صلاح الدين حوراني

0100431

MEASUREMENT LABORATORY NOTES

1

Lab Report Format and Assessment

Item	Full Report	Short Report	Marks Full	Marks Short
First Page (Cover Page)				
Cover Page Format	Yes	Yes	1	1
Second Page				
Abstract	Yes	Yes	3	3
Second Page				
Table of Contents	Yes	No	1	-
List of Figures and Tables	Yes	No	1	-
List of Symbols/Nomenclature	Yes	Yes	1	1
Fourth Page onward				
Objective	Yes	Yes	1	1
Introduction & Theory	Yes	No	2	-
Experimental Setup and Procedure	Yes	Yes	3	3
Data Observed	Yes	Yes	1	1
Sample Calculations	Yes	Yes	2	2
Results & Discussion	Yes	Yes	5	5
Uncertainty Analysis	Yes	Yes	2	2
Summery & Conclusion	Yes	Yes	2	2
Sources of Errors	Yes	Yes	1	1
References	Yes	Yes	1	1
Appendix (If any)	Yes	No	1	-
General Remarks				
Correct Language			2	2
Sum			30	25

- If the appendix is not present one mark will be added to the language section.

(1) Cover page → check the website

don't write anything in bold font , font = 12

(2) abstract → (A) what was done ?

(B) how it was done ?

(C) the basic results

more than 200 word

(3) list of symbols/ nominclature

(4) objective → (A) why we did this experiment ?

(B) what we are going to learn ?

(C) what we are seeking for ?

(5) experimental apparatus

photos, identify and explain every part of the device

(6) Procedure

9. data observed

10. sample of calculations

11. results and discussion → answer the questions in lab. manual

12. uncertainity analysis

13. summary and conclusion → (A) concise version of my discussion

    (B) what I found out ?

    (C) what problems I had ?

    (D) what to do in the future with those problems ?

14. sources of error

15. references

Experiment ①

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Flow measurement

* the main objective is calibration of two devices, not measuring the Flow itself

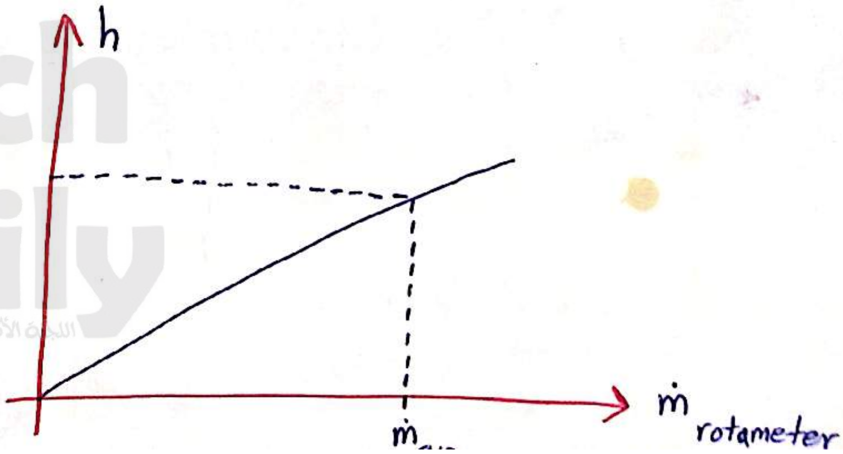
* these two devices are venturi and orifice

$\underbrace{\text{venturi and orifice}}_{\text{obstruction flow measurement}}$

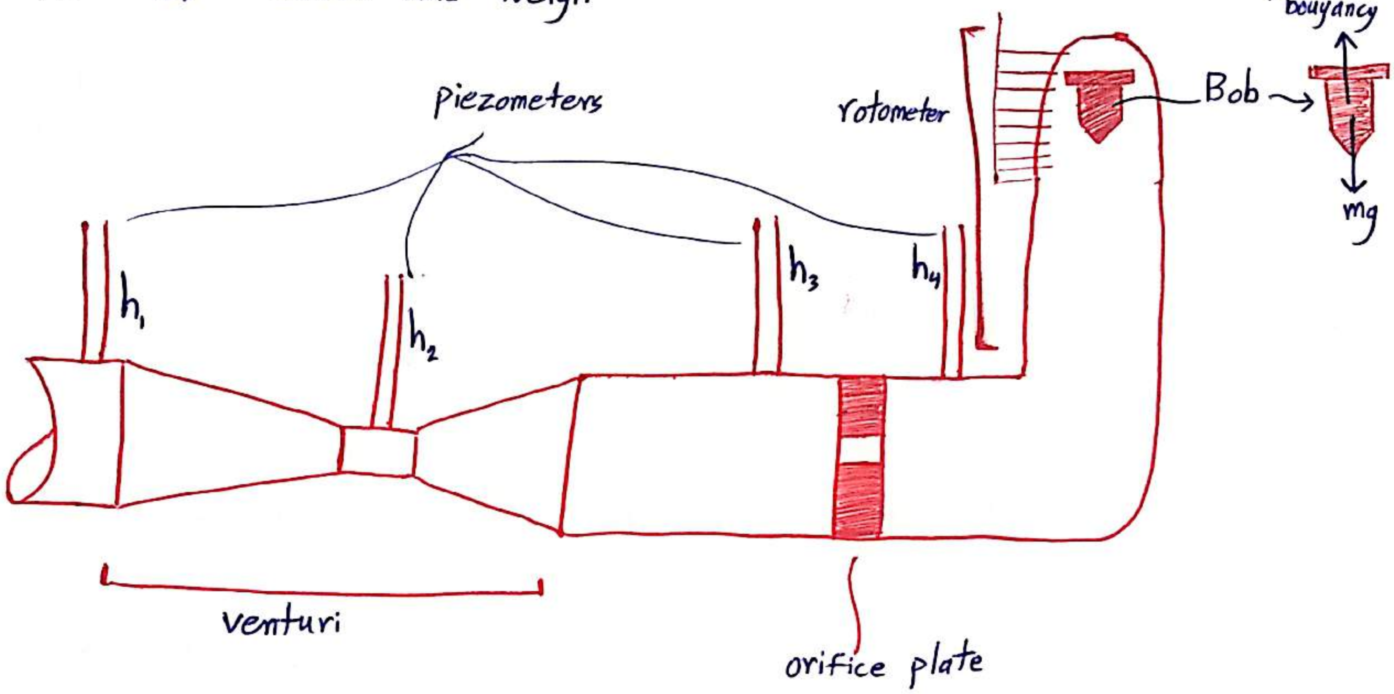
* calibration is done by finding the discharge coefficient (C_D)

$$C_D = \frac{\dot{m}_{experimental}}{\dot{m}_{theoritical}}$$

* variable head device (rotameter) → Find the head (h) → go to calibration curve → then find $\dot{m}$ (which is $\dot{m}_{exp}$)



* the device used in this experiment is called flow prover, it works on principle "catch and weigh"



* C_D for venturi $\longrightarrow$ 0.97 - 0.99

* C_D for orifice $\longrightarrow$ 0.6 - 0.65

* by applying Bernoulli equation

$$\frac{P_1}{\gamma_f} + \frac{U_1^2}{2g} + Z_1 = \frac{P_2}{\gamma_f} + \frac{U_2^2}{2g} + Z_2$$

continuity equation

$$A_1 U_1 = A_2 U_2 \longrightarrow U_1 = \left(\frac{A_2}{A_1}\right) U_2$$

$$\underline{\dot{Q}\ (m^3/s)} = \frac{Y\left(\frac{\pi}{4}\right)(d_2)^2}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}} \sqrt{2g\left(\frac{P_1 - P_2}{\gamma_f}\right)}$$

theoritical

compressibility factor

$$P_1 = \gamma h_1$$
$$P_2 = \gamma h_2$$
$$\dot{Q} = \frac{Y(\frac{\pi}{4})(d_2)^2}{\sqrt{1-(\frac{A_2}{A_1})^2}}\sqrt{2g\,(\Delta h)}$$

