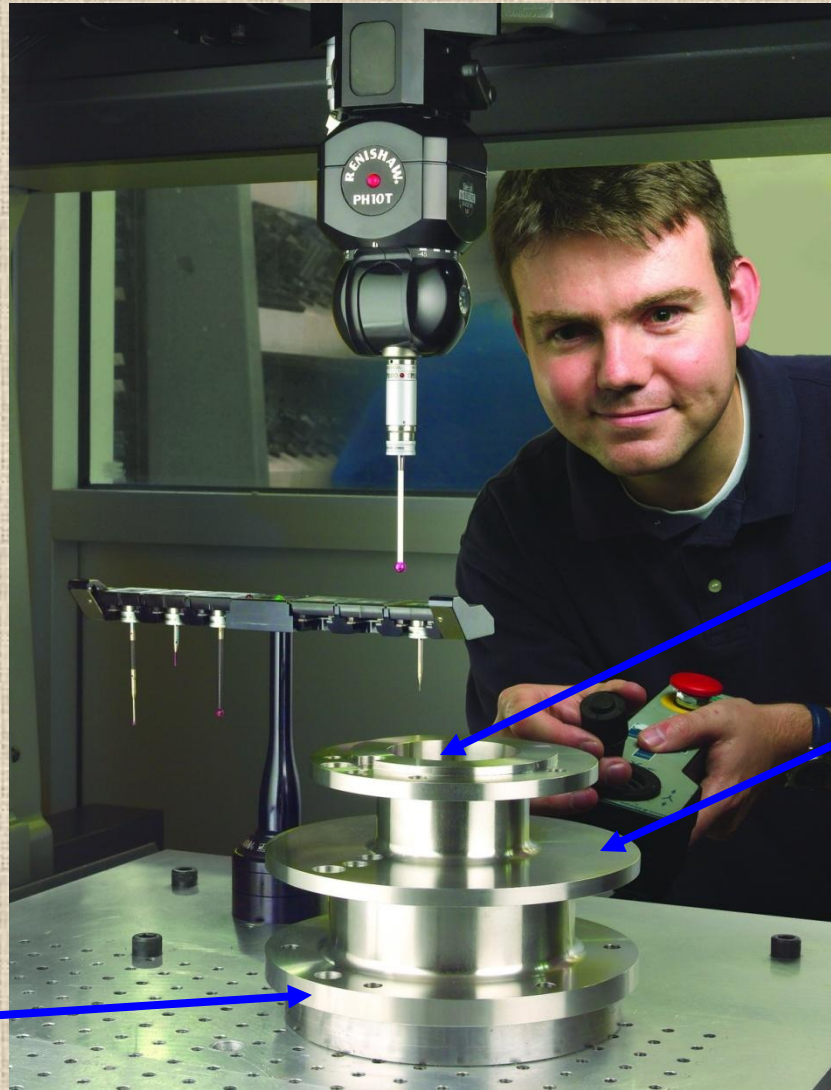


Coordinate Measuring Machine

CMM



Cylindricity

Flatness

Roundness

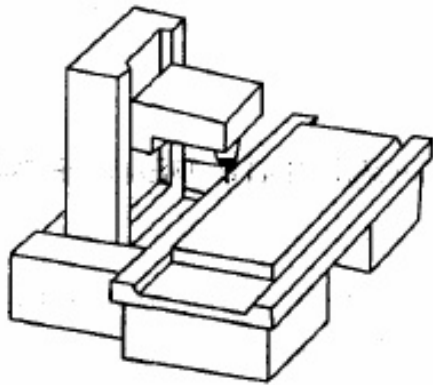
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(i) Column type

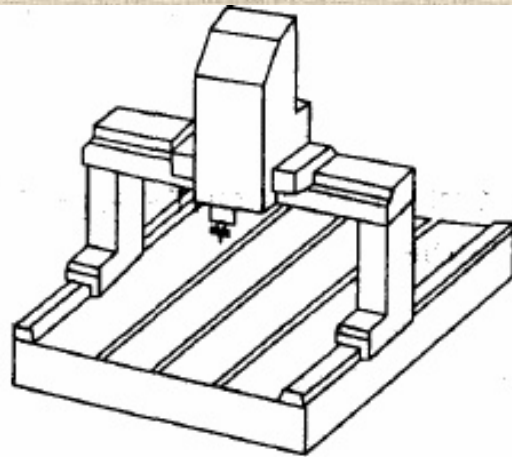
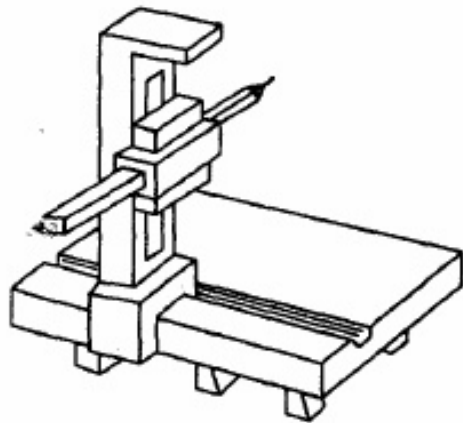
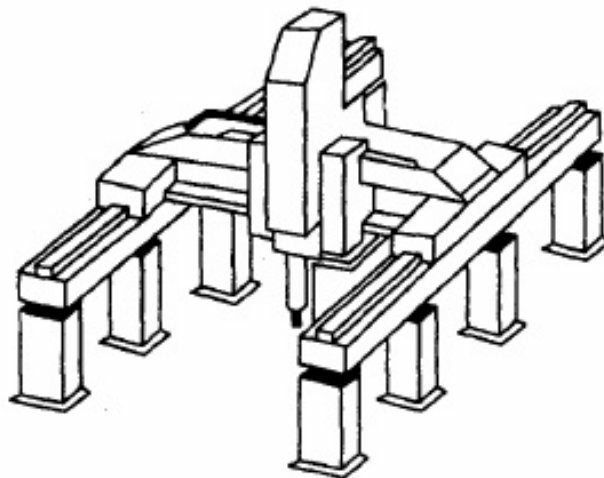


