the dimensions to be measured and aligned with standard dimensions marked on the measuring instruments. Linear measuring instruments are designed either for line measurements or end measurements discussed in the previous chapter.

Linear metrology follows two approaches:

1. Two-Point Measuring-Contact-Member Approach Out of two measuring contact members, one is fixed while the other is movable and is generally mounted on the measuring spindle of an instrument, e.g., vernier caliper or micrometer for measuring distance.

2. Three-Point Measuring-Contact-Member Approach Out of three measuring contact members, two are fixed and the remaining is movable, e.g., To measure the diameter of a bar held in a V-block, which provides two contact points, the third movable contact point, is of the dial gauge.

The instruments used in length metrology are generally classified into two types:

i. Non-precision measuring instruments, e.g., steel rule
ii. Precision measuring instruments, e.g., vernier calipers, micrometer

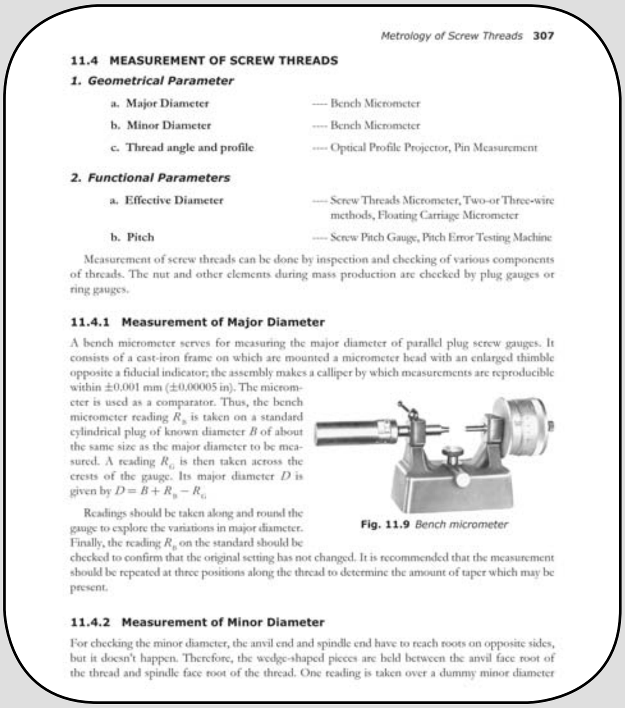
In our day-to-day life, we see almost all products made up of different components. The modern products involve a great deal of complexity in production and such complex products have interchangeable parts to fit in another component. The various parts are assembled to make a final end product, which involves accurate inspection. If there are thousands of such parts to be measured, the instruments will require to be used thousands of times. The instruments in such a case require retaining their accuracy

Introduction

Each chapter begins with an introduction that gives a brief summary of the background and contents of the chapter.

Sections and Sub-sections

Each chapter has been neatly divided into sections and sub-sections so that the subject matter is studied in a logical progression of ideas and concepts.



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11.4 MEASUREMENT OF SCREW THREADS

1. Geometrical Parameter

a. **Major Diameter**	---- Bench Micrometer
b. **Minor Diameter**	---- Bench Micrometer
c. **Thread angle and profile**	---- Optical Profile Projector, Pin Measurement

2. Functional Parameters

a. **Effective Diameter**	---- Screw Threads Micrometer, Two-or Three-wire methods, Floating Carriage Micrometer
b. **Pitch**	---- Screw Pitch Gauge, Pitch Error Testing Machine

Measurement of screw threads can be done by inspection and checking of various components of threads. The nut and other elements during mass production are checked by plug gauges or ring gauges.

11.4.1 Measurement of Major Diameter

A bench micrometer serves for measuring the major diameter of parallel plug screw gauges. It consists of a cast-iron frame on which are mounted a micrometer head with an enlarged thimble opposite a fiducial indicator; the assembly makes a calliper by which measurements are reproducible within ±0.001 mm (±0.00005 in). The micrometer is used as a comparator. Thus, the bench micrometer reading R_B is taken on a standard cylindrical plug of known diameter B of about the same size as the major diameter to be measured. A reading R_G is then taken across the crests of the gauge. Its major diameter D is given by $D = B + R_B - R_G$

Fig. 11.9 *Bench micrometer*

Readings should be taken along and round the gauge to explore the variations in major diameter. Finally, the reading R_B on the standard should be checked to confirm that the original setting has not changed. It is recommended that the measurement should be repeated at three positions along the thread to determine the amount of taper which may be present.

