Abstract:

In this experiment a macro scale surface property of a sample; namely, straightness was investigated.

Auto collimator consisting of a mobile car moving along a marked straight edge with a light source, mirror and display screen was used for this purpose. Rise and fall angles were measured and then rise and fall length was calculated using a conversion factor.

Then using two different methods: line joining two ends and least square method to find best fit and consequently maximum deviation was used. This gave a maximum deviation (error) in straightness of the surface of values of 56.8 μm and -33.74 μm respectively.

Objective:

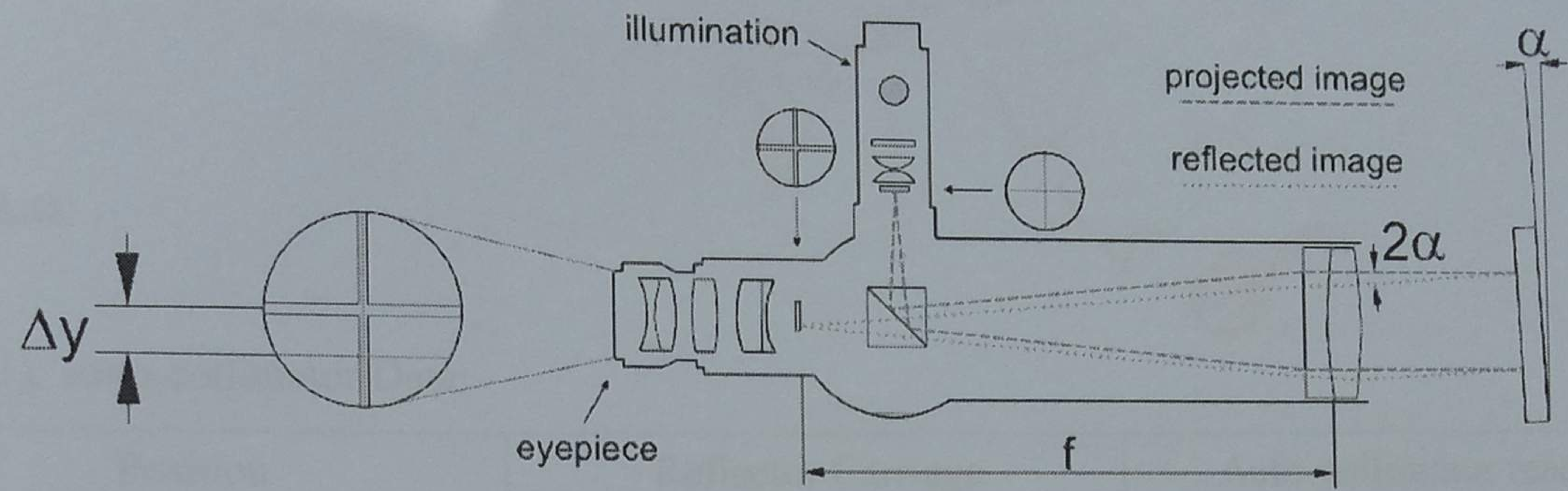
To measure the straightness of a surface of a given sample

List of symbols:

| | | |
|---|---|---|
| C | Constance of linear equation | µm |
| h | Conversion factor | µm |
| l | Carriage length | mm |
| m | Slope | Dimensionless |
| X | Position of carriage | mm |
| $X_m$ | Limiting error in position x (deviation) | mm |
| $X_{prime}$ | The average position value | mm |
| Y | Cumulative Rise/Fall in | µm |
| $Y_{Least}$ | Line joining end points values | µm |
| $Y_{LJEP}$ | Least square equation values | µm |
| $Y_m$ | limiting error in cumulative Rise/fall y (deviation) | µm |
| $Y_{prime}$ | The average cumulative error value | µm |

objective

Apparatus




Fig(1)

How it works?

