ZHCET

Fluid - Mechanics

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Faculty No - 21MEB448

Enroll. No. - GL2254

Section - A-2 M-B

S. No. - 14

OBJECT - Flow Visualisation

Date of Exp. - 07/11/2022

Date of Submission - 14/11/2022

7/10

12/12/22

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JECT: To study the streamline pattern around various objects placed in a fluid stream using simple visualisation technique.

rmula used:-

Reynolds No. → $Re = \frac{UL}{\nu}$; where, U → velocity
ν → kinematic viscosity
L → Projected Length

BSERVATION TABLE-1:-

Object name & orientation	Projected length, L(m)	Reynolds no.(Re)
Cylinder	0.033	$0.006303 \times 10^6 = 6303$
Rectangular Plate	0.103	$0.021873 \times 10^6 = 21873$
Rectangular Plate (tilted)	0.103	$0.019326 \times 10^6 = 19326$
Square (edge along the flow)	0.037	$0.008235 \times 10^6 = 8235$
Square (diagonal along the flow)	0.051	$0.011283 \times 10^6 = 11283$

Flow Rate-1

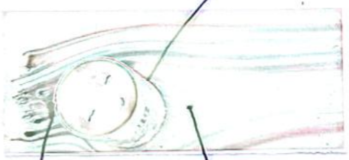
OBSERVATIONS :

→ Kinematic viscosity of water $= \nu = 0.877 \times 10^{-6}\ m^2/s$ at $26^\circ C$

→ We have observed different types of ~~flows~~ patterns at 4 different flow's rate.

Discussion

Point of separation



Stagnation Point

vortex / Eddy

Cylinder

Flow visualisation helps in examine flow pattern around body or over its surface. It helps in providing descripti of flow over model without complicated data reduction. $Re > 2000$ indicates turbulent flow.

OBSERVATION TABLE-2 :

Object name & orientation	Projected length, L(m)	Reynolds No. (Re)
Cylinder	0.033	$0.003239 \times 10^6 = 3239$
Rectangular Plate	0.103	$0.010813 \times 10^6 = 10813$
Rectangular Plate (tilted)	0.103	$0.010529 \times 10^6 = 10529$
Square (edge along the flow)	0.037	$0.004050 \times 10^6 = 4050$
Square (diagonal along the flow)	0.051	$0.005520 \times 10^6 = 5520$

Flow Rate-2

OBSERVATION TABLE-3 :

Object name & orientation	Projected Length, L(m)	Reynolds No. (Re)
Cylinder	0.033	$0.002331 \times 10^6 = 2331$
Rectangular Plate	0.103	$0.007003 \times 10^6 = 7003$
Rectangular Plate (tilted)	0.103	$0.009142 \times 10^6 = 9142$
Square (edge along the flow)	0.037	$0.003003 \times 10^6 = 3003$
Square (diagonal along the flow)	0.051	$0.004319 \times 10^6 = 4319$

Flow Rate-3

OBSERVATION TABLE-4:

Object name & orien.	Projected length, L(m)	Reynolds No.(Re)
Cylinder	0.033	$0.001210 \times 10^6 = 1210$
Rectangular Plate	0.103	$0.010984 \times 10^6 = 10984$
Rectangular Plate (tilted)	0.103	$0.006816 \times 10^6 = 6816$
Square edge along the flow	0.037	$0.001891 \times 10^6 = 1891$
Square (diagonal along the flow)	0.051	$0.002580 \times 10^6 = 2580$

Flow Rate-4

Sample Calculation

For flow rate-1

i) Cylinder → $L = 0.033$ m, $\nu = 0.877 \times 10^{-6}$ m²/s

time = 3.88 s, distance = 65 cm = 0.65 m

velocity, $U = \frac{0.65}{3.88} = 0.167$ m/s

$$Re = \frac{UL}{\nu} = \frac{0.167 \times 0.033}{0.877 \times 10^{-6}} = 0.006303 \times 10^6 = 6303$$

ii) Rectangular plate → $L = 0.103$ m, $\nu = 0.877$ m²/s $\times 10^{-6}$

time = 3.49 s, distance = 65 cm = 0.65 m

velocity, $U = \frac{0.65}{3.49} = 0.186$ m/s

$$Re = \frac{UL}{\nu} = \frac{0.186 \times 0.103}{0.877 \times 10^{-6}} = 0.021873 \times 10^6 = 21873$$

iii) Rectangular plate (Tilted) → $L = 0.353$ m, $\nu = 0.877$ m²/s

time = 3.52 s, distance = 0.65 m

velocity, $U = \frac{0.65}{3.52} = 0.185$ m/s

$$Re = \frac{UL}{\nu} = \frac{0.185 \times 0.353}{0.877} = 0.0744$$

iv) Square (edge) → $L = 0.037$ m, $\nu = 0.877 \times 10^{-6}$ m²/s

time = 3.33 s, distance = 0.65 m

velocity, $U = \frac{0.65}{3.33} = 0.195$ m/s

$$Re = \frac{UL}{\nu} = \frac{0.195 \times 0.037}{0.877 \times 10^{-6}} = 0.008235 \times 10^6 = 8235$$

v) Square (diagonal) → $L = 0.051$ m, $\nu = 0.877 \times 10^{-6}$ m²/s

time = 3.35 s, distance = 0.65 m

velocity, $U = \frac{0.65}{3.35} = 0.194$ m/s

$$Re = \frac{UL}{\nu} = \frac{0.194 \times 0.051}{0.877 \times 10^{-6}} = 0.011283 \times 10^6 = 11283$$

(iii) Rectangular Plate (tilted) → $U = \frac{0.65}{3.95} = 0.164\ m/s$, $L = 0.103\ m$, $t = 3.95\ s$, $\nu = 0.877 \times 10^{-6}\ m$

$$Re = \frac{0.164 \times 0.103}{0.877 \times 10^{-6}} = 19326$$

Result & Discussion Continued...

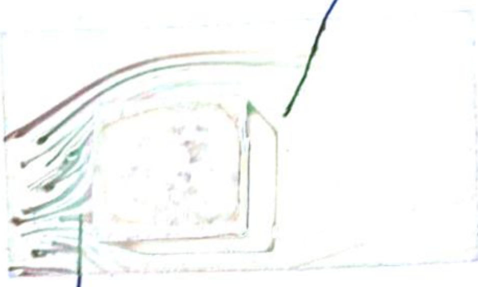
Rectangular Plate

In steady flow the filament lines are identical to streamlines. In above case there is streamline is flow. In rectangular slap, Re > 10000 so it indicates vortex with time variation.

Rectangular Plate (tilted)

Point of separation is the corner of plate and it also indicates streamline flow.
It shows streamline flow.

Point of separation

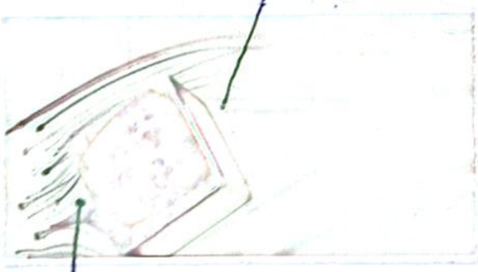


Stagnation Point

(Square → edge)

Bluff body (thick object) has point of sep. at corner.

Point of separation



Stagnation Point

(Square → diagonal)

Cube is positioned diagonally along the flow.

Department of Mechanical Engg.

Zakir Hussain College of Engineering And Technology

AMU, Aligarh

LAB REPORT

Name : PRANAY SINGH

Class : A2MB

Faculty No. : 21MEB448

Serial no. : 14

Enroll No. : GL2254

Course Title : Fluid Mechanics Lab

Course No : MEC292O

7/10

28/11/22

Brief Objective : To determine the friction factor for the horizontal commercial pipe of uniform section under turbulent flow condition

Date of Experiment Performed : 21/11/22

Date of Submission : 28/11/22

Teacher's Remark :

PRANAY SINGH
21MEB448
GL2254

ECT: To determine the friction factor for the horizontal mmercial pipe of uniform section under turbulent flow condition.