11.4.2 Measurement of Minor Diameter

For checking the minor diameter, the anvil end and spindle end have to reach roots on opposite sides, but it doesn't happen. Therefore, the wedge-shaped pieces are held between the anvil face root of the thread and spindle face root of the thread. One reading is taken over a dummy minor diameter

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Illustrative Examples

Example 1 *Design a plug gauge for checking the hole of 70H8. Use* $i = 0.45\sqrt[3]{D} + 0.001L$, *IT8 = 25i, Diameter step = 50 to 80 mm.*

Solution: Internal dimension = 70H8 d1 = 50, d2 = 80

$$D = \sqrt{d_1 \times d_2} = \sqrt{50 \times 80} = 63.245 \text{ mm}$$

$$i = 0.45\sqrt[3]{63.245} + 0.001D = 1.8561 \text{ micron}$$

Tolerance for IT8 = 25i, = 25, 1.8561 = 46.4036 microns

Hole dimensions

GO limit of hole = 70.00 mm

NO GO limit of hole = 70.00 + 0.04640 = 70.04640 mm

GO plug gauge design

Workmanship allowance = 10 % hole tolerance = 10/100 × 0.4640 = 0.004640 mm

Hole tolerance is less than 87.5 micron. It is necessary to provide wear allowance on a GO plug gauge.

Lower limit of GO = 70.000 mm

Upper limit of GO = 70.0000 + 0.004640 = 70.00464 mm

Sizes of GO = 70 [illegible]

NO GO plug gauge

Workmanship allowance = 0.004640

NO GO Sizes = 70 [illegible] = 70 [illegible]

Example 2 *Design and make a drawing of general purpose 'GO' and 'NO-GO' plug gauge for inspecting a hole of 22 D8. Data with usual notations:*

i. i (microns) = $i = 0.45\sqrt[3]{D} + 0.001l$

ii. Fundamental deviations for hole $D = 16^{0.44}$.

iii. Value for $IT8 = 25i$

details would lead to an expensive method of manufacturing. A practical solution (alternative) to this problem is to mark individual parts to meet wider tolerances, and then to separate them into categories according to their actual sizes. An assembly is then made from the selected categories—this process being known as *selective assembly*. It is required ideally where the objective is to make a 'shaft' and 'hole' with a finite fit and not within a permissible

the manufacturer and purchaser, IS: 3455-1971 gives the guidelines for selecting the types of gauges for specific applications. The advantages of using gauges for cylindrical work are that the GO ring gauge may detect errors that may not be detected by the GO gap gauge, such as lobbing and raised imperfections. As per W Taylor, the GO gauge should check a time dimension along with its related (geometrical) parameters.

Illustrative Examples

Illustrative Examples are provided in sufficient number in each chapter and at appropriate locations, to aid in understanding of the text material.

Solved Problems with Detailed Explanations

In case of some of the chapters which involve analytical treatment, problems (numerical) related to those concepts are explained stepwise at the end of the chapters which enable the student to have good comprehension of the subject matter.

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Example 4 *Design 'workshop', 'inspection', and 'general type' GO and NO-GO gauges for checking the assembly ϕ25H7/f8 and comment on the type of fit. Data with usual notations:*

1) *i (microns)* = $i = 0.45\sqrt[3]{D} + 0.001D$
2) *Fundamental deviation for shaft 'f'* = $-5.5\ D^{0.412}$.
3) *Value for IT7 = 16i and IT8 = 25i.*
4) *25 mm falls in the diameter step of 18 and 30.*

Solution:

(a) Firstly, find out the dimension of hole specified, i.e., 25 H7

For a diameter of 25-mm step size (refer Table 6.3) = (18 − 30) mm

$$\therefore D = \sqrt{d_1 \times d_2} = \sqrt{18 \times 30} = 23.2379 \text{ mm}$$

And, $i = 0.45\sqrt[3]{D} + 0.001D$

$$\therefore i = 0.45\sqrt[3]{23.2379} + 0.001(23.2379)$$
$$= 1.3074 \text{ microns}$$

