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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (1)

Experiment title:

Vapor-Liquid Equilibrium

Type of the report: Short Report

Abstract

The main purpose of this experiment was to obtain the vapor liquid equilibrium data for Hexane and Toluene to generate a T_{xy} diagram and calculate the activity coefficient of the two components.

Activity coefficient was calculated by three models: modified Raoult's law, Van Laar model and Two-Suffix margules model, and the data was scattered. A theoretical models were used to compare with the values of activity coefficients that obtained by experimental data. The consistency of data test indicates poor consistency of data with thermodynamics.

Sample of main results: The composition of hexane in liquid mixture X hexane (Vol%)=0.78 and its composition in vapor Y hexane (vol%)=0.83.

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Results

A. Txy-diagram of Hexane and Toluene system.

Table 1: final result of data collected from experiment.

runs	Temperature(°c)	density of n-hexane (kg/m3)	density of toluene (kg/m3)	RF (Vapor)	Vapor Hex (%vol)	Vapor Toluene (Vol%).	Y Hexane	Y Toluene	RF liquid	L-Hex (vol%)	L-Tol. (vol%)	X Hexane	X Toluene
1	56.3	659	-	-	1	0	1	0	-	0	1	1	0
2	61.5	659	828.42	1.397	0.83	0.17	0.8	0.2	1.4	0.78	0.22	0.74	0.26
3	65.4	659	825.66	1.409	0.73	0.27	0.68	0.32	1.42	0.62	0.38	0.57	0.43
4	69.4	659	821.15	1.41	0.72	0.28	0.67	0.33	1.46	0.32	0.68	0.27	0.73
5	72.7	659	818.12	1.4	0.81	0.19	0.77	0.23	1.43	0.52	0.48	0.47	0.53
6	76.7	659	814.43	1.422	0.62	0.38	0.57	0.43	1.46	0.31	0.69	0.27	0.73
7	83	659	808.64	1.436	0.51	0.49	0.46	0.54	1.47	0.19	0.81	0.16	0.84
8	87.53	659	804.47	1.462	0.29	0.71	0.25	0.75	1.48	0.16	0.84	0.13	0.87
9	95.6	659	797.04	1.475	0.18	0.82	0.15	0.85	1.49	0.06	0.94	0.05	0.95
10	106	-	785.74	-	0	1	0	1	-	1	0	0	1

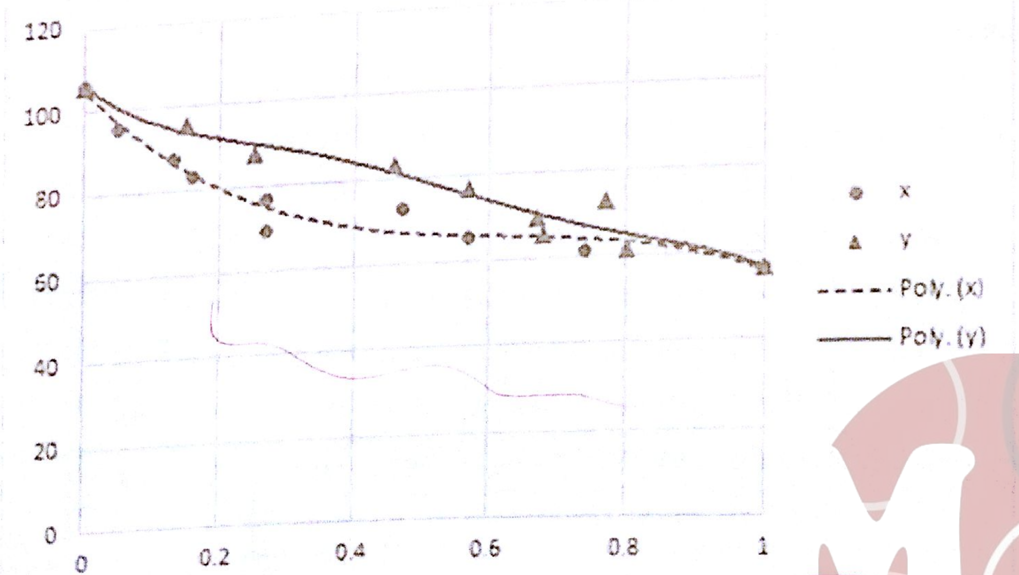


Figure 1: TXY-diagram, represent bubble and Dew curvesof Hexane-Toluene system, X-axis represent composition of hexane while Y-axis is temperature in °C.

Temperature	Y Hexane	X Hexane	PT	A (Antione equation)	B (Antione equation)	C (Antione equation)	P sat (pure hexane)	γ hexane	Ln(γ hexane)
56.30	1.00	1.00	Pure hexane						
61.50	0.80	0.74	680.00	6.89	1,171.53	224.87	623.08	1.18	0.17
65.40	0.68	0.57	680.00	6.89	1,171.53	224.87	707.14	1.16	0.15
69.40	0.67	0.27	680.00	6.89	1,171.53	224.87	802.36	2.08	0.73
72.70	0.77	0.47	680.00	6.89	1,171.53	224.87	888.22	1.27	0.24
76.70	0.57	0.27	680.00	6.89	1,171.53	224.87	1,001.71	1.45	0.37
83.00	0.46	0.16	680.00	6.89	1,171.53	224.87	1,202.92	1.62	0.48
87.53	0.25	0.13	680.00	6.89	1,171.53	224.87	1,365.90	0.92	-0.08
95.60	0.15	0.05	680.00	6.89	1,171.53	224.87	1,697.67	1.23	0.20
106.00	0.00	0.00	Pure toluene						

3: Activity coefficient and values of Antoine equation of toluene calculated from experimental data by modified ts law and Antoine equation.

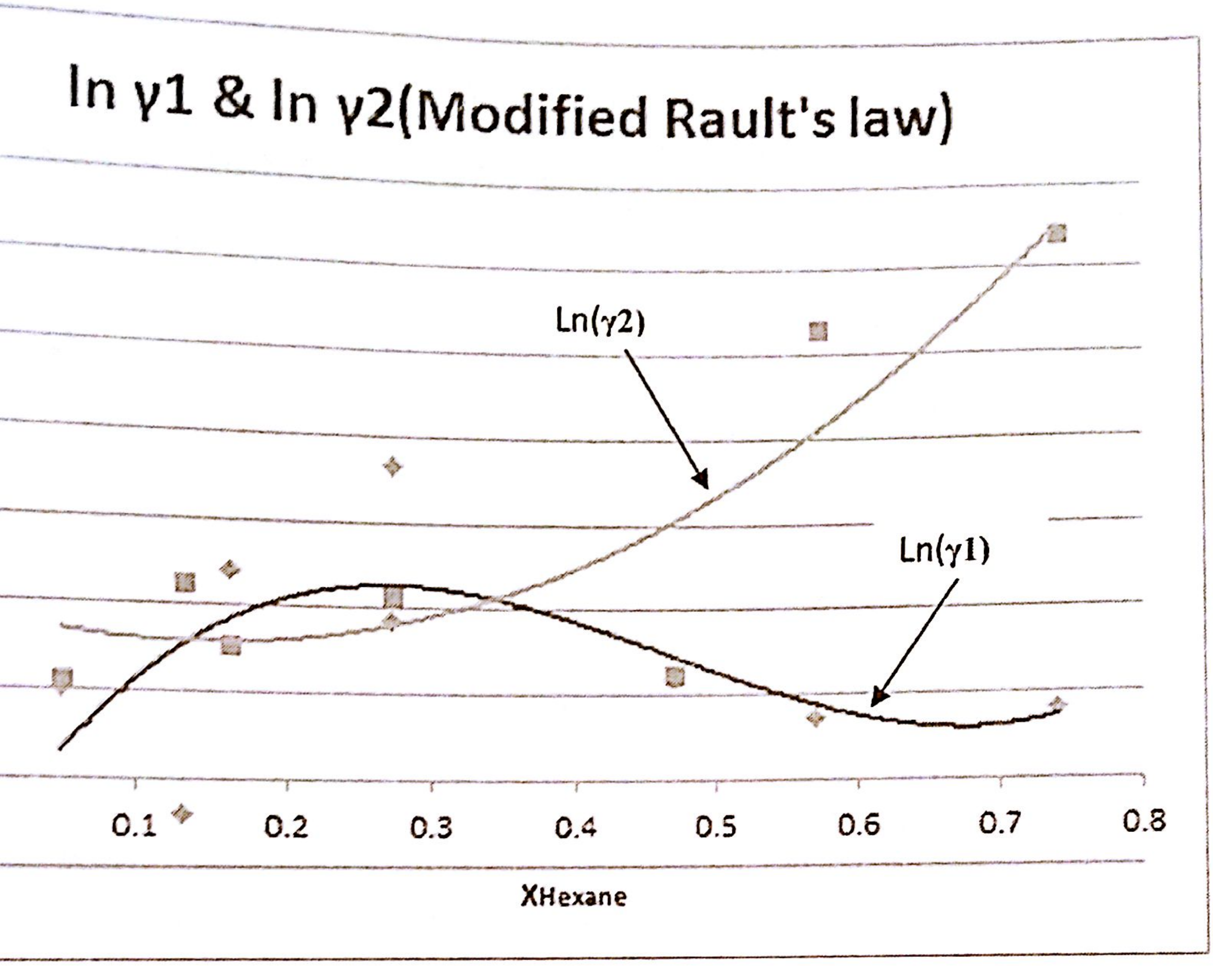
Temperature	Y toluene	X toluene	PT	A (Antione equation)	B (Antione equation)	C (Antione equation)	P sat (pure toluene)	γ toluene	Ln(γ (toluene)

Van Laar Model

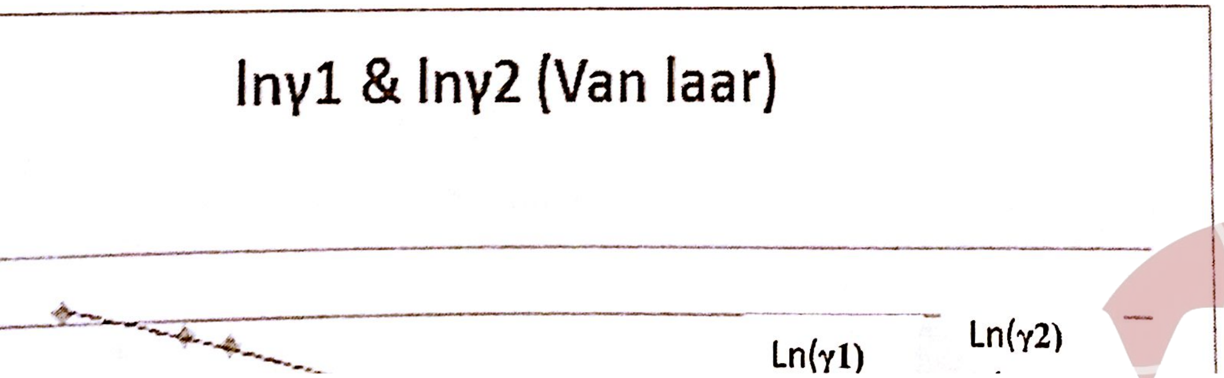
Temperature	X Hexane	X Toluene	γ hexane	Ln(γ hexane)	Ln(γ toluene)	γ toluene
56.3	1.00	0.00	Pure hexane			
61.5	0.74	0.26	1.09	0.09	1.30	0.26
65.4	0.57	0.43	1.19	0.17	1.11	0.11
69.4	0.27	0.73	1.34	0.29	1.02	0.02
72.7	0.47	0.53	1.24	0.22	1.06	0.06
76.7	0.27	0.73	1.34	0.29	1.01	0.01
83	0.16	0.84	1.39	0.33	1.00	0.00
87.53	0.13	0.87	1.40	0.34	1.00	0.00
95.6	0.05	0.95	1.43	0.36	1.00	0.00
106	0.00	1.00	Pure toluene			
A12(hexane-toluene)(Ave.)=	0.374486	A21(toluene-hexane)(Ave.)=	1.02246			

ctivity coefficient calculated by Two suffix margules.

		Two suffix margules				
exane	X toluene	γ hexane	Ln(γ hexane)	γ toluene	Ln(γ toluene)	



exane) and ln γ2 (toluene) with hexane composition that calculated from Rault's Law .



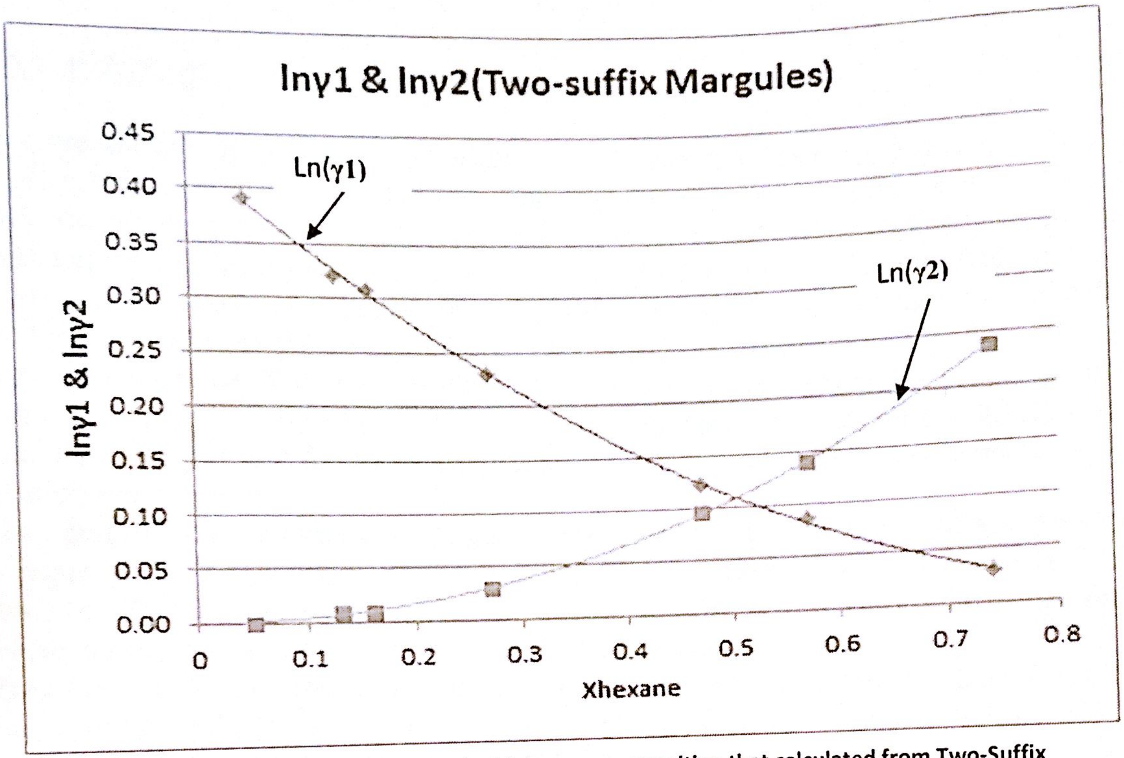


Figure 4: Ln γ1 (hexane) and ln γ2 (toluene) with hexane composition that calculated from Two-Suffix margules model .

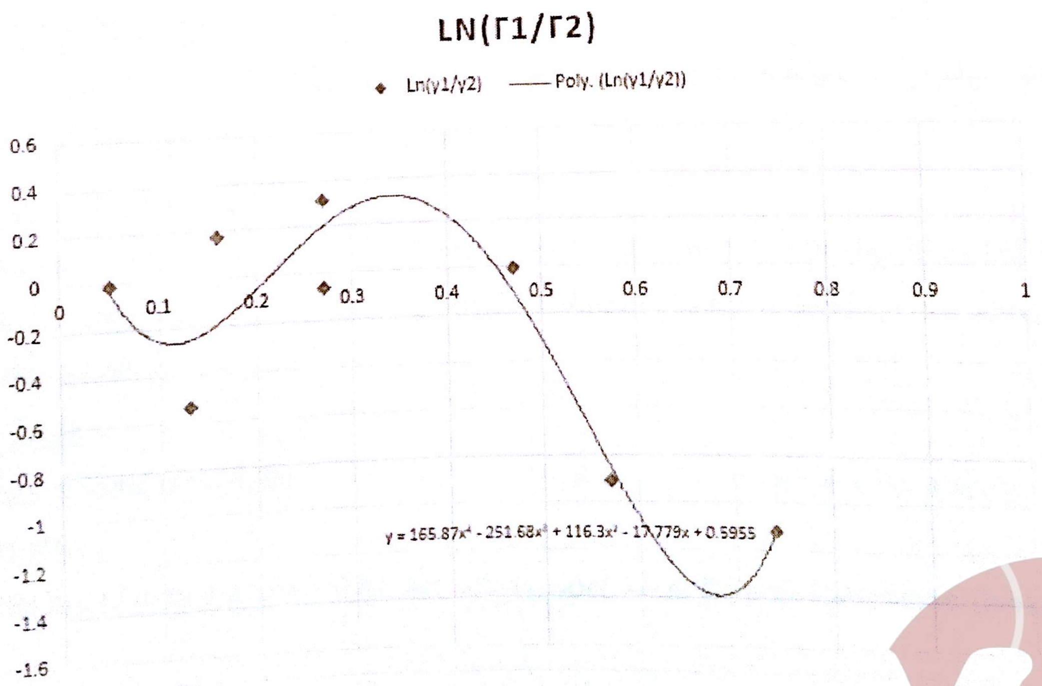


Figure 5: The consistency of data using integral form of Gibbs-Duhem equation states.

Discussion

TXY diagram

To represent the vapor liquid equilibrium, TXY-diagram that has been drawn according to experimental equilibrium data for non-ideal mixture of hexane and toluene, show Figure 1: TXY-diagram, represent bubble and Dew curvesof Hexane-Toluene system, X-axis represent composition of hexane while Y-axis is temperature in °C.. The system shows a positive deviation from Raoult's law since the bubble curve is above the Raoult's Law line, as shown in Figure 1: TXY-diagram, represent bubble and Dew curvesof Hexane-Toluene system, X-axis represent composition of hexane while Y-axis is temperature in °C.,This means that the vapor pressure for the mixture is more high than the vapor pressure for each pure component which leads both components to escape from solution more easily.

Also, minimum boiling azeotropes (when x=y) were founded when x=y=(0.82-1) which is clear in Figure 1: TXY-diagram, represent bubble and Dew curvesof Hexane-Toluene system, X-axis represent composition of hexane while Y-axis is temperature in °C. ,so we can not separate these two liquids at these mole fractions.

From Table 1: final result of data collected from experiment.,the data shows that the boiling temperature of the mixture is between boiling temperature of pure hexane and toluene Tb(hexane) < Tb (mixture) < Tb(Toluene) which indicate a sign of reliability of data.

activity coefficient

The activity coefficient which is a factor to measure the deviations from ideal behavior in a mixture. has been calculated from 3 models:

1- Modified Raoult's law

As shown in figure 2 and table 3, when vapor mole fraction increase and liquid mole fraction decrease for the species ,the mixture deviate from Raoult's law(non-ideality) ,the activity coefficient increase.

2- Van Laar

From figure 3 and table 4,the liquid mole fraction increase for hexane and the activity coefficient increase also.

When the liquid mole fraction =0.61 ,the activity coefficient for both toluene and hexane is the same.

3- Two suffix margules

From figure 4 and table 5, the liquid mole fraction increase for hexane and the activity coefficient also increases.

When the liquid mole fraction =0.50 ,the activity coefficient for both toluene and hexane is the same and are equal to 1.116.

The values of activity coefficient vary in the three models but it is nearly the same.

The parameter A can either be positive or negative

$A > 0$ leads to $\gamma > 1$; $A < 0$ leads to $\gamma < 1$.

There were many errors that affect the data of this experiment:

-Instrument errors in measuring the temperatures

-personal errors

The consistency of data

The consistency of data test indicates poor consistency since the area under the curve is 105.482 of data with thermodynamics, as shown in figure 5.

Conclusion

- If the activity coefficient is far from unity mixture is not ideal and not obey Raoult's law but modified Raoult's law or other model.
- The activity coefficient of a component in a mixture varies with temperature and composition
- If there is a positive deviation in Txy diagram ,the activity coefficients of at least one species in the mixture is greater than one.
- Azeotropes can appear in Txy diagram , when vapor and liquid compositions are the same.

References

1- Chemical Engineering Laboratory (1) (6th ed.). (2016). Amman: University of Jordan.

2- Felder, R. M., & Rousseau, R. W. (2005). Elementary principles of chemical processes. John Wiley & sons.

3- A. M. (n.d.). Reading. Retrieved October 22, 2018, from http://www.mediafire.com/file/x3m5m7mn72bl4uw/152CHE323_L07_Modified_Raoult_Law.pdf/file.

Appendix

1-Sample of calculation:

A row from each table will be discussed as sample of calculations.

<u>**TXY diagram**</u>

At temperature =61.5 c

Refractive index of liquid phase of Hexane=1.4

L%Vol (hexane)=0.78

L%Vol(tolouee)=1-L%=1-0.78=0.23

X(Hex.)=[density of Hex. * L% Hex]/[(density of Hex. * L% Hex) + (density of Tol. * L% Tol.)]

density of Hexane =659 kg/m^3

density of toluene=828.42 kg/m^3

X(Hex)=[659*0.78]/[(659*0.78)+(828.42*0.23)]

X(Hex)=0.74

X(Toluene.)=1-X(Hex.)