$A_1 = \frac{\pi}{4} d_1^2$ and $A_2 = \frac{\pi}{4} d_2^2$

$$\dot{m}_{th} = \rho Q_{th} = \frac{\rho Y(\frac{\pi}{4})(d_2)^2}{\sqrt{1-(\frac{d_2}{d_1})^4}}\sqrt{2g\,(\Delta h)}$$

* rotameter equation (linear equation with constant slope)

$$\dot{m} = 0.02h + 0.05$$

* Reynold's number is never calculated at the inlet, it must be calculated at the specific point under ~~study~~ study

* $$Re_{d_2} = \frac{\rho\, U_{act}\, d_2}{\mu_f}$$ μ_f — 1.08×10^{-3}

* Renold's number is never calculated at the theoritical conditions, it must be calculated at the experimental (actual) conditions

* $\dot{m}_{th} = \rho\, U_{2,th}\, A_2$

* $U_{2,act} = C_D\, U_{2,th}$

* $$\% \text{ error} = \frac{\dot{m}_{th} - \dot{m}_{exp}}{\dot{m}_{exp}} \times 100$$

Example :-

orifice $d_1 = 25$ mm , $h_1 = 355$ mm

$d_2 = 15$ mm , $h_2 = 135$ mm

rotameter $h = 20.5$ mm

water $m = 7.5$ kg , $t = 16.38$ s

?

$$\dot{m}_{act} = \frac{m}{t} = \frac{7.5}{16.38} = \underline{\underline{0.46 \text{ kg/s}}}$$

$$\dot{m}_{th} = \frac{\rho Y (\frac{\pi}{4})(d)^2}{\sqrt{1-(\frac{d_2}{d_1})^4}} \sqrt{2g(\Delta h)}$$

$$= \frac{1000 \times \frac{\pi}{4} \times (15 \times 10^{-3})^2}{\sqrt{1-(\frac{15}{25})^4}} \sqrt{2 \times 9.81 \times (355-135) \times 10^{-3}}$$

$$= \underline{\underline{0.718 \text{ kg/s}}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.46}{0.718} = \underline{\underline{0.64}}$$ → acceptable value, in range of 0.6-0.65

$$Re_{d_2} = \underline{\underline{27,122.52}}$$

error $= \dot{m}_{th} - \dot{m}_{exp} = \underline{+0.258 \text{ kg/s}}$

% error $= 56.22\%$

$$\dot{m}_{th} = \frac{\rho Y (\frac{\pi}{4})(d_2)^2}{\sqrt{1-(\frac{d_2}{d_1})^2}} \sqrt{2g(\Delta h)} \quad , \quad R_e = \frac{\rho V_{act} d_2}{\mu}$$

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①:- Venture

$$\dot{m}_{th} = \frac{1000 (\frac{\pi}{4})(0.016)^2}{\sqrt{1-(\frac{16}{26})^4}} \sqrt{2 \times 9.81 \times (0.364-0.08)} = \underline{0.513 \ \text{Kg/s}}$$

Experiment ① Calculations

Flow measurement

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.483}{0.513} = \underline{0.942}$$

$$Q_{act} = V_{act} A_2$$

$$V_{act} = \frac{Q_{act}}{A_2} = \frac{483 \times 10^{-6}}{(\frac{\pi}{4})(0.016)^2} = \underline{2.402 \ \text{m/s}}$$

$$Re = \frac{\rho V_{act} d_2}{\mu} = \frac{1000 \times 2.402 \times 0.016}{1.08 \times 10^{-3}} = 35,585.2$$

Orifice

$$\dot{m}_{th} = \frac{1000 (\frac{\pi}{4})(0.02)^2}{\sqrt{1-(\frac{20}{51})^4}} \sqrt{2 \times 9.81 \times (0.363-0.02)} = \underline{0.825 \ \text{Kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.483}{0.825} = \underline{0.585}$$

$$Q_{act} = V_{act} A_4$$

$$V_{act} = \frac{483 \times 10^{-3}}{(\frac{\pi}{4})(0.02)^2} = \underline{1.537} \ \text{m/s}$$

$$R_e = \frac{1000 \times 1.537 \times 0.02}{1.08 \times 10^{-3}} = \underline{28,463}$$

② :- Venture

$$\dot{m}_{th} = \frac{1000\left(\frac{\pi}{4}\right)(0.016)^2}{\sqrt{1-\left(\frac{16}{26}\right)^4}}\sqrt{2\times 9.81\times(0.349-0.089)} = \underline{\underline{0.491\ kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.467}{0.491} = \underline{\underline{0.951}}$$

$$V_{act} = \frac{Q_{act}}{A_2} = \frac{467\times10^{-6}}{\left(\frac{\pi}{4}\right)(0.016)^2} = \underline{\underline{2.323\ m/s}}$$

$$Re = \frac{1000\times2.323\times0.016}{1.08\times10^{-3}} = \underline{\underline{34{,}414.8}}$$

Orifice

$$\dot{m}_{th} = \frac{1000\left(\frac{\pi}{4}\right)(0.02)^2}{\sqrt{1-\left(\frac{20}{51}\right)^4}}\sqrt{2\times9.81\times(0.337-0.036)} = \underline{\underline{0.773\ kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.467}{0.773} = \underline{\underline{0.604}}$$

$$V_{act} = \frac{Q_{act}}{A_4} = \frac{467\times10^{-6}}{\left(\frac{\pi}{4}\right)(0.02)^2} = \underline{\underline{1.487\ m/s}}$$

$$Re = \frac{1000\times1.487\times0.02}{1.08\times10^{-3}} = \underline{\underline{27{,}537}}$$

3)- Venture

$$\dot{m}_{th} = \frac{1000\left(\frac{\pi}{4}\right)(0.016)^2}{\sqrt{1-\left(\frac{16}{26}\right)^4}}\sqrt{2\times 9.81\times(0.321-0.098)} = \underline{\underline{0.454\ kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.425}{0.454} = \underline{\underline{0.936}}$$

$$V_{act} = \frac{Q_{act}}{A_2} = \frac{425\times 10^{-6}}{\left(\frac{\pi}{4}\right)(0.016)^2} = \underline{\underline{2.114\ m/s}}$$

$$Re = \frac{1000\times 2.114\times 0.016}{1.08\times 10^{-3}} = \underline{\underline{31,318.5}}$$

Orifice

$$\dot{m}_{th} = \frac{1000\left(\frac{\pi}{4}\right)(0.02)^2}{\sqrt{1-\left(\frac{20}{51}\right)^4}}\sqrt{2\times 9.81\times(0.308-0.054)} = \underline{\underline{0.71\ kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.425}{0.71} = \underline{\underline{0.599}}$$

$$V_{act} = \frac{Q_{act}}{A_4} = \frac{425\times 10^{-6}}{\left(\frac{\pi}{4}\right)(0.02)^2} = \underline{\underline{1.353\ m/s}}$$

$$Re = \frac{1000\times 1.353\times 0.02}{1.08\times 10^{-3}} = \underline{\underline{25,055.6}}$$

(4):- Venture

$$\dot{m}_{th} = \frac{1000(\frac{\pi}{4})(0.016)^2}{\sqrt{1-(\frac{16}{26})^4}} \sqrt{2 \times 9.81 \times (0.299 - 0.104)} = \underline{0.425 \text{ kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.398}{0.425} = \underline{0.936}$$

$$V_{act} = \frac{Q_{act}}{A_2} = \frac{398 \times 10^{-6}}{(\frac{\pi}{4})(0.016)^2} = \underline{1.98 \text{ m/s}}$$

$$Re = \frac{1000 \times 1.98 \times 0.016}{1.08 \times 10^{-3}} = \underline{29,333.3}$$