An autocollimator works by projecting an image onto a target mirror, and measuring the deflection of the returned image against a scale, either visually or by means of an electronic detector

Experimental setup and procedure

1. Clean the surface plate or table.
2. Position the auto-collimator in the line with reflector. Switch on the lamp in the auto-collimator, the alignment between the auto-collimator and reflector should be checked at both extremes of the operational distance to make certain that the target graticule is contained within the eyepiece field.
3. Fix a guide strip to control the horizontal displacement of the reflector and minimize the movement of the target graticlue.
4. Mark off the positions along the surface plate equal to the pitch positions on the reflector base.
5. At the initial position takes the reading and tabulate the reading.
6. This method is to continue until the final outward position is recorded.

given data

Given data:

Table (1): Auto-collimator Data:

| Position | Reflector Carriage (mm) | Auto-collimator reading | |
|---|---|---|---|
| | | Minutes | Seconds |
| 1 | 0 | 0 | |
| 2 | 100 | 14 | 23 |
| 3 | 200 | 15 | 41.8 |
| 4 | 300 | 16 | 27 |
| 5 | 400 | 15 | 50 |
| 6 | 500 | 17 | 35 |

Results and discussion:

Table2: calculated data using line joining end points method.

| Position (mm) | Angle reading (sec) | Difference from first reading (sec) | Rise/fall in interval length"l" (micro m) | Cumulative rise/fall wrt line ab (micro m) | Line joining end points (micro m) | Difference C6-C5 (micro m) |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 863 | 0 | 0 | 0 | 48.1 | 48.1 |
| 200 | 941.8 | 78.8 | 39.4 | 39.4 | 96.2 | 56.8 |
| 300 | 987 | 124 | 62 | 101.4 | 144.3 | 42.9 |
| 400 | 950 | 87 | 43.5 | 144.9 | 192.4 | 47.5 |
| 500 | 1055 | 192 | 96 | 240.9 | 240.9 | 0 |

