Precision Metrology

Metrology=Metro+Logy=Measurement Science

Two Criteria to be satisfied:

1. It must use a system of measurement which is recognized and used by others in the field

   ->Method and Unit

2. Accuracy, Repeatability to be mentioned

Terminology

Quantity: object of measurement to be determined quantitatively

Value (of a quantity): the quantity expressed as number and unit

Legal metrology: a part of metrology treating units, methods as mandatory technical and legal requirements in relation to trading/business

Repeatability of measurement: Quantitative expression of the closeness of successive measurements of the same quantity under the same conditions

Reproducibility of measurement: Quantitative expression of the closeness of successive measurements of the same quantity under differently defined condition, wider concept of repeatability

Deviation: Divergence (or difference) of a value from the standard or reference value

Standard deviation: RMS (root mean square) deviation, or average deviation

Spread, scatter, dispersion: Difference between the largest and the smallest values for the same quantity

Resolution: Ability to respond to the smallest changes of quantity, smallest display of instrument

Units

8 base SI units->Derived Units

Length	metre	m
Mass	kilogram	Kg
Time	second	sec
Current	ampere	A
Temp.	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	Cd

SI Prefixes

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10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	mili	m
10^{-6}	micro	u

10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{1}	deca	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

True value (of a quantity)

A value characterizing a quantity perfectly. Practically, it is determined from the instruments of suitable accuracy.
ex) measured value from precision instrument

Nominal value

Nominally assigned value, or machine display value. Ex)100.000 from machine display

Error

The discrepancy, or algebraic difference, between the true value and the nominal value

Error=True value - Nominal value

or, True value= Nominal value + Error

Calibration:

determining the error of the instrument or machine

Correction or compensation: a number is added to the indicated value to obtain the corrected value

Traceability: establishing a valid calibration of an instrument by step-by-step comparison with better standard, must be "traceable to ISO".

ex) Institution->National level->ISO

Error classification in terms of reproducibility

Systematic error:

An error which, in the course of a number of measurements of the same quantity under the effectively same conditions, remains constant in absolute value and sign. Or, it varies according to a definite law when conditions change. Practically, the systematic error can be evaluated as the average value of the errors from the repeat measurements. Wherever systematic errors have been established, they may be used for correction or compensation for the value measured.

Random error (or random uncertainty):

An error varies in unpredictable manner in absolute value and in sign under effectively identical conditions. It is only possible to fix limits within which the error will lie with a stated probability. Standard deviation, k times σ, of the repeat measurements can be used for the random error. It would be 2σ for 95%, 3 σ for 99% typically

Hysteresis error (reversal or backlash error)

A highly reproducible error, being governed by the play in the transmission components and the friction forces, and it is sign dependent on the direction of approach.

Methods of measurements

1.Direct measurement method: By which the value of a quantity is obtained directly. Ex)Length measurement by scale

2.Indirect measurement method: In which the value of a quantity is obtained from measurements of other quantities linked to the quantity. Ex) Capacitive sensor for displacement measurement

3.Absolute measurement method: method of measurement based on the measurement of the base quantities used to define the quantity.

4.Comparison measurement method: Measurement based on the comparison of a quantity with a known value of the same quantity ex) Roughness measurement using reference mirror

Length measurement units

1 metre = distance travelled by light from Kr lamp in vacuum during a time scale of 1/299,792,458 sec (by ISO since 1967)

Practically this standard is realized by an Iodine(I2) stabilized He-Ne Laser source

1m=1000mm, 1 inch=25.4mm

1um=10^{-6} m 1 mili-inch=1 MIL=1/1,000inch =25.4 um

1nm=10^{-9}m 1 micro-inch=1 uinch=25.4nm

1 Angstrom=10^{-10}m=0.1nm

1 pm=10^{-12}m

Angle measurement units

1 deg=60 min (arcmin)=3,600 sec (arcsec)

1 arcsec= 4.8um/m=4.8 urad

HW1) 10 length measurement data by Vernier Calipers (unit:mm)

14.9, 14.6, 14.8, 14.6, 14.9, 14.9, 14.7, 14.7, 14.8, 14.9

Systematic error of Vernier=-0.2mm (to be corrected)

(1)Average and standard deviation of the measurement data

(2)Range of true value from single measurement

(3)Range of true value from average of 10 repeat measurement

Tips:

Range of single measurement: $\pm 3\sigma$

Range of average of repeat n measurements: $\pm 3\sigma/\sqrt{n}$