Tolerance value for IT7 = 16 i ….(Refer Table 6.4)

$$= 16(1.3074) = 20.85 \text{ microns} \cong 21\text{microns}$$
$$= 0.021 \text{ mm}$$

(b) Limits for $25\ H7 = 25.00^{+0.021}_{+0.0}$ mm

∴ tolerance on hole = 0.021 mm

Tolerance value for IT8 = 25*i* ….(refer Table 6.4)

$$= 25(1.3074)$$
$$= 32.6435 \cong 33 \text{ microns}$$

(c) Fundamental deviation for shaft '*f*' = $-5.5\ D^{0.412}$

$$= -5.5(23.2)^{0.412}$$
$$= -10.34 \cong -10 \text{ microns}$$

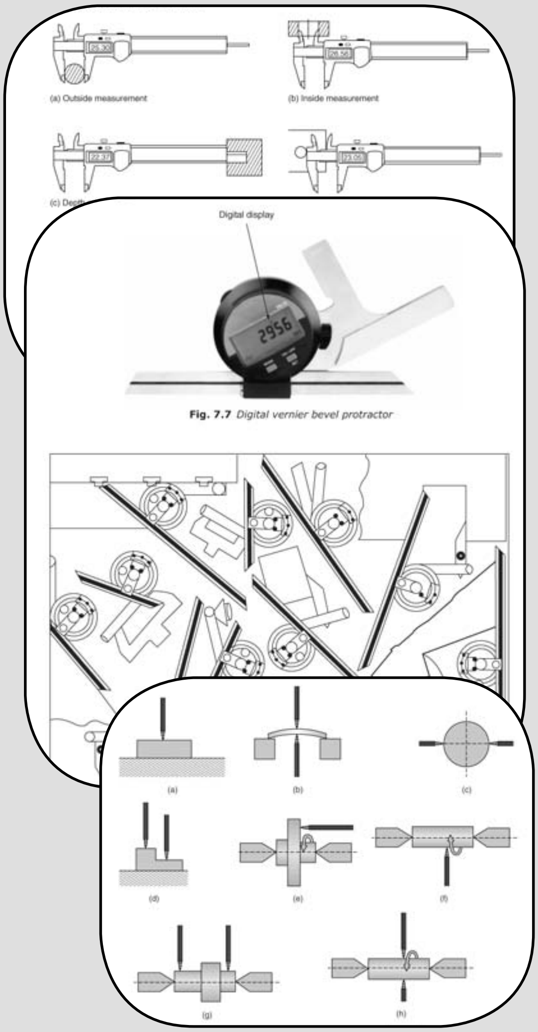

Fig. 7.7 *Digital vernier bevel protractor*

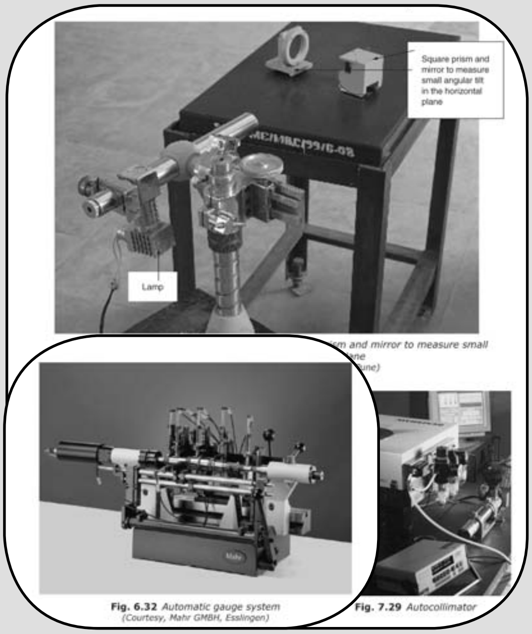

Fig. 6.32 *Automatic gauge system (Courtesy, Mahr GMBH, Esslingen)*

Fig. 7.29 *Autocollimator*

Photographs

Photographs of instruments and their applications are presented at appropriate locations in the book.