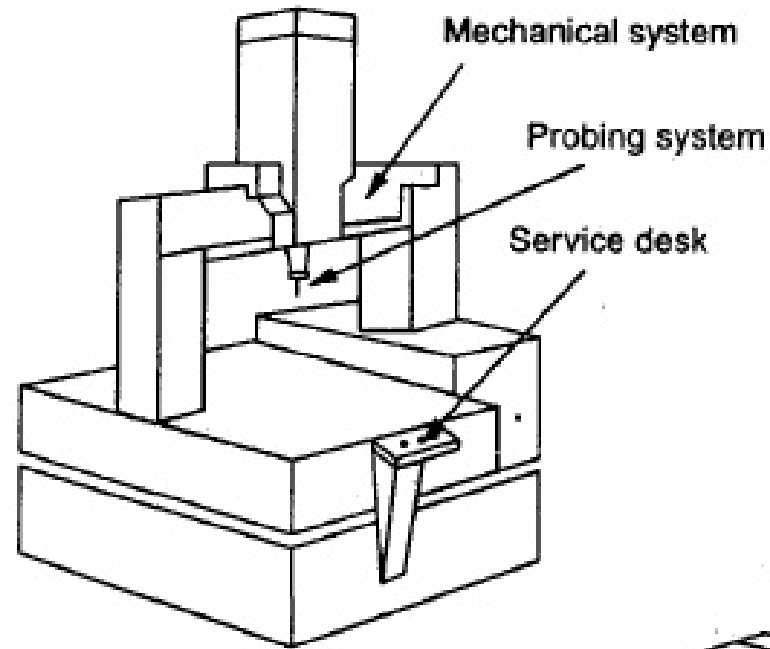
Fig. 5.4. (ii) Bridge type



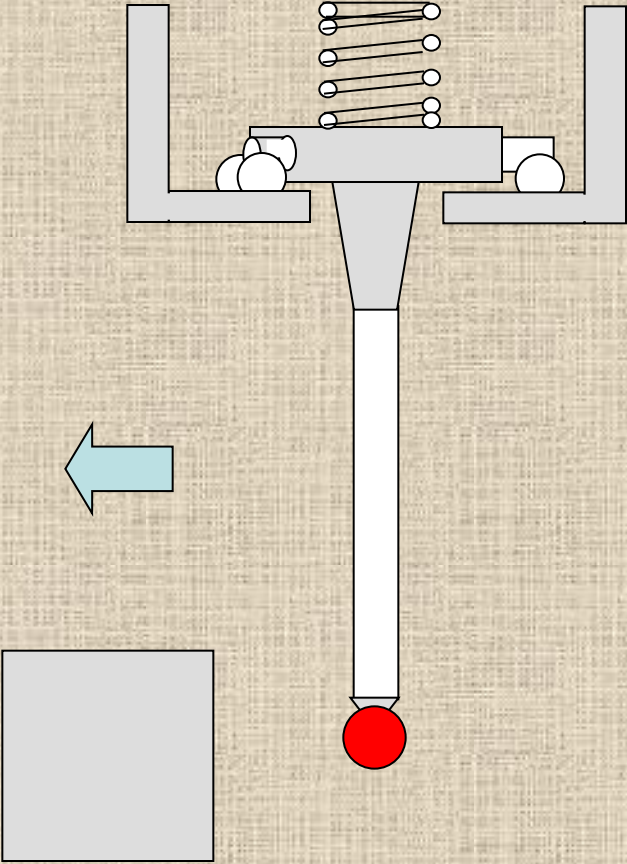
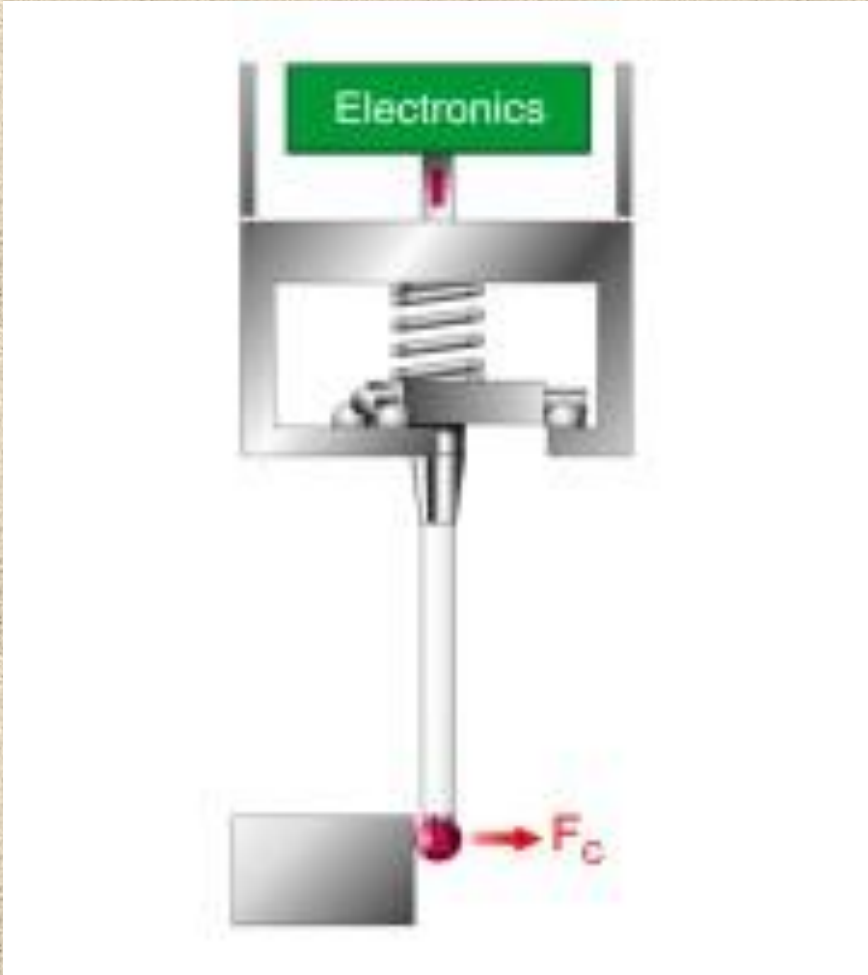
(iii) Cantilever type