X(Toluene.)=1-0.74

X(Toluene)=0.23

Refractive index of the condensate of the vapor phase of Hexane=1.397

V%Vol(Hexane)=0.83

V%Vol(Toluene)=1-0.83=0.17

Y(Hex.)=[density of Hex. * V% Hex]/[(density of Hex. * V% Hex) + (density of Tol. * V%

Tolene)]

Y(Hexane)=0.8

Y(Toluene)=0.2

Activity coefficient (γ)

-Modified Rault's Law

γToluene = (Ptot * Y T)/(PT(saturation) * X T)

γToluene = (680*.2)/(147.42 * .26)

γToluene =3.61

γhexane= (Ptot * Y H)/(P H(saturation) * X H)

γhexane =(680*.8)/(623.08*.74)

γhexane =1.18

-Van Laar model

The average values of Parameters of Van Laar equation was obtained from THERMOSOLVER program

A12(Hexane-Toluene) =0.374486

A21(Toluene-Hexane)=1.02246

Van Laar equations are:

lnγ1=A12/(1+(A12/A21)*(X1/X2))^2

=0.375/((1+(0.375/1.022)*(0.74/0.26))^2

=0.08977

γ1(hexane)=1.0939

lnγ2=A21/(1+(A21/A12)*(X2/X1))^2

=1.022/(1+(1.022/0.375)*(0.26/0.74))^2

=0.2667

γ2(Toluene)=1.306

-Two-Suffix margules model

The average value of Parameter Of Two-Suffix margules equation was obtained from

THERMOSOLVER program

A12=0.432857

lnγ**1**=A12*X2^2

=0.432*0.26^2

=0.029

γ**1(Hexane))**=1.03

lnγ**2**=A12*X1^2

=0.432*0.74^2

=0.237

γ**2(Toluene)**=1.27

Temperature	density of n-hexane	density of toluene (kg/m3)
56.3	-	-
61.5	659	828.42
65.4	659	825.66
69.4	659	821.152
72.7	659	818.116
76.7	659	814.436
83	659	808.64
87.53	659	804.4724
95.6	659	797.048
106	-	785.74

Vapor-Liquid Equilibrium Data Sheet

Atmospheric pressure: 680 mmHg

95% Purity of hexane , 99% purity of toluene

Mixture used	Equilibrium Temperature	RI of vapor	RI for liquid
120 mL hexane	56.3 °C	—	—
120 mL hexane + 26 mL toluene	61.5 °C	1.397	1.403
120 mL hexane + 46 mL toluene	65.4 °C	1.409	1.422
120 mL hexane + 66 mL toluene	69.4 °C	1.410	1.458
120 mL hexane + 86 mL toluene	72.7 °C	1.400	1.434
120 mL toluene + 80 mL hexane	76.7 °C	1.422	1.460
120 mL toluene + 60 mL hexane	83.0 °C	1.436	1.474
120 mL toluene + 40 mL hexane	87.5 °C	1.462	1.477
120 mL toluene + 20 mL hexane	95.6 °C	1.475	1.489
120 mL toluene	106.0 °C	—	—

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Date:	16/10/118

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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (2)

Experiment title:

Liquid-Liquid Equilibrium

Type of the report: Short Report

Done by

Abstract

The objective of this experiment is to study liquid-liquid equilibrium which means that a material dissolved (in this experiment it was acetone) in one liquid phase that usually polar (water) and it is transferred to a second immiscible or nearly immiscible liquid phase that usually non-polar organic solvent (Toluene). The driving force is chemical potential. The solvent that is enriched in solute is called extract, and the solvent that is enriched in feed liquid and small concentration of solute .But in this experiment the raffinate and extract are 50% percent 50% dissolving the acetone. The experiment was carried out at around $25^{0}C$, the ternary phase diagram. Ternary diagram was plotted according to data observed. Cloudiness was helpful in the observed transition from one phase mixture to two phases as well as turbidity.

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Results

Table 1: Data used in calculations.

substance	Density (g/ml) [2]
Water	1
Toluene	0.866
Acetone	0.791

1. Solubility curve formation:

A. Water rich phase

Table 2: Water rich phase results.

Acetone volume (ml)	Water volume (ml)	Toluene volume (ml)	Acetone mass (g)	Water mass (g)	Toluene mass (g)	Total mass (g)	Acetone fraction (by mass)	Water fraction (by mass)	Toluene fraction (by mass)
5.00	20.00	1.20	3.96	20.00	1.04	24.99	0.16	0.80	0.04
10.00	20.00	0.30	7.91	20.00	0.26	28.17	0.28	0.71	0.01
15.00	20.00	0.70	11.87	20.00	0.61	32.47	0.37	0.62	0.02
10.00	10.00	1.00	7.91	10.00	0.87	18.78	0.42	0.53	0.05
20.00	10.00	1.10	15.82	10.00	0.95	26.77	0.59	0.37	0.04
30.00	10.00	0.30	23.73	10.00	0.26	33.99	0.70	0.29	0.01

B. Organic solvent rich phase (Toluene phase)

Table 3: Organic solvent rich phase results.

Acetone volume (ml)	Toluene volume (ml)	Water volume (ml)	Acetone mass (g)	Toluene mass (g)	Water mass (g)	Total mass (g)	Acetone fraction (by mass)	Toluene fraction (by mass)	Water fraction (by mass)
5.00	20.00	0.10	3.96	17.32	0.10	21.38	0.19	0.81	0.00
10.00	20.00	0.25	7.91	17.32	0.25	25.48	0.31	0.68	0.01
15.00	20.00	0.15	11.87	17.32	0.15	29.34	0.40	0.59	0.01
10.00	10.00	0.30	7.91	8.66	0.30	16.87	0.47	0.51	0.02
20.00	10.00	2.50	15.82	8.66	2.50	26.98	0.59	0.32	0.09
30.00	10.00	5.00	23.73	8.66	5.00	37.39	0.63	0.23	0.13

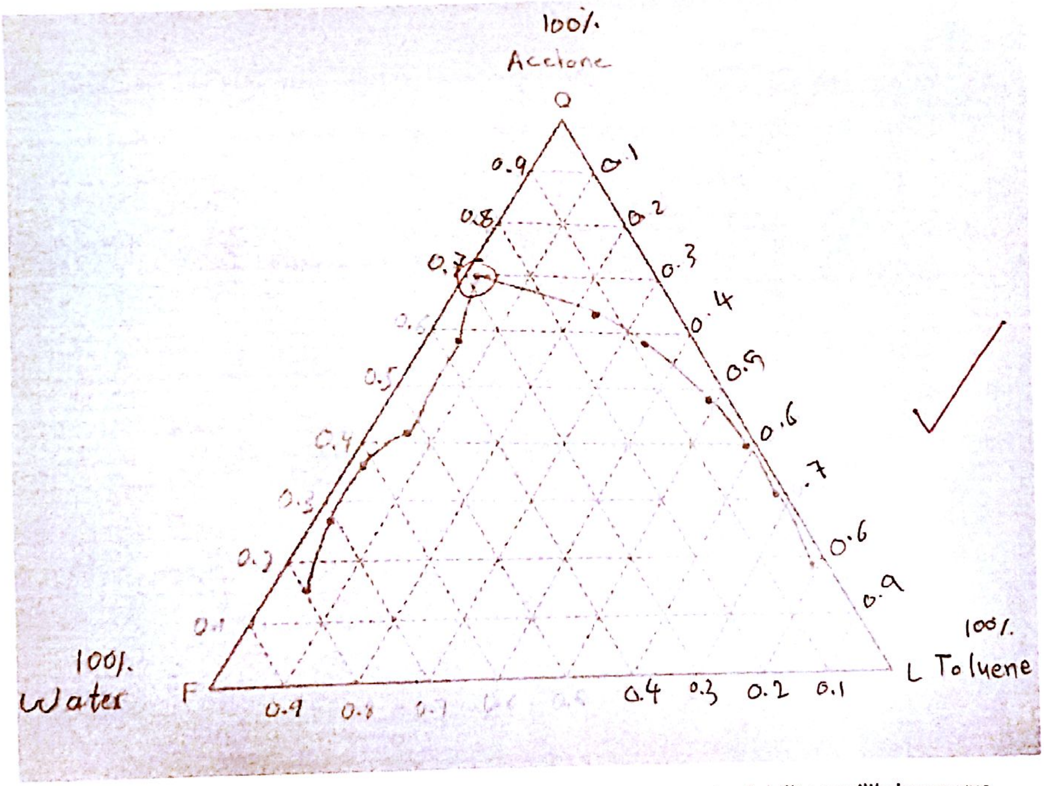

Figure 1: Ternary diagram of acetone, water and toluene. Represent solubility equilibrium curve.

2. Tie line determinations:

Table 4: Tie- lines determination data.

Sample no.	Water volume (ml)	Toluene volume (ml)	Acetone volume (ml)	Water mass(g)	Toluene mass(g)	Acetone mass(g)	Total mass (g)	Water mass fraction	Toluene mass fraction	Acetone mass fraction
1.00	18.00	20.00	13.00	18.00	17.32	10.28	45.60	0.39	0.38	0.23
2.00	26.00	17.00	8.00	26.00	14.72	6.33	47.05	0.55	0.31	0.13
3.00	20.00	25.00	5.00	20.00	21.65	3.96	45.61	0.44	0.47	0.09

Table 5: Tie-line composition and Othmer - Tobias Correlation.

Sample no.	RI of water layer	RI of toluene layer	Raffinate		Extract		Othmer-Tobias Correlation	
			mass fraction of acetone in water layer	mass fraction of water in water layer	mass fraction of acetone in toluene layer	mass fraction of toluene in toluene layer	log((1-a)/a)	log((1-b)/b)
1	1.35	1.46	0.18	0.82	0.26	0.74	-0.65	-0.45
2	1.34	1.48	0.10	0.90	0.16	0.84	-0.93	-0.72
3	1.34	1.49	0.07	0.93	0.06	0.94	-1.10	-1.17

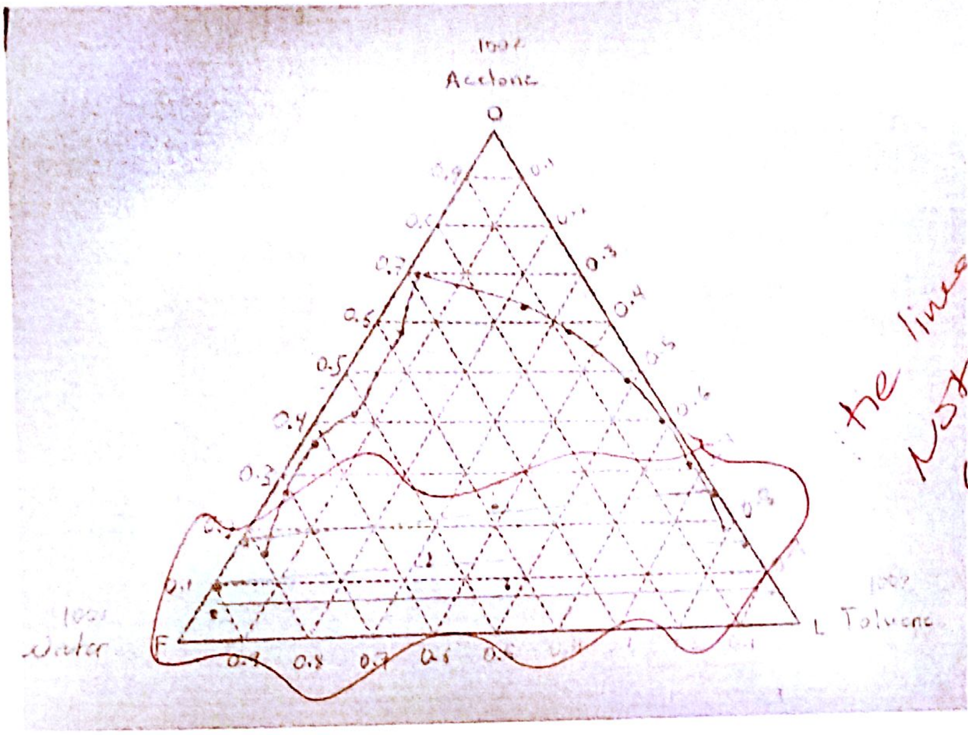

Figure 2: Ternary diagram of acetone, water and toluene. Represent Tie-lines.

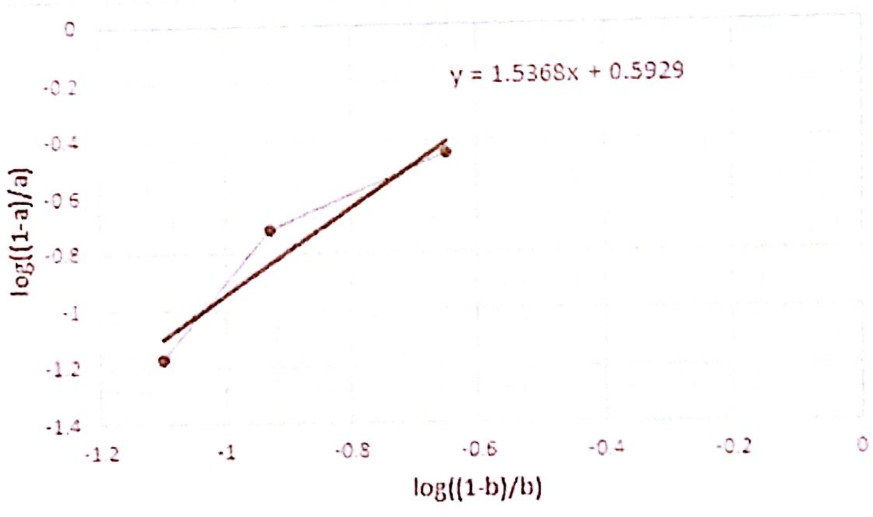

Figure 3: Othmer - Tobias Correlation, where slope = 1.5368 and intercept = .5929.

Discussion

Phase diagrams use to introduce the phase and composition of one or multi component system. Type of it is called ternary diagrams which are a triangular diagrams that show a graphical representation of the phase behavior of the three component in a mixture at constant temperature and pressure, there are two types of them: equilateral triangles that are shown previously and the right triangle.

To form a ternary diagram a system of Acetone, Toluene and water was operated in laboratory to get experimental data needed.

As shown in Table 2: Water rich phase results. , 6 samples of water rich phase were taken and titrated by toluene until cloudiness formed, this indicate that solution change from one phase region to two phase region, after that, data plotted on ternary diagram to produce a water rich side of solubility equilibrium curve.

On the other hand, 6 samples of toluene rich phase (solvent) prepared then titrated with water until turbidity occur, result shown in Table 3: Organic solvent rich phase results. . Plotting of this results formed the solvent side of solubility equilibrium curve.

Connection these two sides with one-line produce fully solubility line which separate the diagram of two regions: one phase and two phases. Show Figure 1: Ternary diagram of acetone, water and toluene. Represent solubility equilibrium curve.

As you notice, deviation present in sample 6 of water rich side (last row), this indicate an error was occurred which maybe a personal error in determining the cloudiness point or reading the burette.

A plait point which is the point where the composition in the water rich phase is equal to that of the solvent rich phase should be determine but due to sample composition range, it was hard to identify.

To form tie-lines three samples were taken as shown in data Table 4: Tie- lines determination data.. These samples indicate the nearly homogeneous mixture, after settling in the cells they separated into two nonhomogeneous phases: water, acetone and toluene, acetone.

the two phases were analyzed by reflect index meter (RI) to know the composition.

As shown in Table 5: Tie-line composition and Othmer - Tobias Correlation. 3 samples gave 3 tie-lines drown as best fit for the three points mentioned before which shown in Figure 2: Ternary diagram of acetone, water and toluene. Represent Tie-lines.

To check linearity Othmer-Tobias correlation was formed as shown in Table 5: Tie-line composition and Othmer - Tobias Correlation. and Figure 3: Othmer - Tobias Correlation, where slope = 1.5368 and intercept = .5929. with best fit line of slope=1.5368 and intercept=.5929 which indicate good linearity.

Conclusion

- Personal errors affect the experimental phase diagram.
- Large numbers of samples must be taken to determine the plait point.
- Cloudiness represent the observed transition from one phase mixture to two phases as well as turbidity.

References

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Appendix

1. Sample of calculation:

A row from each table will be discussed as sample of calculations.

1. **Solubility curve:**

A) Water rich phase:

- **Volume** : water =20 ml Toluene =0.3 ml Acetone =10 ml
- **Density** :Water =1g/ml Toluene =0.866g/ml Acetone =0.791g/ml
- **Mass = density * volume**

Mass of Water =20*1=20 g

Mass of Toluene =0.3*0.866=0.26 g

Mass of Acetone=10*0.791=7.91g

- **Total mass = water mass + toluene mass + acetone mass**

  =20+0.2598+7.91=28.17 g

- **Mass fraction = mass of substance / total mass**

  Mass fraction of: Water =20/28.17=0.71

  Toluene =0.26/28.17=0.009

  Acetone =7.91/28.17=0.28

B) Organic solvent rich phase (Toluene phase)

- **Volume** : water =0.3 ml Toluene =10 ml Acetone =10 m
- **Density** :Water =1g/ml Toluene=0.866g/ml Acetone=0.791g/ml
- **Mass = density * volume**

  Mass of Water =0.3*1=0.3 g

  Mass of Toluene =10*0.866=8.66 g

  Mass of Acetone=10*0.791=7.91g

- **Total mass = water mass + toluene mass + acetone mass**

  =0.3+8.66+7.91=16.87 g

- **Mass fraction = mass of substance / total mass**

  Mass fraction of: water =0.3/16.87=0.02

  Toluene =8.66/16.87=0.51

  Acetone =7.91/16.87=0.47

2. Tie - lines determination:

A) Tie line determination :

- **Volume** : water =18ml Toluene =20ml Acetone =13ml
- **Density** :Water =1g/ml Toluene =.866g/ml Acetone =.791g/ml
- **Mass = density * volume**

  Mass of Water =18*1=18g

mass of Toluene =20*.866=17.32g

mass of Acetone=13*.791=10.28g

- **Total mass = water mass + toluene mass + acetone mass**

  =18+17.32+10.28=45.6g

- **Mass fraction = mass of substance / total mass**

  Mass fraction of : Water =18/45.6=0.39

  Toluene =17.32/45.6=0.38

  Acetone =10.28/45.6=0.23

RI of water layer =1.35

from calibration curve or by applying the calibration equation **y = 0.00065x + 1.33520.**

Mass fraction of acetone in water saturated with water x=(y-1.33520)/0.065, applying this:

x=(1.35-1.33520)/0.065=0.18

Since mass fraction of water in water layer is required instead of Acetone,

Mass fraction of acetone + mass fraction of water = 1

Mass fraction of water = 1- mass fraction of acetone = 1-0.18=0.82=**a**

As represented above, the same procedure is applied here.

x=(y-1.49950)/-0.135

x=(1.46-1.49950)/-0.135=0.26

Mass fraction of toluene in water =1-0.26=0.74=**b**

B) Othmer - Tobias Correlation :

- **Checking reliability by Othmer-Tobias correlation** using excel spreadsheet, where a represents water fraction in water layer, while b represents toluene fraction in toluene layer. Checking reliability by Othmer-Tobias correlation using excel spreadsheet , where a represents water fraction in water layer , while b represents toluene fraction in toluene layer.
- As a sample of calculation , x and f(x) can be found as below
- x= log ((1-b)/b)= log (1-.74.74)= - 0.45
- f(x)=log ((1-a)/a)= log (1-..82.82)= - 0.65

- The same calculation has been applied on the other points and plotted in order to find the linear expression for the resulting line.

2. Data sheet:

Liquid-Liquid Equilibrium Data Sheet

Tie-Lines Determination:

Volume of water (ml)	Volume of Toluene (ml)	Volume of Acetone (ml)	RI of water layer	RI of Toluene layer
20	15	15		
18	20	13	1.347	1.464
26	17	8	1.342	1.478
20	25	5	1.34	1.491
19	29	3		

Solubility curve

A. Water rich phase:

Volume of Acetone (ml)	Volume of water (ml)	Volume of Toluene (ml)
5	20	1.2
10	20	0.3
15	20	0.7
10	10	1
20	10	1.1
30	10	0.3

B. Organic solvent rich phase:

Volume of Acetone (ml)	Volume of Toluene (ml)	Volume of water (ml)
5	20	.1 ± 0.05
10	20	.25 ±
15	20	.15 ±
10	10	.3 ±
20	10	2.5 ±
30	10	5 ±

Instructor signature:	
Date:	25/9/18

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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (3)

Experiment title :

Digital Joulemeter

Type of the report: Short Report

Done by :

Abstract

Physical properties such as specific heat capacity and latent heat was determined using the digital joulemeter, which is an electrical device that measures the electrical energy in joules and power in watts. The results showed that the specific heat of aluminum is 1159.91 J/(kg.K), and the latent heat of vaporization is 2326 J/g.