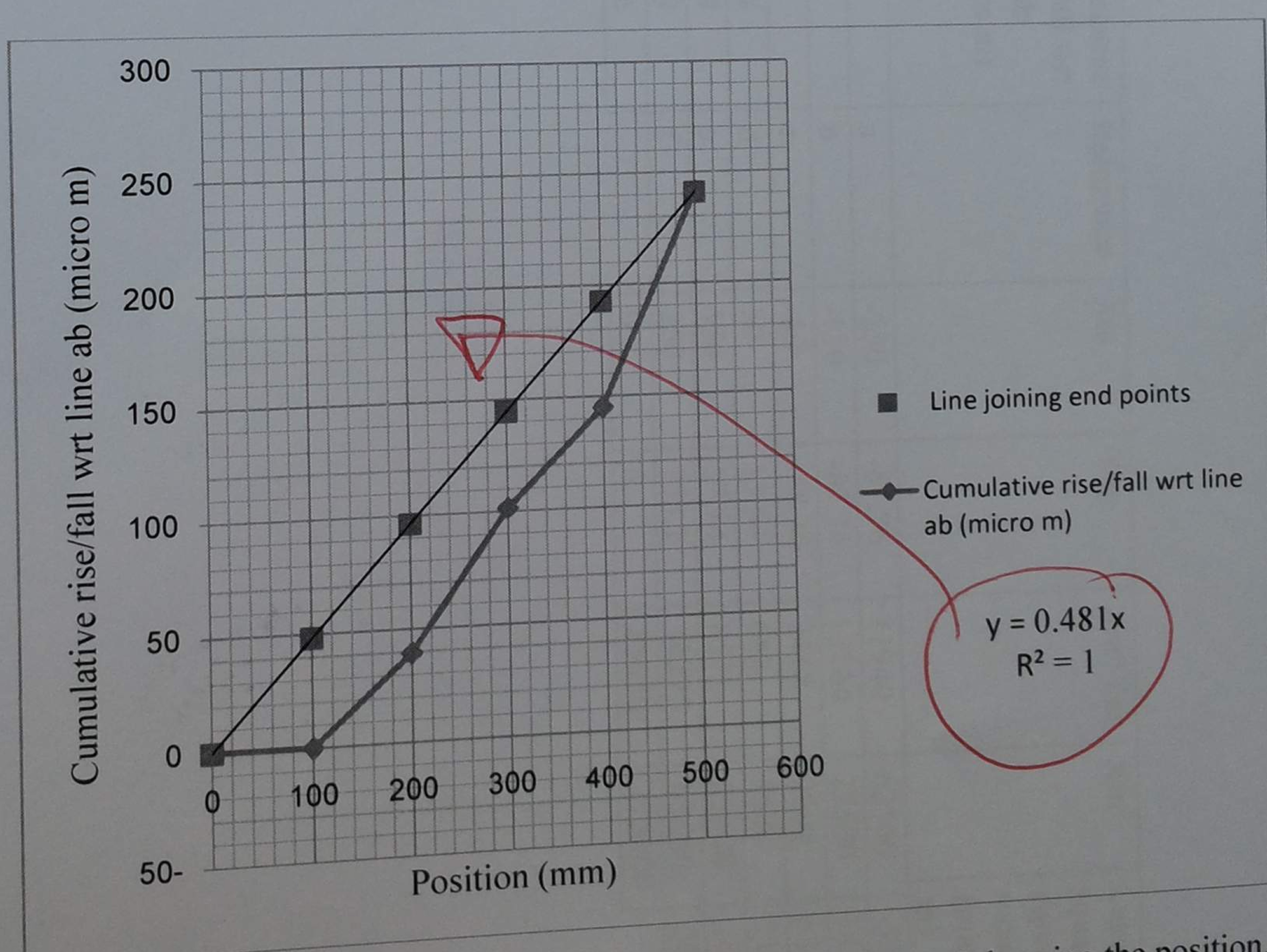



Figure (2): change in cumulative rise/fall wrt line ab as result of changing the position.

Table3 :calculated data using least square error method.

| | Position (mm) | Angle reading (sec) | Difference from first reading (sec) | Rise/fall in interval length "l" (micro m) | Cumulative rise/fall wrt line ab (micro m) | Reference | Xm | Ym | Xm*Ym | $Xm^2$ | Least square equation values (micro m) | Maximum difference (micro m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | 0 | a | -250 | -87.76 | 21940 | 62500 | -33.74 | -33.74 |
| | 100 | 863 | 0 | 0 | 0 | b | -150 | -87.76 | 13164 | 22500 | 14.86 | 14.86 |
| | 200 | 941.8 | 78.8 | 39.4 | 39.4 | c | -50 | -48.36 | 2418 | 2500 | 63.46 | 24.06 |
| | 300 | 987 | 124 | 62 | 101.4 | d | 50 | 13.64 | 682 | 2500 | 112.06 | 10.66 |
| | 400 | 950 | 87 | 43.5 | 144.9 | e | 150 | 57.14 | 8571 | 22500 | 160.66 | 15.76 |
| | 500 | 1055 | 192 | 96 | 240.9 | f | 250 | 153.1 | 38275 | 62500 | 209.26 | -31.64 |
| Σ | 1500 | 4796.8 | 481.8 | 240.9 | 526.6 | | 0 | 0 | 85050 | 175000 | | |