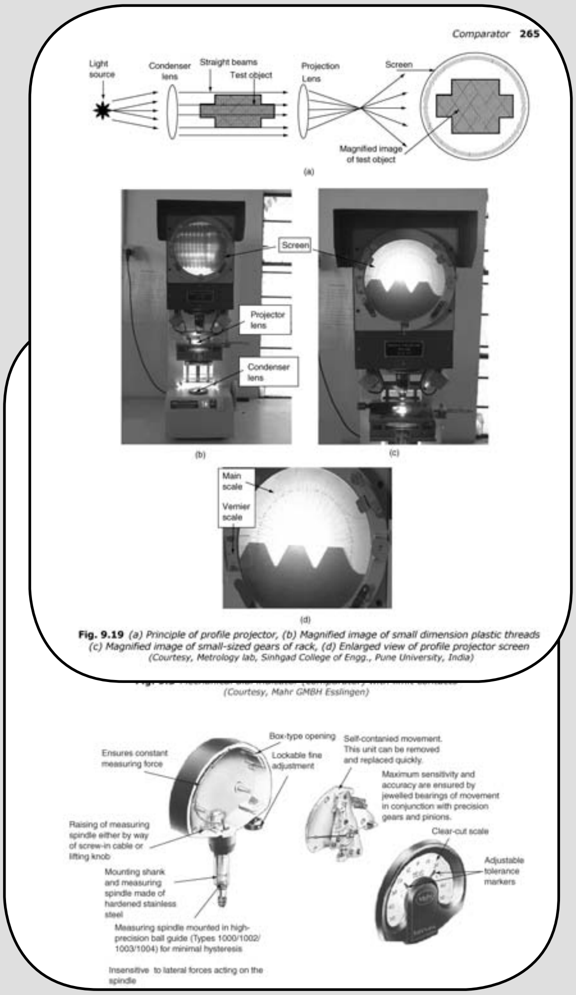

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Fig. 9.19 *(a) Principle of profile projector, (b) Magnified image of small dimension plastic threads (c) Magnified image of small-sized gears of rack, (d) Enlarged view of profile projector screen*
(Courtesy, Metrology lab, Sinhgad College of Engg., Pune University, India)

(Courtesy, Mahr GMBH Esslingen)

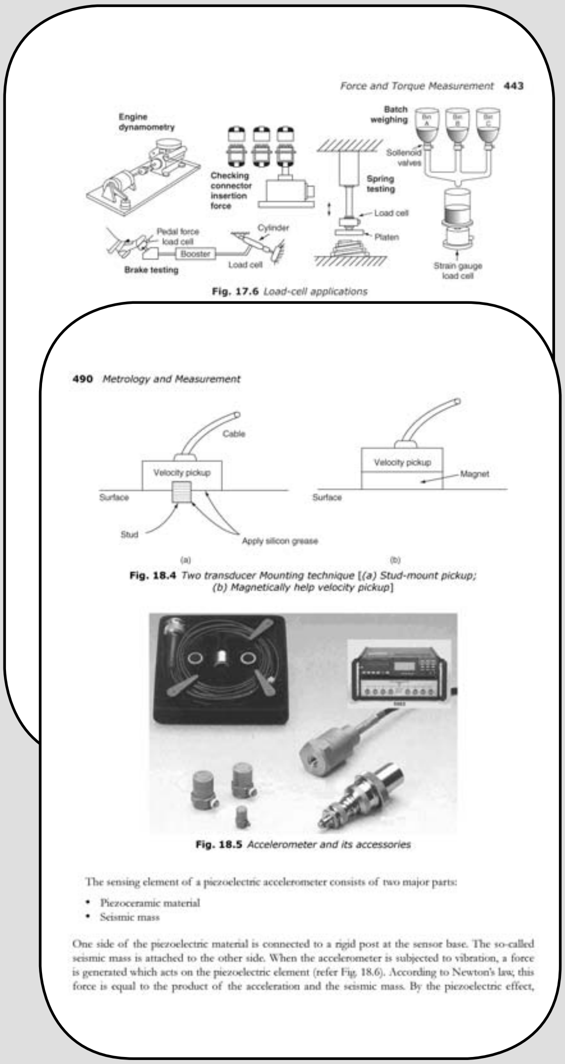

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Fig. 17.6 *Load-cell applications*