Also, the efficiency of devices (such as a motor in this experiment) was calculated by dividing the input and output energies, the input energy was determined due to the joulemeter. Parametric study is discussed in this report, changing the voltage and mass lifted by the motor effect its efficiency, the results represent that changing mass lifted or changing voltage have approximately the same effect.

Variation of values determined may be due to different types of errors, which are explained in details in this report.

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No need for all these details

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Results

- Experiment 1: Determination of the specific heat capacity of a metal

Table 1: Specific heat result

Mass of (Al) block (g)	1012.2
Joule meter reading (J)	2348
Initial temperature (°C)	35.5
Final temperature(°C)	55.5
Temperature difference (K)	20
Specific heat (J/(kg.K))	1159.91

- Experiment 2: Determination of the specific latent heat of vaporization of liquids

Table 2:Latent heat results

Initial mass of liquid (g)	408.36
Final mass of liquid(g)	398.36
Temperature of liquid(C)	93
Pressure (mmHg)	660
Joule meter reading(J)	23260
Mass of vaporized water(g)	10
Latent heat (J/g)	2326

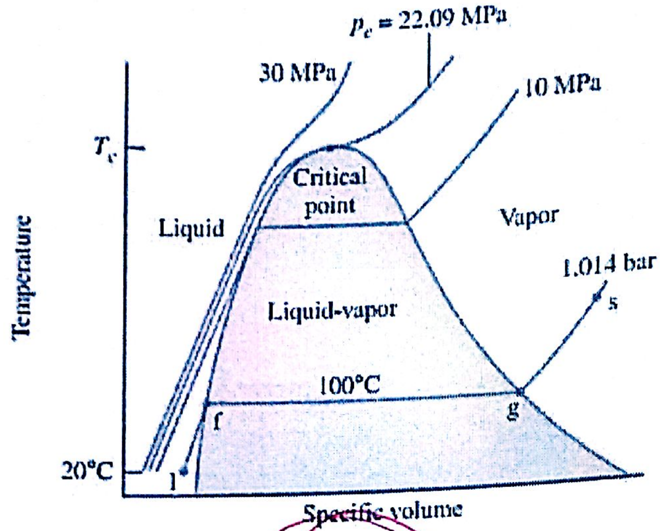

Figure 1:T-V diagram

write complete describtion of the fig.

- <u>Experiment 3: Investigation of the efficiency of a small electrical motor and study its variation with load and applied voltage</u>

Knowing that

change in height = 60 cm

Mass of hanger= 20.32 g

Table 3:parametric study when variating mass lifted at constant voltage

At constant voltage = 5 v				
mass lifted(g)	joule meter reading (J)	Inlet energy	output energy	efficiency%
120.32	1.1	1.1	0.71	64.38%
220.32	2.1	2.1	1.30	61.75%
320.32	6.2	6.2	1.89	30.41%
420.32	161.1	161.1	2.47	1.54%

4

Table 4:parametric study when variating voltage at constant mass lifted

At constant mass = 320.32 g		
Voltage (V)	joule meter reading (J)	efficiency%
5	6.2	30.41%
6	4.3	43.85%
7	3.2	58.92%
8	3	62.85%
9	3.6	52.37%

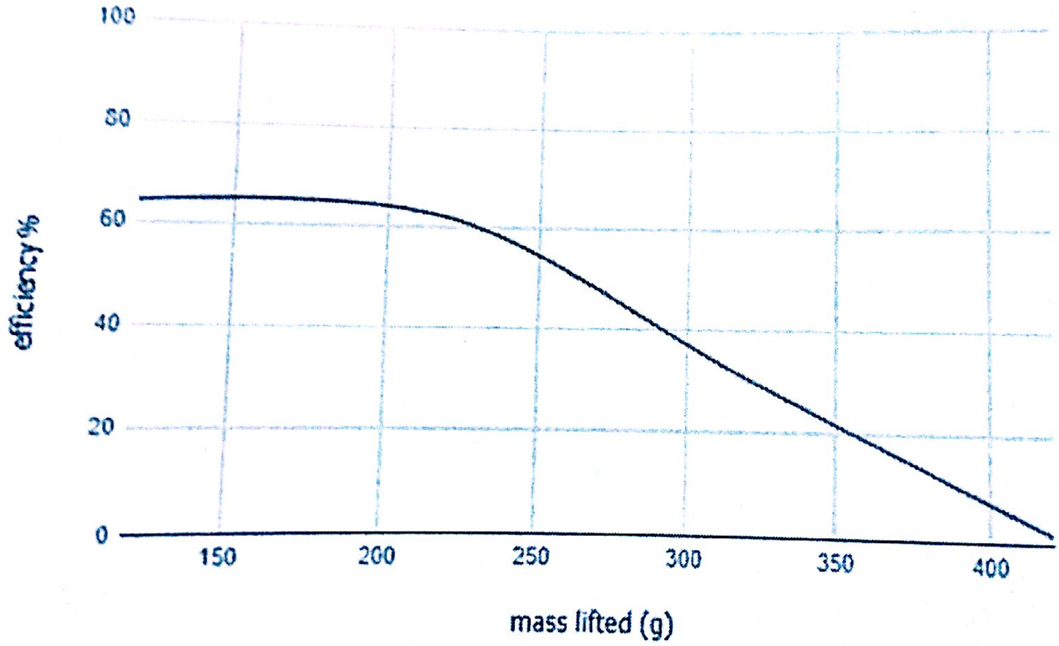

Figure 2:parametric study when variating mass lifted at constant voltage

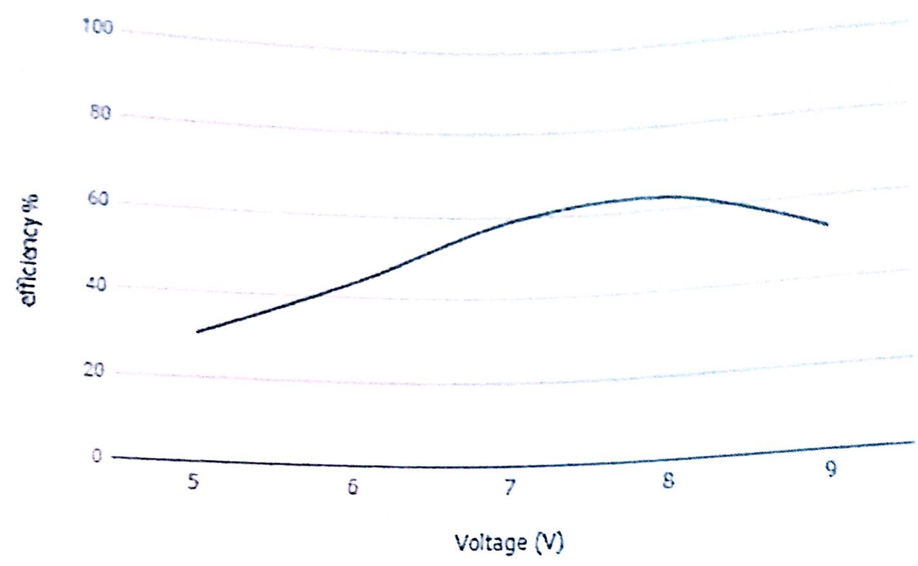

Figure 3: parametric study when variating voltage at constant mass lifted

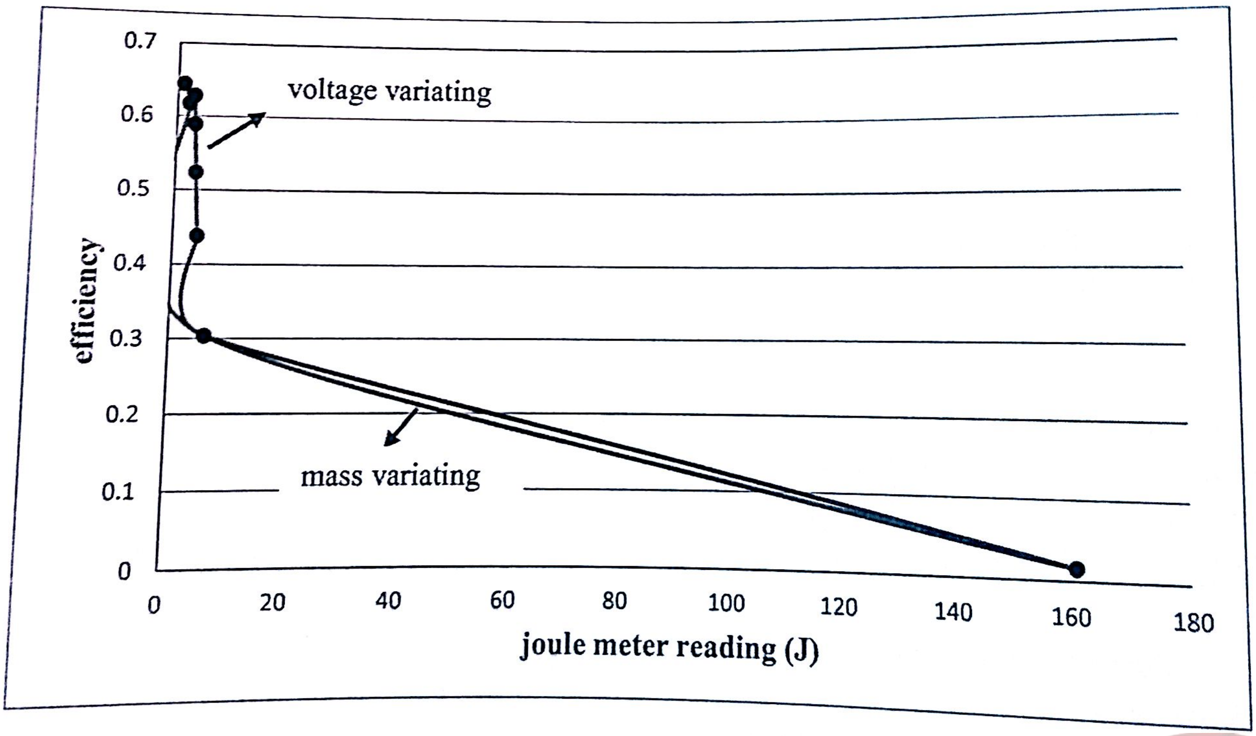

Figure 4:comparig mass and voltage effect on efficiency of motor device

Discussion

- <u>Experiment 1: Determination of the specific heat capacity of a metal</u>

Specific heat is the heat needed to increase the temperature of a substance one degree Kelvin per unit mass, it is heat capacity of a substance per unit mass that depends on temperature as well as the identity of the substance.

To measure specific heat, Joule design an experiment to determine the mechanical energy equivalent of heat. In this experiment, electrical energy of 12 Volt and 7 ampere alternating current (a.c) was transformed to heat using a resistance, and joulemeter was used to measure energy.

As shown in table(1), specific heat of Aluminum was calculated to be equal to 1159.91 J/(kg.K) which is reliable for metal, but according to tabulated data, specific heat of aluminum is 903 J/(kg.K) with positive 28.5% percentage error.

This error mainly occurred because of heat losses to environment due poor insulation. Systematic error due to instrument precision limiting and personal error in reading thermometer also take place.

- <u>Experiment 2: Determination of the specific latent heat of vaporization of liquids</u>

Latent heat, also known as heat of vaporization (ΔH_{vap}) or enthalpy of vaporization or evaporation, is the amount of heat energy (enthalpy) that is required to evaporate 1 unit mass or mole of a substance at constant temperature.

As shown in figure(1) that represents T-V diagram, the point *f* represents saturated liquid, while the point g represents saturated vapor, and the difference between enthalpy of point g and f represents heat of vaporization hfg =hg−hf. It is clear from the figure(1) that as pressure increases, as shown by different pressure lines such as 1.014 bar, 10 MPa, 22.09 MPa and 30 MPa, we move upward the graph and temperature increases, also points g and f become closer to each other, hence the heat of vaporization decreases.

Heat of vaporization decreases as pressure increases; because as pressure increases temperature increases, so that overcoming the intermolecular forces becomes easier, hence less energy is needed to vaporize.

In this experiment, the atmospheric pressure was about 680 mmHg, so it is expected that boiling point temperature of water will be less than 100 C, the measured boiling point was 93 °C.

As shown in table(2), the calculated latent heat according to the data of this experiment was 2326 J/g, the real value of latent heat at 93 C is 2275 J/g ,leading to

If we didn't do it in lab there is No mean to discuss it here !!!

relative error equals 2.24%. The possible sources of errors in this experiment are :
- **Environmental factors (systematic or random)** : errors that caused by uncontrollable vicissitudes in variables that affects the experimental results .
- **Instrument resolution (random):** every instrument has finite precision that limits the ability to resolve small measurements differences
.
- **Failure to calibrate or check zero of instrument (systematic).**
- **Personal error:** error that caused by a wrong adoption procedure by the observer such as making an error in reading the scale (in this experiment often the possibility for making this error is high when reading the temperature degrees from the thermometer) .

- Experiment 3: Investigation of the efficiency of a small electrical motor and study its variation with load and applied voltage

As the first law of thermodynamics states that energy is conserved and the energy is transferred from form to another but never been created nor destroyed.

In our experiment we have applied the first law by many transforms that occur: electrical energy (exerted by power supply unit) was converted to mechanical energy (due to motor rotational motion) and then was converted to potential energy (by handling the lifted mass to certain height).

We have studied the ability of motor to transform energy without big losses of energy (efficiency) and the relation between it and mass and voltage.
The energy that transformed through the motor has lost part from it because of the friction exerted. However, energy is still conserved since heat will be exerted from friction, but it did not appear as an output energy.

As shown in the figure (2), as the mass of the holder increases, more energy is needed to achieve the process (direct relation), but the efficiency has decreases. We can explain this that when we increase the load we need more energy and the loss of energy increases. Also, we can explain it mathematically ; since efficiency is the ratio of output energy to input energy, more mass added means more energy needed to achieve the process, but the increase in energy is bigger (not linear relation) so more input energy mean less efficiency.

As shown in the figure (3) that at constant mass , if we increase the voltage we need less energy to achieve the process (inverse relation) leading to less input energy and high efficiency. We explain this that high voltage means high electrical energy that transforms to joule meter reading.

From figure (4), we see that if we increase voltage or decrease mass added we have approximately the same efficiency, then the variation of these parameters have the same effect on efficiency for the same input energy.

As seen in table 4 ,efficiency increases with increasing the voltage, but the last point in table appears as unusual. This can be explained by the instrument drift (systematic) error; most electronic devices have readings that drift over time, the amount of drift is generally not considered, but sometimes this source of error affects the readings; so it should to be considered(in this experiment the electric device that was used is Digital Joulemeter).

Conclusion

- Experiment 1: Determination of the specific heat capacity of a metal

  Insulation on metal must be increased to achieve higher accuracy.

- Experiment 2: Determination of the specific latent heat of vaporization of liquids

  1- Latent heat is the amount of heat energy (enthalpy) that is required to evaporate 1 unit mass or mole of a substance at constant temperature.

  2- As pressure increases, latent heat decreases. Also ,as pressure decreases, boiling point temperature decreases.

- Experiment 3: Investigation of the efficiency of a small electrical motor and study its variation with load and applied voltage

  1- There is an inverse relationship between efficiency and the mass added to the hanger.

  2-there is a direct relationship between efficiency and the voltage by power supply unit.

  3-Voltage and mass added are parameters that have the same effect on efficiency of motor.

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Appendix

1- Sample of calculation

* Experiment 1: Determination of the specific heat capacity of a metal

*mass of (Al) block (m)= 1012.15g = 1.01215kg
Joule meter reading(Q)= 23480 J
Initial temperature (T_i) = 35.5 °C
Final temperature (T_f) = 55.5 °C
*Temperature difference (ΔT)= T_f-T_i= 55.5-35.5=20 K

$$Q=m*C_p*\Delta T \Rightarrow Cp=\frac{Q}{m*\Delta T}$$

*Specific heat (Cp)= $\frac{23480}{1.012*20}$ =1159.91 J/(kg.K)

* Experiment 2: Determination of the specific latent heat of vaporization of liquids

Initial mass of liquid = 408.36 g
Final mass of liquid = 398.36 g
Temperature of liquid = 93 °C
Pressure = 680 mmHg
Joule meter reading(Q) = 23260 J
* Mass of vaporized water (m_{evap}) = 408.36 g - 398.36 g = 10 g
* Latent heat = $\frac{Q}{mevap} = \frac{23260}{10}$ = 2326 J/g

* Experiment 3: Investigation of the efficiency of a small electrical motor and study its variation with load and applied voltage

Taking the first raw as sample of calculation

- At constant voltage=5 v
  Change in height = 60 cm
  Mass of hanger=20.32 g
  Mass added=100 g
  * Total mass =100+20.32=120.32 g= 0.12032 kg
  Joule meter reading =1.1 J (input energy)
  Potential energy=m *g*z (output energy)
  * Potential energy=120.32*980.7*60cm *10^-7 =0.71 J
  Efficiency=output energy / input energy
  * Efficiency=.71 J / 1.1 J = .6436= 64.36%

- At constant mass=320.32 g= 0.32032 kg
  Change in height = 60 cm
  voltage= 6 V

Joule meter reading =4.3 J (input energy)

Potential energy=m *g*z (output energy)

* Potential energy=320.32*980.7*60cm *10^-7=1.88 J

* **Efficiency**=output energy / input energy= 1.88 J / 4.3J = .4383 = **43.83%**

Digital Joulemeter Data Sheet

1. Specific heat Capacity:

Mass of AL-Block	1012.15 g
Joule meter reading	23480 J
T_1	35.5°c
T_2	55.5°c

2. Specific latent heat of vaporization:

Initial mass of liquid	~~3~~ 408.36 g
Final mass of liquid	398.36 g
Temperature of liquid	93°c
Joule meter reading	23260 J

3. Efficiency of a motor:
   Change in height=.....60..........cm
   Mass of hanger=....20.32.......g

a. At constant Voltage=.....5........V

Mass lifted (g)	Joule meter reading
100 + 20.32 = 120.32g	1.1 J
200 + 20.32 = 220.32g	2.1 J
300 + 20.32 = 320.32g	6.2 J
400 + 20.32 = 420.32g	161.1 J
~~500 + 20.32 = 520.32g~~	

a. At constant mass=...~~300~~ 320.32.....g

Voltage (V)	Joule meter reading
5	6.2 J
6	4.3 J
7	3.2 J
8	3.0 J
9	3.6 J

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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (2)

Experiment title:

Compressible Fluid Flow

Type of the report: Short Report

Done by

Abstract

The experiment was divided into two parts: the first one was for simple pipe friction duct with bore of 13 mm and test portion length L=600mm to study the relation between friction loss and velocity for incompressible flow the calculated friction coefficient (f) is (0006) that is constant during the change of pressure measured using inclined manometer and mercury manometer for high range of pressure.

Part two was for sudden enlargement duct that have a different cross sectional area, this part study the relation between the pressure recovery and the upstream flow velocity assuming the incompressible flow using inclined and mercury manometer. Also correlations have applied to the data to investigate the validity of the assumptions for the pressure rise across the pipe which founded to be invalid.

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Results

Table 1:data needed for calculation.

Raw data			
Temperature	2.70E+01	d12(m)	1.90E-02
ambient P	9.07E+01	viscosity(Ns/m^2)	1.84E-05
L0-L1(m)	2.00E-01	M.W air	2.91E-02
L2-L3(m)	3.00E-01	a1 = a2	5.31E-04
d01(m)	1.30E-02	a3	1.13E-03

A. Simple pipe friction duct:

Table 2: simple pipe result

For simple pipe friction duct										
Sample number	P0-P1	manometer used	position if inclined	value of k	P0-P1 (kPa)	P2-P3	manometer used	position if inclined	value of k	P2-P3 (kPa)
1	0.01	inclined manometer	buttom	0.8452	8.45E-03	0.03	inclined manometer	buttom	0.8456	0.03
2	0.49	inclined manometer	middle	0.8598	4.21E-01	0.62	inclined manometer	middle	0.8648	0.54
3	1.68	inclined manometer	middle	0.88	1.48E+00	2.27	inclined manometer	middle	0.8854	2.01
4	2.08	inclined manometer	top	0.9	1.87E+00	2.35	inclined manometer	top	0.9	2.12
5	0.8	inclined manometer	vertical	0.911	7.29E-01	0.79	inclined manometer	vertical	0.9108	0.72
6	1.24	inclined manometer	vertical	0.9198	1.14E+00	1.16	inclined manometer	vertical	0.9182	1.07
7	5	mercury manometer	-	1	6.67E-01	12	mercury manometer	-	1	1.60
8	19	mercury manometer	-	1	2.53E+00	17	mercury manometer	-	1	2.27
9	23	mercury manometer	-	1	3.07E+00	24	mercury manometer	-	1	3.20
10	35	mercury manometer	-	1	4.67E+00	33	mercury manometer	-	1	4.40

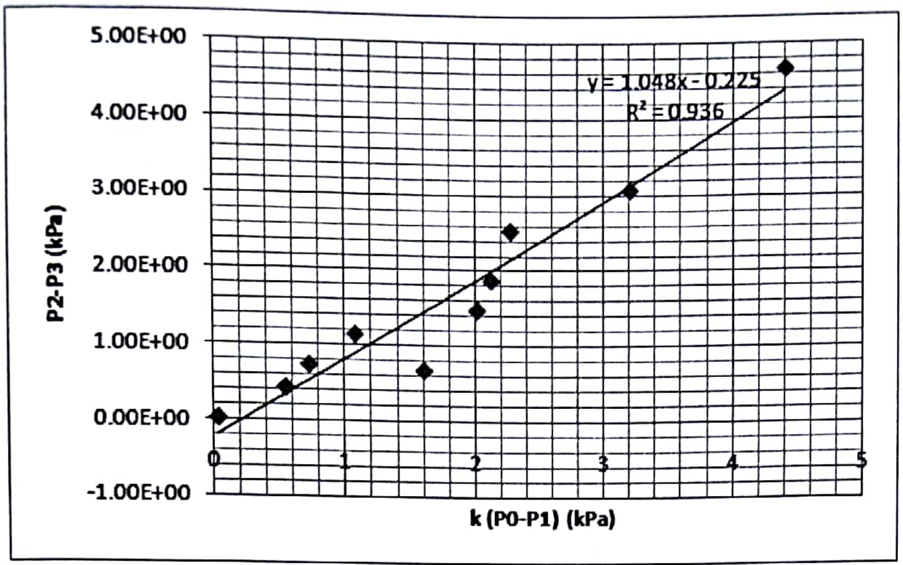

Figure 2plotting to find f.