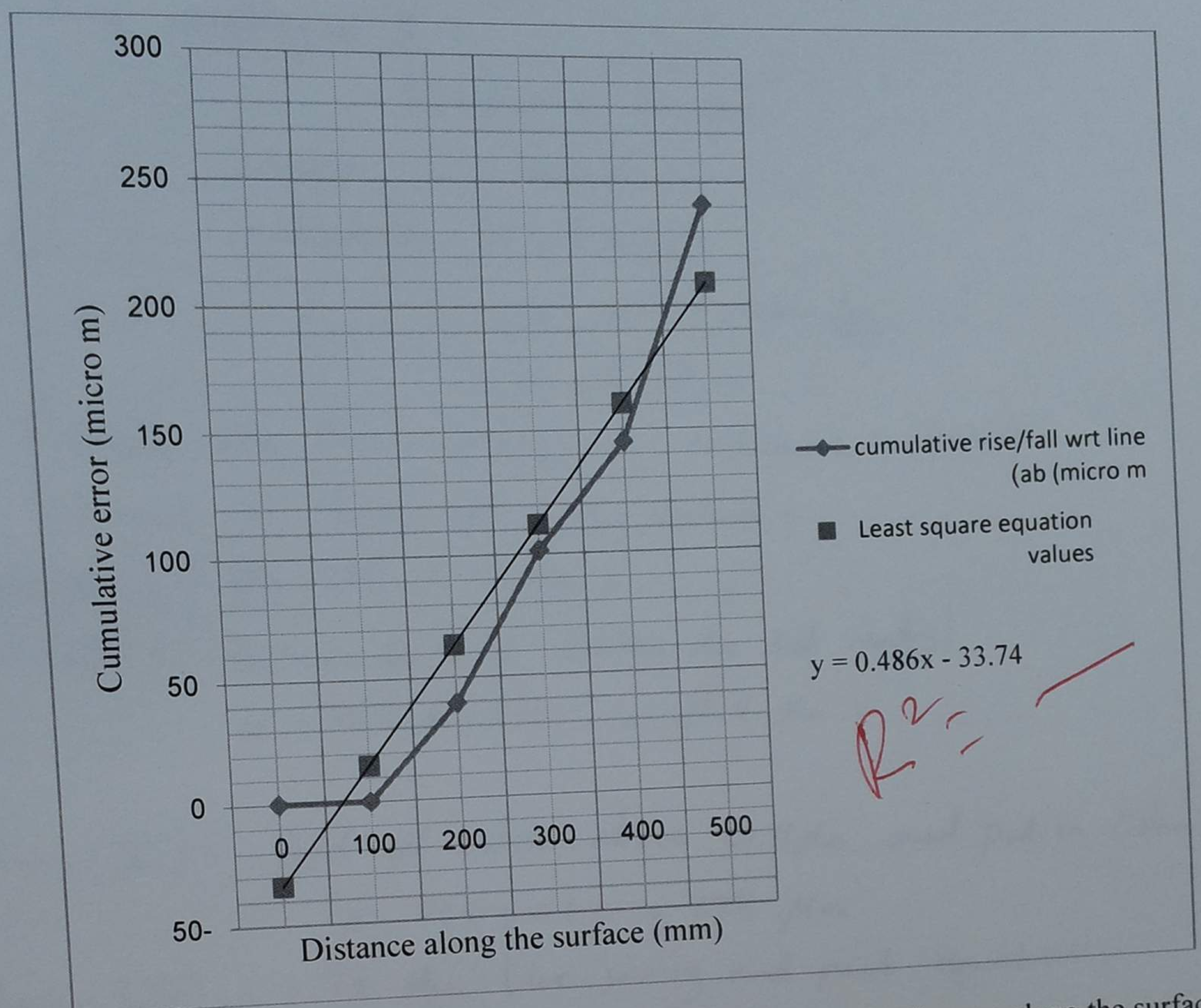



Figure (3): variation of cumulative error as result of changing the distance along the surface.

# Sample calculation:

First using Line joining end points method:

Taking reading # 2:

Position = 200 mm

where $L = 100$ mm.

calculate $h = L \tan\left(\frac{1}{\theta}\right)$

$= 100 \times 10^{-3}$ m $\times \tan \frac{1}{3600}$

$h \cong 0.5 \times 10^{-6}$ m

Taking the first reading as referance: (863 s)

Subtract it from all other values.

Column (III): $|863 - 863| = 0$ sec.

Column (IV): column III * h (taking the 3rd reading).

$= 78.8 * 0.5\ \mu m = 39.4\ \mu m$.

Column (V): Add all values above $39.4\ \mu m$ and put in column (V).