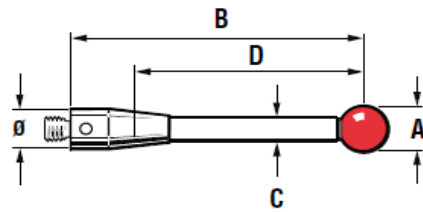
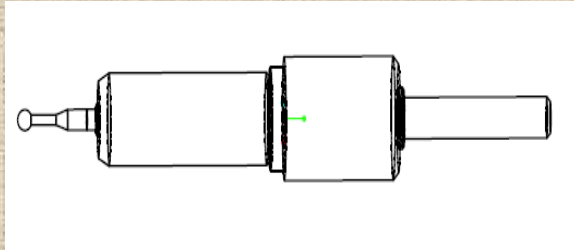
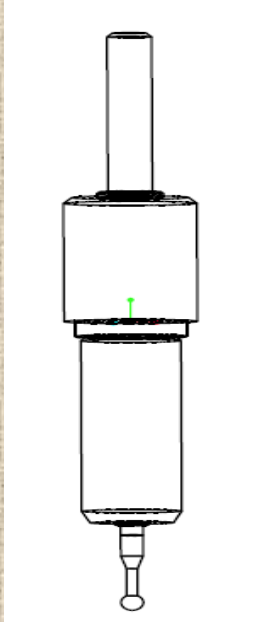
(iv) Gantry type



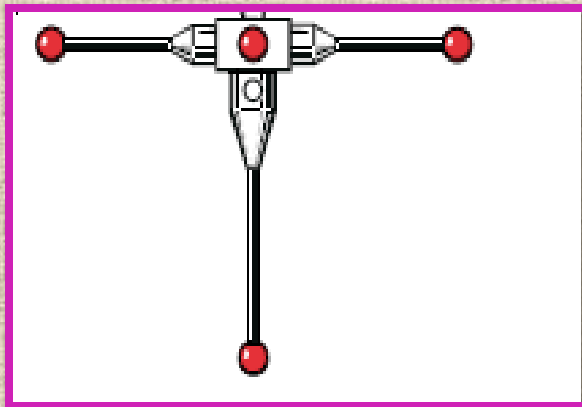
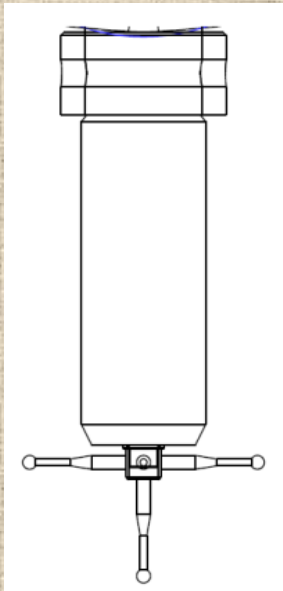
CMM



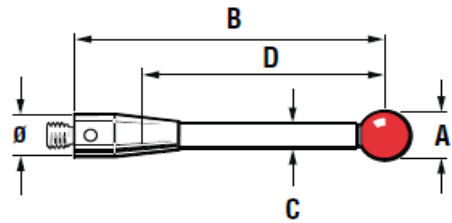
CMM



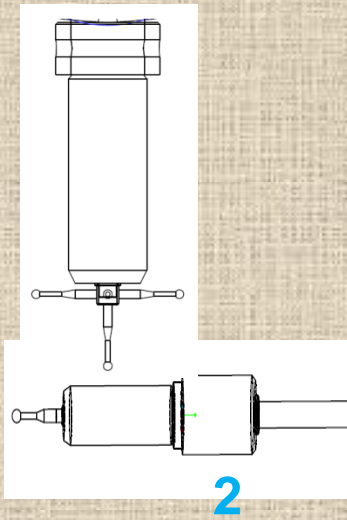
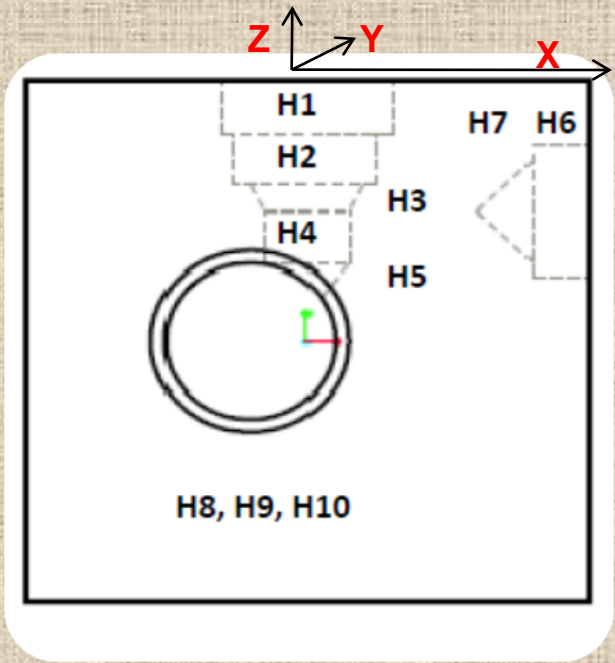
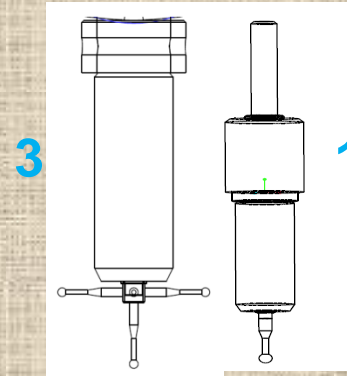
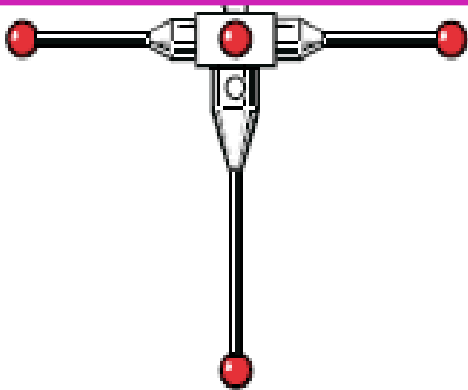
- A** Ball diameter
- B** Overall length
- C** Stem diameter
- D** Effective working length
- Ø M2 = 3 mm
- Ø M3 = 4 mm
- Ø M4 = 7 mm
- Ø M5 = 10 mm