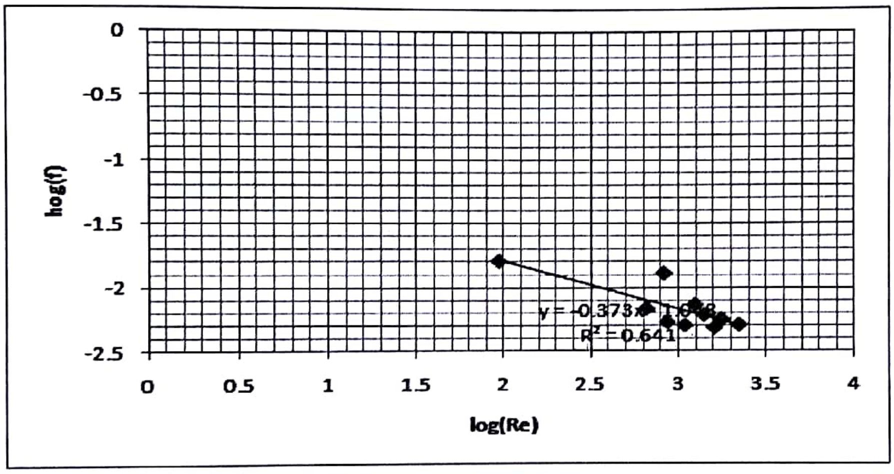

Figure 1: the Blasiusrelation apply check.

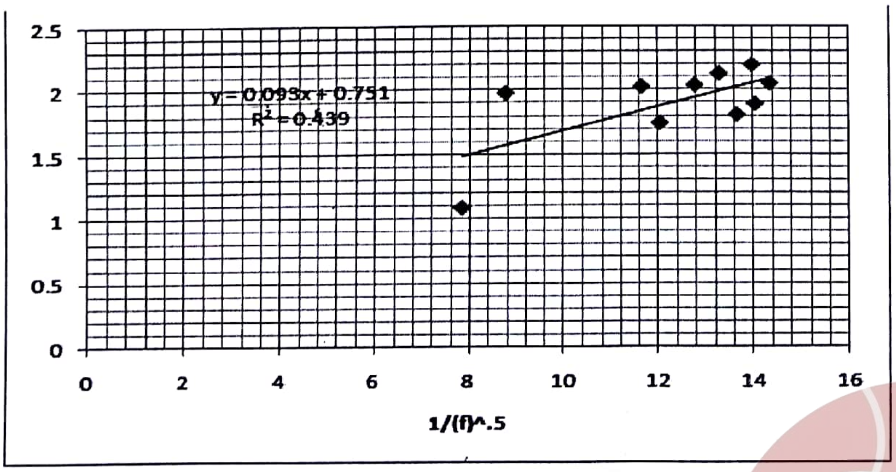

Figure 3: Nikuradse-Von-Karman relation apply check.

B. Sudden enlargement duct:

Table 3:sudden enlargement duct result.

For sudden enlargement duct										
Sample number	P0-P1	manometer used	position if inclined	value of k	P0-P1 (kPa)	P2-P3	manometer used	position if inclined	value of k	P2-P3 (kPa)
1	0.01	inclined manometer	buttom	0.8452	8.45E-03	0.01	inclined manometer	buttom	0.8452	0.01
2	1.38	inclined manometer	buttom	0.8676	4.21E-01	0.48	inclined manometer	buttom	0.8546	0.41
3	1.72	inclined manometer	top	0.8944	1.48E+00	1.02	inclined manometer	middle	0.8704	0.89
4	0.81	inclined manometer	vertical	0.9112	1.87E+00	1.08	inclined manometer	top	0.8866	0.96
5	11	mercury manometer	-	1	7.29E-01	0.36	inclined manometer	vertical	0.8944	0.32
6	16	mercury manometer	-	1	1.14E+00 2.13	5	mercury manometer	-	1	0.67
7	23	mercury manometer	-	1	6.67E-01 3.06	8	mercury manometer	-	1	1.07
8	30	mercury manometer	-	1	2.53E+00 3.99	10	mercury manometer	-	1	1.33
9	41	mercury manometer	-	1	3.07E+00 5.46	15	mercury manometer	-	1	2.00
10	53	mercury manometer	-	1	4.67E+00	21	mercury manometer	-	1	2.80

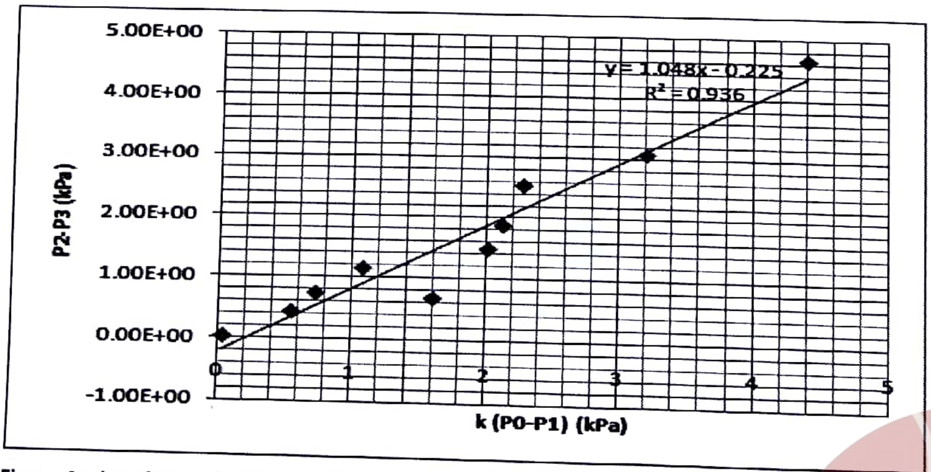

Figure 4: plot of P2-P3 (kPa) and k (P0-P1).

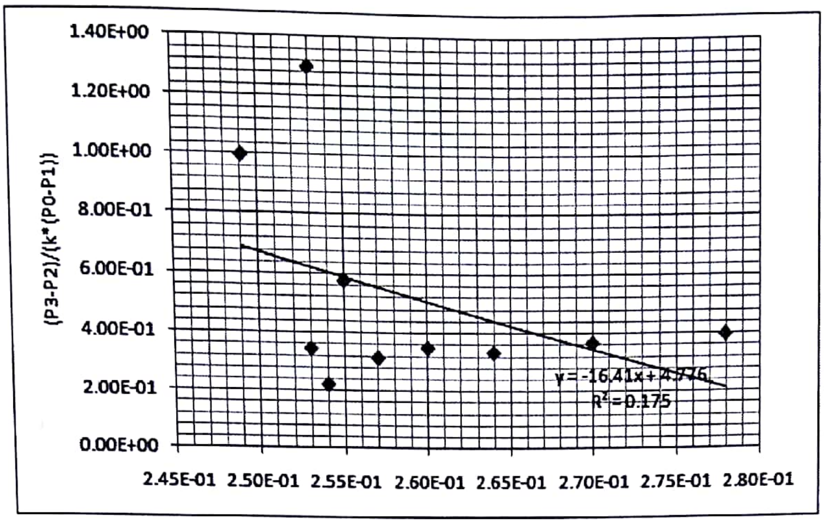

Figure 5: plot of (P3-P2)/(k*(P0-P1)) and $[\frac{a2.\rho 0}{a3.\rho 2} - \left(\frac{a2}{a3}\right)^2 \frac{\rho 0}{\rho 3}]$.

Discussion

For simple pipe friction duct

1- Plotting (P2-P3) against k (P0-P1)

Losses of pressure are expected to happen in simple pipe due to effect of the fluid's viscosity near the surface of the duct.

It could be measuredby calculating the friction coefficient (f) usingdarcy'sequation.

From figure (1), the value of f= (0.006)founded by taking the slope =4.f.L/d from linearizeddarcy'sequation. As well as the slope is constant, the friction coefficient is constant since it is function of Re and relative roughness, if the cross sectional area and flow ratedoes not change the velocity and Re will be constant. The flocculation of point above and below linear line is due to instrumental error such leakage

2- Plotting log f against log Re.

After normalizationof Blasius relation,the empirical correlation for flow of incompressible fluid, this equation must be valid log(f)=log(.079)-0.25*log(Re). As shown in figure (2),

The slope of data is -0.373 which is differ from -0.25 by 49.2% which is high present indicate that the two relations are not consistent. So the Blasius relation can't apply and the fluid is compressible.

3- Plot against log.

Nikuradse-Von-Karman relation, empirical correlation for flow:$(1/f^{.5})$ =4*log$(Re.f^{0.5})$ - 0.396 has been applied to data collected. As shown in figure (3), the slope is 0.093 which extremely differ. From this, Nikuradse-Von-Karman relation does not apply to the data.

For sudden enlargement duct

In this part of experiment, the pipe diameter changes from one size to another, this change means that the area changes; specifically, abruptly change.

The action of sudden enlargement leads to decrease the velocity and increase the pressure, by assuming no change in potential energy.

1- Plotting (P3-P2) against k (P0-P1)

It is clear from the figure (4) that the slope obtained equals 1.048 while the theoretical value equals 1.91 so the experimental value does not consist with theoretical value.

2- Plotting (p3-p2)/(k.(p0-p1)) against ((a2.ρ0)/(a3.ρ2)−(a2a3)^2*(ρ0/ρ3))

This plot in figure (5) represents Kikuradse-Von Karman as a linear relationship.

The theoretical value of slope is 2 while the actual slope is -8.2 There is a big error as a result of personal and instrumental errors.

in your calculation

Conclusion

In the simple friction duct :

-The friction coefficient (f) along the duct is constant cause of the same velocity along the duct for fixed cross-sectional area for incompressible gas flow.

-For incompressible flow ,the Blasius relation and Nikuradse-Von-Karman relation are not applicable with the data from the graphs, since there is a variation in the value of slope, So assuming that the gas is incompressible is wrong or the percentage of error in the experiment is large enough to say the data not correspondence with theoretical.

In the sudden enlargement duct:

-Changing the cross-sectional area to large one decreases the velocity of the gas flow and increase the pressure.

-The density increase, when (P0-P1) and (P2-P3) also increase.

-For compressible flow, the pressure drop affect it in noticeable way than the incompressible gas flow.

References

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Appendix

1. Sample of calculation:

A row from each table will be discussed as sample of calculations.

For simple pipe friction duct

To find friction factor using equation:

P2-P3=(4.f.L/d) .k.(P0-P1)

(P0-P1) =.01 0.0005 kPa.

P2-P3=.03 0.03x0.05 = 15x10^-4

L=600 mm

d=13 mm

T=27c

From tale 3.1 (from manual)

The value of k =0.8452

f=(P2-P3)*d / (4.L.k.(P0-P1))

=.03*13 / 4*600*.8452 *.01

=0.0192

Mair =1.71*10^-5 (393/T+393)*((T+273)/273)^3/2

Where T is operating temperature and equal 27C

Mair =1.71*10^-5 (393/27+393)*((27+273)/273)^3/2

Mair =1.843*10^-5 N/m^2

Density = (P0 * Mwt)/RT

Density = (90.7 *29)/(8.314*300)

Density =1.057Kg/m^3

To find Reynolds number, the following equation is used:

Re=([d*(2*density)^.5]/Mair)*(k.(P0-P1))^.5

Re=([.013*(2*1.057)^.5]/1.843*10^-5)*(00071))^.5

Re=86.68

log f= -1.43

1/(f)^.5= 5.20

Position number.

0.01 * 0.05 = 0.0005 kPa

K(P0-P1) = 0.0005 * 0.8452

= 0.0004

4.266 * 10^-4 kPa

converted to Pa

log Re=1.938

For sudden enlargement duct:

Density 0 = (P0 * Mwt)/RT , P0=90.7 Kpa

Density 0 = (90.7 *29)/(8.314*300)

Density 0 =1.057 Kg/m^3

27

Density 2 = [Mwt of air*P2]/RT , P2=90.65 Kpa

Density 2 =[29.01*90.65]/((27+273)*.008314)

Density 2 =1.0576 Kg/m^3

Density 3= [Mwt of air*P3]/RT , P3=90.66 Kpa

Density 3 =[29.01*90.66]/((27+273)*.008314)

Density 3 =1.0577 Kg/m^3 ✓

area = π/4 d^2

a1=a2=(22/7)*0.013^2 =5.31*10^-4 m^2 x 1.33 x10^-4

a3=(22/7)*0.019^2=1.13*10^-3 m^2 x 2.83 x10^-4

2*[a2/a3 - (a2/a3)^2]

=2*[5.31*10^-4/1.13*10^-3 -(5.31*10^-4/1.13*10^-3)^2]

=.498

[(a2 *Density 0)/(a3*Density 2) - (a2/a3)^2 * (Density 0 /Density 3)]

=(5.31*10^-4 *1.057)/(1.13*10^-3*1.0576) - (5.31*10^-4/1.13*10^-3)^2 *(1.057/1.0577)

=.249 x ?

Table (1): data plotted for for simple pipe friction duct.

plot 1		plot 2					plot 3	
P2-P3 (kPa)	k (P0-P1)	F	log f	density	Re	log Re	1/(f)^.5	
0.03	8.45E-03	1.63E-02	-1.788941149	1.057198538	9.43E+01	1.97	7.842789783	1.079968515
0.54	4.21E-01	6.89E-03	-2.16155404	1.057198538	6.66E+02	2.82	12.04417397	1.742479086
2.01	1.48E+00	7.36E-03	-2.132894468	1.057198538	1.25E+03	3.10	11.65325458	2.029408088
2.12	1.87E+00	6.12E-03	-2.213263362	1.057198538	1.40E+03	3.15	12.78296739	2.040480586
0.72	7.29E-01	5.35E-03	-2.27182614	1.057198538	8.76E+02	2.94	13.67455084	1.806350457
1.07	1.14E+00	5.06E-03	-2.295987702	1.057198538	1.10E+03	3.04	14.06027617	1.891523039
1.60	6.67E-01	1.30E-02	-1.886056648	1.057198538	8.37E+02	2.92	8.770580193	1.979867534
2.27	2.53E+00	4.85E-03	-2.314572569	1.057198538	1.63E+03	3.21	14.36436012	2.055501371
3.20	3.07E+00	5.65E-03	-2.247784484	1.057198538	1.80E+03	3.25	13.30124344	2.130382531
4.40	4.67E+00	5.11E-03	-2.291821994	1.057198538	2.22E+03	3.35	13.99300525	2.19953388

Table (1): data plotted for for sudden enlargement duct.

plot 1		plot 2						
P2-P3 (kPa)	k (P0-P1)	(P3-P2)/(k*(P0-P1))	density 0	density 2	density 3	P2	P3	$[\frac{a2.\rho0}{a3.\rho2} - \left(\frac{a2}{a3}\right)^2 \frac{\rho0}{\rho3}]$
0.01	0.0071436304	1.183151917	1.06E+00	1.06E+00	1.06E+00	90.6520669	90.66	2.49E-01
0.41	1.038767069	0.3948989262	1.06E+00	1.05E+00	1.05E+00	89.62044346	90.03	2.53E-01
0.89	1.375916339	0.6452485334	1.06E+00	1.04E+00	1.05E+00	89.28329419	90.17	2.55E-01
0.96	0.6725312064	1.423767389	1.06E+00	1.05E+00	1.06E+00	89.98667932	90.94	2.53E-01
0.32	1.466546053	0.2195526008	1.06E+00	1.04E+00	1.04E+00	89.19266447	89.51	2.54E-01
0.67	2.133157895	0.3125	1.06E+00	1.03E+00	1.04E+00	88.52605263	89.19	2.57E-01
1.07	3.066414474	0.347826087	1.06E+00	1.02E+00	1.03E+00	87.59279605	88.66	2.60E-01
1.33	3.999671053	0.3333333333	1.06E+00	1.01E+00	1.03E+00	86.65953947	87.99	2.64E-01
2.00	5.466217105	0.3658536585	1.06E+00	9.93E-01	1.02E+00	85.19299342	87.19	2.70E-01
2.80	7.066085526	0.3962264151	1.06E+00	9.75E-01	1.01E+00	83.593125	86.39	2.78E-01

Compressible Fluid Flow Data Sheet

Atmospheric Pressure = ...680.....mmHg.

For simple pipe friction duct:

		(P_0-P_1)	(P_2-P_3)
Inclined manometer	1	0.01 buttom	0.03 buttom
	2	0.49 middle	0.62 middle
	3	1.68 midde	2.27 middle
	4	2.08 top	2.35 top
	5	0.8 vertical	0.79 vertical
	6	1.24 vertical	1.16 vertical
Mercury mano.	7	5 mmHg	12 mmHg
	8	19 mmHg	17 mmHg
	9	23 mmHg	24 mmHg
	10	35 mmHg	33 mmHg
Sudden enlargement → Inclined mano.	1	0.01 buttom	0.01 buttom
	2	1.38 buttom	0.48 buttom
	3	1.72 top ~~middle~~	1.02 middle
	4	0.81 vertical	1.08 top
	5	11 mmHg ~~vertical~~	0.36 vertical
Both	6	16 mm Hg	5 mm Hg
Mercury mano.	7	23 mm Hg	8 mm Hg
	8	30 mmHg	10 mm Hg
	9	41 mmHg	15 mmHg
	10	53 mmHg	21 mmHg

Instructor signature: Rula Mustafa	
Date: 22/10/2018	

The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (4)

Experiment title:

Efflux Time for a Tank with Exit Pipe

Type of the report: Short Report

Done by

AseelAlsayeh 0154679

Abstract

The objective of this experiment is to show the dependence of the efflux time for a tank with exit pipe on pipe length and diameter. A cylindrical tank in a vertical position filled with fluid of glycerol and water mixture was drained through a pipe which is vertically attached to the bottom of the tank.

The affect of two parameters on efflux time were studied, length and diameter of the pipe, which shows that affected inversely by length, and directly by diameter of the pipe .The density of the mixture was calculated and it equals to 1.15 g/ml. The flow was laminar because Re less than 2100. The theoretical efflux time was calculated in both study cases, and it equals to 9.64 s at constant diameter 5.35mm and length 87.4mm.

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Results

Table 1: Raw data of the experiment.

H_1(m)	0.134	viscosity (Pa.s)	0.01
H_2(m)	0.084	water density (g/ml)	9.99E-01
RT(^{0}C)	17	volume of bottle (ml)	49.92
mass empty(g)	29.981	density of mix(g/ml)	1.15
mass bottle+water(g)	79.843	g (m/s^2)	9.81
mass bottle+mix(g)	87.611	volume in tank (m^3)	0.001
viscosity (cp)	10	Area (m^2)	0.02

Table 2: Results for pipes with variating length and constant diameter = 5.35 mm.

constant D = 5.35 mm							
	constant D =	5.35	mm	Area =	2.25E-05	m^2	
Length (mm)	time1 (s)	time2 (s)	average time	Q (m3/s)	velocity	Re	teff
87.4	114.12	118.1	116.11	8.61E-06	0.38	236.51	19.64
163.4	125.48	126.21	125.85	7.95E-06	0.35	218.22	26.41
318.4	134.23	141.63	137.93	7.25E-06	0.32	199.10	32.74

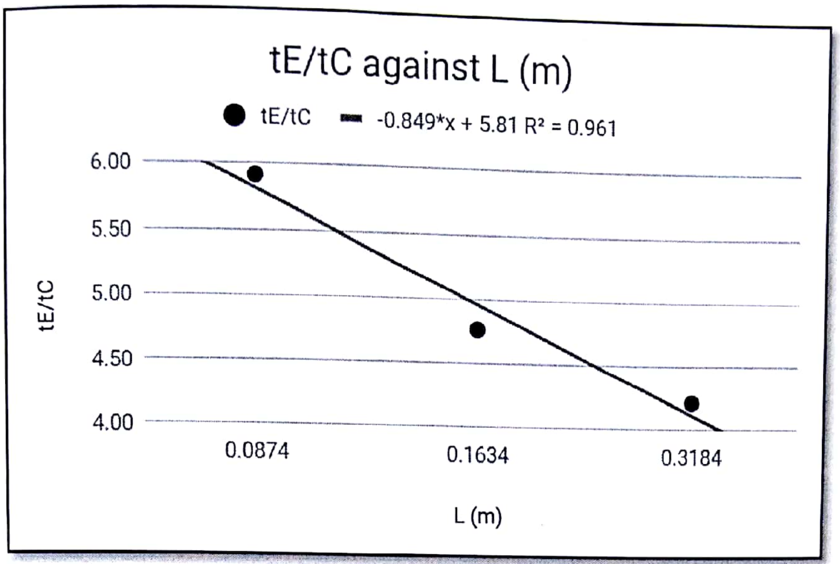

Figure 1: Plot of tE/tC against L (m) for constant diameter = 5.35mm.

