FACULTY OF ENGINEERING

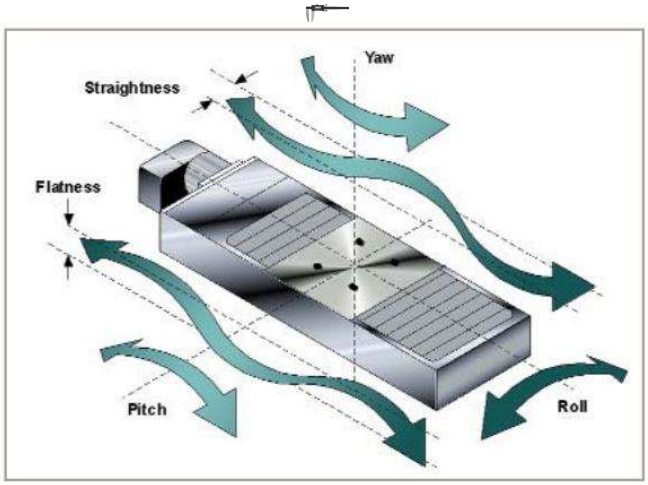
DESIGN AND PRODUCTION ENGINEERING DEPARTMENT

Credit Hour System
Metrology

Assignment No.

(4)

Out of Flat Straightness Problems



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ID	*Signature*

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1. 1. A straight edge was tested by means of sprit level having a vial radius of 50 mt, and scale division of 2.5 mm. The following readings were taken every 100 mm:

divisions	-1	+2	0	-3	+2.5	0	-1

Determine the out of straightness both graphically and analytically.

2. The straightness of a slide was tested using a spirit level of 1.5 mm scale value and a radius of curvature of 3 m. The readings are:

divisions	-3	+4	-1	+2	-3	+4	-2	-7

Find out the straightness both graphically and semi analytically. The distance between any two points is 100 mm.

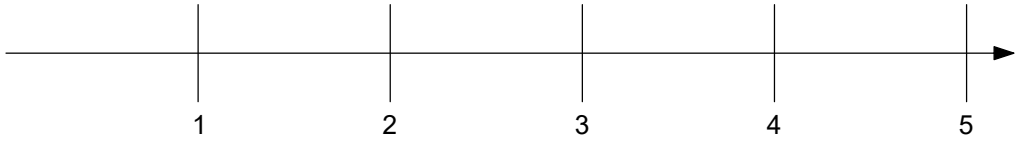
3. The straightness of the slide way of a lathe was tested using a sensitive level of a scale value of 0.0004 radian/mt. The readings taken every 200 mm are:

From left to right	+1	+2	0	-3	+2	-1	+3
From right to left	-2	+1	-1	+2	0	-1	1

Find out the out of straightness both analytically and experimentally.

Solved Example

A straight edge of rectangular cross section is checked using a precision spirit level which was marked " 1 division = 0.5 mm in 100 mm. The readings of the bubble in the forward and backward directions for the five positions taken along the edges as shown in the following table, readings are taken as divisions. The interval distance is 100 mm. Find Out the out of straightness both analytically and semi analytically.



	First	Second	Third	Fourth	Fifth
Forward	0	13	17	7	15
Backward	0	11	15	5	13

Solution

Step No. 1

Convert the reading from division to their corresponding mm values.

Scale value of the level = 0.5 mm/100 mm
The reading were taken at 100 mm interval
Thus each reading must be multiplied by 0.5 mm

	First	Second	Third	Fourth	Fifth
Forward	0	6.5	8.5	3.5	7.5
Backward	0	5.5	7.5	2.5	6.5

Step No. 2

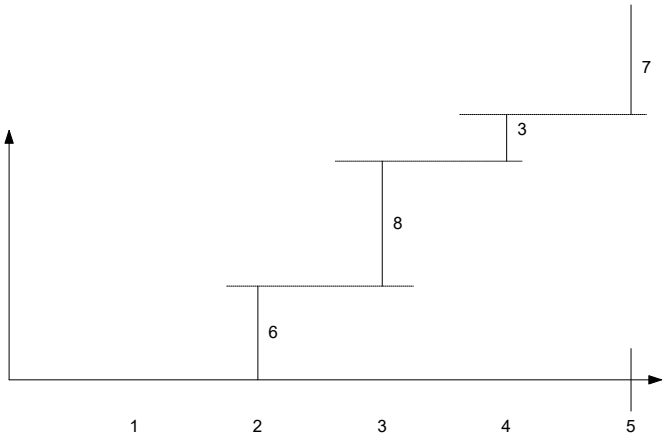
Exclude the error of position by taking the average of reading in both forward and backward at each point