CMM



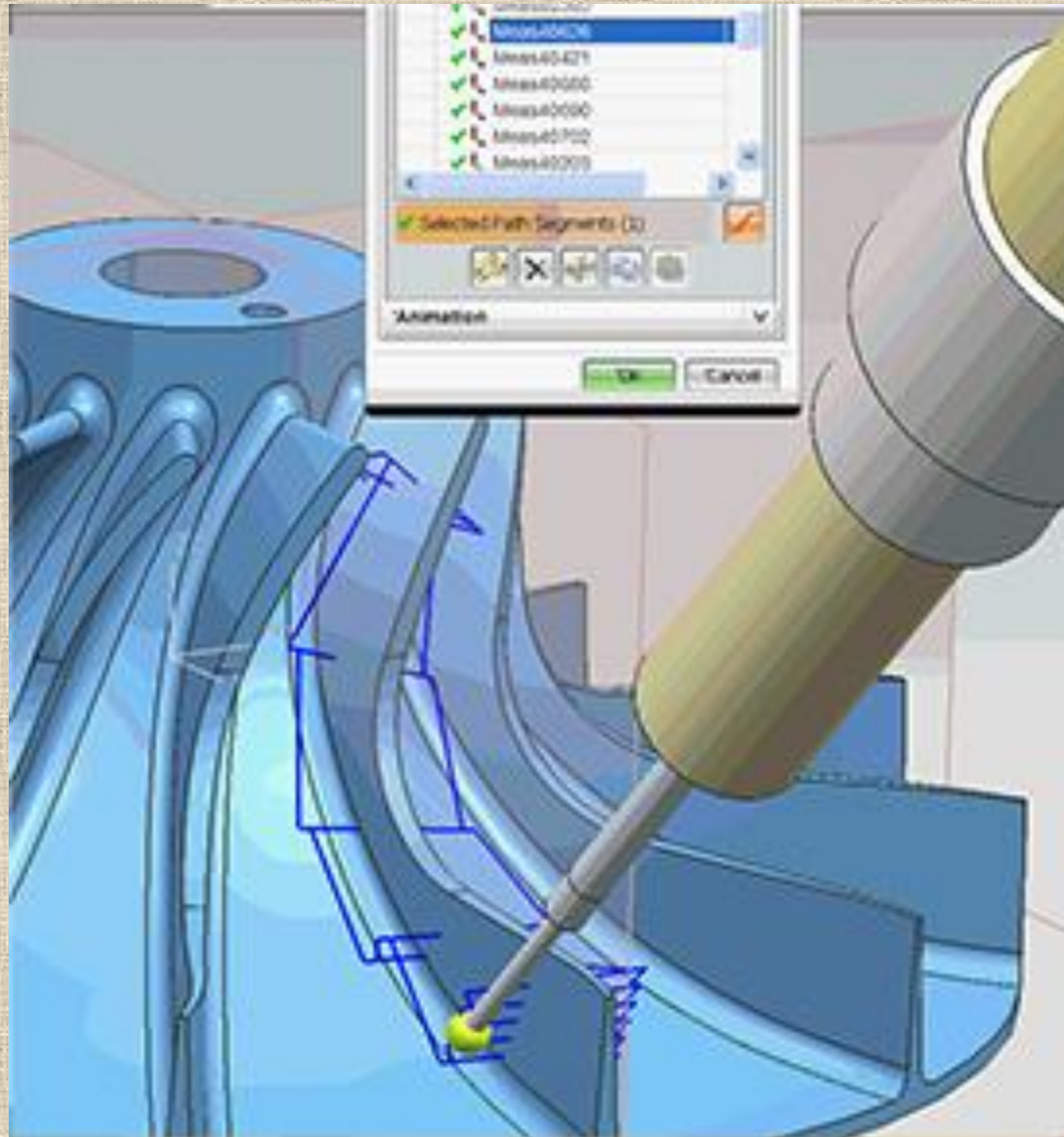
- A** Ball diameter
- B** Overall length
- C** Stem diameter
- D** Effective working length
- Ø M2 = 3 mm
- Ø M3 = 4 mm
- Ø M4 = 7 mm
- Ø M5 = 10 mm