21/11/22

ven Data:

Pipe diameter $(d) = 0.01905\ m$

Pipe Area $(a) = 2.8502 \times 10^{-4}$

Area of tank $= 2ft \times 2ft = 0.3716\ m^2$

Specific gravity of working fluid, $S_g = 1$

Specific gravity of manometric fluid, $S_{gm} = 13.6$

Length of pipe b/w the pressure tapping $(L) = 9.15\ m$

Observations:

i) Temp. of water $= 23^\circ C$

ii) Kinematic viscosity of water $= 0.938 \times 10^{-6}\ m^2/s$

S.No.	Manometer Reading x_1 (m)	x_2 (m)	Level in collecting tank (m)	Time of water collection (t)
1.	0.18	0.36	0.1	70
2.	0.19	0.35	0.1	77
3.	0.20	0.34	0.1	78
4.	0.21	0.33	0.1	84
5.	0.22	0.32	0.1	88
6.	0.23	0.31	0.1	103
7.	0.24	0.30	0.1	122
8.	0.25	0.29	0.1	138

Formula used:

Actual volume flow rate, $Q_a = \frac{Ah}{t}$

velocity of flow, $v = \frac{Q_a}{a}$ m/s

Reynold's No., $Re = \frac{vd}{\nu}$

Loss of head, $h_L = \left(\frac{S_{gm}}{S_g} - 1\right)(x_2 - x_1)$

Friction factor, $\lambda = h_L\left(\frac{2gd}{LV^2}\right)$

Sample Calculations:

Given:
Diameter of pipe ⇒ $d = 0.01905$ m

⇒ Area of pipe $= \frac{\pi}{4}(0.01905)^2 = 2.8502 \times 10^{-4}\ m^2$

For reading no. 7

$x_1 = 0.24$ $x_2 = 0.30$

$h = 0.1$ m $t = 122$ s

Area of collecting tank $(A) = 0.3716\ m^2$ (2ft × 2ft)

→ Loss of head, $h_L = \left(\frac{S_{gm}}{S_g} - 1\right) \times (x_2 - x_1)$

$= \left(\frac{13.6}{1} - 1\right) \times (0.30 - 0.24)$

$= 12.6 \times 0.06 = 0.756$ m

$h_L = 0.756$ m

→ Actual volume rate of flow, $Q_a = \frac{Ah}{t}$

$Q_a = \frac{0.3716 \times 0.1}{122} = 3.0459 \times 10^{-4}\ m^3/s$

velocity of flow, $v = \frac{Q_a}{a}$

$= \frac{3.0459 \times 10^{-4}}{2.8502 \times 10^{-4}} = 1.0686$ m/s

Reynold's No., $Re = \frac{vd}{\nu}$

$= \frac{1.0686 \times 0.01905}{0.938 \times 10^{-6}}$

$Re = 21656.81$

Friction factor, $\lambda = h_L\left[\frac{2gd}{LV^2}\right]$

$= 0.756\left[\frac{2 \times 9.81 \times 0.01905}{9.15 \times (1.0686)^2}\right]$

$\lambda = 0.0271$

→ $\log(h_L) = \log(0.756) = -0.1214$

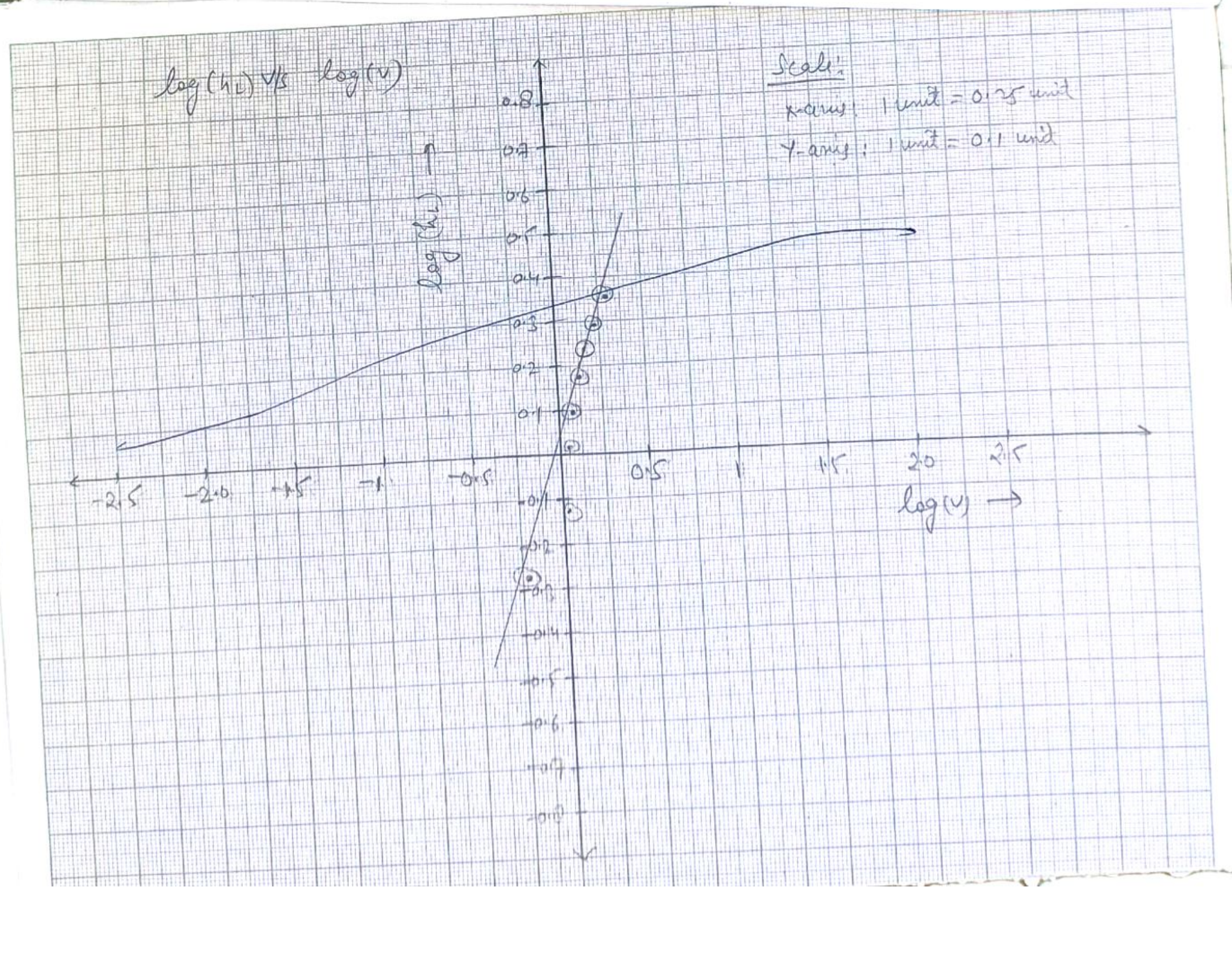
→ $\log(\lambda) = \log(0.0271) = -1.5671$

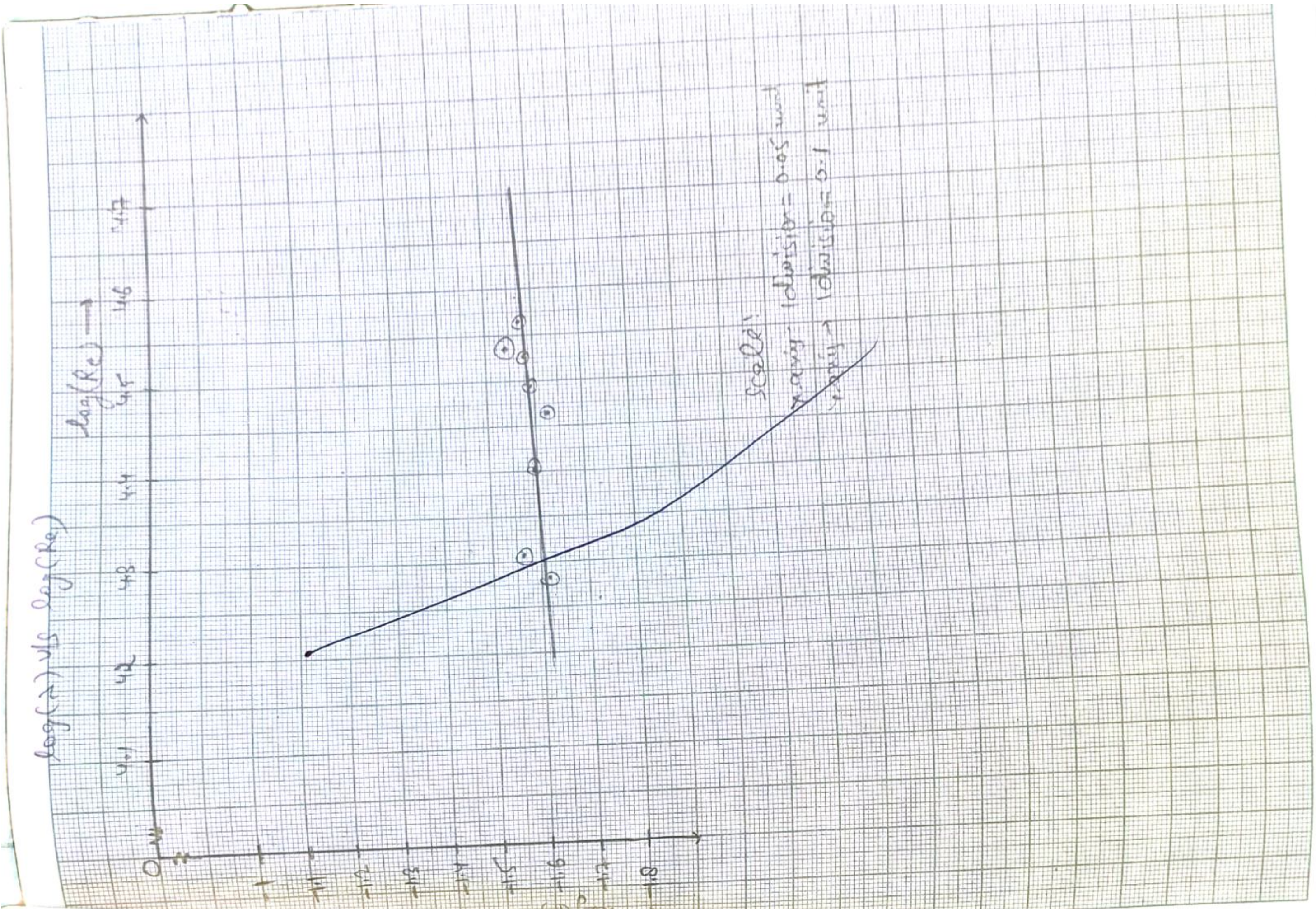
→ $\log(Re) = \log(21656.81) = 4.3355$

→ $\log(v) = \log(1.0686) = 0.0288$

Observation & Result Table:

S.No.	1	2	3	4	5	6	7	8
Manometer reading x_1(m)	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25
Manometer reading x_2(m)	0.36	0.35	0.34	0.33	0.32	0.31	0.30	0.29
Loss of head $h_L = \left(\frac{S_{gm}}{S_g}-1\right)(x_2-x_1)$ m of H_2O	2.268	2.016	1.764	1.512	1.260	1.008	0.756	0.504
Level rise in collecting tank (m)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Time of water collected t(s)	70	77	78	84	88	103	122	138
Actual volume rate of flow $Q_a = Ah/t$	5.3085×10^{-4}	4.8259×10^{-4}	4.7641×10^{-4}	4.4238×10^{-4}	4.2227×10^{-4}	3.6077×10^{-4}	3.0459×10^{-4}	2.6927×10^{-4}
Velocity of flow $v = (Q_a/a)$ m/s	1.8625	1.6932	1.6714	1.5521	1.4815	1.2657	1.0686	0.9447
$Re = vd/\nu$	37825.82	34387.48	33944.74	31521.86	30088.03	25705.31	21656.01	19186.07
$\lambda = h_L 2gd/Lv^2$	0.0267	0.0287	0.0258	0.0256	0.0234	0.0257	0.0271	0.0231
$\log h_L$	0.3556	0.3044	0.2465	0.1795	0.1004	0.00346	−0.1214	−0.2975
$\log \lambda$	−1.5734	−1.5421	−1.5883	−1.5917	−1.6307	−1.5901	−1.5671	−1.6364
$\log Re$	4.5777	4.5364	4.5307	4.4986	4.4783	4.4101	4.3355	4.2829
$\log v$	0.2701	0.2287	0.2231	0.1909	0.1707	0.1023	0.0288	0.0247




log(λ) vs log(Re)
log(Re) →
Scale:
x-axis → 1 division = 0.05 unit
y-axis → 1 division = 0.1 unit
log(λ)

Discussion:-

Discuss the physical significance of the experiment.
In turbulent flow regime, the friction factor plays a very important role as the pumping power is related to the friction factor. The aim is to reduce the friction factor value by taking into account the fluid properties and the material of construction.
The estimation of head losses due to friction in pipes is an important task in optimization studies and hydraulic analysis of pipelines and water distribution system.
It is vital in new pipeline design to have a good estimate of flow capacity as the larger part of the economics will be dependent on this.

Q2- Comment on why 'f' becomes independent of Re for very large Re?

A- Friction Factor is independent of the Reynold's number of very large Reynold numbers. This is because the thickness of the laminar sublayer (viscous sublayer) decreases with increasing Reynolds number. For very large Reynolds numbers, the thickness of the laminar sublayer is comparable to the surface roughness, and it directly influences the flow.
The laminar sublayer becomes so thin that the surface roughness protudes into the flow. The friction losses, in this case, are produced in the main flow primarily by the protuding roughness elements, and the contribution of the laminar sublayer is negligible.

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LAB REPORT

Name : Pranay Singh

Class : A2MB

Faculty No. : 21MEB448

Serial no. : 14

Enroll No. : GL2254

Course Title : Fluid Mechanics lab

Course No : MEC2920

Brief Objective : To compare the loss of head 90° easy bend.

Date of Experiment Performed : 28/11/22

Date of Submission : 05/12/22

6/10

Teacher's Remark :

Pranay Singh
21MEB440
28/11/22

OBJECT: To compare the loss of head of 90° easy band.

Formula used: $h_m = \frac{K\bar{V}^2}{2}$

$$K = 0.388\,\alpha\left(\frac{R}{d}\right)^{0.84} Re_D\,, \quad \alpha = 0.95 + 4.42\left(\frac{R}{d}\right)^{-1.96} \geq 1$$

Constant observations: (i) Diameter of pipe (d) = 13.6 mm

(ii) Length of pipe (l) = 0.914 m

Observation Table:

S.No	Level of water rise (L)	Time (s)	Easy bend r = 100 mm		Easy bend r = 150 mm		Easy bend r = 50 mm	
			x_1 (mm)	x_2 (mm)	x_1 (mm)	x_2 (mm)	x_1 (mm)	x_2 (mm)
1	20	90.88	505	265	485	260	520	270
2	20	94.34	485	270	465	260	495	270
3	20	98.5	465	275	450	265	475	275
4	20	107.6	445	275	425	265	450	275
5	20	119.68	425	280	410	270	425	275
6	20	128.6	405	285	395	275	410	280
7	20	150.2	385	285	370	275	380	280
8	20	168.4	365	290	350	280	360	280

Sample Calculation Consider Reading No. 3

Given,

Level of water rise $= 20L = 20\times10^{-3}\ m^3$

Time for water collection $= t = 98.5\ s$

Volume flow rate, $Q = \dfrac{20\times10^{-3}}{98.5} = 2.03\times10^{-4}\ m^3/s$

Velocity of flow in pipe, $v = \dfrac{Q}{A} = \dfrac{2.03\times10^{-4}}{\frac{\pi}{4}(0.0136)^2} = \dfrac{2.03\times10^{-4}}{0.000145}$

$v = 1.4\ m/s$

Reynold's number, $Re = \dfrac{\rho v d}{\nu}$

$Re = \dfrac{1\times1.4\times0.0136}{1.032\times10^{-6}} = \dfrac{0.01904}{1.032}\times10^{6} = 18449.61$

Now, velocity head: $\dfrac{v^2}{2g} = \dfrac{(1.4)^2}{2\times9.81} = 0.0998\ m$

Given, surface roughness of pipe; $\epsilon = 0.002\ mm$

$\epsilon = 0.002\times10^{-3}$

$\Rightarrow$ Relative roughness of pipe; $\dfrac{\epsilon}{d} = \dfrac{0.002\times10^{-3}}{0.0136} = 1.47\times10^{-4}$

Also, we know that, $\dfrac{1}{\sqrt{f}} = -1.8\log\left[\left(\dfrac{6.9}{Re}\right)+\left(\dfrac{\epsilon/d}{3.7}\right)^{1.11}\right]$

Putting $Re = 18449.61$ and $\epsilon/d = 1.47\times10^{-4}$, we get:

friction factor: $f = 2.65\times10^{-2}$

- Now, frictional loss, $h_{fl} = \dfrac{flv^2}{2gd} = \dfrac{2.65\times10^{-2}\times0.914\times(1.4)^2}{2\times9.81\times0.0136}$

$\Rightarrow h_{fl} = 0.178\ m$

We know that,

$$\frac{\Delta P}{\rho g} = h_{fl} + h_{me} \Rightarrow h_{me} = \frac{\Delta P}{\rho g} - h_{fl}$$

where, $\frac{\Delta P}{\rho g}$ = Total head loss, h_{fl} = head loss due to friction, h_{me} = head loss due to easy bend

- Also, bending coefficient:

$$K_b = \frac{h_{me} \cdot 2g}{v^2}$$

(a) Now, for $r = 100$ mm

$$h_{me} = 0.190 - 0.178 = 0.012 \text{ m}$$

$$\Rightarrow \log(h_{me}) = -1.921$$

$$\therefore K_b = \frac{h_{me} \cdot 2g}{v^2} = \frac{0.012 \times 2 \times 9.81}{(1.4)^2} = 0.121$$