Orifice

$$\dot{m}_{th} = \frac{1000(\frac{\pi}{4})(0.02)^2}{\sqrt{1-(\frac{20}{51})^4}} \sqrt{2 \times 9.81 \times (0.287 - 0.065)} = \underline{0.664 \text{ kg/s}}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.398}{0.664} = \underline{0.599}$$

$$V_{act} = \frac{Q_{act}}{A_4} = \frac{398 \times 10^{-6}}{(\frac{\pi}{4})(0.02)^2} = \underline{1.267 \text{ m/s}}$$

$$Re = \frac{1000 \times 1.267 \times 0.02}{1.08 \times 10^{-3}} = \underline{23,463}$$

5 :- Venture

$$\dot{m}_{th} = \frac{1000\left(\frac{\pi}{4}\right)(0.016)^2}{\sqrt{1-\left(\frac{16}{26}\right)^4}}\sqrt{2\times 9.81\times(\cancel{0.264-0.072}\ 0.273-0.108)} = \cancel{0.422\ Kg/s}\ \underline{0.396\ Kg/s}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.369}{\cancel{0.422}\ 0.396} = \cancel{0.874}\ \underline{0.932}$$

$$V_{act} = \frac{Q_{act}}{A_2} = \frac{369\times10^{-6}}{\left(\frac{\pi}{4}\right)(0.016)^2} = \underline{1.835\ m/s}$$

$$Re = \frac{1000\times1.835\times0.016}{1.08\times10^{-3}} = \underline{27,185.2}$$

Orifice

$$\dot{m}_{th} = \frac{1000\times\left(\frac{\pi}{4}\right)\times(0.02)^2}{\sqrt{1-\left(\frac{20}{51}\right)^4}}\sqrt{2\times 9.81\times(0.264-0.072)} = \underline{0.617\ Kg/s}$$

$$C_D = \frac{\dot{m}_{exp}}{\dot{m}_{th}} = \frac{0.369}{0.617} = \underline{0.598}$$

$$V_{act} = \frac{Q_{act}}{A_4} = \frac{369\times10^{-6}}{\left(\frac{\pi}{4}\right)(0.02)^2} = \underline{1.175\ m/s}$$

$$Re = \frac{1000\times1.175\times0.02}{1.08\times10^{-3}} = \underline{21,759.3}$$

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Experiment (2)

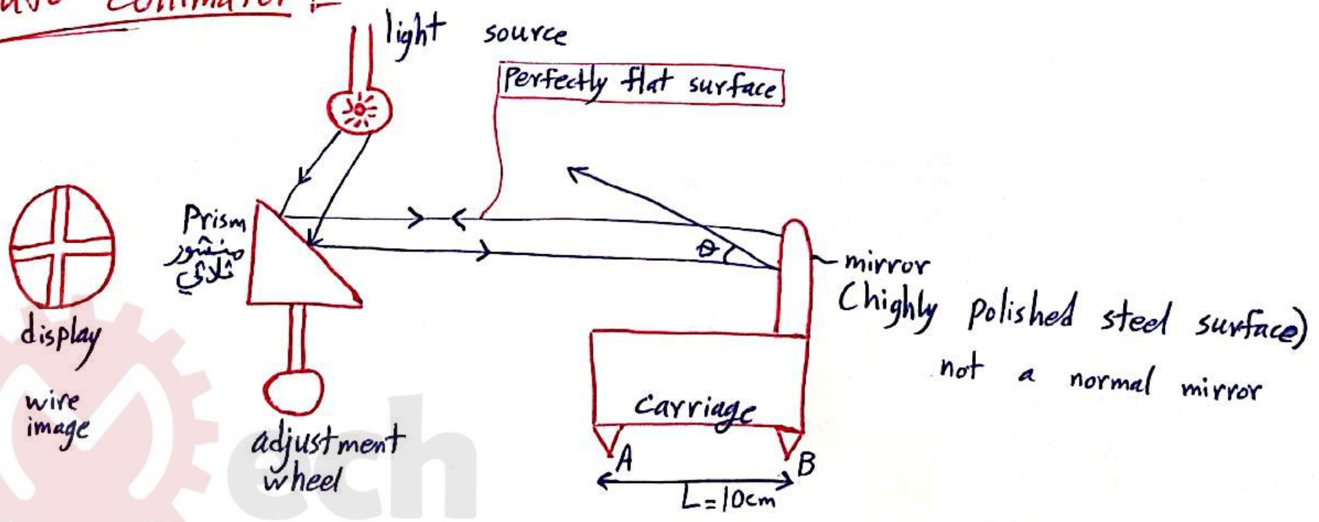
Measurement of straightness of a beam

* the device used in this experiment is called auto collimator

Straightness (flatness):- two dimensional property, the reference is defined as a plane, two distinct features → elevation, horizontal] both are the same but not equal

* there are three modes of straightness error (out of straightness)
* to measure the out of straightness we use the auto collimator

Auto collimator:-



the two vertical lines represent the limiting error

angle of reflection (θ) is to be found

* if the beam is perfectly flat → زاوية الإنعكاس = زاوية السقوط

angle of fall = angle of reflection

* we keep ~~changing~~ adjusting the prism untill angle of fall = angle of reflection

* the wheel is divided into 30 divisions

30 divisions = $\frac{1}{2}'$ minute = $30''$ seconds → each division = $1''$ second

1 major division → $1''$ (one second)

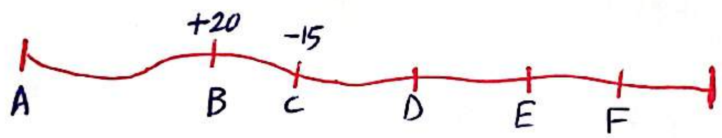
5 subdivisions in each $1''$ (5 subdivisions from one major division)

1 subdivision = $0.2''$

so, 1 division = $0.01''$ (each one subdivision has 20 divisions)

* uncertainity (w) = $\pm 0.5(0.01'')$ (نصف أصغر تدريج)

*



C is up to A by +5

all readings must be converted to one reference (Probably the first reading)

* table (A) , handout no. (4) (line joining)

(1) Column (4) → converting from angles to linear

(2) Position is the X- axis and cumulative is the y-axis

(3) solid line in the graph is representing the actual surface while the dashed line is representing the theoritical line

(4) the equation of the dashed line is

y-intersection

$$y = mx + \cancel{b}\ 0$$

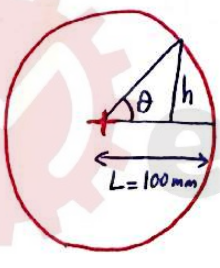
$$\text{slope} = \frac{\Delta y}{\Delta x}$$

$$= \frac{y_{end} - y_{initial}}{x_{end} - x_{initial}}$$

آخر نقطة و أول نقطة

(5) we choose the largest vertical distance between the two lines, these two lines represent the out of straightness (column (7))

(6) * lab. manual, Page (14) , the relation between micro m and seconds is



$$h = L \cdot \tan(\theta)$$

1 second

$$= 0.1 \tan\left(\frac{1}{3600}\right) = \underline{\underline{0.5\ \mu m}}$$

this means that every 1 second there is a 0.5 μm height

* in line joining method we took the absolute value

* in Least square method we take signs into consideration

* least square equation

$$\underset{\text{slope}}{m} = \frac{\Sigma (X_m Y_m)}{\Sigma (X_m)^2}$$

where

$$\left.\begin{array}{l} X_m = X - \boxed{\bar{X}} \\ Y_m = Y - \boxed{\bar{Y}} \end{array}\right] \text{deviations}$$

$$\bar{X} = \frac{\Sigma X}{n} \quad , \quad \bar{Y} = \frac{\Sigma Y}{n}$$

* handout no. 5

$$X' = \frac{\Sigma X}{K} \quad , \quad Y' = \frac{\Sigma Y}{K}$$

عدد النقاط وليس عدد الفترات

* intersect equation $\quad C = \bar{Y} - m\bar{X}$

* نطرح العمود الأخير من العمود القبل الأخير بإشاراتهم

* error by −70 (−ve) ⟶ 70 below the surface

error by +70 (+ve) ⟶ 70 above the surface

* least square method is more accurate ~~than than~~ because it passes through all points