Table 3:Results for pipes with variating diameter and constant length = 623.4 mm.

constant L=623.4 mm						
Diameter (mm)	time1 (s)	Area(m^2)	Q (m^3/s)	velocity	Re	teff
8.4	19.35	5.54E-05	5.17E-05	0.93	903.90	6.15
5.35	157.76	2.25E-05	6.34E-06	0.28	174.07	37.38
2.1	2235	3.47E-06	4.47E-07	0.13	31.30	1,574.64

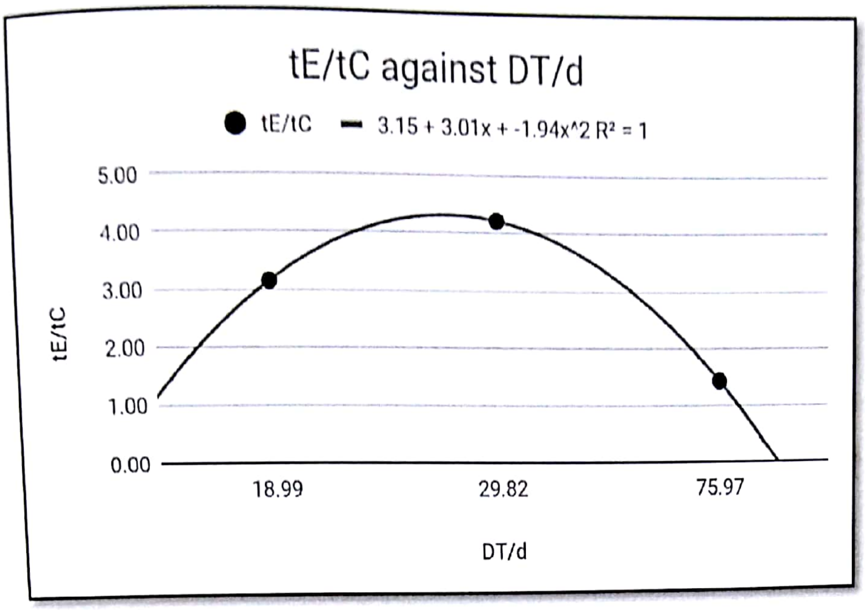

Figure 2: Plot of tE/tC against DT/d for constant length = 623.4mm.

Confirming the dimensionality of equations (7) and (8) p.25 of chemical Engineering Laboratory (1)

1. Equation (7) $t_{eff} = \frac{32 \times \mu \times L \times DT^2}{\rho \times g \times d^4} \times \ln\left(\frac{L+H1}{L+H2}\right)$ ……(1)

Units of expression must be in second, however, the ln is unitless

$$\frac{Pa\,.\,s\,.\,m\,.\,m^2}{\frac{kg}{m^3}\cdot\frac{m}{s^2}.m^4} = \frac{Pa\,.\,s^3\,.\,m}{kg} = \frac{\frac{N}{m^2}\,.\,s^2\,.\,m}{kg} = \frac{\frac{kg\,.m}{m^2.s^2}.s\,.m}{kg} = s\ \#$$

2. Equation (8) $t_{eff} = \frac{7}{3} \cdot \frac{DT^2}{d^2} \cdot \frac{1}{C} \cdot [(L+H1)^{\frac{3}{7}} - (L+H2)^{\frac{3}{7}}]$ …..(2)

Where $C = [\frac{g\,.\,d^{\frac{5}{4}}.\rho^{\frac{1}{4}}.}{(.079\times2).\,L\,.\,\mu^{\frac{1}{4}}}]$^(4/7) $= [\frac{g^{\frac{4}{7}}.\,d^{\frac{5}{7}}.\,\rho^{\frac{1}{7}}}{(.079\times2)^{\frac{4}{7}}.\,L^{\frac{4}{7}}.\,\mu^{\frac{1}{7}}}]$

Units for C : $[C] = \frac{\frac{m^{\frac{4}{7}}}{s^{\frac{8}{7}}}.m^{\frac{4}{7}}.m^{\frac{1}{7}}.\frac{kg^{\frac{1}{7}}}{m^{\frac{3}{7}}}}{m^{\frac{4}{7}}.\frac{N^{\frac{1}{7}}.\,s^{\frac{1}{7}}}{m^{\frac{2}{7}}}} = \frac{m^{\frac{4}{7}}.\,kg^{\frac{1}{7}}}{s\,.\,N^{\frac{1}{7}}} = \frac{m^{\frac{4}{7}}.\,kg^{\frac{1}{7}}}{s\,.\,\frac{kg^{\frac{1}{7}}}{s^2}.m}$ = m^-(3/7) . s

Units for t_{eff}: $[t_{eff}] = \frac{m^2}{m^2} \cdot \frac{s}{m^{\frac{3}{7}}} . m^{\frac{3}{7}} = s$ #

Discussion

The most important parameters should be taken in the consideration while designing tanks are the length and diameter of the pipe.

As shown in Table 2: Results for pipes with variating length and constant diameter = 5.35 mm. the area of constant diameter pipes is constant, where the flow is laminar (Re less than 2100). Reynolds number increase if the length decrease due to increasing of velocity, more the pipe is long more friction is carried in the pipe that will decrease the velocity then Reynolds number so that the flow is laminar.

The time required for draining out the vessel contents (efflux time) changed with the length, it is proportionally increasing because longer pip has lower velocity, so more time is needed to drain out the tank.

From Figure 1: Plot of tE/tC against L (m) for constant diameter = 5.35mm.) increasing the length of the pipe, increase the ratio of efflux time between time calculated and measured (experimental) while all data is bigger than one, this means that the measured value is higher than that calculated due to the equation (2). Also, the differences decrease while length increases because it is more easily to determine specific volume drain at lower velocity.

As shown in Table 3:Results for pipes with variating diameter and constant length = 623.4 mm. in constant length of pipe, the flow is also laminar while increasing the diameter of pipe increases the velocity due to large cross sectional area so that increase Re number, and decrease the head loss due to friction. The efflux time is changed with diameter proportionally decreased, because the velocity in small diameter is slower and need more time to drain out the contents in the tank.

From Figure 2: Plot of tE/tC against DT/d for constant length = 623.4mm. the relation is not linear as in Figure 1: Plot of tE/tC against L (m) for constant diameter = 5.35mm.when the ratio of the diameter of tank to diameter of pipe is increased (diameter of tank constant=.16m while diameter of pipe is changing) the ratio of experimental time to calculated time is increase then decrease.

Noticing that when diameter is much low the experimental time and calculated time are vigorously increased and the values come closer to each one that make the ratio low .this explains why the curve is coming down when decreasing the diameter of pipe with respect to the diameter of tank.

From figure (1) and figure (2), deviation between experimental time and calculated time is founded. This may be due to personal error in reading the scale and instrumental error like inaccurate scaling.

Conclusion

-The most important parameters that should take the consideration while designing tanks is the length and diameter of the pipe.

-Under experiment condition, the flow of the mixture is laminar in both study cases due to Re less than 2100.

-The velocity affected inversely by length, and affected directly by diameter of pipe.

-There is a deviation between experimental and theoretical efflux time.

References

Chemical Engineering Laboratory (1) (6th ed.). (2016). Amman: University of Jordan.

Appendix

SAMPLE OF CALCULATION

- **Finding the density of the mixture**
  Mass of empty bottle = 29.981 g .
  Mass of bottle and water = 79.843 g .
  Mass of water = Mass of bottle and water - Mass of empty bottle = 79.843 – 29.981 = 49.862 g .
  Density of water = 0.998 g/ml .
  Water volume = bottle volume = $\frac{\text{water mass}}{\text{water density}} = \frac{49.86}{.998}$ = 49.86 ml = 49.86 *10 ^-6 m^3 .
  Mixture density = $\frac{mixture\ mass}{mixture\ volume} = \frac{mass\ of\ bottle\ and\ mixture - mass\ of\ bottle}{bottle\ volume} =$
  $\frac{87.611-29.981}{49.92}$ = 1.15 g/ml.
- **Finding the tank volume**
  Area (A) = tank volume / height = .001 / (.134-.084) = 0.02 m^2.
  $D_T = \sqrt{4*A/\pi} = \sqrt{4} * .02/\pi$ = 0.16 m .

Taking the first row from table2

- Time 1 = 114.12 s
  Time 2 = 118.1 s
  Average time = $\frac{time\ 1 + time\ 2}{2} = \frac{114.12+118.1}{2}$ = 116.11 s.
- Tank volume = .001 m^3
  Volumetric flow rate (Q) = $\frac{tank\ volume}{average\ time} = \frac{0.001}{116.11} = 8.61 * 10^{-6}$ m^3/s .
- Pipe area (A) = $\frac{d^2 \times \pi}{4} = \frac{\pi \times 0.00535^2}{4}$ = 2.25 * $10^{-5} m^2$.
  Velocity (u) = $\frac{Q}{A} = \frac{8.61*10^{-6}}{2.25*10^{-5}}$ = 0.38 m/s .

- $\underline{Re} = \frac{\rho\, u\, d}{\mu} = \frac{1160 * .38 * 0.00535}{0.01} = 236$. Since Re<2100 it is laminar flow.
- $t_{eff} = \frac{32 \times \mu \times L \times DT^2}{\rho \times g \times d^4} \times \ln\left(\frac{L+H1}{L+H2}\right) = \frac{32 \times .01 \times .0874 \times .16^2}{1150 \times 9.81 \times .00535^\wedge 4} \times \ln\left(\frac{.0874+.134}{.0874+.084}\right) = 19.64$ s .
- $\frac{\text{tE (average time)}}{\text{tC}} = \frac{116.11}{19.64} = 5.91$.

Taking the first row from table3

- $\underline{Time} = \frac{time\ 1 + time\ 2}{2} = \frac{114.12+118.1}{2} = 116.11$ s.
- Tank volume = .001 m^3
  $\underline{\text{Volumetric flow rate}}$ (Q) $= \frac{tank\ volume}{time} = \frac{0.001}{19.35} = 5.17 * 10^{-5}$ m^3/s .
- $\underline{\text{Pipe area}}$ (A) $= \frac{d^2 \times \pi}{4} = \frac{\pi \times 0.0084^2}{4} = 5.54 * 10^{-5} m^2$.
  $\underline{\text{Velocity}}$ (u) $= \frac{Q}{A} = \frac{5.17 * 10^{-5}}{5.54 * 10^\wedge{-5}} = 0.93$ m/s .
- $\underline{Re} = \frac{\rho\, u\, d}{\mu} = \frac{1160 * .93 * 0.0084}{0.01} = 906$. Since Re<2100 it is laminar flow.
- $t_{eff} = \frac{32 \times \mu \times L \times DT^2}{\rho \times g \times d^4} \times \ln\left(\frac{L+H1}{L+H2}\right) = \frac{32 \times .01 \times 0.6234 \times .16^2}{1150 \times 9.81 \times .0084^\wedge 4} \times \ln\left(\frac{.6234+.134}{.6234+.084}\right) = 6.20$ s .
- $\frac{tE}{tC} = \frac{19.35}{6.14} = 3.15$.

TABLES USED FOR PLOTTING

Table A: Data used for plotting figure 1.

Figure 1	
L (m)	tE/tC
0.0874	5.91
0.1634	4.77
0.3184	4.21

Table B: Data used for plotting figure 2.

Figure 2	
DT/d	tE/tC
18.99	3.15
29.82	4.22
75.97	1.42

Efflux Time for a Tank with Exit Pipe Data Sheet

	Pipe dimensions	Time (s) Trial number 1	Time (s) Trial number 2
Same diameter	D=5.35mm L=87.4mm	1:54.12	1:58.10
	D=5.35mm L=163.4mm	2:05.48	2:06.21
	D=5.35mm L=318.4mm	2:14.23	2:21.63
Same length	D=8.4mm L=623.4mm	00:19.35	–
	D=5.35mm L=623.4mm	2:37.76	–
	D=2.1mm L=623.4mm	37:15.00	–

H1	13.4 cm
H2	8.4 cm
Room Temperature	17°C
Mass of empty bottle	29.981 g
Mass of bottle+ water	79.843 g
Mass of bottle + mixture	87.611 g
Viscosity	10 cP

Instructor signature:	[signature]
Date:	8/11/18

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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (6)

Experiment title:

Determination of Losses in Small Bore Piping System

Type of the report: Short Report

Done by

Abstract

The head loss occurs due to friction in the pipe. The objective of this experiment was to study the effects of many parameters include length, pipe diameter, internal surface roughness, type of fitting, sudden contraction, sudden expansion, and friction factor on the head loss.

The relations between head loss and parameters was plotted according to experimental data, the head losses measured were compared to the calculated head losses by a plots too.

The main results was:

- The gate valve better than globe valve for a low loss piping system.
- The loss coefficient decreases as the flowrate increases.
- The radius of curvature of a pipe bend has inverse relation with head loss coefficient

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Results

Table 1: straight pipe data for dark blue system.

straight pipe	Q(m^3/s)	u(m/s)	Re	f
264	0.0002473	1.6768	22972.255	0.0007037
246	0.0002346	1.5908	21793.823	0.0007285
224	0.0001923	1.3040	17865.346	0.0009872
200	0.0002027	1.3745	18831.041	0.0007934
175	0.0001672	1.1339	15535.084	0.0010200

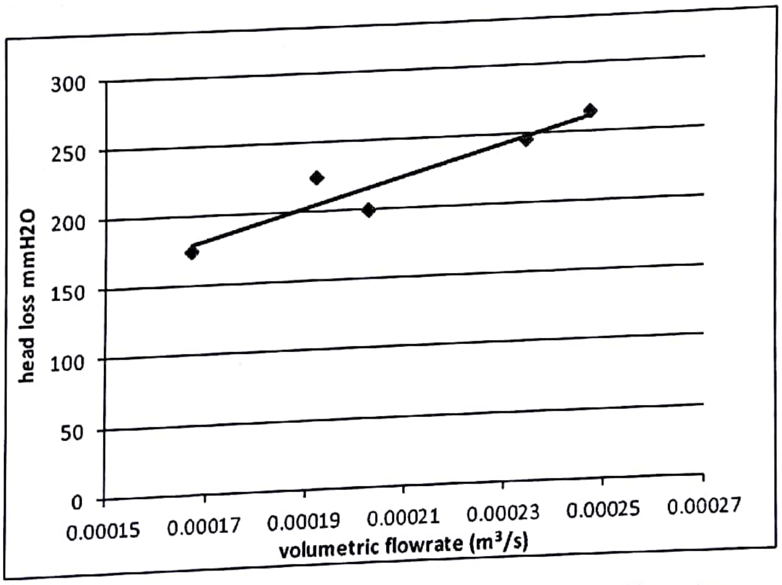

Figure 1: Head loss with volumetric flow rate for straight line of dark blue system.

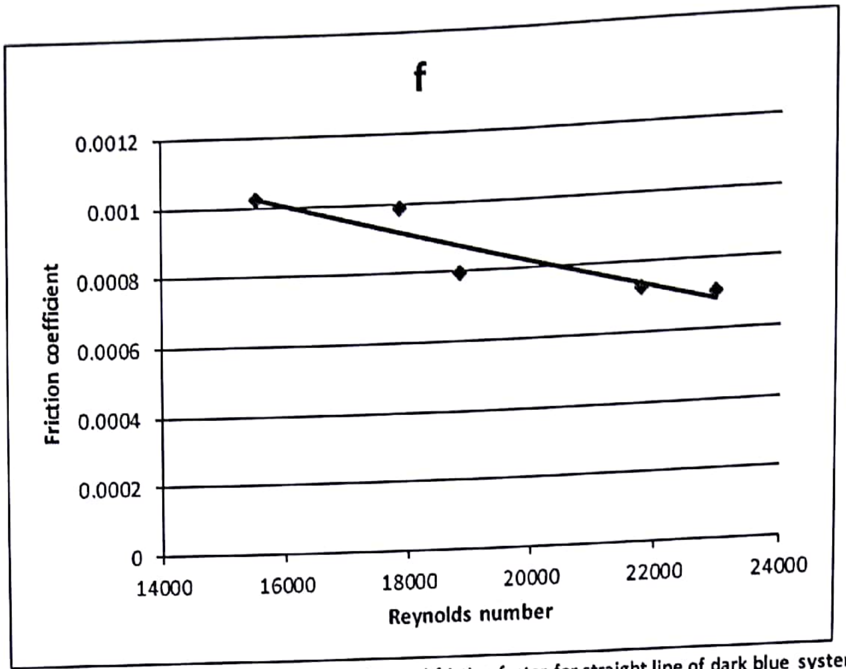

Figure 2: The relation between Reynolds number and friction factor for straight line of dark blue system.

Table 2: Gate valve data (dark blue system).

gate valve (2-1) mmHg	mass(kg)	time(s)	Q%	H2-H1 (mH2O)	k (gate valve)
10	7.5	30.33	100	0.136	0.9487
150	7.5	31.97	94.87	2.039	15.8106
85	7.5	39	77.77	1.156	13.3327
127	7.5	37	81.97	1.727	17.9299
165	7.5	44.85	67.63	2.243	34.2278

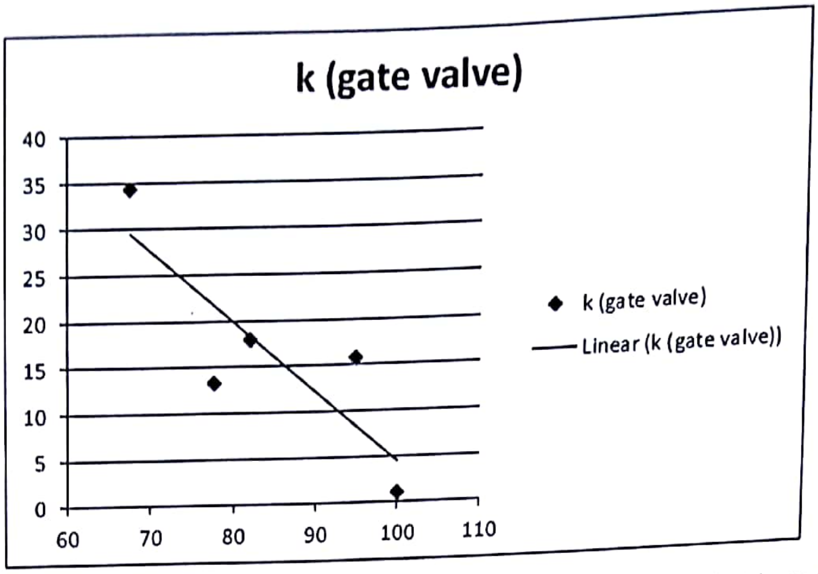

Figure 3: perecent volume flow rate(x-axis) with loss coefficient(y-axis) of gate valve for dark blue system.

Table 3: Standard 90° elbow data of Dark blue system.

std elbow 90 (r=12.7mm)	mass(kg)	time(s)	Q(m³/s)	u(m/s)	dalta H (mH2O)	k
412	7.5	30.33	0.0002473	1.6768	0.148	1.0327
385	7.5	31.97	0.0002346	1.5908	0.139	1.0777
359	7.5	39	0.0001923	1.3040	0.135	1.5576
310	7.5	37	0.0002027	1.3745	0.11	1.1423
270	7.5	44.85	0.0001672	1.1339	0.095	1.4496

Table 4: 90° Miter data of Dark blue system.

miter bend 90 (r=0)	mass(kg)	time(s)	Q(m³/s)	u(m/s)	dalta H (mH2O)	k
507	7.5	30.33	0.0002473	1.6768	0.243	1.6957
468	7.5	31.97	0.0002346	1.5908	0.222	1.7212
415	7.5	39	0.0001923	1.3040	0.191	2.2037
373	7.5	37	0.0002027	1.3745	0.173	1.7965
317	7.5	44.85	0.0001672	1.1339	0.142	2.1667

Table 5: Globe valve data (Light blue system).