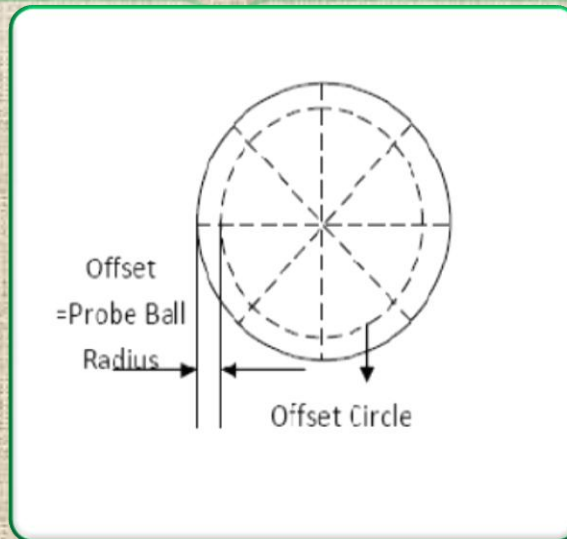
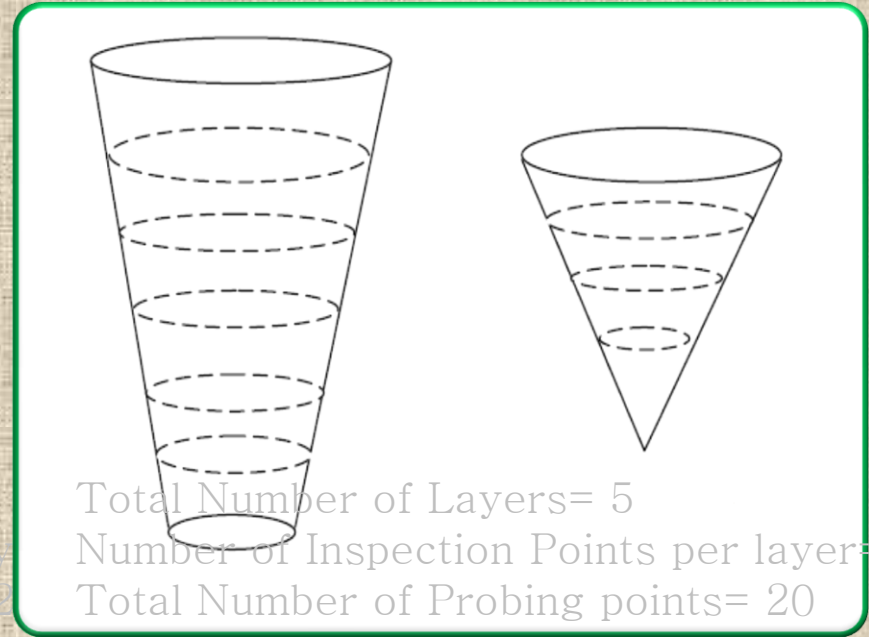
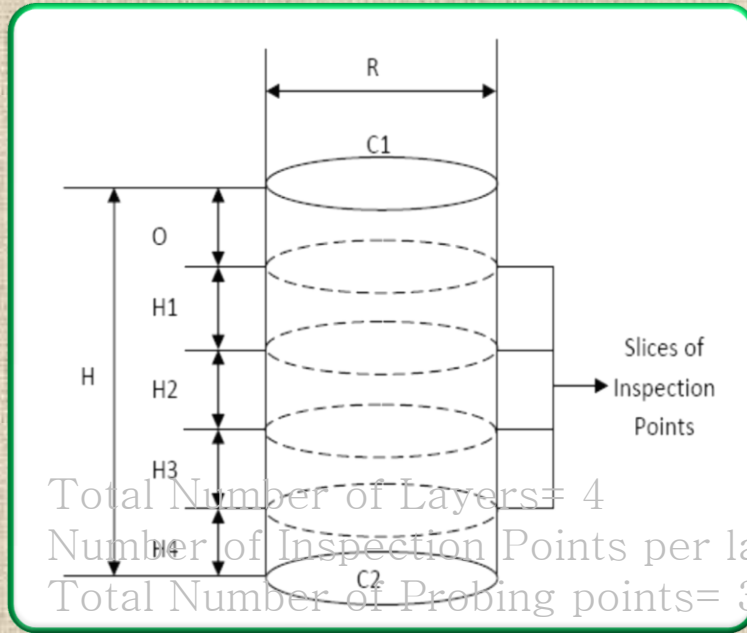
CMM



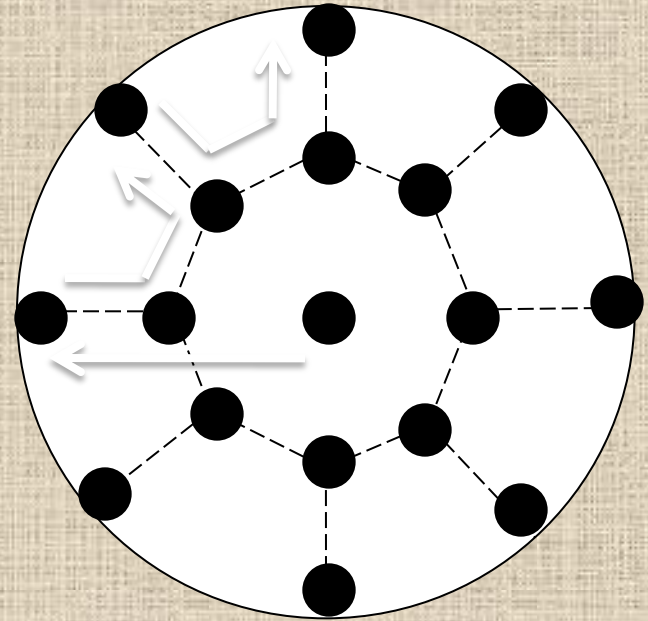
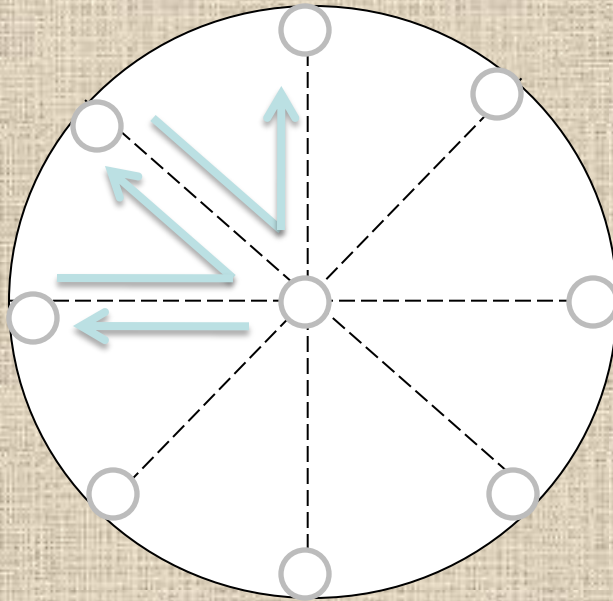
CMM