* line joining method is less accurate than least square method because it takes only ~~and~~ initial and end points

* line joining method $\longrightarrow$ limiting error (maximum allowable error)

  least square method $\longrightarrow$ exact error

* designing should be based on the maximum error $\xrightarrow[\text{example}]{\text{for}}$ designing a sealing for leak proof ~~for example~~ (an application where measurement of straightness may be used)

4

Conversion Factor = 0.5 micrometer for one minute

(A) **Line Joining End Points**

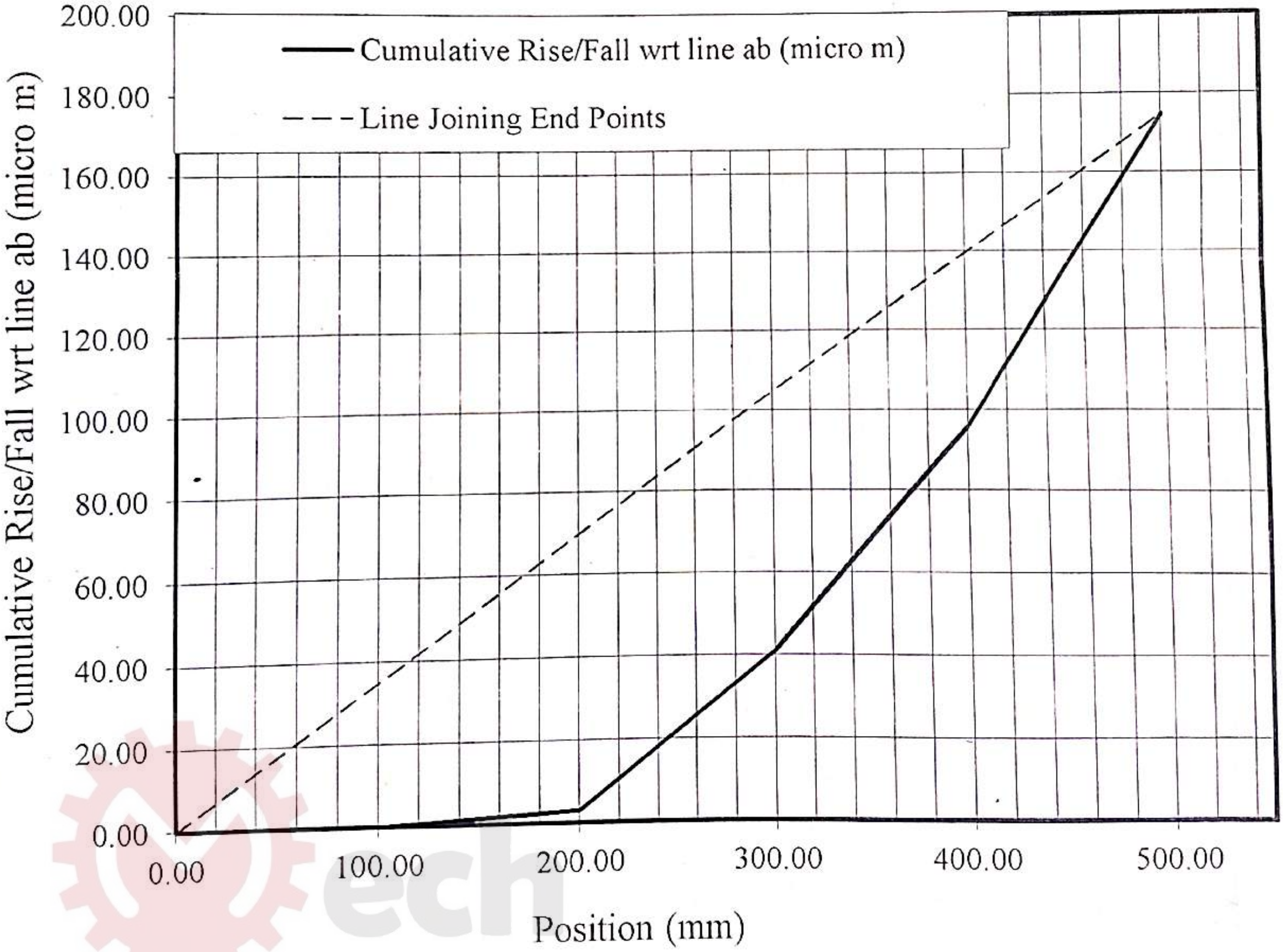
Position	Angle Reading (Sec)	Difference from first Reading (Sec)	Rise/Fall in interval length "l" (micro m)	Cumulative Rise/Fall wrt line ab (micro m)	Line Joining End Points	Difference C6-C5
0.00	0.000	0.00	0.000	0.000	0.000	0.000
100.00	327.000	0.00	0.000	0.000	34.920	34.920
200.00	333.000	6.00	3.000	3.000	69.840	66.840
300.00	250.800	76.20	38.100	41.100	104.760	63.660
400.00	217.000	110.00	55.000	96.100	139.680	43.580
500.00	170.000	157.00	78.500	174.600	174.600	0.000

this reading will be the reference

largest vertical distance

Slope = 0.3492 $= \frac{\Delta Y}{\Delta X} = \frac{Y_{end} - Y_{start}}{X_{end} - X_{start}} = \frac{174.6-0}{500-0}$

h = 0.583333



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$C = Y_m - m X_m$

Conversion Factor = (0.5) micro per one second

Table (1) :

Position	Angle Reading (Sec)	Difference from first Reading (sec)	Rise/Fall in interval length "l" (micro m)	Cumulative Rise/Fall wrt line ab (micro m)
0				0
100.00	497.000	0.000	0.000	0.000
200.00	483.000	-14.000	-7.000	-7.000
300.00	400.000	-97.000	-48.500	-55.500
400.00	337.000	-160.000	-80.000	-135.500
500.00	*250.000*	*-247.000*	-123.500	*-259.000*
1500.00	1967.00	-518.00	-259.00	-457.00