(b) For, $r = 150$ mm

$$h_{me} = 0.185 - 0.178 = 0.007 \text{ m}$$

$$\Rightarrow \log(h_{me}) = -2.155$$

$$\therefore K_b = \frac{0.007 \times 2 \times 9.81}{(1.4)^2} = 0.701$$

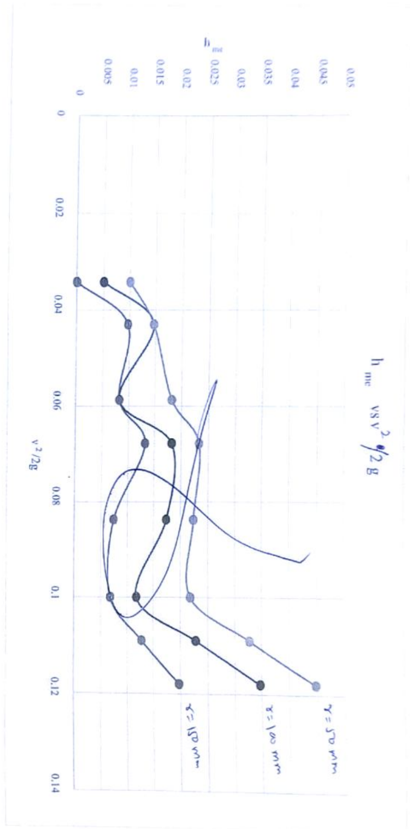
(c) For, $r = 50$ mm

$$h_{me} = 0.200 - 0.178 = 0.022$$

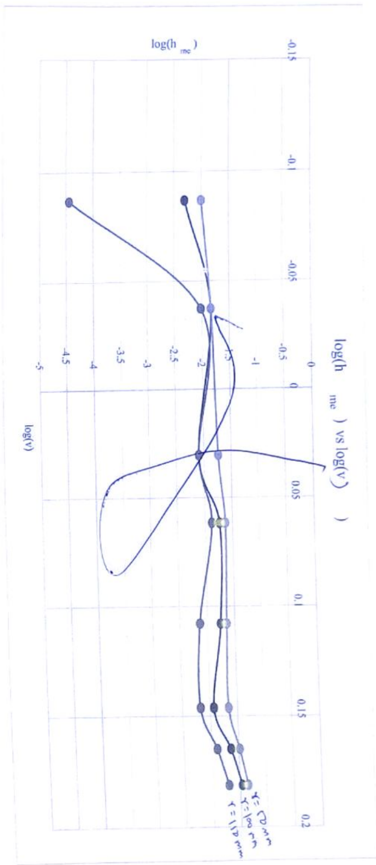
$$\Rightarrow \log(h_{me}) = -1.657$$

$$\therefore K_b = \frac{0.022 \times 2 \times 9.81}{(1.4)^2} = 0.221$$

Level of water	time	Velocity of flow	R_e	Friction factor	h_{fl}	h_{me}			K_b			log(v)	v2/2g	$\log(h_{me})$		
						r=150mm	r=100m	r=50mm	r=150mm	r=100m	r=50mm			r=150mm	r=100m	r=50mm
0.02	90.88	1.52E+00	2.00E+04	0.02599	0.205276	0.034724	0.019724	0.044724	2.95E-01	1.68E-01	3.81E-01	0.181194	1.18E-01	-1.45937	-1.705	-1.34946
0.02	94.34	1.46E+00	1.93E+04	0.026227	0.192236	0.022764	0.012764	0.032764	2.09E-01	1.17E-01	3.00E-01	0.164966	1.09E-01	-1.64276	-1.89403	-1.48461
0.02	98.5	1.40E+00	1.85E+04	0.026506	0.178217	0.011783	0.006783	0.021783	1.18E-01	6.78E-02	2.18E-01	0.146226	1.00E-01	-1.92874	-2.16857	-1.66188
0.02	107.6	1.28E+00	1.69E+04	0.027093	0.152652	0.017348	0.007348	0.022348	2.07E-01	8.76E-02	2.67E-01	0.10785	8.38E-02	-1.76074	-2.13381	-1.65076
0.02	119.68	1.15E+00	1.52E+04	0.027827	0.126737	0.018263	0.013263	0.023263	2.69E-01	1.96E-01	3.43E-01	0.06164	6.78E-02	-1.73842	-1.87735	-1.63333
0.02	128.6	1.07E+00	1.41E+04	0.028342	0.111795	0.008205	0.008205	0.018205	1.40E-01	1.40E-01	3.10E-01	0.030421	5.87E-02	-2.08593	-2.08593	-1.73981
0.02	150.2	9.18E-01	1.21E+04	0.029507	0.085322	0.014678	0.009678	0.014678	3.41E-01	2.25E-01	3.41E-01	-0.03701	4.30E-02	-1.83333	-2.01421	-1.83333
0.02	168.4	8.19E-01	1.08E+04	0.030415	0.069964	0.005036	3.63E-05	0.010036	1.47E-01	1.06E-03	2.93E-01	-0.08668	3.42E-02	-2.29789	-4.44058	-1.99843



h mc vs v²/2g
r = 50 mm
r = 100 mm
r = 150 mm
v²/2g
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05


log(h mc) vs log(v)
log(h mc)
log(v)

Discussion

Q1. Discuss the physical significance of the experiment.

Sol: The flow in a piping system may be required to pass through a variety of fittings and abrupt changes in area. Additional head losses are encountered primarily as a result of flow separation which is is termed as minor losses.

The minor loss is of following types:

1. Pipe entrance or exist
2. Sudden/ Gradual expansion or contraction
3. Bends or elbows
4. Values

In Engineering practices, these pipes are designed to increase their productivity i.e. maximising the flow rate capacity and minimising the head loss per unit length and as a consequent to decrease these losses.

Q2 Show with the help of buckingham Pi theorem, the dependence of K_b on other factors.

Sol:- Consider K_b to depend upon velocity of the flow, acceleration due to gravity and head loss, i.e.

$$K_b = f(h_m, v, g)$$

$K_b = [M^0L^0T^0]$, $[h_m] = [M^0L^1T^0]$, $[v] = [M^0L^1T^{-1}]$, $[g] = [M^0L^1T^{-2}]$

Now, $\pi_1 = h_m^a \cdot v^b \cdot K_b^c$ and $\pi_2 = h_m^d v^e g$

$\Rightarrow M^0L^0T^0 = L^a \cdot L^b T^{-b} \cdot M^0L^0T^0$

$a+b=0$, $a=0$, $b=0$, $c=0$

$\Rightarrow \pi_1 = K_b$ --(i)

$\Rightarrow M^0L^0T^0 = L^d L^e T^{-e} \cdot L^1T^{-2}$

$\Rightarrow M^0L^0T^0 = M^0 L^{d+e+1} \cdot T^{-2-e}$

$\Rightarrow d+e+1=0$; $-2-e=0$

$\Rightarrow d=1$; $e=-2$

$\Rightarrow \pi_2 = h_m v^{-2} g$ --(ii)

Also, $\pi_1 = f(\pi_2)$

from eq(i) & (ii) $\pi_1 = f(h_m v^{-2} g)$

or $\boxed{K_b = f(h_m v^{-2} g)}$

Hence K_b depends on h_m, v and g.

Q3. Why K_{bc} is not equal to K_{bs}.

Sol:- Losses from bends are not all the same. These can be a just 45° bend or a 180 degree turn, that can be sharp or gradual, threaded or unthreaded. All of these factors plays an important role in the magnitude of losses. The lower the K-value for a bend, smoother it is, and opposite is true for a high K-valued bend.

$$K \simeq 0.388\,\alpha\left(\frac{R}{d}\right)^{0.84} \cdot Re^{-0.17}$$ where R is radius of bend and $\alpha = 0.95 + 4.42\left(\frac{R}{d}\right)^{-1.96}$

The value of coefficient of bending would be larger for sharp bends as compared to easy bends because of larger separation on the wall.

The value of K_{bc} and K_{bs} depends on the total length of the bend and the ratio of radius of curvature of the bend and the pipe diameter i.e. R/d. As the sharp and easy bends have different radii, they will give different values of K_{bc} and K_{bs}.

AMU

ZHCET

NAME - PRANAY SINGH

FACULTY - 21MEB448

ENROLL. NO. - GL-2254

CLASS - A-2 MB

S. NO. - 14

SUBJECT - FLUID MECHANICS LAB

EXPERIMENT - No. 1

VANE COEFFICIENT

Reason for value of deviations in K vs Re

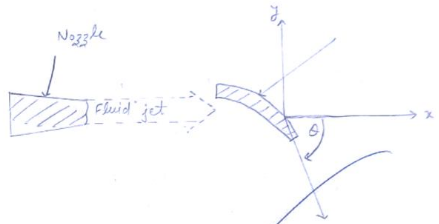
7.5/10

23/9/22

EXPERIMENT-01

PRANAY SINGH
-21MEB448
A2MB-14

OBJECTIVE: To appreciate the linear momentum equation as applied to fluid system and to calculate vane coefficient for a flat plate or 180° vane.