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Fig. 18.4 *Two transducer Mounting technique [(a) Stud-mount pickup; (b) Magnetically help velocity pickup]*

Fig. 18.5 *Accelerometer and its accessories*

The sensing element of a piezoelectric accelerometer consists of two major parts:

- Piezoceramic material
- Seismic mass

One side of the piezoelectric material is connected to a rigid post at the sensor base. The so-called seismic mass is attached to the other side. When the accelerometer is subjected to vibration, a force is generated which acts on the piezoelectric element (refer Fig. 18.6). According to Newton's law, this force is equal to the product of the acceleration and the seismic mass. By the piezoelectric effect,

Exploded Views of Photographs

Wherever required, exploded views of the instruments are also shown.

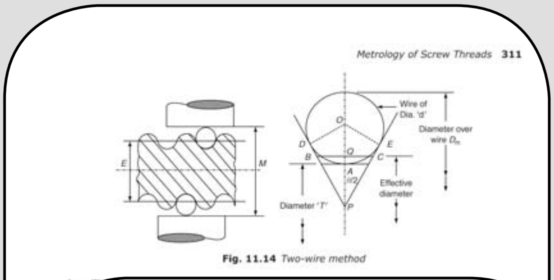

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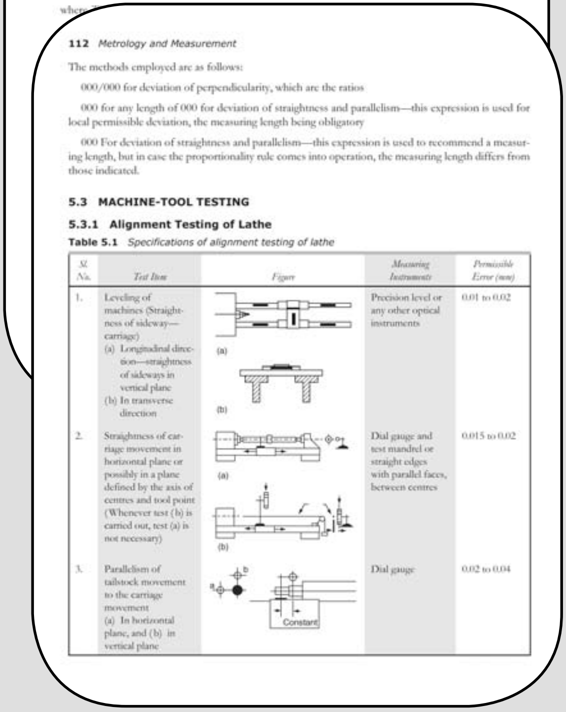
Fig. 11.14 *Two-wire method*

where



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The methods employed are as follows:

000/000 for deviation of perpendicularity, which are the ratios

000 for any length of 000 for deviation of straightness and parallelism—this expression is used for local permissible deviation, the measuring length being obligatory

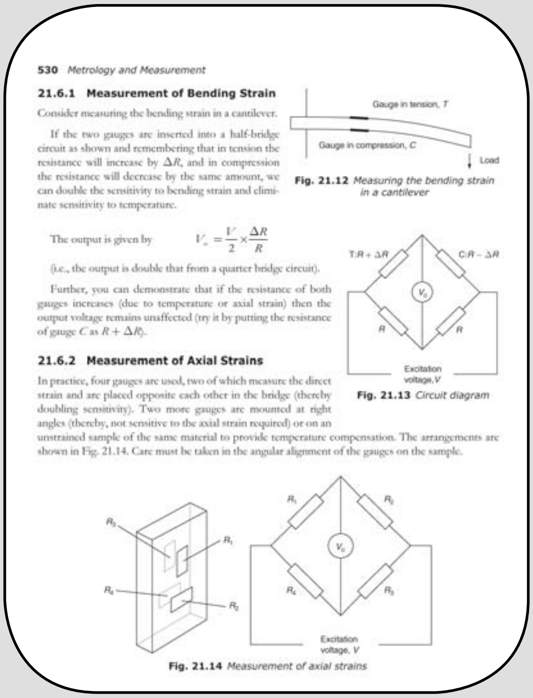
000 For deviation of straightness and parallelism—this expression is used to recommend a measuring length, but in case the proportionality rule comes into operation, the measuring length differs from those indicated.