CMM



CMM



Four Modes of Operation

Manual Mode

Teaching Mode

Interactive Mode

Programming Mode

- Manual Program
- Automatic Program

CMM



Flatness = 6 faces

Parallelism = 3

Perpendicularity = 12

Total = 21 tolerances

CMM – Coordinate Measuring Machine

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Measuring Cylinder

Probing Strategy

Ref: AUTO

Nbr of Paths: 4

Depth 1: 0.500

Depth 2: 9.500

Nbr Pnts/Path: 8

Total Pnts Nbr: 32

Starting Angle: 285.654

Total Angle: 360.000

Probing Mode

Mode: Static

Nominal Outer

CNC Distances

Approach: 7.000

Search: 1.500

Retract: 7.000

5.000

Program

E:\it project\DMIS

00001 *** AT Path: DMIS File for this

00002 \$\$-> DMIS File Number - 1

00003 \$\$-> Manifold Part / MFG001

00004 DMISMN / DMIS Program

00005 UNITS / MM, ANGDEC

00006 S(1)= SNSDEF / PROBE, INDE

00007 0.000000, -1.000000, 0.000000,

00008 \$\$-> FEATNO / 161

00009 # MODE / PROG, AUTO

00010 SNSLCT / S(1)

00011 FEDRAT / MESVEL, MPM, 15.C

00012 FEDRAT / POSVEL, MPM, 10.C

00013 ACLRAT / MESACL, MPMM, 5.L

00014 ACLRAT / POSACL, MPMM, 10

00015 PRCOMP / OFF

00016 SNSSET / APPRCH, 7.000000

00017 SNSSET / RETRACT, 7.000000

00018 SNSSET / CLRSRF, 0.000000

Error

Warning line 014: Major word ignored.

Warning line 030: Major word ignored.

Warning line 032: Major word ignored.

Warning line 034: Major word ignored.

Warning line 036: Major word ignored.

Warning line 038: Major word ignored.

	Actual	Nominal	Iso	Tol -	Tol +	Dev	Tendency	Out of Tol.
DIST		40.000						
XoY		90.000						
YoZ		0.000						
ZoX								
F.F.								