X prime = 250.00

$= \frac{0+100+200+300+400+500}{6}$

Y prime = -65.2857 micro m

$= \frac{0+0-7-55.5-135.5-259}{6}$

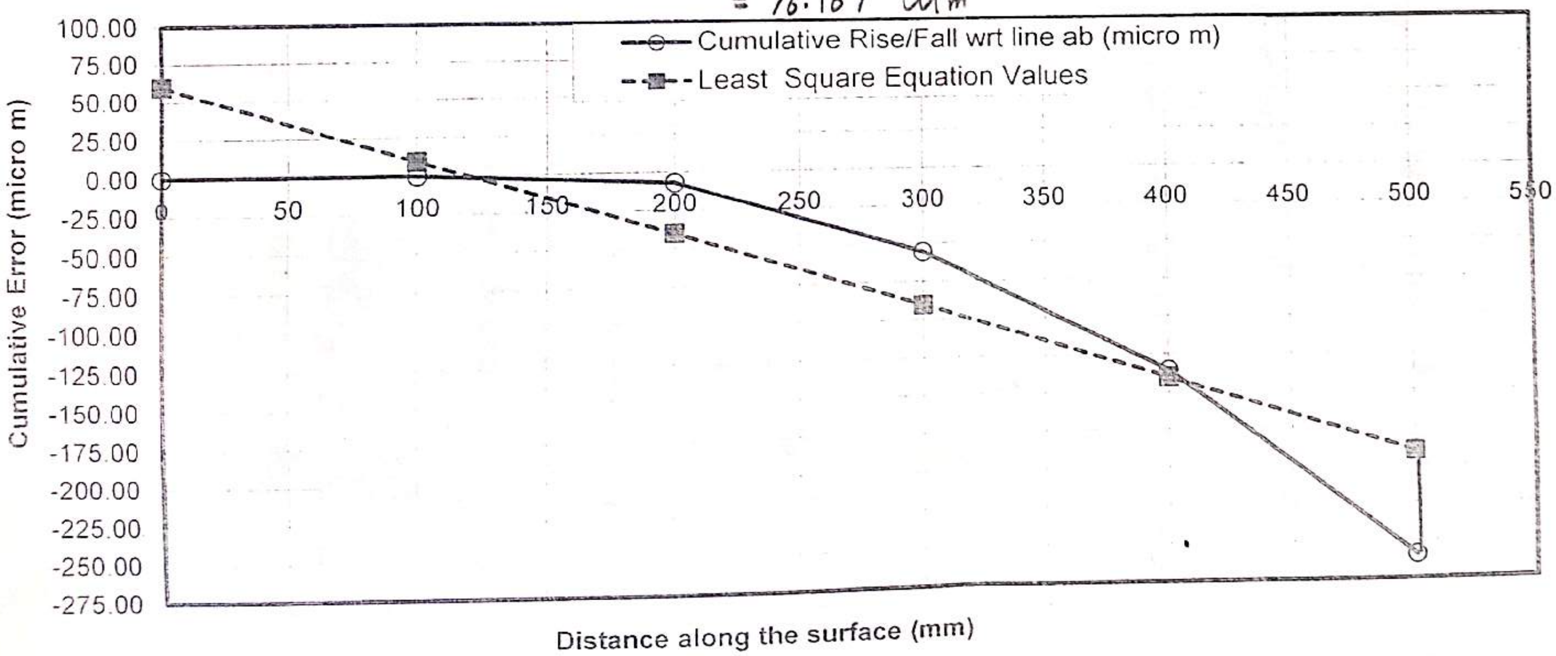
$= 76.167\ \mu m$

Table (2) :

	Xm	Ym	Xm Ym	Xm^2	Least Square Equation Values	Maximum Difference
	-250.00	65.28571	-16321.42857	62500	59.71429	59.71429
	-150.00	65.28571	-9792.857143	22500	9.714286	9.714286
	-50.00	58.28571	-2914.285714	2500	-40.2857	-33.2857
	50.00	9.785714	489.2857143	2500	-90.2857	-34.7857
	150.00	-70.2143	-10532.14286	22500	-140.286	-4.78571
	250.00	*-193.714*	*-48428.57143*	*62500*	*-190.286*	*68.71429*
sum	0.00	-65.29	-87500.00	175000.00		

m = -0.5

c= 59.71428571



Experiment ③

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Strain Gauge

* The main objective is to verify Hooke's law by using a cantilever

* strain gauge is a transducer (sensor) that is used to for strain/stress measurement, it converts the strain to resistance ($\varepsilon \rightarrow \Delta R$)

* $R = \frac{\rho L}{A}$

ρ: resistivity, a material property [$\Omega . m$]

* there are two types of strain gauges → metals
→ semi-conductors

* the disadvantage of metal is in its gauge factor (G_f)

* Gauge factor (G_f) = $\frac{\text{Percentage change in output}}{\text{Percentage change in input}} = \frac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}}$

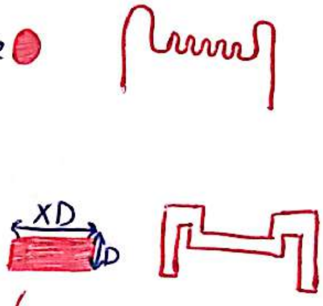
$$* \; R = \rho \frac{L}{A}$$

$\ln(R) = \ln(\rho) + \ln(L) - \ln(A)$ differentiate with respect to R

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{dA}{A}$$

Foil metal strain gauge is used in this experiment

two types of metal strain gauge are → wire, → foil



$A = C D^2$

$$\frac{dA}{A} = \frac{2dD}{D}$$

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{2dD}{D}$$

$$\frac{\Delta R}{R} = \frac{\Delta\rho}{\rho} + \frac{\Delta L}{L} - \boxed{\frac{2\Delta D}{D}} \leftrightarrow -2\nu$$ divide by strain $(\varepsilon) = \frac{\Delta L}{L}$

$$G_f = \frac{\cancel{\frac{\Delta\rho}{\rho}}^{\,0}}{\cancel{\frac{\Delta L}{L}}} + \frac{\cancel{\frac{\Delta L}{L}}^{\,1}}{\cancel{\frac{\Delta L}{L}}} - \frac{\frac{2\Delta D}{D}}{\frac{\Delta L}{L}}$$ — lateral / — axial

$$G_f = 1 + 2\nu$$

ν: Poisson's ratio

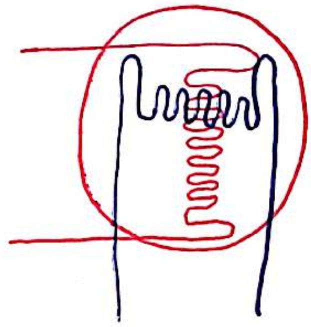
* metals have too weak sensitivity, thats why we use semi-conductors

$(G_F = -133)$

-ve for tension

+ve for compression

Strain rosett :- to catch the lateral strains



* to find hysterisis, increasing decreasing analysis must be done

* find the following

① hysterisis

② experimental modulus of elasticity (E)

③ draw stress Vs. loading and strain Vs. loading, also find error and maximum error for each

* random inputs are done to find the real readings from the device

Experiment (3)

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Strain Gauge

* the objective is to find the stress on a cantilever beam by using a strain gauge

* Hooke's law → stress (σ) = modulus of elasticity (E) X strain (ε)

* in this experiment, four strain gauges are ~~mounted~~ attached, two on the upper side and two on the lower side

* resistance changes due to changing in length (L) and cross-sectional area (A) → $R = \dfrac{\rho L}{A}$

* voltage change is to be measured

* strain gauge is a variable resistance (wheatestone circuit)

* there are half bridge circuit and full bridge circuit

* $G_F = \dfrac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}}$

* find hysterisis of the strain gauge by increasing and decreasing the loads

* weight of holder = 1N

* the negative sign in readings means the downward deflection of the beam

* some sources of error → heat (sunlight)
  → vibration (the device is not stable)

* Find the following

① calculate stress and strain (as the example in the lab. manual)

② draw the stress strain diagrams for both experimental and theoritical values

③ name two types of strain gauges → foul
  → semi-conductor

④ draw change in voltage vs. load

increasing and decreasing the added weights

to find hysterisis

(specify the maximum deviation)

210 GPa

⑤ find actual and $\boxed{\text{theoritical}}$ modulus of elasticities, compare between them and calculate the error (exact error and percentage error)

Experiment (4)

صلاح الدين حوراني

Temperature measurement

* there are three types of temperature transducers (sensors) :-

(1) RTD (resistance ~~thermal~~ temperature detector) :- converts from temperature to resistance

(2) Thermistor :- converts from temperature to resistance

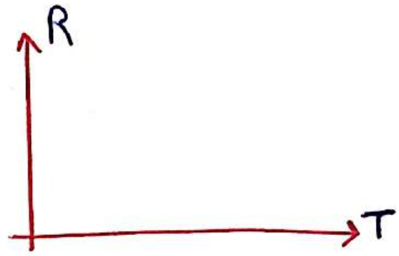
(3) Thermocouple :- converts from temperature to voltage

* RTD and thermocouple are metals, when they gain heat their resistance increase.

* thermistor is made from semi-conductor material, when it gains heat its resistance decreases.