5.3 MACHINE-TOOL TESTING

5.3.1 Alignment Testing of Lathe

Table 5.1 *Specifications of alignment testing of lathe*

Sl. No.	*Test Item*	*Figure*	*Measuring Instruments*	*Permissible Error (mm)*
1.	Leveling of machines (Straightness of sideway—carriage) (a) Longitudinal direction—straightness of sideways in vertical plane (b) In transverse direction	(a) (b)	Precision level or any other optical instruments	0.01 to 0.02
2.	Straightness of carriage movement in horizontal plane or possibly in a plane defined by the axis of centres and tool point (Whenever test (b) is carried out, test (a) is not necessary)	(a) (b)	Dial gauge and test mandrel or straight edges with parallel faces, between centres	0.015 to 0.02
3.	Parallelism of tailstock movement to the carriage movement (a) In horizontal plane, and (b) in vertical plane	a b Constant	Dial gauge	0.02 to 0.04



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21.6.1 Measurement of Bending Strain

Consider measuring the bending strain in a cantilever.

If the two gauges are inserted into a half-bridge circuit as shown and remembering that in tension the resistance will increase by ΔR, and in compression the resistance will decrease by the same amount, we can double the sensitivity to bending strain and eliminate sensitivity to temperature.

Fig. 21.12 *Measuring the bending strain in a cantilever*

The output is given by $$V_o = \frac{V}{2} \times \frac{\Delta R}{R}$$

(i.e., the output is double that from a quarter bridge circuit).

Further, you can demonstrate that if the resistance of both gauges increases (due to temperature or axial strain) then the output voltage remains unaffected (try it by putting the resistance of gauge C as $R + \Delta R$).

Fig. 21.13 *Circuit diagram*

21.6.2 Measurement of Axial Strains

In practice, four gauges are used, two of which measure the direct strain and are placed opposite each other in the bridge (thereby doubling sensitivity). Two more gauges are mounted at right angles (thereby, not sensitive to the axial strain required) or on an unstrained sample of the same material to provide temperature compensation. The arrangements are shown in Fig. 21.14. Care must be taken in the angular alignment of the gauges on the sample.

Fig. 21.14 *Measurement of axial strains*

Illustrations

Illustrations are essential tools in books on engineering subjects. Ample illustrations are provided in each chapter to illustrate the concepts, functional relationships and to provide definition sketches for mathematical models.

Case Studies

Case Studies are an important part of books on engineering subjects. Many case studies are provided in the chapters to explain the concepts and their practical significances.

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also designed a much thicker membrane (1.5 mm) to come into contact with the process fluid, but instead of transmitting the pressure value by a liquid such as oil or mercury, a solid 'push rod' was designed to do the job. The membrane and push rod are indicated in Fig. 19.19; the sensor is mounted just behind the push rod and connected to it with a special connector so that the two may be separated during the installation phases on the machine.

Fig. 19.18 *Chip mounted on its carrier*

The resulting sensor package has impressive specifications—it measures pressures from 100 to 1000 bar at operating temperatures up to 350°C, with a degree of accuracy of 0.25% full scale. The greater thickness of the membrane—it is 10 to 15 times thicker than membranes on previous instruments—is the key to the long life of Impact. There are no longer any concerns about the wear and tear of the membrane due to charged polymers.