G: A = 90.0 B = 0.0

X 21.759

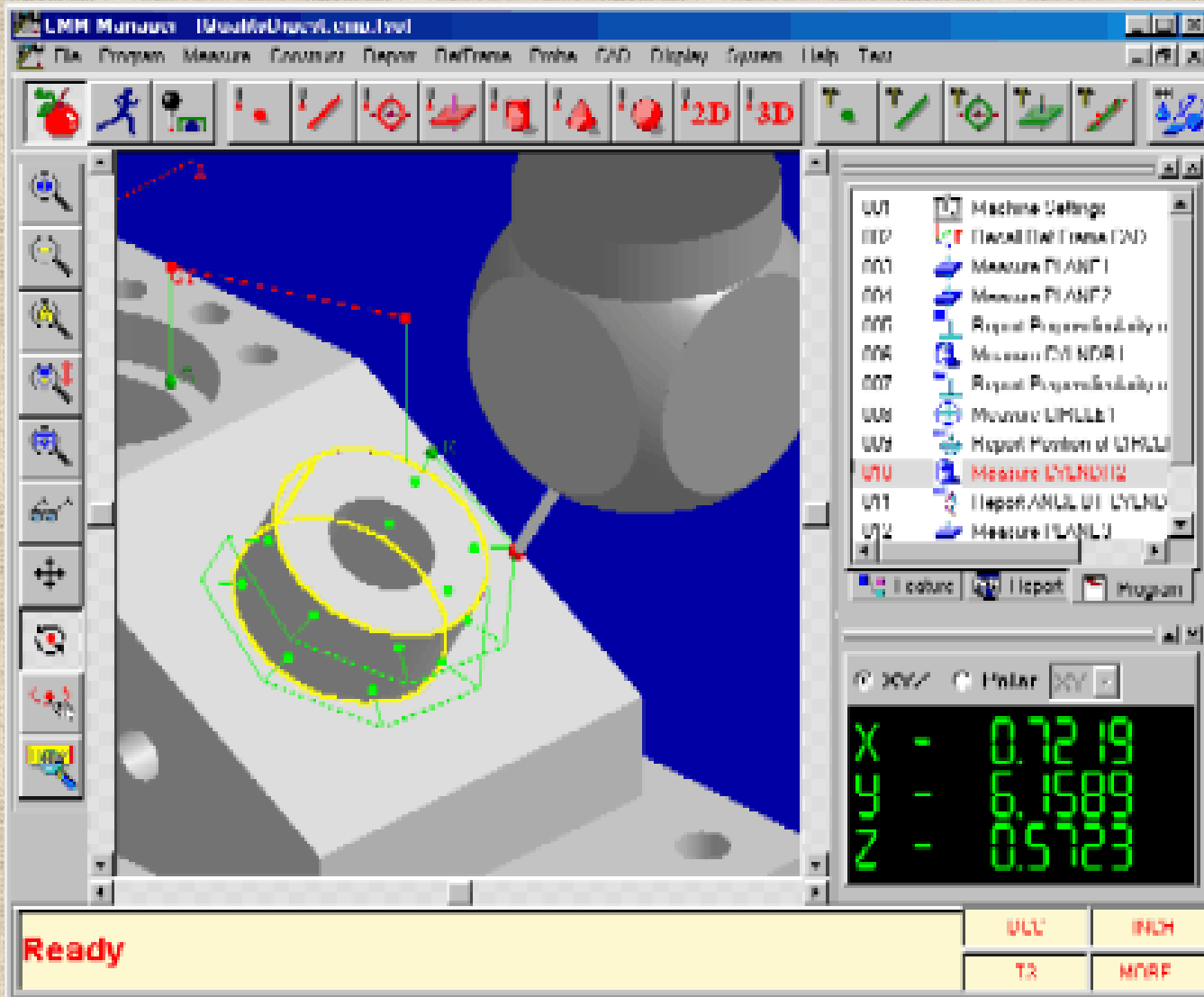
Y -63.626

Z -32.775

Silma XG metropass MM DEGD 6:48 PM

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CMM



CMM – Coordinate Measuring Machine

DMIS

\$\$* IIT Delhi- DMIS File For Verifying Conicity:

Generated by Bhaskar

\$\$-> DMIS File Number - 2

\$\$-> Manifold Part / MFG002

DMISMN / DMIS Program

UNITS / MM, ANGDEC

\$\$-> FEATNO / 88

\$\$ Verify Gtol g02

T(CONICITY)= TOL / CNCTY, 0.005000

OUTPUT / FA(M_CN02), TA(CONICITY)