* find the following :-

① draw characteristic curve for each transducer



② find time constant (τ) for each transducer

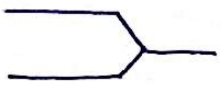
* R_o is the calibrated resistance

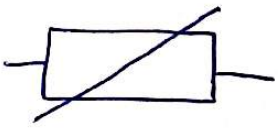
* compare true value of each transducer with the rest

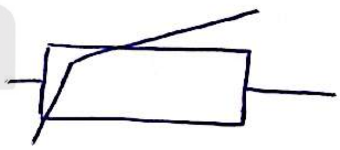
* find time constant (τ) for each transducer

67% from steady-state input

* derive the equations of RTD and thermistor

* thermocouple → 

thermistor → 

RTD → 

heating

True (°C)	Thermometer (°C)
13	19
13	19
14	19
14	19
14	20
14	20
14	22
15	24
16	32
17	34
18	36
20	37
22	38
24	40
27	41
29	50
32	50
34	52
37	54
40	58
43	60
46	62
48	62
51	62
54	64
56	64
60	68

Cooling

True (°C)	Thermometer (°C)
66	60
66	58
67	58
66	56
66	56
65	54
65	52
64	52
64	52
63	50
62	50
61	48
60	48
60	47
59	46
58	44
57	44
56	44
55	43
54	42
53	42
52	42
51	40
51	40
49	40
49	39
48	38
48	38
47	37
46	37
46	37
45	36

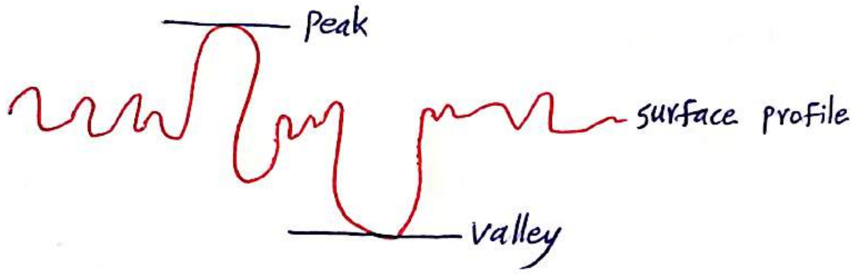
Experiment ⑤

صلاح الدين حوراني

Surface roughness (texture)

* any manufacturing process has its own profile on the specimen being manufuctured

*



* this experiment is done to find the roughness (average peak) of a specific specimen

* friction coefficient is to be found, Friction coefficient has direct relation with surface roughness

* $R_a \equiv$ roughness average

* reasons of non-smooth surface →
  - manufacturing process
  - material
  - heat → expansion and ~~retraction~~ contraction during manufacturing process
  - lubricant
  - cutting tool
  - cutting speed
  - Feed rate
  - specimen vibrations during manuf...

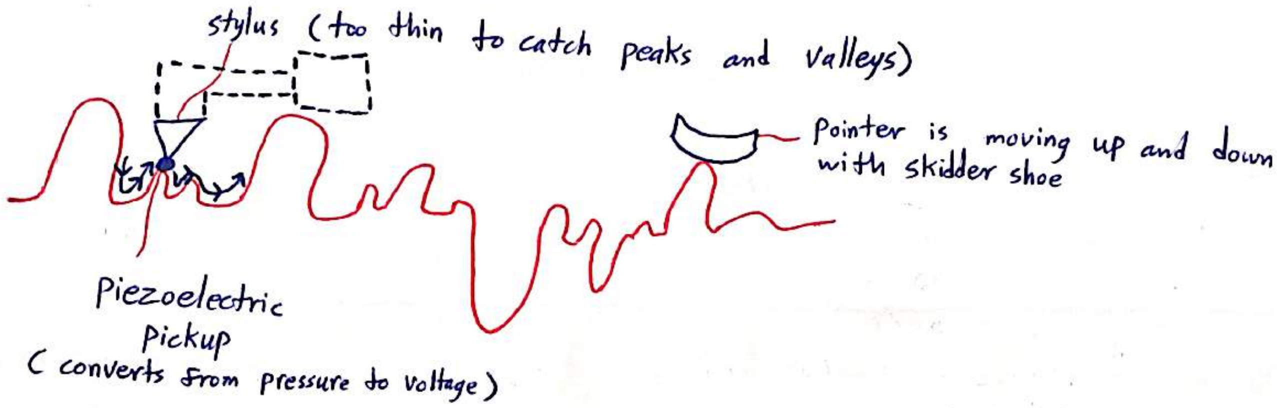
* there are three methods to measure surface roughness :-

① By hand (by inspection) / rough or not rough, no exact number,
toching and sensing the surface by fingers

② Light scatter / as roughness increases, light scattering increases, gives an idea not an exact number (surface is rough or not)

③ Stylus-Probe device / used in this experiment

*



* there are five different methods to calculate surface roughness

① Peak to valley height (R_p) :-

$$R_p = \frac{H_P - H_V}{V.M.} \times 1000 \quad [\mu m]$$

where H_P is highest peak height [mm]
H_V is lowest valley height [mm]
V.M. is the vertical magnification

$\frac{1000}{V.M.}$ is called a factor

* the major drawback (disadvantage) of Peak to valley height is it considers only two points (highest and lowest points)

② Five - Points average :-

two peaks and three valleys or two valleys and three peaks

③ Ten - Points average(R_z) :-

peaks average and valleys average

$$R_z = \left(\frac{\Sigma H_p - \Sigma H_v}{5}\right)\underbrace{\left(\frac{1,000}{V.M.}\right)}_{\text{Factor}} \quad [\mu m]$$

highest five peaks and lowest five valleys from the same reference line

④ RMS value (R_q) :-

RMS stands for root mean square, we have to draw a center line (100% center line is where areas above center line = areas below center line)

Find A_{above} and A_{below} ($\Delta A = A_{\uparrow} - A_{\downarrow}$)

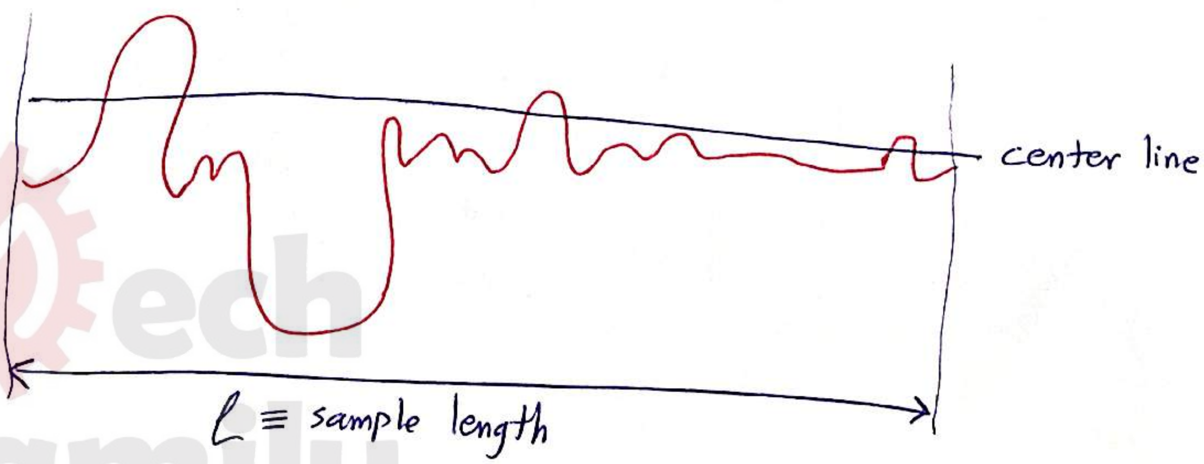
the first center line is found by initially guessing its location, then this correction is applied to find the location of the new center line

$$\text{correction} = \frac{\Delta A}{2\ell} \quad , \quad R_q = \sqrt{\frac{\Sigma(h^2)}{N}} \quad [\mu m]$$