OBSERVATION TABLE:-

12/9/22

S.No.	Height of tank (m)	Time (s)	Weight (g)
1.	0.2	320	0.05
2.	0.2	242	0.10
3.	0.2	202	0.15
4.	0.2	177	0.200
5.	0.2	163	0.25
6.	0.2	149	0.3
7.	0.2	126	0.4
8.	0.2	116	0.5

Given Data:

Temperature of water (θ) = 27 °C

Kinematic viscosity of water at θ°C (ν) = 0.858×10^{-6} m^2/s

Nozzle dia (d) = 0.9 cm, Nozzle area (a) = 6.36×10^{-5} m^2

Length of lever arm from fulcrum to weight hanger (l_1) = 0.54 m

Length of lever arm from fulcrum to vane spindle (l_2) = 0.27 m

Area of collecting tank (A) = 0.3716 m^2

Formula Used:-

Vane Coefficient, $K = \frac{\text{Actual force}}{\text{Theoretical force}} = \frac{F_a}{F_{Th}}$

$F_{Th} = \rho A U^2$ (for flat plate)

$F_{Th} = 2\rho A U^2$ (for hemispherical plate)

where, ρ = Density of water

A = Area of Nozzle (Jet)

U = Velocity of jet

Actual force, $F_a = \frac{W l_1 \times 9.81}{l_2}$

Sample Calculation:

Level rise (h) = 0.2 m

time of collecting water = 116 s

Volume flow rate $Q_a = \frac{Ah}{t}$

A = 0.3716

$\Rightarrow Q_a = \frac{0.3716 \times 0.2}{116} = 6.40 \times 10^{-4}$ m^3/s

Velocity of flow, $V = \frac{Q}{a}$

$a = \frac{\pi d^2}{4} = \frac{\pi (0.009)^2}{4} = 6.36 \times 10^{-5}$ m^2

$V = \frac{Q}{a} = \frac{6.4 \times 10^{-4}}{6.36 \times 10^{-5}} = 10.062$ m/s

Theoretical force, $F_{Th} = 2\rho A U^2$

$= 2 \times 1000 \times 6.36 \times 10^{-5} \times (10.062)^2$

$= 12.88$ N

Weight placed = 0.5 kg

Actual force = $F_a = \frac{W l_1 \times 9.81}{l_2}$

$= \frac{0.5 \times 0.54 \times 9.81}{0.27} = 9.81$ N

Vane coeff. = $K = \frac{F_a}{F_{Th}} = \frac{9.81}{12.88} = 0.761$

$\frac{U^2}{2g} = (10.06)^2 / 2 \times 9.81 = 5.158$ m

$Re = \frac{Ud}{\nu} = \frac{10.062 \times 0.009}{0.858 \times 10^{-6}} = 105545.45$

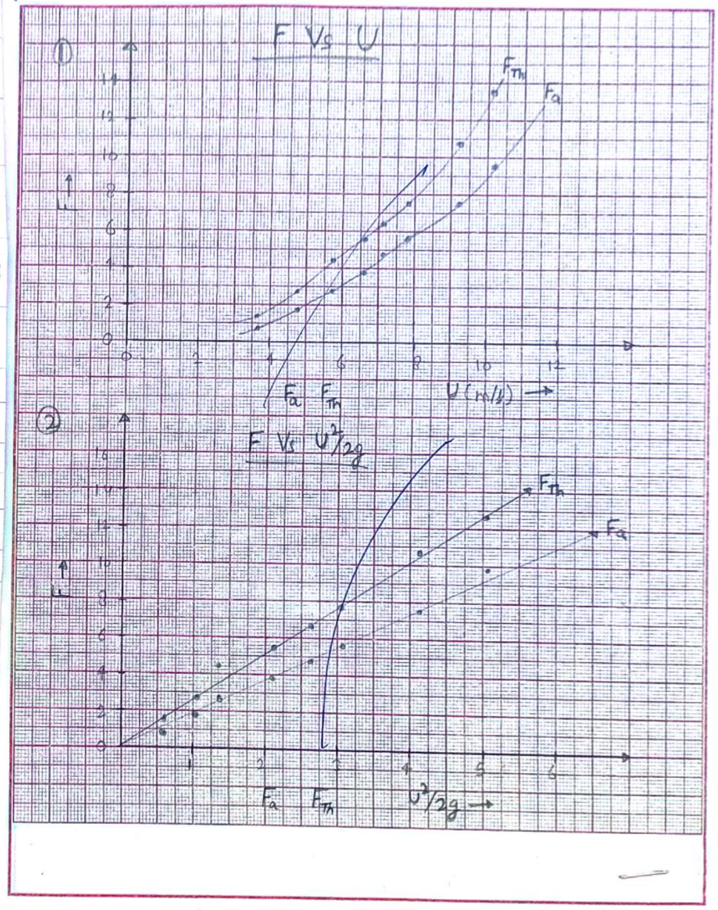
$\log F_a = 0.991$

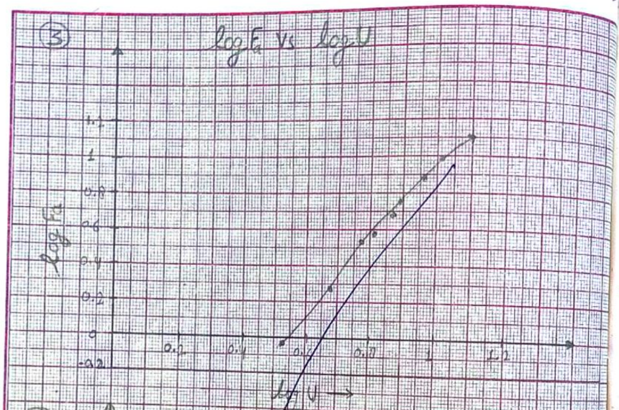
$\log F_{Th} = 1.1099$

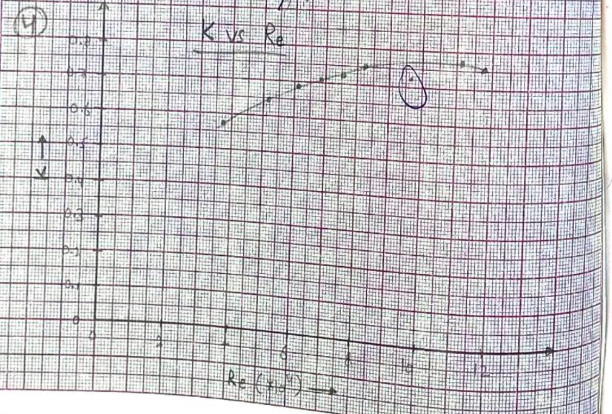
Result table :

S.No.	1	2	3	4	5	6	7	8
Level Rise in collecting tank (h). m	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Time of water collection (t) sec	320	242	202	177	163	149	126	116
Volume rate of flow ($Q = Ah/t$) (10^{-4}) m^3/s	2.32	3.07	3.68	4.18	4.56	4.98	5.89	6.4
Velocity of flow ($U = Q/a$) m/s	3.65	4.82	5.78	6.60	7.17	7.83	9.261	10.06
($U^2/2g$). m	0.68	1.18	1.702	2.22	2.63	3.124	4.37	5.158
Theoretical force of jet (F_{Th}). N	1.69	2.95	4.24	5.54	6.82	7.79	10.90	12.88
Weight balanced on hanger for Balance (w). kgf	0.05	0.10	0.15	0.200	0.25	0.3	0.4	0.5
Actual force of jet (F_a).N	0.98	1.96	2.94	3.94	4.9	5.88	7.84	9.81
Vane Coefficient $K = (F_a/F_{Th})$	0.58	0.66	0.69	0.708	0.718	0.75	0.719	0.761
$Re = Ud/\nu$ (10^4)	3.83	5.09	6.06	6.92	7.51	8.29	9.714	10.55
log Fa	-0.008	0.292	0.468	0.593	0.69	0.769	0.894	0.991
log Fth	0.23	0.469	0.627	0.743	0.834	0.891	1.037	1.1099
log U	0.56	0.68	0.76	0.81	0.88	0.89	0.96	1.002

- $F_{Th} = \rho A U^2$ (for flat plate)
- $F_{Th} = 2\rho A U^2$ (for hemispherical plate)







Discussion:

Discuss the physical significance of experiment.

Acc. to the law of conservation of linear momentum & Newton's second law of motion, rate of change of linear momentum will be equal to the force applied. When the jet impringes the vane, it gets bend by 90°, so change in linear momentum will be equal to the -ve times of mass times velocity of incoming jet.

Hence, applying Reynold's theorem,

$$F_{Th} = \rho A U^2 \quad (\text{flat})$$

$$F_{Th} = 2\rho A U^2 \quad (\text{hemispherical})$$

The flow is assumed to the incompressible as well as inviscid. We have assumed no loss by friction, etc. Also there will be some losses & hence, the actual value of force acting on the jet will be different from theoretical one. The ratio of Fa to Fm is termed as vane coefficient (K). If we know the vane coeff. then we can calculate Fa and losses.

Increasing the velocity of jet, the value of vane coeff. approaches towards unity meaning that the actual & theoretical forces tending closer to each other, ultimately losses are reduced.

$$K = \frac{\text{Actual Force}}{\text{Theoretical force}}$$

Discussion on graph

The graph of F vs U is a non-linear curve. With the increase of jet velocity, theoretical as well as actual force increases. Also, the value of F_{Th} is more than Fa for a particular value of U.

The graph of F vs $U^2/2g$ is a linear curve which shows that the value of actual as well as theoretical force is directly proportional to U^2.

The graph of K vs Re is non-linear curve which shows that as soon as flow becomes turbulent value of K becomes constant.

The graph of log Fa and log U is linear and from the graph the value of n calculated is 1.967 and Ka is 0.09.