\$\$-> END /

ENDFIL

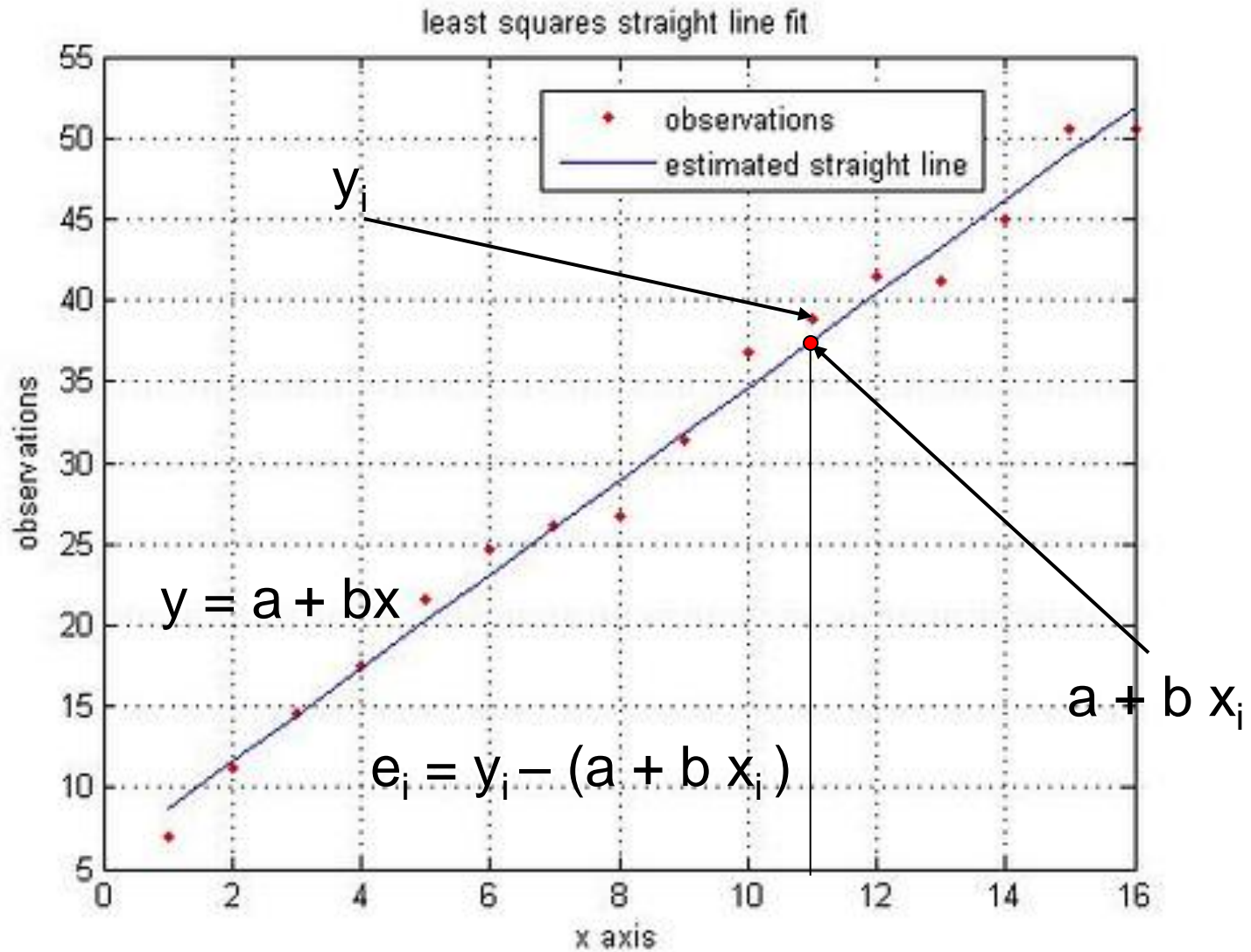


DMIS

```
$$$* IIT Delhi- DMIS File For Measuring A Cone: Generated by Bhaskar
$$-> DMIS File Number - 2
$$-> Manifold Part / MFG002
DMISMN / DMIS Program
UNITS / MM, ANGDEC
0.000000, 0.000000, 1.000000, 100.000000, 2.000000
$$-> FEATNO / 88
MODE / PROG, AUTO
SNSLCT / S(2)
FEDRAT / MESVEL, MPM, 15.000000
FEDRAT / POSVEL, MPM, 20.000000
ACLRAT / MESACL, MPMM, 5.000000
ACLRAT / POSACL, MPMM, 10.000000
PRCOMP / OFF
SNSET / APPRCH, 0.249996
SNSET / RETRCT, 0.249996
SNSET / CLRSRF, 0.000000
F(M_CN02)= FEAT / CONE, INNER, CART, $
0.000000, 0.000000, -44.999981, $
0.000000, 0.000000, 1.000000, 36.870000
MEAS / CONE, F(M_CN02), 6.000000
RAPID / 1.000000
GOTO / 0.0000000000, 0.0000000000, 2.000000
RAPID / 1.000000
GOTO / 0.000000, 0.000000, 2.000000
RAPID / 1.000000
GOTO / 0.000000, 0.000000, -37.000000
PTMEAS / CART, 6.000008, 0.000000, -37.000000, $
-0.799999, 0.000000, 0.600001
PTMEAS / CART, 0.000000, 6.000008, -37.000000, $
0.000000, -0.799999, 0.600001
PTMEAS / CART, -0.000000, -6.000008, -37.000000, $
0.000000, 0.799999, 0.600001
PTMEAS / CART, 9.192388, 9.192388, -2.000000, $
0.707107, 0.707107, 0.000000
```



CMM



CMM – Coordinate Measuring Machine

Straightness

$$y = a + bx$$

$$\therefore \sum_{i=1}^n [y_i - (a + bx_i)]^2 = \min.$$

$$\left\{ \begin{array}{l} \frac{\partial \Pi}{\partial a} = 2 \sum_{i=1}^n [y_i - (a + bx_i)] = 0 \\ \frac{\partial \Pi}{\partial b} = 2 \sum_{i=1}^n x_i [y_i - (a + bx_i)] = 0 \end{array} \right.$$

Straightness

$$\left\{ \begin{array}{l} \frac{\partial \Pi}{\partial a} = 2 \sum_{i=1}^n [y_i - (a + bx_i)] = 0 \\ \frac{\partial \Pi}{\partial b} = 2 \sum_{i=1}^n x_i [y_i - (a + bx_i)] = 0 \end{array} \right.$$

$$\left\{ \begin{array}{l} \sum_{i=1}^n y_i = a \sum_{i=1}^n 1 + b \sum_{i=1}^n x_i \\ \sum_{i=1}^n x_i y_i = a \sum_{i=1}^n x_i + b \sum_{i=1}^n x_i^2 \end{array} \right.$$

Straightness

$$\begin{cases} \sum_{i=1}^n y_i = a \sum_{i=1}^n 1 + b \sum_{i=1}^n x_i \\ \sum_{i=1}^n x_i y_i = a \sum_{i=1}^n x_i + b \sum_{i=1}^n x_i^2 \end{cases}$$

$$\begin{cases} a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{n \sum x^2 - (\sum x)^2} \\ b = \frac{n \sum xy - (\sum x)(\sum y)}{n \sum x^2 - (\sum x)^2} \end{cases}$$

Compute straightness for following data
captured using CMM

(10.03, 29.98)

(12.96, 39.02)

(40.05, 119.89)

(14.94, 45.1)

(50.0, 149.88)

$$(x - x_c)^2 + (y - y_c)^2 + (z - z_c)^2 = r^2$$

$$x^2 + y^2 + z^2 + x_c^2 + y_c^2 + z_c^2 - 2xx_c - 2yy_c - 2zz_c = r^2$$

$$(x_c^2 + y_c^2 + z_c^2 - r^2)/2 - xx_c - yy_c - zz_c + (x^2 + y^2 + z^2)/2 = 0$$

$$\text{Let } (x_c^2 + y_c^2 + z_c^2 - r^2)/2 = K$$

$$\text{Then } xx_c + yy_c + zz_c - K = (x^2 + y^2 + z^2)/2$$

$$x_1x_c + y_1y_c + z_1z_c - K = (x_1^2 + y_1^2 + z_1^2)/2$$

$$x_2x_c + y_2y_c + z_2z_c - K = (x_2^2 + y_2^2 + z_2^2)/2$$

$$\begin{bmatrix} x_1 & y_1 & z_1 & -1 \\ x_2 & y_2 & z_2 & -1 \\ x_3 & y_3 & z_3 & -1 \\ \vdots & \vdots & \vdots & \vdots \\ x_n & y_n & z_n & -1 \end{bmatrix} \begin{bmatrix} xc \\ yc \\ zc \\ K \end{bmatrix} = \begin{bmatrix} \frac{x_1^2 + y_1^2 + z_1^2}{2} \\ \frac{x_2^2 + y_2^2 + z_2^2}{2} \\ \frac{x_3^2 + y_3^2 + z_3^2}{2} \\ \vdots \\ \frac{x_n^2 + y_n^2 + z_n^2}{2} \end{bmatrix}$$

$$A * X = B$$

$$A^T A X = A^T B$$

$$X = (A^T A)^{-1} A^T B$$

$$A^* X = B$$

$$A^T A X = A^T B$$

$$X = (A^T A)^{-1} A^T B$$