Globe valve H2-H1	mass (kg)	time (s)	Q%	H2-H1(mH2o)	k
107	7.5	30.91	100	1.4547	10.5427
150	7.5	42.71	72.3718	2.0393	28.2177
187	7.5	39.52	78.2136	2.5423	30.1194
226	7.5	48.79	63.3531	3.0725	55.4805
270	7.5	71.79	43.0561	3.6707	143.5034

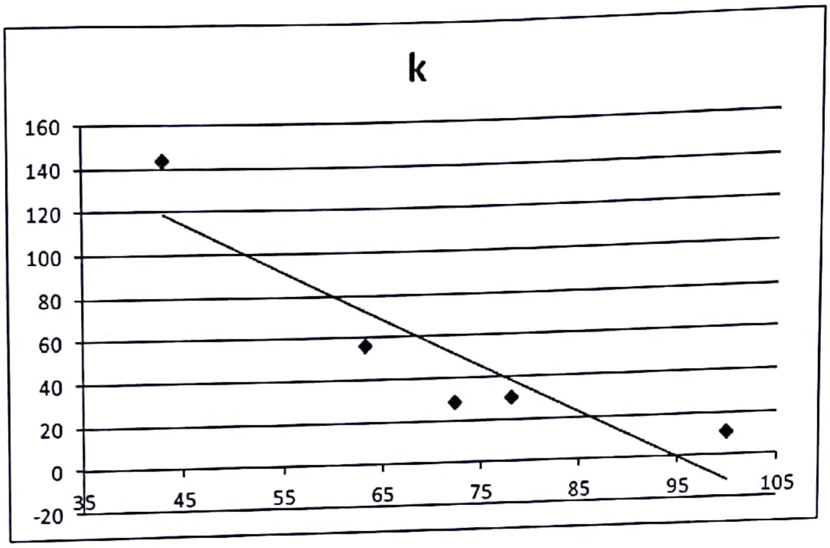

Figure 4: perecent volume flow rate(x-axis) with loss coefficient(y-axis) of globe valve for light blue system.

Table 6: Sudden Expansion data for Light blue system.

sudden expansion (mmH2O)	mass (kg)	time (s)	u1(m/s)	u2(m/s)	Deltah (no loss) (mH2O)	hL (mH2O)	dalta H
50	7.5	30.91	1.6453	0.4431	0.12797	0.07367	0.05430
37	7.5	42.71	1.1908	0.3207	0.06703	0.03859	0.02844
30	7.5	39.52	1.2869	0.3466	0.07829	0.04507	0.03322
25	7.5	48.79	1.0424	0.2807	0.05136	0.02957	0.02179
20	7.5	71.79	0.7084	0.1908	0.02372	0.01366	0.01007

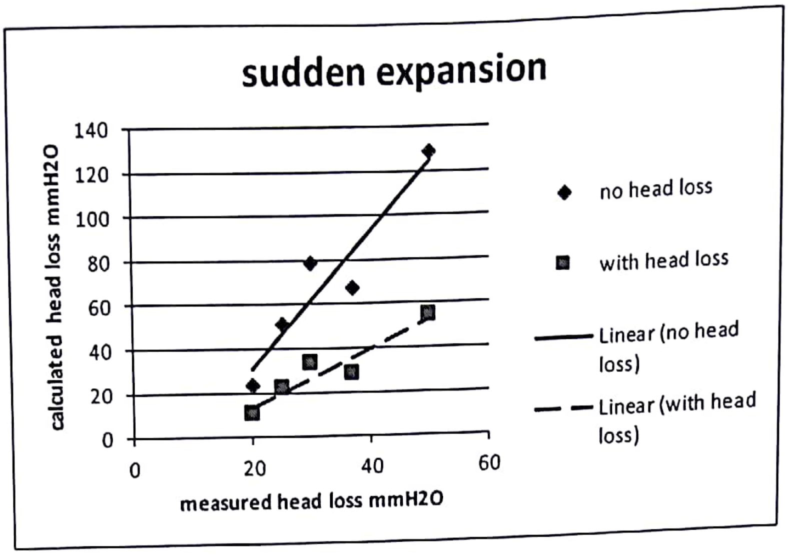

Figure 5: The head loss measured with head loss calculated for sudden expansion in light blue system.

Table 7: Sudden Contraction data for Light blue system.

sudden contraction	mass (kg)	time (s)	Q(m^3/s)	u1(m/s)	u2(m/s)	delta h (no loss) (mH_2O)	Hf (mH_2O)	delta H
200	7.5	30.91	0.0002426	0.4431	1.6453	0.1280	0.03153	0.15950
190	7.5	42.71	0.0001756	0.3207	1.1908	0.0670	0.02282	0.08985
157	7.5	39.52	0.0001898	0.3466	1.2869	0.0783	0.02466	0.10295
110	7.5	48.79	0.0001537	0.2807	1.0424	0.0514	0.01998	0.07134
70	7.5	71.79	0.0001045	0.1908	0.7084	0.0237	0.01358	0.03730

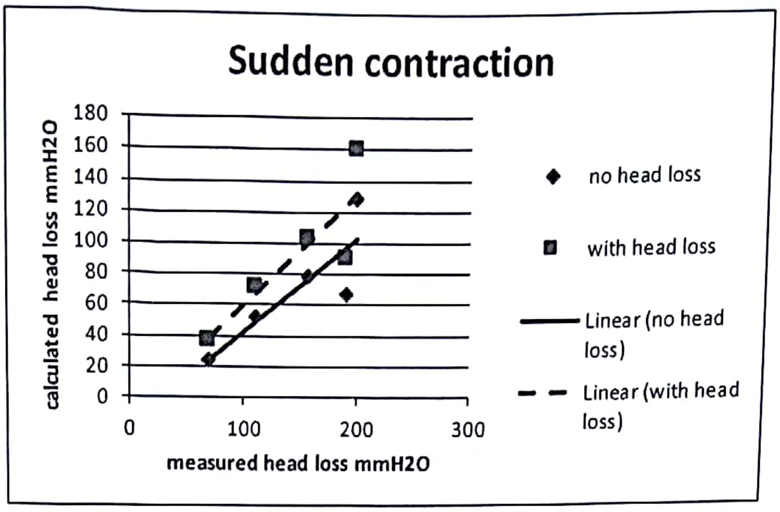

Figure 6:The relation ofhead loss measured with head loss calculated for sudden contraction of light blue system.

Table 8: 50⁰radius bend data of Light blue system.

r/D	3.6496								
redius bend 50	mass (kg)	time (s)	$Q(m^3/s)$	u(m/s)	Re	f	dalta hf (mH2O)	dalta H (mH2O)	k
240	7.5	30.91	0.0002426	1.6453	22541.200	0.006447	0.2374	0.0026	0.0188
212	7.5	42.71	0.0001756	1.1908	16313.475	0.006990	0.1348	0.0772	1.0681
180	7.5	39.52	0.0001898	1.2869	17630.276	0.006856	0.1544	0.0256	0.3030
143	7.5	48.79	0.0001537	1.0424	14280.560	0.007227	0.1068	0.0362	0.6536
110	7.5	71.79	0.0001045	0.7084	9705.370	0.007959	0.0543	0.0557	2.1764

Table 9: 100⁰ radius bend data for Light blue system.

r/D	7.2993								
redius bend 100	mass (kg)	time (s)	$Q(m^3/s)$	u(m/s)	Re	f	dalta hf (mH2O)	dalta H (mH2O)	k
214	7.5	30.91	0.0002426	1.6453	22541.200	0.006447	0.237401	-0.023401	- 0.1696
206	7.5	42.71	0.0001756	1.1908	16313.475	0.006990	0.134812	0.071188	0.9850
164	7.5	39.52	0.0001898	1.2869	17630.276	0.006856	0.154428	0.009572	0.1134
128	7.5	48.79	0.0001537	1.0424	14280.560	0.007227	0.106801	0.021199	0.3828
94	7.5	71.79	0.0001045	0.7084	9705.370	0.007959	0.054331	0.039669	1.5509

Table 10: 150°radius bend data for Light blue system.

r/D	10.9489								
radius bend 150	mass (kg)	time (s)	Q(m^3/s)	u(m/s)	Re	f	dalta hf (mH2O)	dalta H (mH2O)	k
240	7.5	30.91	0.0002426	1.6453	22541.200	0.006447	0.2374	0.0026	0.0188
205	7.5	42.71	0.0001756	1.1908	16313.475	0.006990	0.1348	0.0702	0.9712
173	7.5	39.52	0.0001898	1.2869	17630.276	0.006856	0.1544	0.0186	0.2200
130	7.5	48.79	0.0001537	1.0424	14280.560	0.007227	0.1068	0.0232	0.4189
96	7.5	71.79	0.0001045	0.7084	9705.370	0.007959	0.0543	0.0417	1.6290

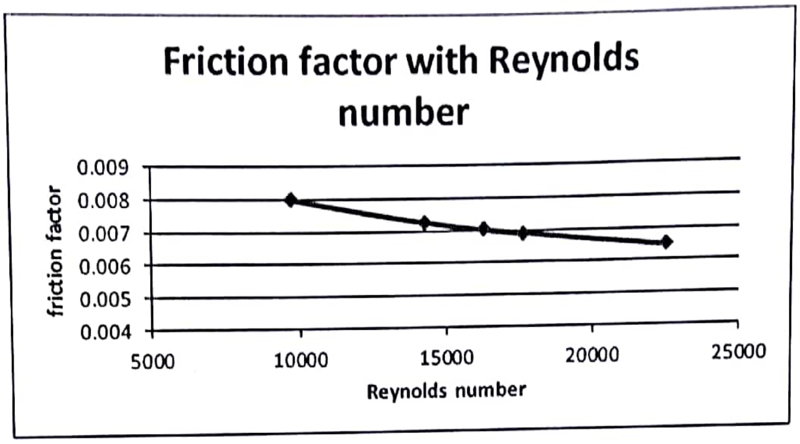

Figure 7: The relation of friction factors for bends with Reynolds number for bends in light blue system.

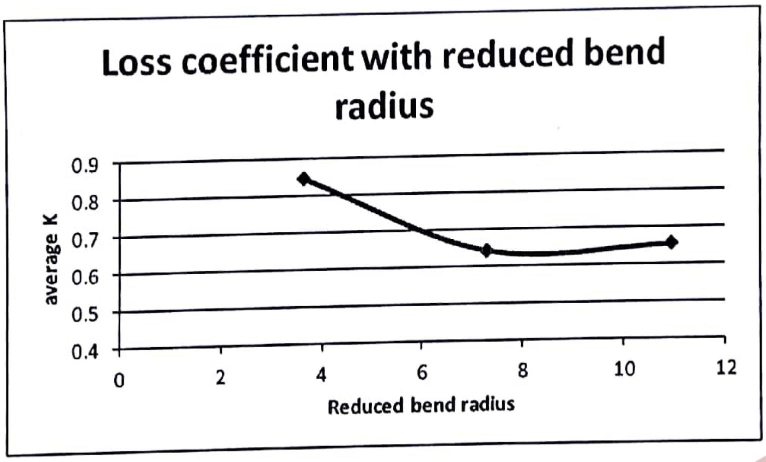

Figure 8: changing of loss coefficient with reduced bend radius for bends in light blue system.

Discussion

"The laws of nature state if you want something you have to pay for it. If you want to move something, there will be resistance."

As seen in figure 1, as the flow rate increases, the head loss increases. Because the flow rate increase with pressure (the head loss is the difference of pressure / density * gravity constant).

Also, as Reynolds number, the friction factor decreases as shown in figure 2.friction affects when the velocity of liquid is increasing then Reynolds increase, so friction factor decrease at high velocity, and moody diagram shows that at laminar flow the relation between f and Re is: f=16/Re .However, all values show that the flow is turbulent, and (f) calculated from the head loss equation (that proportional inversely with u2).

The fittings such as elbows, tees, strainers, valves have a value of k. in this experiment the value of k for the gate and globe valve are shown in tables 2 and 5. These values can be compared to the tabulated values.

For the first raw of the both tables, the tabulated values for the gate and globe valve are 0.2and 10.0, while the values founded experimentally are 0.95 and 10.5 respectively.

From figures (3, 4) the comparison between gate and globe valves shows that globe valve have higher values of loss coefficient when changing the flow rate, making the gate valve a chose for less loss pipe system. Gate valve have very little fluid flow resistance in fully open position and also have small pressure drop across the valve. Globe valve on the other hand have a high pressure drop even in fully open conditions and remain a big resistance to fluid flow.

the percent volume flow rate changed with loss coefficient inversely for gate valve in the dark blue system, see figure (3). The loss coefficient is a function of total head loss and velocity (inverse relation), so when flow rate increase the velocity increase then loss coefficient decrease. That is clear when the velocity is faster the less friction occurs.

The loss coefficient (k) for elbows is represented in tables 3 and 4. For comparison for the first raw in the table, the tabulated values for Standard 90° elbow and 90° miter are 1.1 and 1.1, while the experimental values were 1.0 and 3.5.

Sudden expansion and contraction in piping system has two velocities: in inlet and outlet, that affect the pressure difference and head loss. A comparison between calculated and measured heat loss is shown in figures (5, 6).

As shown in tables (8, 9, 10), head losses of different diameter bends is examine. As Reynold increase the friction factor decrease for the three bends. Also, as the reduced radius increase the loss coefficient decrease. This shown in figure (7) and figure (8).

There are different between tabulated data and the data calculated of K this could be because of:

-personal error: because the time is small (in second) and the time calculated and recorded might be not precise that affect the values of velocity calculated.

-The pipe consider as smooth pipe which is not precise.

Conclusion

-The radius of curvature of a pipe bend has inverse relation with head loss coefficient.

-The loss coefficient decreases as the flowrate increases.

-The gate valve better than globe valve for a low loss piping system.

References

1. Head Loss in Piping Systems. (n.d.). Retrieved December 4, 2018, from http://www.hydromatic.com/ResidentialPage_techinfopage_headloss.aspx
2. Chemical Engineering Laboratory (1) (6th ed.). (2016). Amman: University of Jordan.

Appendix

Sample of calculation:

A row from each table will be discussed as sample of calculations.

1. Dark Blue system:

For gate valve:

$\Delta h = h_1 - h_2 = 240 - 230 = 10$ mmHg

10 mmHg * 10.333 mH_2O/760 mmHg=0.13596 mH_2O

- Q (Volumetric flowrate) =m/(ρ*t)

→Q=7.5 kg/(1000kg/m^3*30.33s) =0.0002473m^3/s

- u=Q/A, A=π/4*d^2, d=13.7*10^{-3} m

→u=0.0002473/(π/4*(13.7*10^{-3})^2)=1.6768m/s

- Q%=Q/$Q_{\text{fully open}}$*100%=0.0002473/0.0002473*100%=100%

- k=Δh*2*g/u^2=0.136*2*9.81/ (1.6768)^2=0.9487

For straight pipe

L=914*10^{-3}m, d=13.7*10^{-3}m

- $\Delta h_f = h_1 - h_2$=630-366=264 mmH_2O = 0.264 mH_2O

→$Q=7.5\ kg/(1000 kg/m^3 * 30.33 s) = 0.0002473 m^3/s$
- $u=Q/A$, $A=\pi/4*d^2$, $d=13.7*10^{-3}$ m
→$u=0.0002473/(\pi/4*(13.7*10^{-3})^2)=1.6768 m/s$

- $Re= \rho*d*u/\mu= (1000*13.7*10^{-3}*1.6768)/(1*10^{-3})=22972.255$

- $f=(\Delta h_f*d*g)/(2*L*u^2) = (0.264*13.7*10^{-3}*9.81)/(2*914*10^{-3}*(1.6768)^2)$

→$f=0.0007037$

For standard elbow 90

$\Delta h=h_1-h_2=780-368=412$ $mmH_2O = 0.412$ mH_2O

→$Q=7.5\ kg/(1000 kg/m^3 * 30.33 s) = 0.0002473 m^3/s$
- $u=Q/A$, $A=\pi/4*d^2$, $d=13.7*10^{-3}$ m
→$u=0.0002473/(\pi/4*(13.7*10^{-3})^2)=1.6768 m/s$

- $\Delta H=\Delta h-\Delta h_f=0.412-0.264=0.148$ mH_2O

- $k=\Delta H*2*g/u^2=0.148*2*9.81/ (1.6768)^2= 1.0327$

- $r/d= (12.7*10^{-3})/ (13.7*10^{-3}) =0.9270$

For 90 miter bend

$\Delta h=h_1-h_2=1035-528=412$ mmH2O = 0.507 mH2O

→Q=7.5 kg/(1000kg/m³*30.33s) =0.0002473m3/s

- u=Q/A, A=π/4*d², d=13.7*10-3 m

→u=0.0002473/(π/4*(13.7*10-3)2)=1.6768m/s

- ΔH=Δh-Δhf=0.507-0.264=0.243 mH2O

- k=ΔH*2*g/u2=0.243*2*9.81/ (1.6768)²= 1.6957

- r/d= (12.7*10-3)/ (13.7*10-3) =0.9270

2. Light blue system:

Globe valve:

$\Delta h=h_1-h_2=305-198=107$ mmHg

107 mmHg * 10.333 mH2O/760 mmHg=1.4548mH2O

- Q (Volumetric flowrate) =m/(ρ*t)

→Q=7.5 kg/(1000kg/m³*30.91s) =0.0002426m³/s

- u=Q/A, A=π/4*d², d=13.7*10-3 m

→u=0.0002426/(π/4*(13.7*10-3)²)=1.6453m/s

- Q%=Q/Q $_{\text{fully open}}$*100%=0.0002426/0.0002426*100%=100%

- k=Δh*2*g/u2=1.4548*2*9.81/ (1.6768)2=10.5427

Sudden expansion

$d_1=13.7*10^{-3}$ m, $d_2=26.4*10^{-3}$ m

- $\Delta h_{exp}=h_1-h_2=520-570=-50$ mmH2O = -0.5 mH2O

- Q (Volumetric flowrate) =m/(ρ*t)

→$Q=7.5$ kg/(1000kg/m3*30.91s) =0.0002426m3/s

- $u_1=Q/A_1$, $A=\pi/4*d_1$, $d_1=13.7*10^{-3}$ m
→$u_1=0.0002426/(\pi/4*(13.7*10^{-3})^2)$ =1.6453m/s
- $u_2=Q/A_2$, $A=\pi/4*d_2$, $d_2=26.4*10^{-3}$ m
→$u_2=0.0002426/(\pi/4*(26.4*10^{-3})^2)$ =0.4431m/s

- $\Delta h_{(no\ loss,\ cal)} = (u_1 - u_2)/(2*g) = ((1.6453)^2 - (0.4431)^2)/\ (2*9.81)$ =0.12797mH2O

- $\Delta h_{(loss,\ cal)} = (u_1 - u_2)^2/(2*g) = (1.6453-0.4431)^2/\ (2*9.81)$ =0.07367mH2O

- $\Delta h_{(loss)} = \Delta h_{(no\ loss,\ cal)} - \Delta h_{(loss,\ cal)}$ =0.05430 mH2O

Sudden contraction

d1=26.4*10-3 m, d2=13.7*10-3 m

- Δhexp=h1-h2=565-365=200 mmH2O = 0.200 mH2O

- Q (Volumetric flowrate) =m/(ρ*t)
→Q=7.5 kg/(1000kg/m3*30.91s) =0.0002426m3/s

- u1=Q/A1, A=π/4*d1^2, d1=26.4*10-3 m
→u1=0.0002426/(π/4*(26.4*10-3)2) =0.4431m/s
- u2=Q/A2, A=π/4*d22, d2=13.7*10-3 m
→u2=0.0002426/(π/4*(13.7*10-3)2) =1.6453m/s

- Δh (no loss, cal) = (u2- u1)/(2*g) = ((1.6453)2-(0.4431)2)/ (2*9.81) =.1280 mH2O
- A2/A1=d2/d1= (13.7*10-3)/ (26.4*10-3) =.5189=.52

From table (A), making interpolation=.376

hf =k*u2^2/2*g = .376*1.6453^2/2*9.81 =.0315

ΔH=Δh + hf =.1280+.0315 = .15950

50^0 radius bend:

- Δh=h1-h2=470-230=239 mmH2O = 0.239 mH2O

- Q (Volumetric flowrate) =m/(ρ*t)

→Q=7.5 kg/(1000kg/m3*30.91s) =0.0002426m3/s

- u=Q/A, A=π/4*d2, d=13.7*10-3 m

→u=0.000203/(π/4*(13.7*10-3)2) =1.6453m/s

- Re= ρ*d*u/μ= (1000*13.7*10-3*1.6453)/ (1*10-3) =22541.200

- f=0.079*(22541.200)-0.25=0.006497 good
- Δhf=(4*f*L*u^2)/(2*d*g) = (4*6.74*10-3*914*10-3*$(1.6453)^2$)/ (2*13.7*10-3*9.81)

→Δhf=0.2347 mH2O

- ΔH=Δh-Δhf=0.0026 mH2O

- k=ΔH*2*g/u^2=0.065*2*9.81/ $(1.6453)^2$= .0188
- r/d= (50*10-3)/ (13.7*10-3) =3.650

100^0 radius bend:

Δh=h1-h2=534-320=214 mmH2O = 0.214 mH2O

- Q(Volumetric flowrate)=m/(ρ*t)

→Q=7.5 kg/(1000kg/m3*30.91s)= 0.0002426m3/s

- u=Q/A , A=π/4*d2 , d=13.7*10-3 m

→u=0.000203/(π/4*(13.7*10-3)2)=1.377 m/s

- Re= ρ*d*u/μ=(1000*13.7*10-3*1.6453)/(1*10-3)= 22541.200

- f=0.079*(22541.200)-0.25=0.006497
- Δhf=(4*f*L*u^2)/(2*d*g)=(4*6.74*10-3*914*10-3*(1.6453)^2)/(2*13.7*10-3*9.81)

→Δhf=0.2374 mH2O

- ΔH=Δh-Δhf= -0.023 mH2O
- k=ΔH*2*g/u^2=-0.023*2*9.81/(1.6453)^2= -.1696
- r/d=(100*10-3)/(13.7*10-3)=7.299

150^0 radius bend:

Δh=h1-h2=587-347=240 mmH2O = 0.240 mH2O

- Q(Volumetric flowrate)=m/(ρ*t)

→Q=7.5 kg/(1000kg/m3*30.91s)= 0.0002426m3/s

- u=Q/A , A=π/4*d2 , d=13.7*10-3 m

→u=0.0002426/(π/4*(13.7*10-3)2)= 1.6453m/s

- Re= ρ*d*u/μ=(1000*13.7*10-3*1.377)/(1*10-3)= 22541.200

- f=0.079*(22541.200)-0.25=0.006497
- Δhf=(4*f*L*u2)/(2*d*g)

= (4*6.74*10-3*914*10-3*(1.6453)2)/(2*13.7*10-3*9.81)

→Δhf=0.2347mH2O

- ΔH=Δh-Δhf=0.0026 mH2O

- k=ΔH*2*g/u^2=0.077*2*9.81/(1.6453)^2=0.0188
- r/d=(150*10-3)/(13.7*10-3)=10.949

Table (A): Loss coefficient for sudden cotraction.