	First	Second	Third	Fourth	Fifth
Forward	0	6.5	8.5	3.5	7.5
Backward	0	5.5	7.5	2.5	6.5

Average	*0*	*6*	*8*	*3*	*7*

Step No. 3

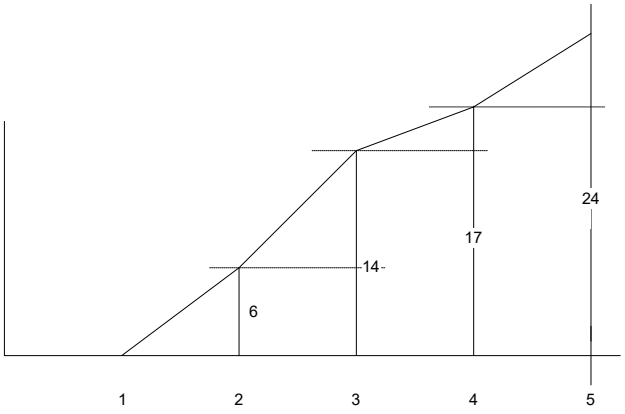
Convert the relative readings to absolute readings



	First	*Second*	*Third*	*Fourth*	*Fifth*
Average	*0*	*6*	*8*	*3*	*7*
Absolute	*0*	*6*	*14*	*17*	*24*

The readings now are as shown below

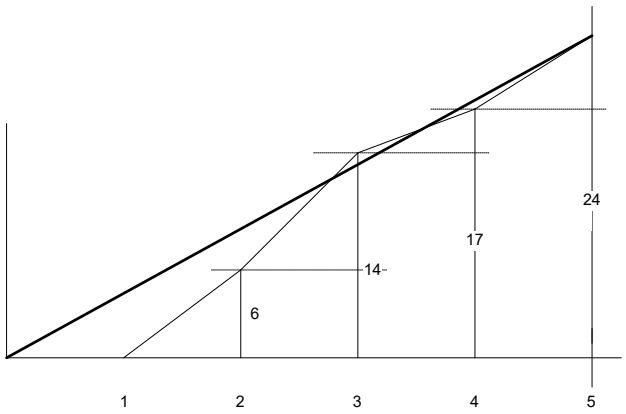
	First	*Second*	*Third*	*Fourth*	*Fifth*
Absolute	*0*	*6*	*14*	*17*	*24*



Semi Analytical Solution

Step - 1

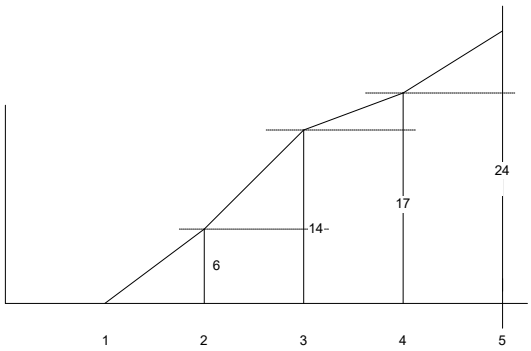
Connect the first and last points. Consider this line as reference line



Step No-2

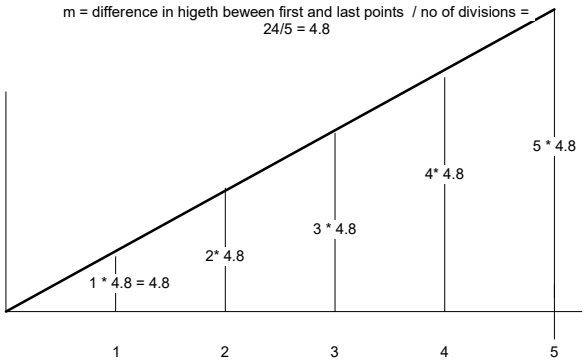
Find the height of the measured points refereed to the reference line instead of the horizontal line.