summation of height of each divison squared

no. of divisions

minimum data for acceptance is twenty $\rightarrow$ 20 intervals



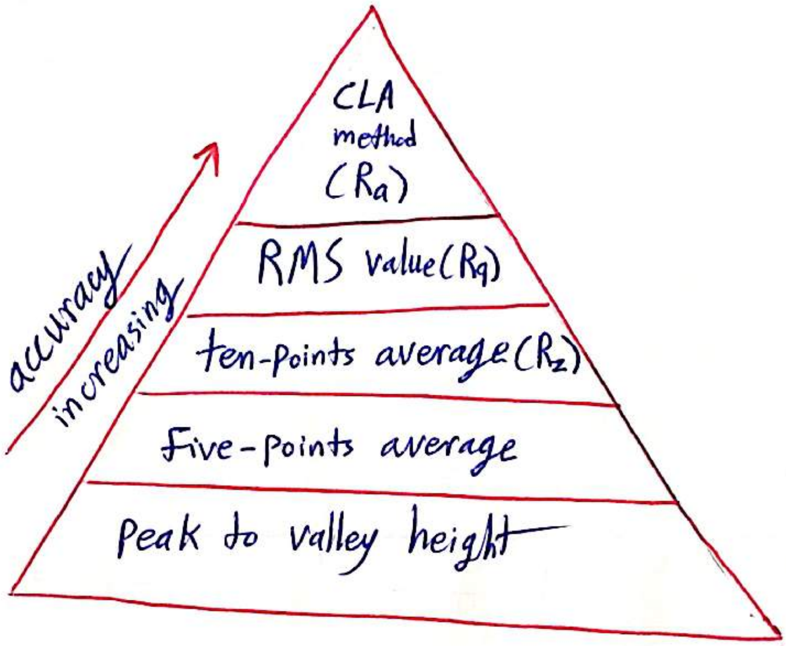
divide ℓ into 20 intervals at least

(5) CLA method (R_a):- the most accurate method

$$R_a = \frac{\Sigma A}{l} \underbrace{\left(\frac{1,000}{(V.M.)(H.M.)}\right)}_{\text{gives the average height}}$$

H.M. — horizontal magnification $[\mu m]$

*



Surface Roughness Calculation:

[1] <u>Peak-To-Valley height</u> (R_p) صلاح الدين حوراني

* Take the reference line anywhere below the profile.
* Find the height (in mm) of the highest peak and lowest valley.

$H_p = 102$ mm at ΔC مثلث C

$H_v = 9$ mm at ΔB مثلث B

$$\therefore R_p = (102 - 9) * \frac{1000}{125000} = \underline{0.744\ \mu m}$$

[2] <u>Ten-Point Average (R_z)</u>

* Take the highest 5 peaks and lowest 5 valleys from the same ref. line.

Peaks are ~~71~~ 71 + 102 + 78 + 86 + 52 = 389 mm

Valleys are : 9 + 24 + 24 + 16 + 32 = 105 mm

$$\therefore R_z = \left(\frac{389 - 105}{5}\right) * \frac{1000}{125000} = \underline{0.4544\ \mu m}$$

[3] <u>The RMS method</u> (R_q) and <u>Area Method</u> (R_a)

* First we have to locate the center line.
* Assume the line drawn A-A' to be initial guess.
* Calculate Areas of all triangles.

$A = \frac{1}{2} * 13 * 21 = 136.5$ mm² $\quad B = \frac{1}{2} * 22 * 42 = 462$

$C = \frac{1}{2} * 22 * 40 = 440$ " $\quad D = \frac{1}{2} * 15 * 27 = 202.5$

$E = \frac{1}{2} * 19 * 26 = 247$ " $\quad F = \frac{1}{2} * 25 * 28 = 350$

$G = \frac{1}{2} * 19 * 34 = 323$ " $\quad H = \frac{1}{2} * 24 * 36 = 432$

$I = \frac{1}{2} * 10 * 10 = 50$ " $\quad J = \frac{1}{2} * 29 * 20 = 290$

$$Area = \frac{1}{2} * Base * Height \text{ (for simplicity).}$$

$\therefore \sum A_{above} = 1069.5 \ mm^2$

$\sum A_{below} = 1736.5$ "

$$Correction = \frac{\sum A_{above} - \sum A_{below}}{2L} \qquad L = \text{Sample length}$$

$$= \frac{1069.5 - 1736.5}{2 * 196}$$

$$= -1.7 \ mm$$

$$\simeq -2 \ mm$$

The minus sign means downward.

the new center line is below the guessed center line by 2 mm

* Area Method (R_a)

$$R_a = \frac{\sum A}{L} * \frac{1000}{(VM)(HM)}$$

$$= \frac{1069.5 + 1736.5}{196} * \frac{1000}{125000(1250)} = 9.162 \times 10^{-5} \ \mu m$$

* RMS Method (R_q)

* Divide the whole length to minimum 20 divisions and measure their hights.

* $\Delta x = \frac{196}{20} = 9.8 mm \simeq 10 mm$ So we have 19 points.

$$\sum h^2 = [12^2 + 11^2 + 5^2 + 0^2 + 24^2 + 10^2 + 25^2 + 11^2 + 18^2 + 3^2 + 28^2 + 3^2 + 25^2 + 13^2 + 46^2 + 0^2 + 41^2 + 2^2 + 15^2]$$

$$= 7658 \ mm^2 \quad \text{(check)}$$

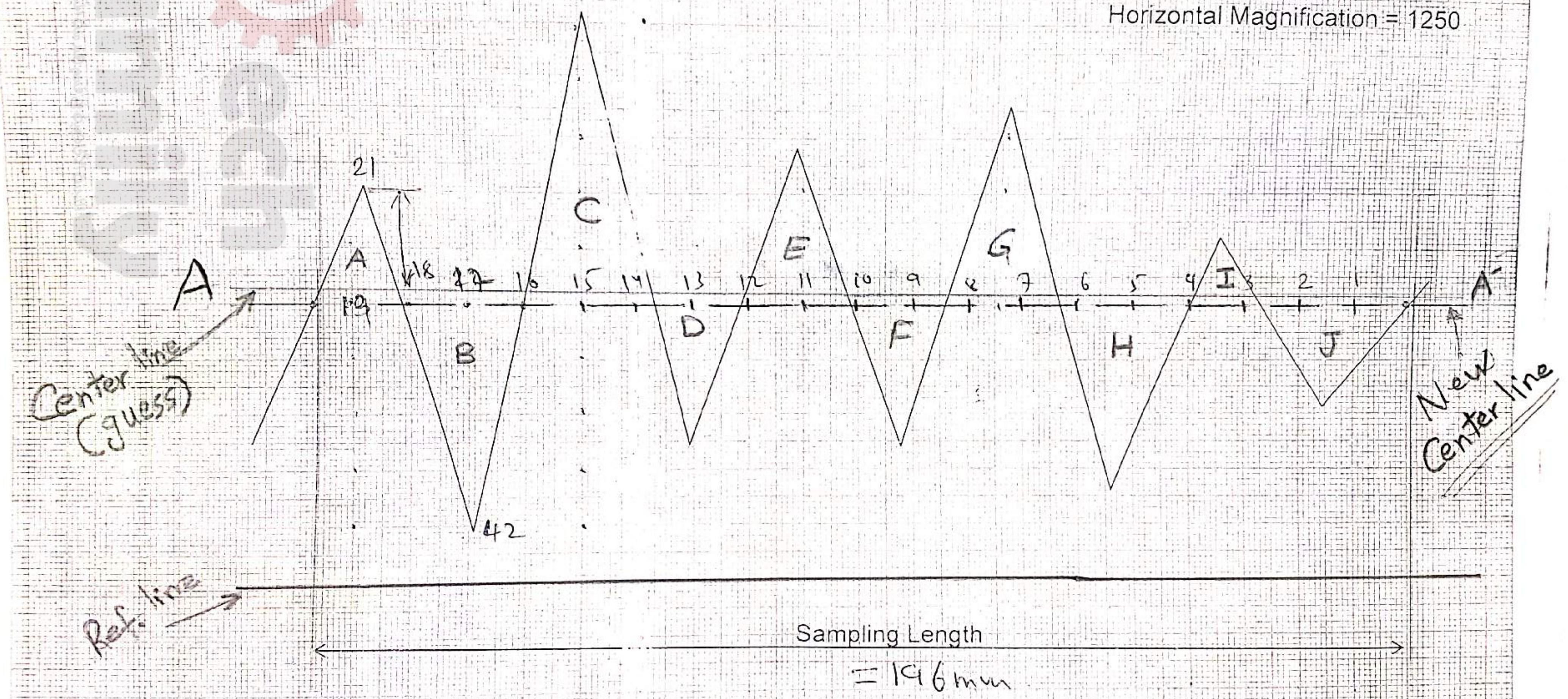
$$\therefore R_q = \sqrt{\frac{\sum h^2}{19}} * \frac{1000}{125000} = 0.1606 \ \mu m$$