A_2/A_1	0	0.1	0.2	0.3	0.4	0.6	0.8	1.10
K	0.50	0.46	0.41	0.36	0.30	0.18	0.06	0

Determination of Losses in Small Bore Piping System

Data Sheet

T = 19°C   P = 1000mbar

For Gate va[lve]

open Full

H_2-H_1 Gate valve	1-2 Std Elbow 90	3-4 Straight pipe	5-6 Miter bend 90	Mass (kg)	Time (s)	
10 = 240-230	780-368	630-366	1035-528	7.5	~~42.93~~	30.33
365-215	815-430	633-469	1032-564		~~44.83~~	31.97
280-195	775-416	634-434	1020-605			39.00
300-173	770-469	630-455	1012-639			37
320-155	760-490	630-384	997-680			44.85

For Globe valve

Full

H_2-H_1 Globe valve	7-8 Sudden expansion	9-10 Sudden contraction	11-12 Radius bend 100	13-14 Radius bend 150	15-16 Radius bend 50	Mass (kg)	Time (s)
305-198	520-574	565-365	534-320	587-347	470-230	7.5	30.91
325-175	605-642	635-445	535-347	587-382	472-260		42.71
345-158	685-715	700-543	540-376	588-415	472-292		39.52
365-131	490-515	510-400	530-402	586-450	468-325		48.79
385-115	640-660	680-610	534-440	577-481	465-355		1:11.79

27/11/2018

Instructor signature:

Date:

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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (7)

Experiment title:

Pitot tube experiment

Type of the report: Short Report

Abstract

The main objectives of this experiment is to measure and plot the radial velocity profile of airflow in pipe by pitot tube and check if the flow is laminar or turbulent,in this experiment the flow was turbulent.The average velocity was determined by two ways, the first one is by calculating the mass flow(W) from the orifice discharge equation and it equals 0.0416 kg/s, and the other way by calculating W from radial velocity profile and it equals 0.0121 kg/s, and according to mass flow the mean velocity was calculated by two ways from the orifice discharge equation and it equals 53.84 m/s, and the other way by calculating W from radial velocity profile and it equals 15.72 m/s. The Re was calculated by two ways from the orifice discharge equation and it equals 89083.46, and the other way from radial velocity profile and it equals 26003.67, the both values of Re are greater than 2100, so the flow is turbulent.

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Results

Table 1 : Parametric data of orifice

Atmospheric pressure (Pa)	89700
Air temperature(K)	302.15
Fan pressure (pa)	5021.01
Pressure drop across orifice (pa)	1333.70
Pressure drop over test length (pa)	1353.32
Orifice area(m2)	0.001257
Pressure at orifice(pa)	94721.01
R(N.m/(kg.K))	287.05

Table 2 : Calculations of air density

Air density in pitot tube plane (kg/m3)	1.03704
Air density at the orifice (kg/m3)	1.09211

good

Table 4 : Air mass flow rate calculated by two method.

	Radial velocity profile	Orifice discharge equation
W(kg/s)	0.0121	0.0416 ✓
Reynold's number	26003.67	89083.46
Average velocity (m/s)	15.72	53.84 ↑45.16 check plz

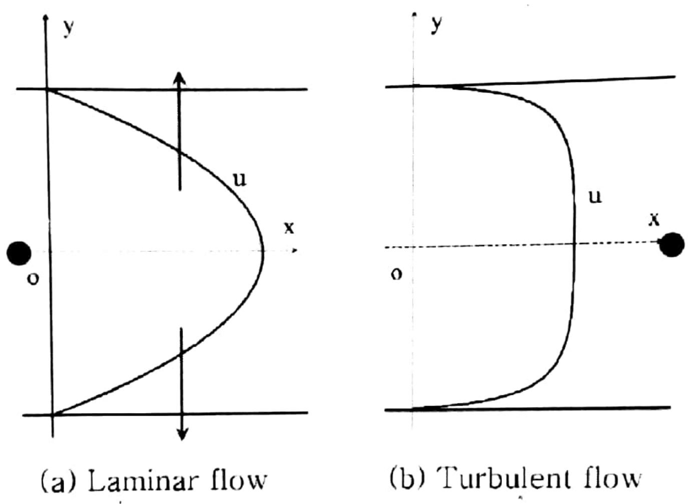

Figure 1 : The velocity profile of laminar and turbulent flow in references.

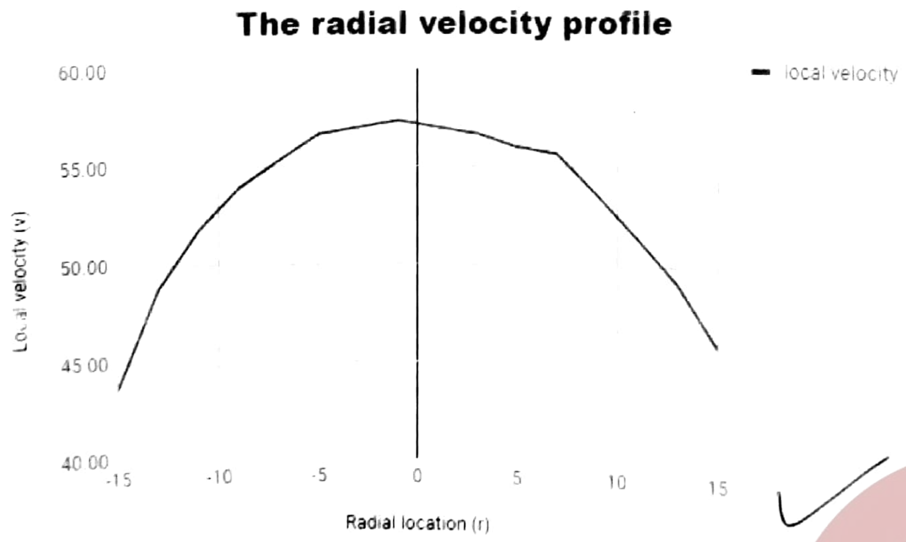

Figure 2 : The velocity profile generated from pitot tube data.

Table 5 : Data used for plotting v*r against r

v*r	integrate of r*v dr (wrong)
0.6904	0.35924
0.6396	
0.5660	
0.4825	
0.3898	0.13483
0.2802	
0.1701	
0.0570	
-0.0574	-0.13565
-0.1711	
-0.2835	
-0.3875	
-0.4857	-0.35665
-0.5701	
-0.6346	
-0.6556	
sum	0.0018

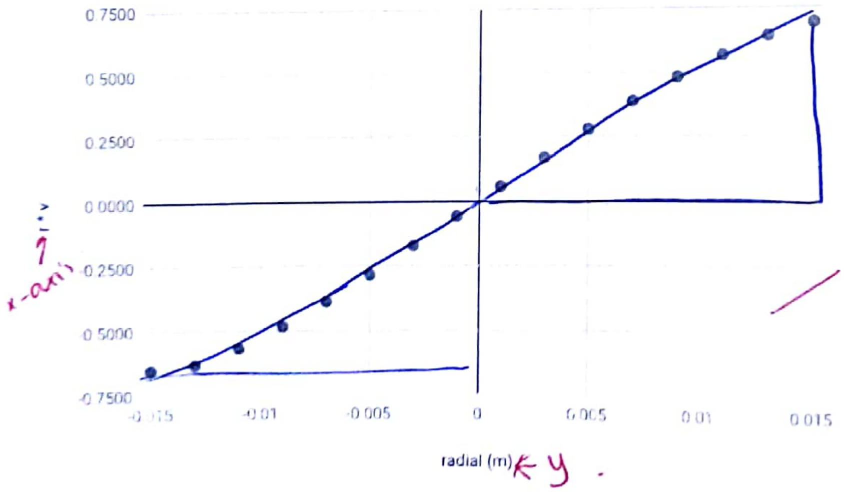

Figure 3 : Plot of r*v against r

Discussion

Pitot tube is a pressure measurement instrument used to measure fluid flow velocity,consists of a tube pointing directly into the fluid flow, commonly used to measure air flow in a duct. In this experiment the measurements of the pitot tube used to plot radial velocity profile.

The pitot tube measures two pressures: static pressure and stagnation pressure.

It is clear from the figure(2) that the velocity of the flow increases as get closer to the center, and decreases as get closer to the sides of the tube this because of the friction that occurs at the sides of the pipe by shear stress, so that the maximum velocity of the flow is at the center of the tube.

As shown in table(4)The mass flow rate of air (W) was calculated by two ways:

1-Radial velocity profile, The value of W is 0.0214 Kg/s was calculated by using ⅜ Simpson's rule.

2-Orifice discharge equation (measure pressure drop across the orifice)

The value of W is 0.0416 kg/s.

The reason of this differences is because orifice measures the full flow stream while the pitot tube detects the flow velocity at only one point in the flow stream.

The main difference is that, while an orifice measures the full flow stream, the pitot tube detects the flow velocity at only one point in the flow stream.

(after reaching turbulent) the velocity profile tends to be flat enough so that the insertion depth is not critical.

As shown in table(4)

The average velocity was also calculated by the two ways:

1-Radial velocity profile, $V_{avg.}$=15.72

2-Orifice discharge equation, $V_{avg.}$ =53.8363

As shown in table(4) Also, Reynold's number was also calculated by the two ways:

1-Radial velocity profile. The value of Re is 26003.67 .

2-Orifice discharge equation, The value of Re is 89083.46 .

The value of Re in both ways is greater than 2100 which means that the flow is turbulent.

As shown in figure(1), the velocity profile for turbulent is similar to plate(turns to be flat) at the center while the velocity profile is quadratic for laminar ,so that as shown in figure(2) the shape of velocity profile in this experiment is more closer to flat shape so it is more closer to turbulent flow.

Conclusion and recommendation

- From the velocity profile, the velocity is higher when the flow is at the center of the pipe and then it decreases away from center due to the frictions in the pipe.
- The mass flow rate in the orifice is little larger than the mass flow rate in the pitot tube that affect the average air velocity then Re.
- Reynold number is an indication for the type of flow in the pipe, the flow is turbulent since the two values of(Re) using the different values of average velocity is above 2000.
- Orifice measures the full flow stream, while the pitot tube detects the flow velocity at only one point in the flow stream.
- After some time, the temperature of the fan increasing due to over work, so that the density of the air will change and that's will affect the data, it is advised to turn off the fan until the temperature becomes lower to insure that the temperature is constant during experiment.

References

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4. T. (n.d.). What is the measure of a pitot tube? Retrieved November 13, 2018, from https://www.quora.com/What-is-the-measure-of-a-pitot-tube?fbclid=IwAR00i6-4wRy4vi6GvbiuQr3dlXjtAu92p9q1g-P66kEjiu1bScWW690guqQ

Appendix

1. Sample of calculation

All data represented in SI unit

- $Air\ dnsity\ at\ the\ orifice(\rho) = pressure\ at\ the\ orifice/(R * temperature)$
  =94721.01/ (287.05*302.15)
  =1.092 kg/m3
- $pressure\ at\ the\ orifice = Barometric\ pressure\ +\ Fan\ pressure$ 91033.7

  $$pressure\ at\ the\ orifice = 89700 + 1333.7044 = 94721.0048 \text{ pa}$$

  $$\rho at\ orifice = 94721.0048/(287.05 * 302.15)$$

  $$\rho at\ orifice = 1.09211 \text{ kg/m3}$$

- Air density in pitot tube plane(ρ) $= \frac{The\ static\ pressure\ in\ the\ pitot\ plane}{R*temperature}$
  =89945.09/ (287.05*302.15)
  =1.037 kg/m3
- The static pressure in the pitot plane =
  Barometric pressure + $\frac{276}{1524}$ test length pressure drop

  $$\text{The static pressure in the pitot plane} = 89700 + \frac{276 * 1353.3177}{1524} = 89945.089 \text{ pa}$$

- $\rho\ at\ pitot\ plane = 89945.08903/(287.05 * 302.15)$

  $$\rho\ at\ pitot\ plane = 1.03704 \text{ kg/m3}$$

- $mass\ flow\ rate(W) = \rho * orificearea * Cd * \sqrt{2\Delta p/\rho}$

  $$where\ Cd = Orifice\ discharge\ coefficient\ (0.613)$$

  $$\Delta p = pressure\ drop\ across\ the\ orifice\ (N/m^2)$$

  $$\rho = Air\ density\ at\ the\ orifice\ (Kg/m3)$$

  $$W = 1.09211 * 0.001257 * 0.613 * \sqrt{\frac{2 * 1333.7044}{1.09211}}$$

  $$W = 0.0416 \text{ kg/s}$$

- $Average\ air\ velocity\ in\ the\ pipe\ = \frac{W}{\rho\pi R^2}$

$$\rho = Air\ density\ in\ the\ pipe\ (Kg/m3)$$

$$R = Pipe\ radius\ (m)$$

$$Average\ air\ velocity\ in\ the\ pipe = \frac{0.0416}{1.09211*\pi*0.03^2} = 53.8363\ \text{m/s}$$

* pipe r = 0.0163

$$Air\ velocity\ at\ a\ point\ in\ the\ pitot\ plane = \sqrt{2(P_s - P)/\rho}$$

$$P_s = Stagnation\ pressure\ (N/m^2)$$

$$P = Static\ pressure (N/m^2)$$

$$\rho = Air\ density\ in\ pitot\ tube\ plane\ (Kg/m3)$$

$$local\ velocity\ for_{(r=0.015)} = \sqrt{2*\frac{1098.3448}{1.03704}} = 46.02\ \text{m/s}$$

The static pressure

- To plot v*r vs. r ,we calculate v*r at each radial position

  Where v is the local velocity

  v=46.02

  r=0.015

  v*r=0.69036

- To calculate mass flow rate

  w=density * volumetric flow rate = density *2*22/7 * (the integration of v*r wrt r)

- Using the numerical integration (⅜ simpson rule) 4 times for 16 points in this formula :

  3*h/8 *(f(x0)+3*f(x1)+3*f(x2)+f(x3))

  The sum of these integration was equal 0.0018

  w=1.092*2*22/7*0.0018

  w=0.012136

  Air average velocity = w / (density * 22/7 * (pipe radius)^2)

  Air average velocity = 0.012136 / (1.092 * 22/7 * (0.03/2)^2)

  Air average velocity = 15.714

  Re = density * air average velocity * diameter of pipe / viscosity

  Re =1.092 *15.714 * 0.03 /(1.98*10^-5)

  Re =26003.67

Pitot tube Data Sheet

Atmospheric Pressure: 997 - 100 = 897 mili bar

Air Temperature: 29 °c

Fan Pressure: 51.2 cm.H₂O

Pressure drop across the Orifice: 13.6 cm.H₂O

Pressure drop over the Test length: 13.8 cm.H₂O

Pitot Tube position (mm)	Vernier reading (mm)	Pressure Difference ($P_S - P$) (cmH₂O)
0	6.6	11.2
2	6.8	12.8
4	7.0	14.0
6	7.2	15.2
8	7.4	16.4
10	7.6	16.6
12	7.8	17.0
14	8.0	17.2
16	8.2	17.4
18	8.4	17.2
20	8.6	17.0
22	8.8	16.2
24	9.0	15.4
26	9.2	14.2
28	9.4	12.6
30	9.6	10.10

6/11/2016

95/100

The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (8)

Experiment title:

Positive Displacement Pumps Characteristics

Type of the report: Short Report

Abstract

The goal of this experiment is to demonstrate how pumps work, and show the performance of a selection of positive displacement pumps at constant and variable speed and pressure.
The rotary vane pump is a positive displacement pump that is ideally deliver a fixed quantity of fluid with each revaluation of the pump rotor or drive shaft,the pump performs differently for a range of delivery pressure at constant speed.
The expected flow and overall pump and volumetric efficiencies was calculated , a sample of main results are:
At constant speed =400 rev/min
expected flow=4.44E-05 m^3/s
overall pump efficiency % = 37.83%
Volumetric efficiency% = 106.45%

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Results

Part (1) : The Effect of Delivery Pressure at Constant Speed.

Table 1: result of varying pressure at constant speed= 400 rev/min.

Constant speed							
Speed (rev/min)=					400		
Trial num.	Torque (Nm)	Speed (rev./min)	Shaft Power (W)	P1 (bar)	P2 (bar)	T1 (C)	F (L/min)
1	0.67	404	28	-0.05	2	18.2	3.1
2	0.80	405	33	-0.05	3	18.2	3.1
3	0.92	403	39	-0.05	4	18.1	3.1
4	1.07	401	45	-0.05	5	18.2	3.0
5	1.22	400	51	-0.05	6	18.2	3.0
6	1.35	398	56	-0.05	7	18.2	3.0
7	1.52	396	63	-0.04	8	18.1	2.9
8	1.66	402	70	-0.04	9	18.2	3.0
9	1.80	403	76	-0.04	10	18.2	3.0
10	1.94	401	80	-0.04	11	١٨,٢	2.9
11	2.06	399	86	-0.05	12	18.3	2.7
12	2.19	396	91	-0.05	13	18.4	2.3
13	2.32	400	97	-0.05	14	19.7	1.9

Table 2:result of varying pressure at constant speed= 1100 rev/min.

Constant speed							
Speed (rev/min)=					1100		
Trial num.	Torque (Nm)	Speed (rev./min)	Shaft Power (W)	P1 (bar)	P2 (bar)	T1 (C)	F (L/min)
1	1.15	1096	133	-0.11	2	18.8	7.7
2	1.30	1107	150	-0.10	3	19.7	7.7
3	1.37	1103	158	-0.10	4	18.9	7.7
4	1.44	1101	167	-0.10	5	19.0	7.9

5	1.51	1100	173	-0.10	6	19.0	7.6
6	1.66	1098	191	-0.10	7	19.1	7.5
7	1.78	1097	204	-0.10	8	19.2	7.4
8	1.91	1100	219	-0.10	9	19.8	7.4
9	2.00	1100	230	-0.10	10	20.0	7.5
10	2.12	1097	244	-0.10	11	20.0	7.3
11	2.24	1095	257	-0.10	12	0.0	7.1
12	2.33	1097	268	-0.10	13	22.0	6.7
13	2.43	1097	280	-0.10	14	22.0	6.2

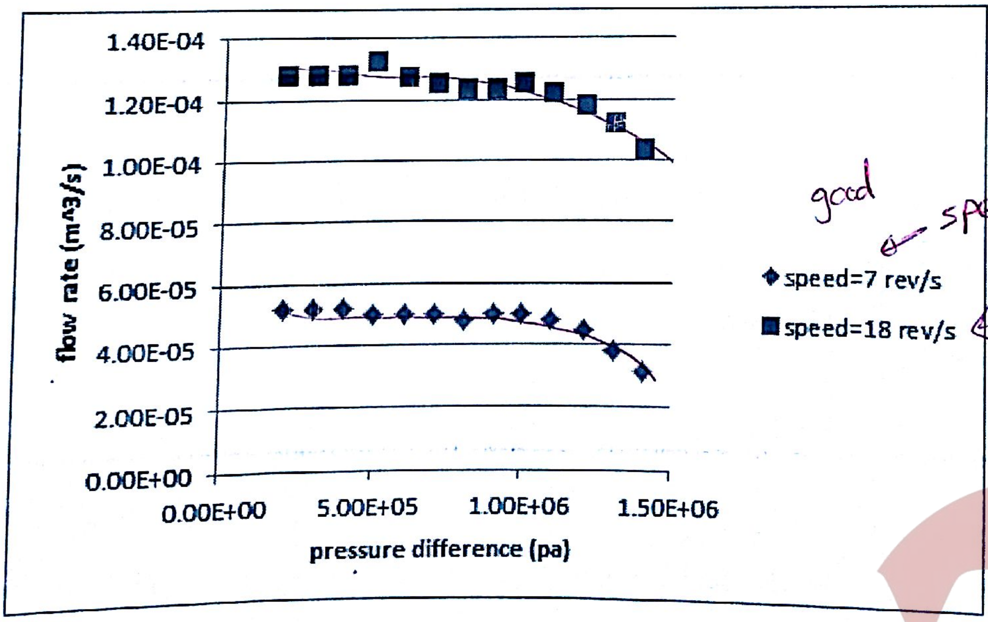
Table 3: parameters at constant speed=400 rev/min.