Fig. 19.19 *Process contact membrane and push rod*

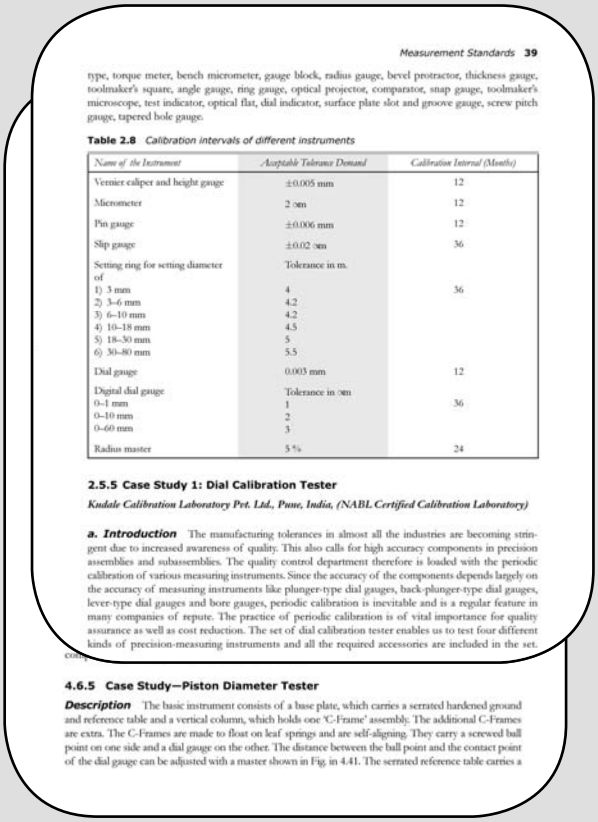
19.9 CASE STUDY OF PRESSURE MEASUREMENT AND MONITORING

19.9.1 Vehicle Tyre-Pressure Monitoring

Tyre-pressure monitoring systems (TPM or TPMS) were implemented a number of years ago as a factory-installed feature found only on high-end vehicles. TPMS, as an embedded electronic system, is expected to be standard equipment in the next few years.

System Overview To do real-time sensing of the exact pressure inside the tyre, the sensing device must be located in the tyre. This pressure-measurement information must then be carried to the driver and displayed in the cabin of the car. The remote-sensing module is comprised of a pressure sensor, a signal processor, and an RF transmitter. The system must compensate pressure variations due to temperature. Hence, a temperature sensor is also required.

The power supply is provided by a long-life battery that the embedded intelligence helps to manage as effectively as possible. The receiver could be either dedicated to TPM use, or shared with the other functions in the car.



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type, torque meter, bench micrometer, gauge block, radius gauge, bevel protractor, thickness gauge, toolmaker's square, angle gauge, ring gauge, optical projector, comparator, snap gauge, toolmaker's microscope, test indicator, optical flat, dial indicator, surface plate slot and groove gauge, screw pitch gauge, tapered hole gauge.

Table 2.8 *Calibration intervals of different instruments*

Name of the Instrument	*Acceptable Tolerance Demand*	*Calibration Interval (Months)*
Vernier caliper and height gauge	±0.005 mm	12
Micrometer	2 µm	12
Pin gauge	±0.006 mm	12
Slip gauge	±0.02 µm	36
Setting ring for setting diameter of	Tolerance in m.	
1) 3 mm	4	36
2) 3–6 mm	4.2	
3) 6–10 mm	4.2	
4) 10–18 mm	4.5	
5) 18–30 mm	5	
6) 30–80 mm	5.5	
Dial gauge	0.003 mm	12
Digital dial gauge	Tolerance in µm	
0–1 mm	1	36
0–10 mm	2	
0–60 mm	3	
Radius master	5 %	24

2.5.5 Case Study 1: Dial Calibration Tester

Kudale Calibration Laboratory Pvt. Ltd., Pune, India, (NABL Certified Calibration Laboratory)

a. Introduction The manufacturing tolerances in almost all the industries are becoming stringent due to increased awareness of quality. This also calls for high accuracy components in precision assemblies and subassemblies. The quality control department therefore is loaded with the periodic calibration of various measuring instruments. Since the accuracy of the components depends largely on the accuracy of measuring instruments like plunger-type dial gauges, back-plunger-type dial gauges, lever-type dial gauges and bore gauges, periodic calibration is inevitable and is a regular feature in many companies of repute. The practice of periodic calibration is of vital importance for quality assurance as well as cost reduction. The set of dial calibration tester enables us to test four different kinds of precision-measuring instruments and all the required accessories are included in the set.

4.6.5 Case Study—Piston Diameter Tester

Description The basic instrument consists of a base plate, which carries a serrated hardened ground and reference table and a vertical column, which holds one 'C-Frame' assembly. The additional C-Frames are extra. The C-Frames are made to float on leaf springs and are self-aligning. They carry a screwed ball point on one side and a dial gauge on the other. The distance between the ball point and the contact point of the dial gauge can be adjusted with a master shown in Fig. in 4.41. The serrated reference table carries a