Data for 14/11/2013 Section (3)

Group (A)

Vertical Magnification = 125000

Horizontal Magnification = 1250



Experiment (6)

صلاح الدين حوراني

Block Gauge

* the objective of this experiment is: to calibrate measurement tools like vernier caliper and micrometer

* block gauges is blocks with high accuracy thickness or width
  0.005 mm

* line standard → ruler

  end standard → block gauge

* Block gauges have various accuracies among various divisions

* highest accuracy block → 1.005 mm

* 1.001 - 1.009 → 0.001 increment

  1.01 - 1.49 → 0.01 increment

  0.5 - 9.5 → 0.5 increment

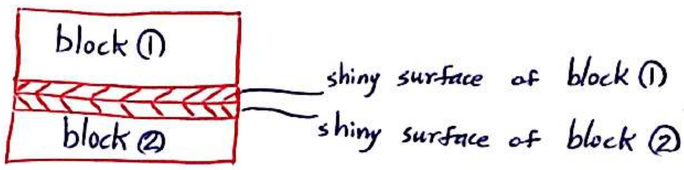
* for any thickness / width, try to have the minimum number of added block gauges

حاول تشكيل أي طول بأقل عدد ممكن من الـ blocks

* start from the smallest number then get rid from the smaller number then the smaller and so on

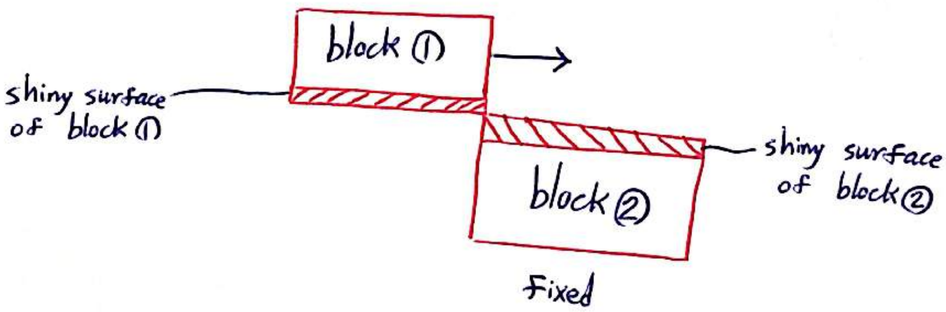
* start measuring the thickness / width from the shiny surface

* in case of adding blocks, add shiny surfaces on such a way they're facing each other



this is done by two methods :-

① slipping / slip one surface on the other surface to create air vacuum between the blocks



② wringing

* block gauges should have the following properties :-

hardness, straightness and parallelism

* try to have the minimum number of added block gauges in order to have the minimum amount of error (maximum accuracy)

Example:- 30.967 mm ?

$$
\begin{array}{r}
30.967 \\
1.007 - \\
\hline
29.96 \\
1.46 - \\
\hline
28.5 \\
8.5 - \\
\hline
20 \\
20 - \\
\hline
00.0
\end{array}
$$

1.007 → get rid from the smallest number

1.46 → try to make the whole number easier to be substracted

4 - blocks → this is the minimum number of blocks

Example:- 59.876 ?

$$
\begin{array}{r}
59.876 \\
1.006 - \\
\hline
58.87 \\
1.37 - \\
\hline
57.5 \\
7.5 - \\
\hline
50 \\
50 - \\
\hline
00.0
\end{array}
$$

4 - blocks

Example :- 41.389 ?

$$
\begin{array}{r}
41.389 \\
1.009\ - \\ \hline
40.38 \\
1.38\ - \\ \hline
39.0 \\
9\ - \\ \hline
30 \\
30\ - \\ \hline
00.0
\end{array}
$$

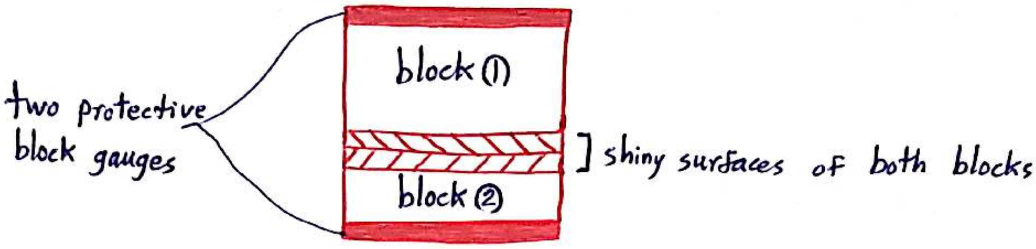
4-blocks

Example :- 9.999 ?

$$
\begin{array}{r}
9.999 \\
1.009\ - \\ \hline
8.99 \\
1.49\ - \\ \hline
7.5 \\
7.5\ - \\ \hline
0.0
\end{array}
$$

3-blocks

Protective block gauges :- have a specified thickness (about 2 mm), used to surround the blocks being measured



* smallest division → accuracy

$\frac{\text{smallest division}}{2}$ → uncertainity

* accuracy of the micrometer

smallest division on main scale → 0.5 mm

smallest division on thumbile scale → $\frac{0.5}{50} = 0.01$ mm

smallest division on third thumbile scale → $\frac{0.01}{10} = 0.001$ mm

* micrometer is used for measuring the following quantities :-
thickness, width and diameter

* accuracy of the vernier caliper

smallest division on main scale ⟶ 1 mm

smallest division on vernier scale ⟶ $\frac{1}{50} = 0.02$ mm

* vernier caliper is used for measuring length, depth, thickness, width and diameter

mechanical comparator :- gives tolerance range and used to detect the correct number of blocks needed to the desired length

Experiment (7)

صلاح الدين حوراني

Linear Measurements

Vernier Caliper:- For external width, thickness and depth

* accuracy $\equiv \dfrac{\text{smallest division (main scale)}}{\text{no. of divisions (Vernier scale)}}$

* accuracy of the vernier caliper $= \dfrac{1 \text{ mm}}{20} = \pm 0.05 \text{ mm}$

* $10 \text{ mm} + 9\,(0.05) = \underline{10.45 \text{ mm}}$

Dual vernier Caliper:-

* accuracy $= \pm 0.05$ mm

Micrometer:- for outer diameters and outer thickness

* accuracy $\equiv \dfrac{\text{smallest division (main scale)}}{\text{no. of divisions (thumbile division)}}$

$= \dfrac{0.5 \text{ mm}}{50} = \pm 0.01$ mm

* micrometer is more accurate than vernier caliper

* maximum reading for micrometer $\longrightarrow$ 25 mm $\boxed{\text{micrometer (1)}}$

For a diameter / thickness larger than 25 mm , use micrometer (2)

maximum reading = 50 mm

zero from 25 mm

* both micrometers (1) and (2) have the same accuracy (±0.01 mm), since both of them have the same number of divisions and identical smallest division

Depth micrometer :-

$$* \text{ accuracy} \equiv \frac{\text{smallest division (main scale)}}{\text{no. of divisions (thumbile scale)}}$$

$$= \frac{0.5 \text{ mm}}{25} = \pm 0.02 \text{ mm}$$