The following are the measured values measured refereed to the horizontal line



	First	Second	Third	Fourth	Fifth
Average	0	6	8	3	7
Absolute	0	6	14	17	24

While the following are their corresponding at the generated reference line



Find the slope m = 24/5 4.8
Find the height of line (with slope m) at each point

	First	*Second*	*Third*	*Fourth*	*Fifth*
	*1 * 4.8*	*2 * 4.8*	*3 * 4.8*	*4* 4.8*	*5 * 4.8*
Absolute	*4.8*	*9.6*	*14.4*	*19.2*	*24*

Calculate the difference between the two corresponding values

to get the measured valued measured from the reference line

	First	*Second*	*Third*	*Fourth*	*Fifth*
Measured to Hl line	*0*	*6*	*14*	*17*	*24*
Reference line	*4.8*	*9.6*	*14.4*	*19.2*	*24*
Measured to ref Line	*-4.8*	*-3.6*	*-.4*	*-2.2*	*0*

The previous valued were determined normal to horizontal line. These values have to be normal to the reference line

Calculate the inclination of reference line
$\tan \theta = 24/ (100 * 5) = 0.048$
$\theta \approx 0.05^{o} = 3 \backslash$
$\cos \theta = 0.9988$

	First	*Second*	*Third*	*Fourth*	*Fifth*
Measured to Hl line	*0*	*6*	*14*	*17*	*24*
Reference line	*4.8*	*9.6*	*14.4*	*19.2*	*24*
Measured to ref Line	*-4.8*	*-3.6*	*-.4*	*-2.2*	*0*
Measured normal to ref line cos 3	*-4.794*	*-3.5955*	*-.3995*	*-2.197*	*0*

Now the out of straightness values are

	First	*Second*	*Third*	*Fourth*	*Fifth*
values	*-4.794*	*-3.5955*	*-.3995*	*-2.197*	*0*

And the maximum out of straightness is 4.794

Analytical Solution

As previously mentioned, the point heights are

	First	*Second*	*Third*	*Fourth*	*Fifth*
Absolute	*0*	*6*	*14*	*17*	*24*

Step -1

Find the centroid Point

	Point (x)	Height (Y)
	0	0
	1	0
	2	6
	3	14
	4	17
	5	24
Sum	15	61
Average = Sum/ no of points	2.5	10.1667

The centroid point coordinates are ($X^{\backslash}$, $Y^{\backslash}$) = (2.5, 10.1667)

Step -2

Calculated X and Y for each point related to the centroid point

X at any point = X - ($X^{\backslash}$)

Y at any point = Y - ($Y^{\backslash}$)

Point	Height	X- X\	Y- Y\
0	0	-2.5	-10.1667
1	0	-1.5	-10.1667
2	6	-.5	-4.1667
3	14	0.5	3.8333
4	17	1.5	6.8333
5	24	2.5	13.8333

Step -3

Find the reference line which is the least square line

$m = \sum (X - X\backslash) (Y-Y\backslash) / \sum (X - X\backslash)^2$

Therefore, two additional column must be determined to calculate

$(X - X\backslash) (Y-Y\backslash)$ and $(X - X\backslash)^2$

Point	X- X\	Y- Y\	(x-x\) (y-y\)	$(X- X\backslash)^2$
1	-2.5	-10.1667	25.41667	6.25
2	-1.5	-10.1667	15.25	2.25
3	-.5	-4.16667	2.083333	0.25
4	0.5	3.833333	1.916667	0.25
5	1.5	6.833333	10.25	2.25
6	2.5	13.83333	34.58333	6.25
Sum			89.5	17.5

$m = \sum (X - X\backslash) (Y-Y\backslash) / \sum (X - X\backslash)^2$

= 89.5/17.5 = 5.114286

Find the height of line (with slope m) at each point

Point		
1	-2.5*5.114286	-12.7857
2	-1.5*5.114286	-7.67143
3	-0.5*5.114286	-2.55714
4	0.5*5.114286	2.557143
5	1.5*5.114286	7.671429
6	2.5*5.114286	12.78571