$= 39.4 + 0 + 0 = 39.4\ \mu m$.

Column (VI): Is the Line joining end point equation.

$Y_{LJEP} = mX + C$

where $C = 0$, m the line slope $= \frac{Y_{end}}{X_{end}} = \frac{240.9}{500}$

$m = 0.481$

$Y_{LJEP} = 0.481\,X$

for the (2nd) Reading ($x = 200$ mm)

$Y_{LJEP} = 0.481\,(200) = 96.2\ \mu m$

Column (VII): Error $= Y_{LJEP} - Y_{column(V)}$ [taking the first Reading $x = 100$ mm].

$= 48.1 - 0 = 48.1\ \mu m$.

For the Least Square error method:

taking the 2nd reading as example: ($X = 200$ mm) (941.8 s)

- check carriage length "L" and calculate conversion factor "h"

  $L = 100$ mm , $h = L \tan\frac{1}{\theta} \doteq 0.5\ \mu m$.

- taking the first reading as reference: ($X = 100$ mm) (863 s)

  Subtract it from all other values:

Column (III): $941.8 - 863 = 78.8$ s

Column (IV): column(III) * h $= 78.8 * 0.5 = 39.4\ \mu m$.

Column (V): add all values above $39.4\ \mu m$ to it and put in column (V):

$= 39.4 + 0 + 0 = 39.4\ \mu m$.

To find the least square equation we must find those:

$x_m, y_m, \bar{x}, \bar{y}$ and $x_m * y_m$.

where, $\bar{X} = \frac{\sum x}{n} = \frac{1500}{6} = 250$ mm (x is Column (I))

$\bar{y} = \frac{\sum y}{n} = \frac{526.6}{6} = 87.76\ \mu m$ (y is column (V))

$x_m = x - \bar{x} = 200 - 250 = -50$ mm.

$y_m = y - \bar{y} = 39.4 - 87.76 = -48.36\ \mu m$.

Find $x_m * y_m$ and $x_m^2$ then,

$C = \bar{y} - m\bar{x}$ , m is the line slope $= \frac{\sum(x_m y_m)}{\sum(x_m)^2} = 0.486$

$C = 87.76 - 0.486(250) = -33.74$.

$Y_{Least} = 0.486X - 33.74$.

Column (XI):

$Y_{least} = 0.486(200) - 33.74 = 63.46\ \mu m$.

Column (XII): error $= Y_{least} - Y_{column(V)}$

$= 63.46 - 39.4 = 24.06\ \mu m$.

Discussion:

- This device projects a beam of light at a mirror mounted on a carriage. The mirror reflects the light back into the Auto-collimator. Then the light hits a sensor(scaled) that measures the deflection to determine the angle of the target.
- The existence of burrs or dust on the plate surface will lead to change the position of the reflector carriage which is very sensitive (take reading as small as 1μm).
- Auto-collimator works on the principle light reflection. It concerned with the idea that flat surface will reflect light at zero angle.
- The main scale is divided into 30 divisions each reads one second.
- The accuracy of the device is 0.02 sec.
- The alignment between the auto-collimator and reflector should be checked at both extremes of the operational distance to the end for less error in the observed data.
- The maximum straightness error with respect to:

  a) A line joining end pints is56.8μm.

  b) The least square method is-33.74μm.
- The least-square method is more accurate because it takes all the points in consideration, while the line joining end point's method takes the first and last points only so more error will exist.

Source of error:

1- The existence of dust on the surface.
2- Misalignment between the autocollimator and the reflector.

Summery and conclusion:

In this experiment autocollimator was use to determine the straightness of a beam.

The straightness of the surface was found by measuring the relative angle between the points on the surface; the angle was measured by turning the wheel of the prism until the image of the wire is contained within the acceptable range on the display screen.

Two methods were use to do the analysis of this experiment:

1- Line Joining Method.
2- Least Square Method.

The limiting error was found by using the line joining method and the uncertainty was found by using least square method.