AMU
ZHCET

Name - Pranay Singh

Fac. No. - 21MEB448

Enr. No. - GL2254

Section - A2-MB

S.No. - 14

Subject - Fluid Mechanics Lab

Exp. - Bernoulli's Theorem

Submission Date - 07/11/2022

7/10

12/12/22

PRANAY SINGH
A2B-14
21MEB445

OBJECT:- To verify Bernoulli's theorem for a viscous and incompressible fluid.

31/10/2022

FORMULA USED:

$$h_{avg} + \frac{V_{avg}^2}{2g} = H$$

$a = bd \ m^2$, $H_z = \frac{d}{2} \ m$

$V = \frac{Q_a}{a} \ m/s$, $H_v = V^2/2g \ m$

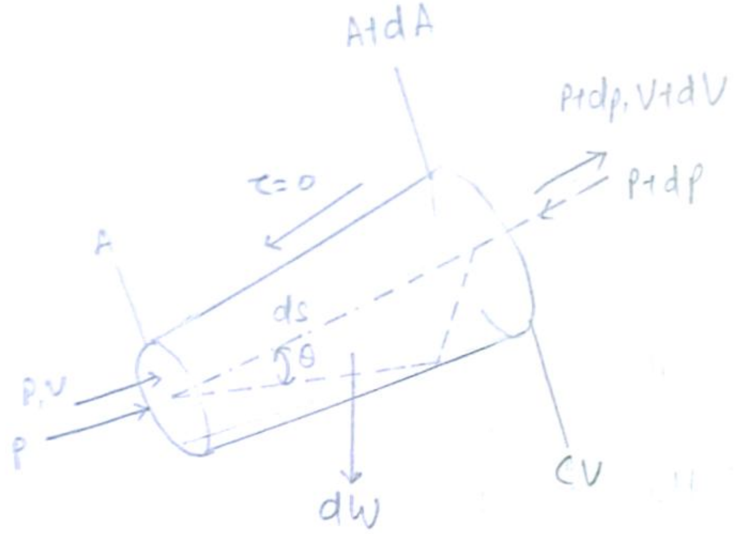
$\frac{p}{\rho g} = x + y + \frac{d}{2} \ m$, $H_s = p + \rho g + H_z$

$H_t = H_v + H_s$, $R = 2Q_a/(b+d)v$

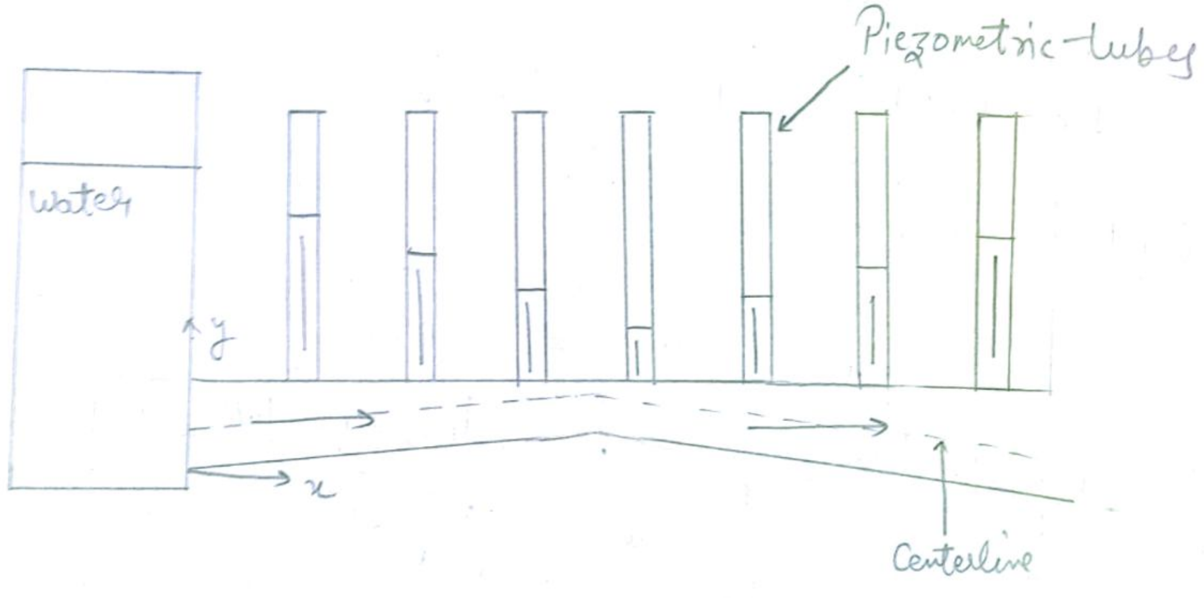
GIVEN DATA:

Temperature of water = 28°C
Flow rate (Q) = 1.65 m^3/h

Tube No.	Distance from the tank (m)	Piezometric tube-head (h)
1	1	28
3.	3	27.7
5.	5	27.5
7.	7	27.3
9.	9	27.1
11.	11	26.4
13.	13	27.2
15	15	27.5
17.	17	27.5
19.	19.	27.6
21.	21	28



1- Forces & Fluxes for Bernoulli's Equation



2- Block diagram of the setup

Result Table:

Piezometric Tube No.	1	3	5	7	9	11	13	15	17	19	21
Height of passage under Piezotube (d) m	0.0306	0.034	0.0294	0.0248	0.0207	0.0155	0.0207	0.0248	0.0294	0.034	0.0306
Datum / Pot Head $H_z = d/2$ m	-0.0193	-0.017	-0.0147	-0.0124	0.01035	-0.00775	-0.01035	-0.0124	-0.0147	-0.017	-0.0193
Flow of passage area $(a=bd)\ m^2$	0.00139	0.001224	0.001058	0.000893	0.000745	0.000558	0.000745	0.000893	0.001058	0.001224	0.00139
Width of tube (b) m	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
Flow rate $(Q_a)\ m^3/s$	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}	4.5834×10^{-4}
Velocity of flow $(U = Q_a/a)$ m/s	0.3297	0.374	0.4330	0.535	0.6152	0.821	0.6152	0.535	0.4330	0.374	0.3297
Velocity head (Kinetic) $(H_v = v^2/2g)$ m of H_2O	0.00554	0.00713	0.00956	0.0146	0.0193	0.0344	0.0193	0.0146	0.00956	0.00713	0.00554
Scale error (Y) m	0.026	0.025	0.025	0.025	0.026	0.026	0.025	0.026	0.026	0.025	0.025
Piezo reading (X) m of H_2O	0.28	0.277	0.275	0.273	0.271	0.264	0.272	0.275	0.275	0.276	0.28
Pressure head $(P/\rho g = X+Y+d/2)$ m of H_2O	0.3253	0.319	0.3147	0.3104	0.30735	0.29775	0.30735	0.3134	0.3157	0.318	0.3243
Static piezo head $(H_s = P/\rho g + H_z)$ m of H_2O	0.306	0.302	0.30	0.298	0.2970	0.29	0.2970	0.301	0.301	0.301	0.305
Total head $(H_t = H_v + H_z$	0.31154	0.30913	0.30956	0.3126	0.3163	0.3244	0.3163	0.3156	0.31056	0.30813	0.31054

Sample Calculations :-

For tube No. 13

Height of passage under piezotube, $d = 0.0207\ m$

Datum / pot head $(H_z) = -\frac{d}{2} = -0.01035\ m$

Flow passage area $(a = bd) = 0.036 \times 0.0207$

$= 0.00074520$

Velocity of flow $\Rightarrow \left(V = \frac{Q_a}{a}\right) \Rightarrow \frac{1.65}{0.00074520 \times 3600} = \frac{1.65}{2.68272}$

$= 0.615\ m/s$

Velocity head $\Rightarrow$

$$H_v = \frac{(0.615)^2}{2 \times 9.8} = \frac{0.378225}{19.6} = \boxed{0.0193 = H_v}$$