Point	Reading	Line	Deviation
1	-10.1667	-12.7857	2.619047619
2	-10.1667	-7.67143	-2.495238095
3	-4.1667	-2.55714	-1.60952381
4	3.8333	2.557143	1.276190476
5	6.8333	7.671429	-0.838095238
6	13.8333	12.78571	1.047619048

Max out of straightness = 2.619 + 2.495 = 5.114

Distance (Xi)	Heights (Yi)	Xc=Xi-Xa	Yc=Yi-Ya	Xc*2	Xc*Yc	Y=mXi	Deviation = Yc-Y
0	0	-500	-7	250000	3500	-6.31818	-0.681818182
100	0	-400	-7	160000	2800	-5.05455	-1.945454545
200	6	-300	-1	90000	300	-3.79091	2.790909091
300	8	-200	1	40000	-200	-2.52727	3.527272727
400	3	-100	-4	10000	400	-1.26364	-2.736363636
500	7	0	0	0	0	0	0
600	6	100	-1	10000	-100	1.263636	-2.263636364
700	10	200	3	40000	600	2.527273	0.472727273
800	10	300	3	90000	900	3.790909	-0.790909091
900	15	400	8	160000	3200	5.054545	2.945454545
1000	12	500	5	250000	2500	6.318182	-1.318181818
5500	77			1100000	13900		

Solved Example:

A straight edge of rectangular cross section is checked using sensitive level and the readings of the bubble in the forward directions for the five positions taken along the edge are 0. 6.5, 8.5, 3.5, 7.5 and O, 5.5, 7.5, 2.5, 6.5 respectively. The straight edge when checked was supported its end as in Fig. 39.

The procedure often determining the mean value, column 4, is to force the end points. A, B to zero and then to adjust all the other points accordingly, referring to the following Fig. , then:

X	Y			Heights of pat C`, D`, E`, F`	Deviation from ZAB	Deflec-tion	out of straigh-t ess
	Forward	ba kward	average				
0	o	0	0	0	0	0	0
1	0	0	0	m = 1.4	c-c`=-1.4	Y_1	$Z_1 - Y_1$
2	6.5	5.5	6	2m = 2.3	d-d`=+3.2	Y_2	$Z_2 - Y_2$
3	8.5	7.5	8	3m = 4.2	E-E`=+3.6	Y_3	$Z_3 - Y_3$
4	3.5	2.5	3	4m = 5.6	F-F`=-2.6	Y_4	$Z_4 - Y_4$
5	7.5	6.5	7	5m = 7.o	0	0	0
	$m = \frac{Y_n}{n} = \frac{7}{5} = 1.4$						

Measured distance	Heights Y_i	Centroid X, Y	$X_i = X_i - \bar{X}$	X_i^2	$Y_i = Y_i - \bar{Y}$	$X_i Y_i$	Slope m	$Y` = mX_i$	Deviation $Y_i - Y`$
X_1	Y_1	$\bar{X} = \frac{X_i}{n}$							
X_2	Y_2								
X_3	Y_3	$\bar{Y} = \frac{Y_i}{n}$					$m = \frac{X_i Y_i}{X_i^2}$		
⋮	⋮								
X_n	Y_n								
X_i	Y_i			X_i^2		$X_i Y_i$			

X_i	Y_i	$\bar{X}$, $\bar{Y}$	X_i	X_i^2	Y_i	X_iY_i	slope	$Y = mX_i$	Deviation
0	0		-500	250000	-7	3500		-6.33	-0.67
100	0		-400	160000	-7	2800		-5.06	-1.94
200	6		-300	90000	-1	300		-3.79	+2.79
300	8	$\bar{X}$ =	-200	40000	+1	-200		-2.53	+3.53
400	3	$\frac{5500}{11}$	-100	10000	-4	400	$m=\frac{13900}{1100000}$	-1.27	-2.73
500	7	=500	0	0	0	0	=0.0127	0	0
600	6	$\bar{Y}=\frac{77}{11}$-	100	10000	-1	-100		1.27	-2.73
700	10	=7	200	40000	+3	600		2.53	+1.53
800	10		300	90000	+3	900		3.97	-0.79
900	15		400	160000	+3	3200		5.06	+3.06
1000	12		500	250000	+5	2500		6.33	+1.33
5500	77			1100000		13900			