Scale error $(Y) = 0.025\ m$

Piezo reading $(X) = 0.272\ m$

Pressure head $= X + Y + \frac{d}{2}$

$= 0.272 + 0.025 + 0.01035$

$= 0.30735$ ~~0.3074~~

Static Piezometer head $(H_s) = \frac{p}{\rho g} + H_z$

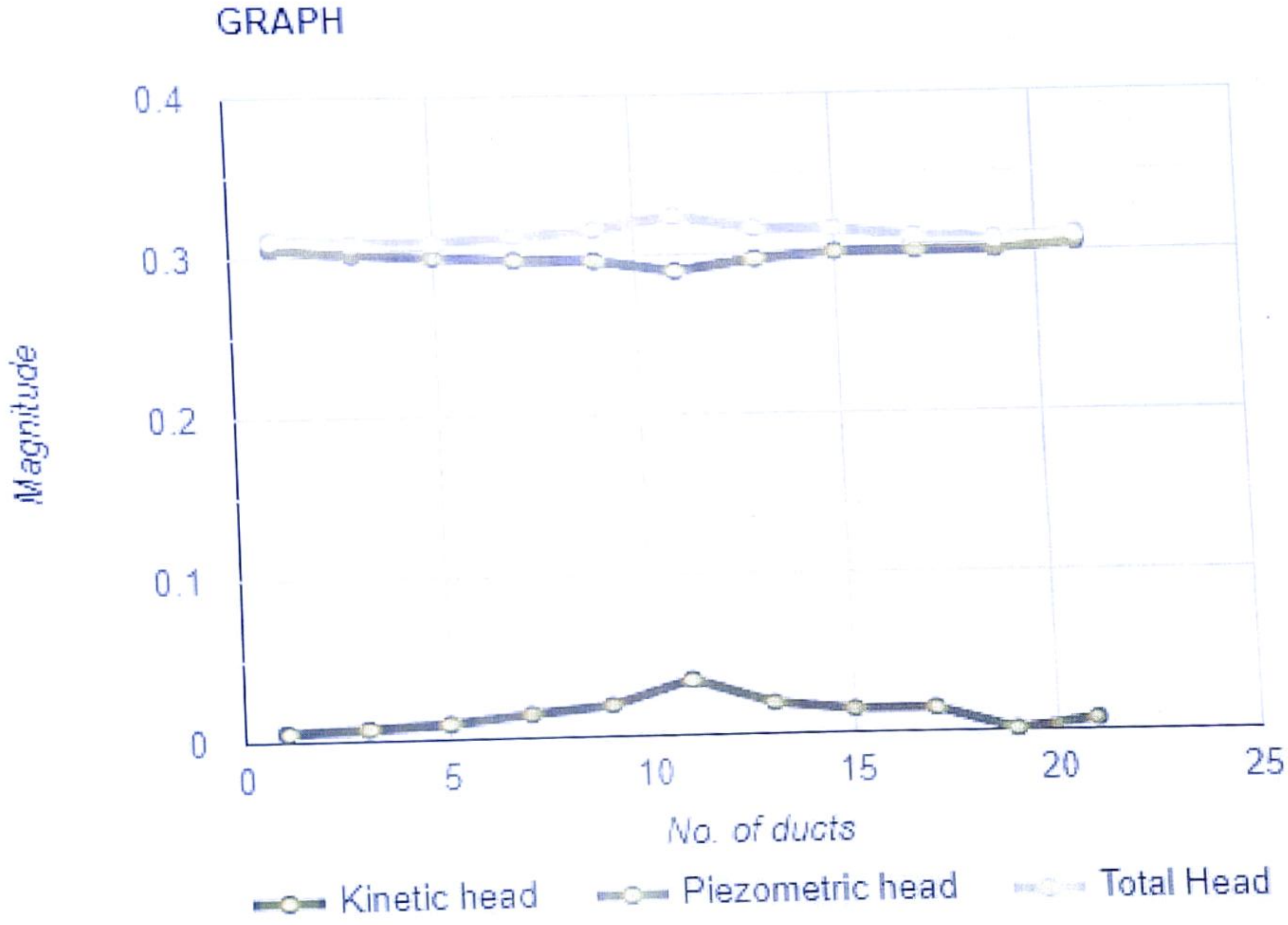
$= 0.30735 - 0.01035$

$\boxed{H_s = 0.2970}$

Total head, $H_T = H_v + H_s$

$= 0.0193 + \cancel{0.0193}\ 0.2970$

$\boxed{H_T = 0.3163}$


GRAPH
Magnitude
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
No. of ducts
Kinetic head
Piezometric head
Total Head

Discussion

Q① Discuss the physical significance of the experiment.

Sol:- This experiment focuses on the Bernoulli's theorem which provides a mathematical relation to the real world applications, used for studying unsteady potential flow, used for approximation of parameters like pressure and speed of the fluid. It can be applied to all problems of incompressible fluid flow. It has many real world applications, ranging from understanding the aerodynamics of an airplane, calculating wind load on buildings, measuring flow devices such as weirs, Parshall flumes and venturimeter and estimating seekage through soil, etc.

Q② Explain the limitations of BE.

Sol:- While deriving Bernoulli's eq^n, the viscous drag of the liquid has not been taken into consideration. The viscous drag comes into play when a liquid is in motion. Bernoulli's eq^n has been derived on the assumption that there is no loss of energy, when a liquid is in motion. In fact, some kinetic energy is converted into heat energy and a part of it is lost due to shear force. If the liquid is flowing along a curved path, the energy due to centrifugal force should also be taken into consideration.

Q3 Explain the dynamics of ping-pong ball.

Solⁿ:- The reason of spin in such a dominating force in a ping-pong ball can be seen when you consider that the ball is travelling through the fluids in this case or when a ball travels without spin, the air moves on the top, bottom and sides at the same speed and pressure forces are balanced.

Q4 Explain why a piece of paper is dragged towards a ~~fast~~ moving train when it enters a station?

Solⁿ:- Air b/w paper and the train moves with high velocity due to dragging effect and the air behind paper is approximately still.

Therefore, due to Bernoulli's principle, the pressure b/w the paper and the train decreases and the air behind the paper pushes it towards train due to which it is dragged towards the train.

Department of Mechanical Engg.

Zakir Hussain College of Engineering And Technology

AMU, Aligarh

LAB REPORT

Name : PRANAY SINGH

Class : A2MB

Faculty No. : 21MEB448

Serial no. : 14

Enroll No. : GL2254

Course Title : FLUID MECHANICS

Course No : MEC 2920

Brief Objective : To determine minor loss coefficients for sudden expansion and contraction in a circular pipe.

Date of Experiment Performed : 14/11/2022

Date of Submission : 21/11/2022

Teacher's Remark :

7/10

12/12/22

Pranay Singh
21MEB448
A2MB-14

ECT: To determine minor loss coefficients for sudden expansion nd contraction in a circular pipe.

en Data:

Pipe diameter before exp/after cont. (d_1 or d_4): 13.6 mm

Pipe diameter after exp/ before cont. (d_2 or d_3): 26.2 mm

14/11/22

servation Table:

Sudden Expansion		Sudden Contraction		Time
x_1	x_2	x_3	x_4	t (s)
487	530	520	364	88
483	520	510	310	91
465	500	495	312	96
445	476	465	362	105
430	455	450	315	113
410	430	425	315	128
395	415	410	315	136
380	395	390	315	155

Sample Calculation:

(i) a = Area of smaller pipe (A_1 or A_4) = $\frac{\pi}{4}(0.0136)^2 = 1.4527 \times 10^{-4}\ m^2$

A = Area of bigger pipe (A_2 or A_3) = $\frac{\pi}{4}(0.0262)^2 = 5.392 \times 10^{-4}\ m^2$

(ii) It is given that, diameter of small pipe : $d = 0.0136$ m
diameter of bigger pipe : $D = 0.0262$ m

∴ Head loss coefficient for sudden expansion:

$$K_{SE} = \left[1 - \frac{d^2}{D^2}\right]^2 = \left[1 - \left(\frac{0.0136}{0.0262}\right)^2\right]^2$$
$$= 0.534$$

∴ Head loss coefficient for sudden contraction:

$$K_{SC} = 0.42\left[1 - \left(\frac{d}{D}\right)^2\right] = 0.307$$

(iii) Considering reading 'I':
Given, for sudden Expansion: $x_1 = 0.487$ m, $x_2 = 0.530$ m
$x_3 = 0.520$ m, $x_4 = 0.364$ m

Flow rate, $Q = \frac{V}{t} = \frac{207 \times 10^{-3}}{88} = 2.27 \times 10^{-4}\ m^3/s$

$$v_1, v_4 = \frac{2.27 \times 10^{-4}}{a} = 1.562\ m/s$$

$$v_2, v_3 = \frac{2.27 \times 10^{-4}}{A} = 0.421\ m/s$$

I Sudden expansion:

(a) Experimental value of head loss = $\frac{\Delta P}{\rho g} = 0.530 - 0.487 = 0.043$

(b) By using Bernoulli's eq^n with head loss, at same datum:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} - h_{mSE}$$
$$\frac{\Delta P}{\rho g} = \frac{v_1^2 - v_2^2}{2g} - h_{mSE}$$

but, $h_{mSE} = K_{SE} \times \frac{v_1^2}{2g} = 0.534 \times \frac{(1.562)^2}{2 \times 9.81} = 0.0664$

By considering head loss;

$$\left(\frac{\Delta P}{\rho g}\right)_{WL} = \frac{v_1^2 - v_2^2}{2g} - h_{mSE} = \frac{(1.562)^2 - (0.421)^2}{19.62} - 0.0664 = 0.0486\ m$$

(c) Assuming No head loss: $\left(\frac{\Delta P}{\rho g}\right)_{w/L} = \frac{v_1^2 - v_2^2}{2g} = 0.1150$ m

II. Sudden Contraction:

a) Experimental value of head loss = $\frac{\Delta P}{\rho g} = \Delta x = 0.156$

b) For no head loss,
Using Bernoulli's eq^n at same datum:

$$\left(\frac{\Delta P}{\rho g}\right)_{NL} = \frac{v_4^2 - v_3^2}{2g} = \frac{(1.562)^2 - (0.421)^2}{2 \times 9.81} = 0.115$$

Head loss → $K_{SC} = 0.307$

$$h_{mSC} = K_{SC} \times \frac{v_4^2}{2g} = 0.307 \times \frac{(1.562)^2}{19.62} = 0.0382\ m$$

c) $\left(\frac{\Delta P}{\rho g}\right)_{WL} = 0.115 + 0.0382 = 0.1532$ m

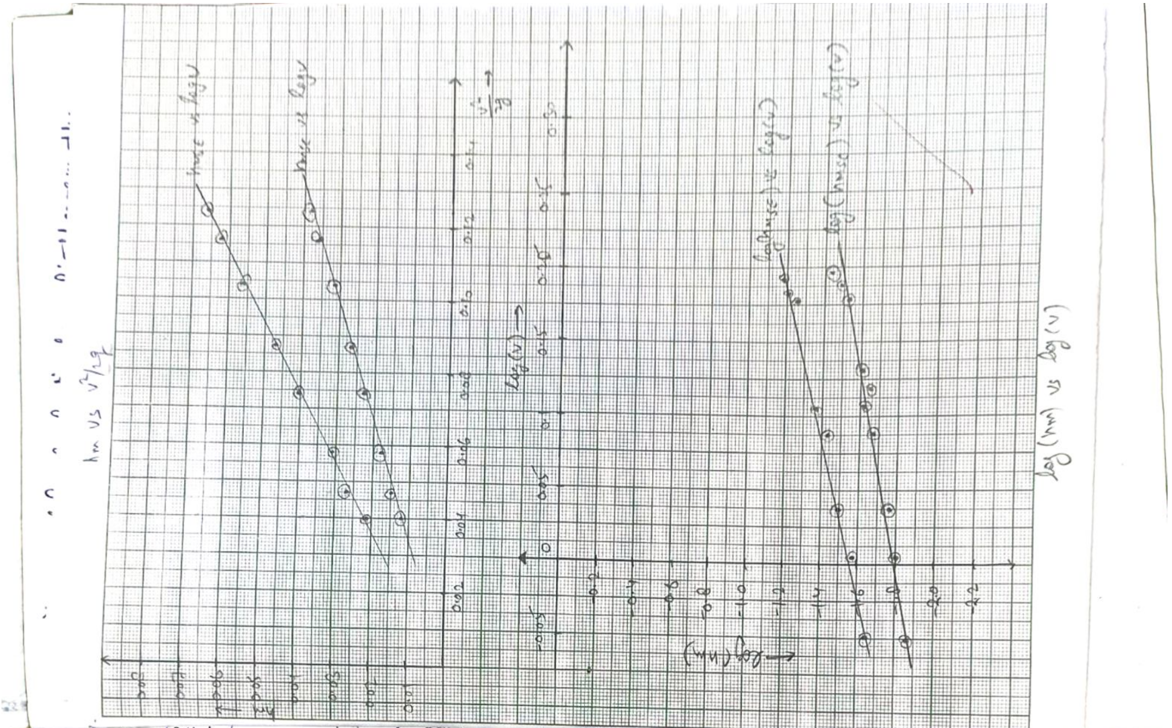
[Considering head loss]

∴ For sudden expansion: $\left(\frac{\Delta P}{\rho g}\right)_{Exp} = 0.043$, $\left(\frac{\Delta P}{\rho g}\right)_{WL} = 0.0486$

$\left(\frac{\Delta P}{\rho g}\right)_{NL} = 0.115$

∴ For sudden contraction: $\left(\frac{\Delta P}{\rho g}\right)_{exp} = 0.156$, $\left(\frac{\Delta P}{\rho g}\right)_{WL} = 0.1532$

$\left(\frac{\Delta P}{\rho g}\right)_{NL} = 0.0382$



of water rise	Collecting water	x_1 (m)	x_2 (m)	$(\Delta P/\rho g)$ Exp	$(\Delta P/\rho g)$ w/o loss	$(\Delta P/\rho g)$ with loss	x_3 (m)	x_4 (m)	$(\Delta P/\rho g)$	$(\Delta P/\rho g)$ w/o loss	$(\Delta P/\rho g)$ with loss	V (m/s)	log v	$v^2/2g$	h_{msc}	log (h_{msc})	h_{mse}	log (h_{mse})
							Sudden Contraction											
20	88	0.487	0.530	0.043	0.115	0.0486	0.520	0.364	0.156	~~0.0382~~ 0.115	0.1532	1.562	0.194	0.124	0.0382	-1.418	0.0664	-1.178
20	91	0.483	0.520	0.037	0.1083	0.0459	0.510	0.310	0.200	0.1083	0.1442	1.514	0.180	0.116	0.0359	-1.445	0.0624	-1.205
20	96	0.465	0.500	0.035	0.0969	0.0411	0.495	0.312	0.183	0.0969	0.1290	1.432	0.155	0.104	0.0321	~~0.0558~~ -1.493	0.0558	-1.253
20	105	0.445	0.476	0.031	0.081	0.0344	0.465	0.362	0.103	0.081	0.1078	1.309	0.116	0.087	0.0268	-1.571	0.0466	-1.331
20	113	0.430	0.455	0.025	0.069	0.0291	0.450	0.315	0.135	0.069	0.0919	1.211	0.083	0.074	0.0229	-1.64	0.0399	-1.399
20	128	0.410	0.430	0.020	0.054	0.0231	0.425	0.315	0.110	0.054	0.072	1.074	0.031	0.058	0.0180	-1.744	0.0314	-1.503
20	136	0.395	0.415	0.020	0.0483	0.0213	0.410	0.315	0.095	0.0483	0.0633	1.011	0.004	0.052	0.015	-1.823	0.027	-1.568
20	155	0.380	0.395	0.015	0.037	0.016	0.390	0.315	0.075	0.037	0.049	0.888	-0.051	0.040	0.012	-1.92	0.021	-1.677

Log (hmse)	1.178	205	253	31	399	.503	.568	1.677

Show with the help of Buckingham Pi-theorem the dependence of K_{se} & K_{sc} on other factors.

K_{se} and K_{sc} depends upon velocity of smaller pipe acceleration due to gravity and head loss.

i.e. $K = f(h_m, g, v) \rightarrow$

$$K: M^0L^0T^0 \quad h_m: M^0L^1T^0 \quad v: M^0LT^{-1} \quad g: M^0L^1T^{-2}$$

$x = 2$, $m - x = 2$

$$\pi_1 = h_m^a v^b K \Rightarrow M^0L^0T^0 = L^a L^b T^{-b} M^0L^0T^0$$

$$\boxed{\pi_1 = K}$$

$$\pi_2 = h_m^c v^d g \Rightarrow M^0L^0T^0 = L^c L^d T^{-d} L^{1} T^{-2}$$

$-d - 2 = 0$, $c + d + 1 = 0$

$d = -2$, $c = 1$

$$\pi = h_m v^{-2} g$$

$$\boxed{\pi_1 = f(\pi_2)}$$

$$\boxed{K = f(h_m v^{-2} g)}$$

Q3- Explain why K_{se} and K_{sc} are not equal.

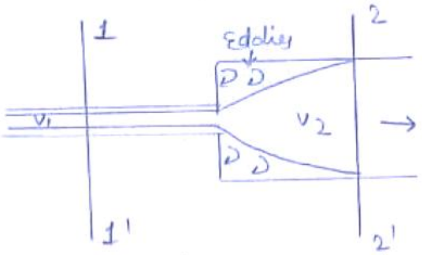
In sudden contraction, right after the sudden contraction A_c, a vena contracta is formed; and then right after, the flow widens again to fill the entire pipe. The region b/w the wall interior pipe and the vena contracta will be a region of separated flow.

The flow pattern after the vena contracta and the loss is caused due to expansion of flow after sudden contraction. That's why K_{se} and K_{sc} are not equal.

Discussion :

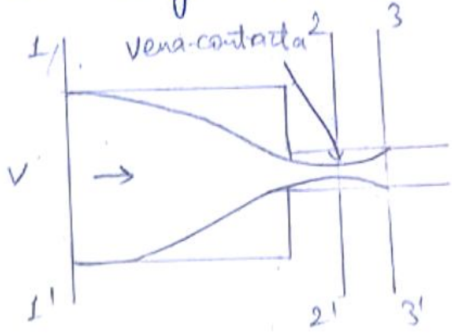
1. Discuss the physical significance of the experiment.

Solⁿ:- Loss of head due to sudden expansion is the energy loss due to sudden enlargement. Sudden expansion in the diameter of pipe results in the formation of eddies in the flow at the corners of enlarged pipe. This results in the loss of head across the fitting.



Sudden expansion

In reality, the head loss due to sudden ~~expansion~~ contraction but due to sudden enlargement, which takes place just after vena-contracta.



Sudden Contraction

If we see the result table, we observe that head loss due to sudden contraction of pipe is less than the head loss due to sudden expansion. From the graph, we conclude that h_{msc} & h_{mse} varies linearly with velocity of flowing liquid (v). They decrease as the velocity decreases in both sudden expansion and sudden contraction of pipe.