Trial num.	delta P(Pa)	Wp(W)	Expected flow rate	overall pump efficiency %	Volumetric efficiency	Vs= 6.60E-06 (m3/rev)
1	2.05E+05	10.59	4.44E-05	37.83%	116.26%	6.60E-06
2	3.05E+05	15.76	4.46E-05	47.75%	115.97%	6.60E-06
3	4.05E+05	20.93	4.43E-05	53.65%	116.55%	6.60E-06
4	5.05E+05	25.25	4.41E-05	56.11%	113.35%	6.60E-06
5	6.05E+05	30.25	4.40E-05	59.31%	113.64%	6.60E-06
6	7.05E+05	35.25	4.38E-05	62.95%	114.21%	6.60E-06
7	8.04E+05	38.86	4.36E-05	61.68%	110.96%	6.60E-06
8	9.04E+05	45.20	4.42E-05	64.57%	113.07%	6.60E-06
9	1.00E+06	50.20	4.43E-05	66.05%	112.79%	6.60E-06
10	1.10E+06	53.36	4.41E-05	66.70%	109.57%	6.60E-06
11	1.21E+06	54.23	4.39E-05	63.05%	102.53%	6.60E-06
12	1.31E+06	50.03	4.36E-05	54.97%	88.00%	6.60E-06
13	1.41E+06	44.49	4.40E-05	45.87%	71.97%	6.60E-06

check plz → OK

Table 4: parameters at constant speed=1100 rev/min

Trial num.	delta P (Pa)	Wp(W)	Expected flow rate m3/s	overall pump efficiency %	Volumetric efficiency%	Vs=6.60E-06 (m3/rev)
1	2.11E+05	27.08	1.21E-04	20.36%	106.45%	6.60E-06
2	3.10E+05	39.78	1.22E-04	26.52%	105.39%	6.60E-06
3	4.10E+05	52.62	1.21E-04	33.30%	105.77%	6.60E-06
4	5.10E+05	67.15	1.21E-04	40.21%	108.72%	6.60E-06
5	6.10E+05	77.27	1.21E-04	44.66%	104.68%	6.60E-06
6	7.10E+05	88.75	1.21E-04	46.47%	103.49%	6.60E-06
7	8.10E+05	99.90	1.21E-04	48.97%	102.21%	6.60E-06
8	9.10E+05	112.23	1.21E-04	51.25%	101.93%	6.60E-06
9	1.01E+06	126.25	1.21E-04	54.89%	103.31%	6.60E-06
10	1.11E+06	135.05	1.21E-04	55.35%	100.83%	6.60E-06
11	1.21E+06	143.18	1.20E-04	55.71%	98.24%	6.60E-06
12	1.31E+06	146.28	1.21E-04	54.58%	92.54%	6.60E-06
13	1.41E+06	145.70	1.21E-04	52.04%	85.63%	6.60E-06



good
speed 400 rev/min
1100
No need to convert.

Figure 1: flow rate against pressure difference.

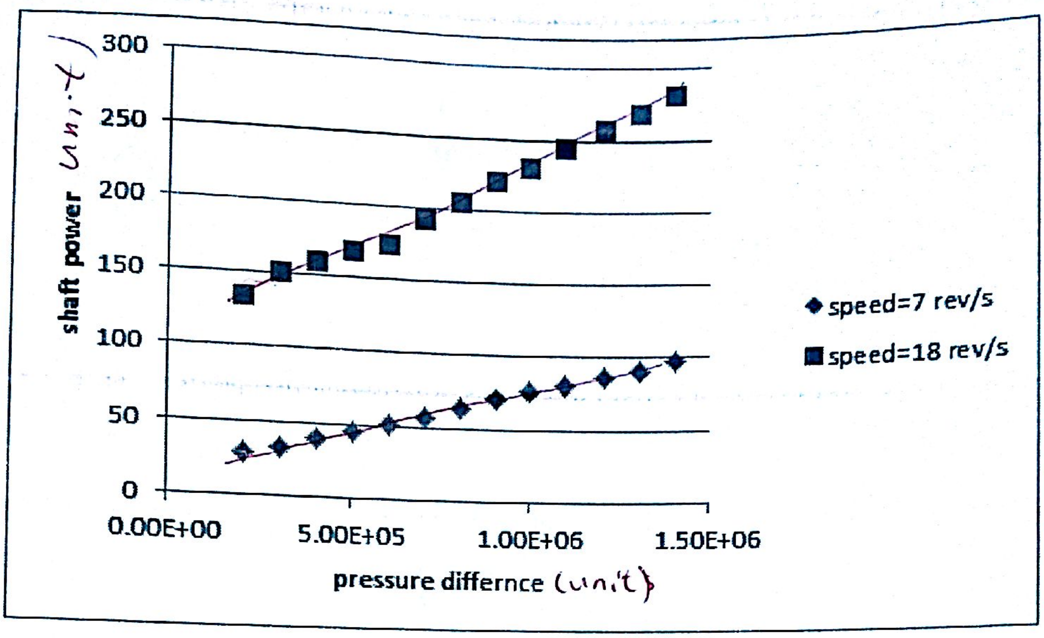


Figure 2: shaft power against pressure difference and comparing different values of speed

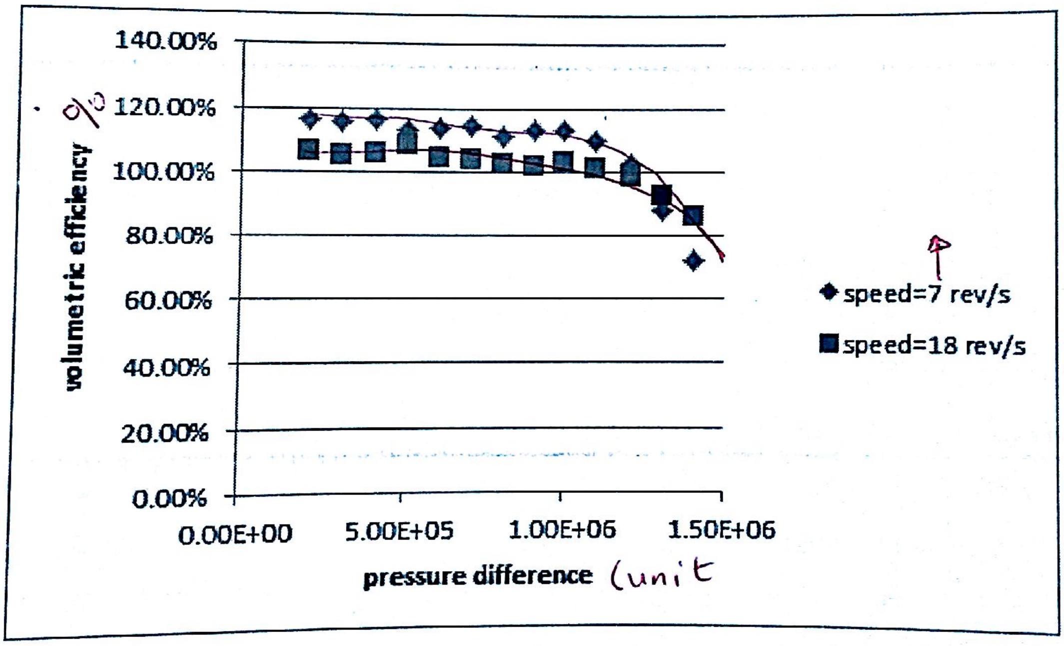


Figure 3 :volumetric efficiency against pressure difference and comparing different values of speed

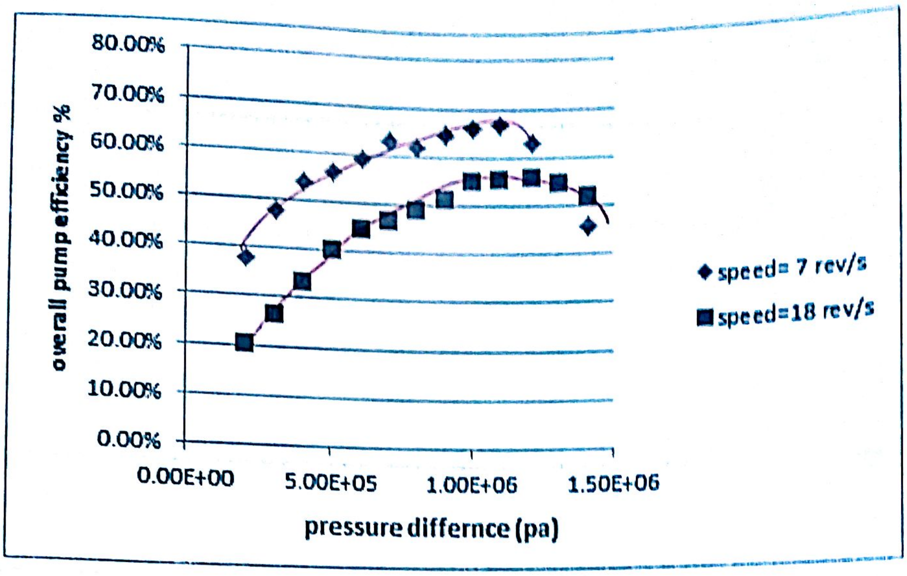


Figure 4 : overall efficiency against pressure difference and comparing different values of speed

Part (2) : The Effect of Speed at Constant Delivery Pressure.

Row Data

Table 5 : Results of varying speed at constant pressure = 3 bar.

Constant pressure							
	Pressure P2 (bar)=				3		
Trial num.	Torque (Nm)	Speed (rev./min)	Shaft Power (W)	P1 (bar)	P2 (bar)	T1 (C)	F (L/min)
1	0.66	200	14	-0.02	3.1	21.5	1.4
2	0.68	301	22	-0.03	3.0	21.4	2.2
3	0.79	405	33	-0.04	3.0	21.6	3
4	0.85	505	45	-0.05	3.0	21.5	3.7
5	0.91	605	57	-0.06	3.0	21.1	4.5
6	0.95	703	70	-0.07	3.0	21.4	5.2
7	1.01	803	85	-0.07	3.1	21.5	5.9
8	1.04	899	98	-0.08	3.0	21.5	6.5
9	1.06	998	111	-0.09	3.0	21.5	7.0
10	1.11	1103	128	-0.09	3.0	21.6	7.6
11	1.18	1201	149	-0.10	3.0	21.7	8.1

Table 6 :Results of varying speed at constant pressure = 7 bar.

Constant pressure							
Pressure P2 (bar)=						7	
Trial num.	Torque (Nm)	Speed (rev./min)	Shaft Power (W)	P1 (bar)	P2 (bar)	T1 (C)	F (L/min)
1	1.31	197	27	-0.02	7.1	21.7	1.3
2	1.23	297	38	-0.03	7.0	21.6	2.1
3	1.38	395	57	-0.04	7.0	21.5	2.9
4	1.47	501	77	-0.05	7.1	21.6	3.7
5	1.52	604	97	-0.05	7.1	21.3	4.4
6	1.58	700	113	-0.06	7.0	21.4	5.1
7	1.58	800	133	-0.07	7.0	21.6	5.8
8	1.61	901	151	-0.08	7.0	22.0	6.4
9	1.61	1001	169	-0.08	7.0	22.0	6.9
10	1.65	1102	192	-0.09	7.0	21.8	7.5
11	1.69	1201	212	-0.10	7.1	22.1	8.0

Table 7 : Parameters of constant pressure = 3 bar

Trial num.	delta P (Pa)	Wp(W)	Expected flow rate m3/s	overall pump efficiency %	Volumetric efficiency%	Vs= 6.60E-06 (m3/rev)
1	3.12E+05	7.28	2.20E-05	52.00%	106.06%	6.60E-06
2	3.03E+05	11.11	3.31E-05	50.50%	110.74%	6.60E-06
3	3.04E+05	15.20	4.46E-05	46.06%	112.23%	6.60E-06
4	3.05E+05	18.81	5.56E-05	41.80%	111.01%	6.60E-06
5	3.06E+05	22.95	6.66E-05	40.26%	112.70%	6.60E-06
6	3.07E+05	26.61	7.73E-05	38.01%	112.07%	6.60E-06
7	3.17E+05	31.17	8.83E-05	36.67%	111.32%	6.60E-06
8	3.08E+05	33.37	9.89E-05	34.05%	109.55%	6.60E-06
9	3.09E+05	36.05	1.10E-04	32.48%	106.27%	6.60E-06
10	3.09E+05	39.14	1.21E-04	30.58%	104.40%	6.60E-06

11	3.10E+05	41.85	1.32E-04	28.09%	102.19%	6.60E-06

Table 8 : Parameters of constant pressure = 7 bar

Trial num.	delta P (Pa)	Wp(W)	Expected flow rate m3/s	overall pump efficiency %	Volumetric efficiency%	Vs= 6.60E-06 (m3/rev)
1	7.12E+05	15.43	2.17E-05	57.14%	99.98%	6.60E-06
2	7.03E+05	24.61	3.27E-05	64.75%	107.13%	6.60E-06
3	7.04E+05	34.03	4.35E-05	59.70%	111.24%	6.60E-06
4	7.15E+05	44.09	5.51E-05	57.26%	111.90%	6.60E-06
5	7.15E+05	52.43	6.64E-05	54.05%	110.38%	6.60E-06
6	7.06E+05	60.01	7.70E-05	53.11%	110.39%	6.60E-06
7	7.07E+05	68.34	8.80E-05	51.39%	109.85%	6.60E-06
8	7.08E+05	75.52	9.91E-05	50.01%	107.62%	6.60E-06
9	7.08E+05	81.42	1.10E-04	48.18%	104.44%	6.60E-06
10	7.09E+05	88.63	1.21E-04	46.16%	103.12%	6.60E-06
11	7.20E+05	96.00	1.32E-04	45.28%	100.93%	6.60E-06

good

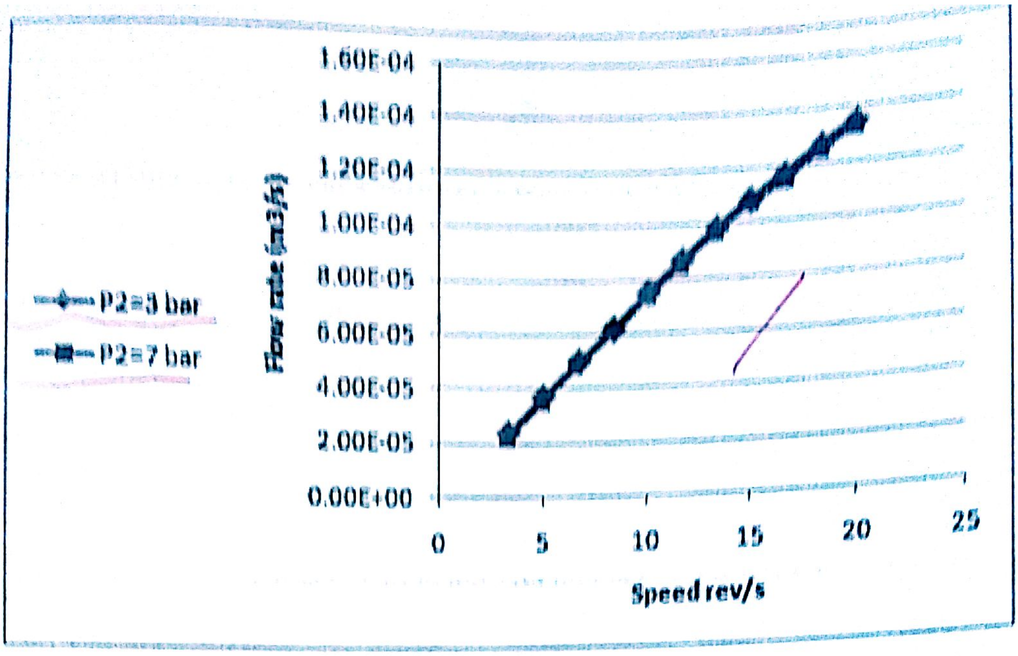


Figure 5 : Flow rate against speed for 2 values of pressure: 3 , 7 bar.

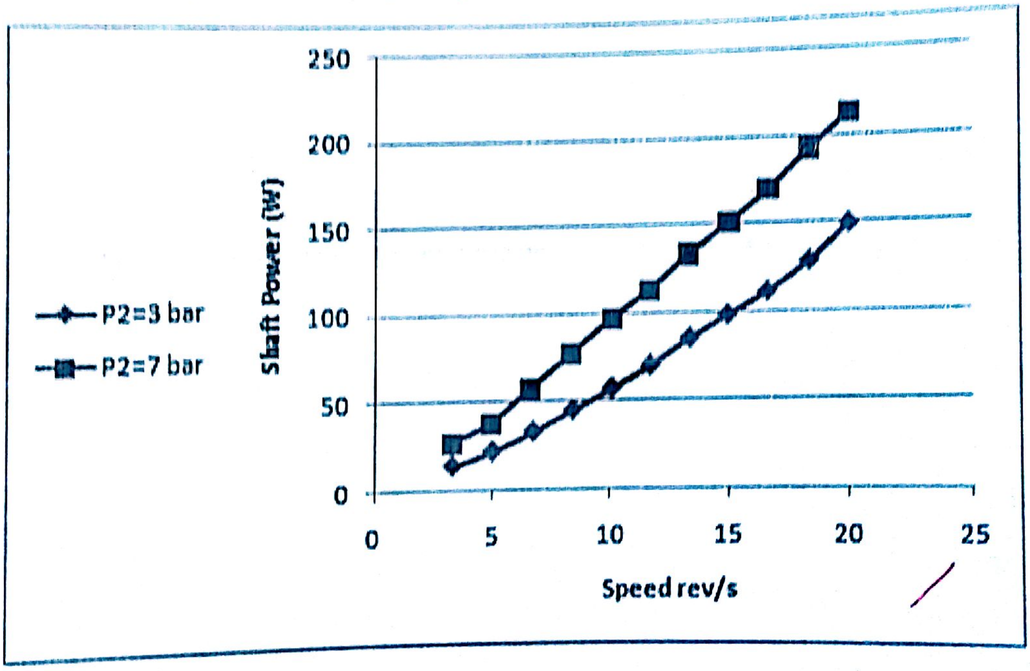


Figure 6 :Shaft power against speed for 2 values of pressure: 3 , 7 bar.

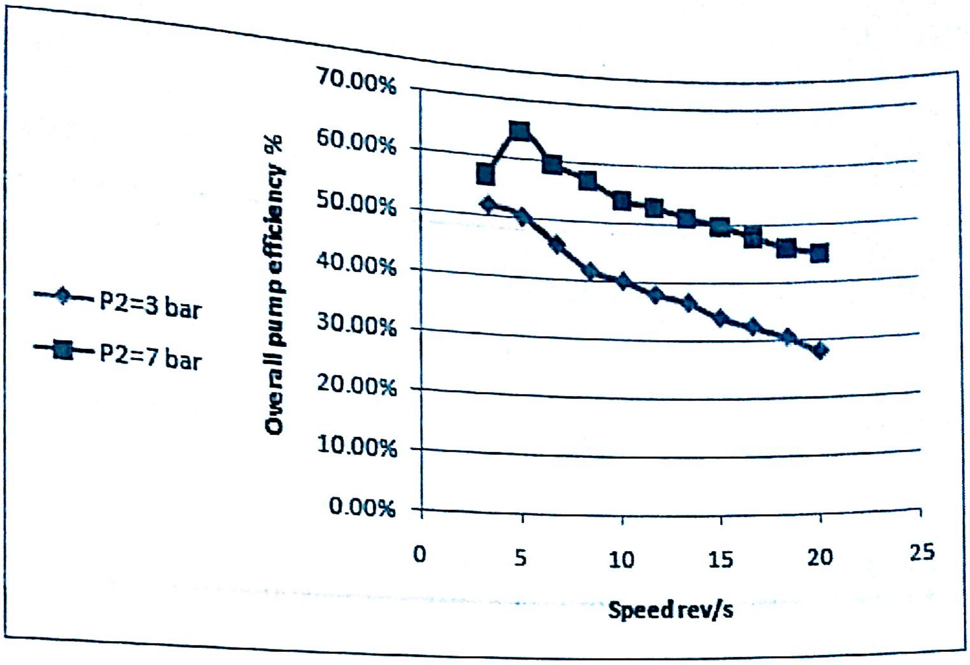


Figure 7 : Overall pump efficiency against speed for 2 values of pressure: 3 , 7 bar.

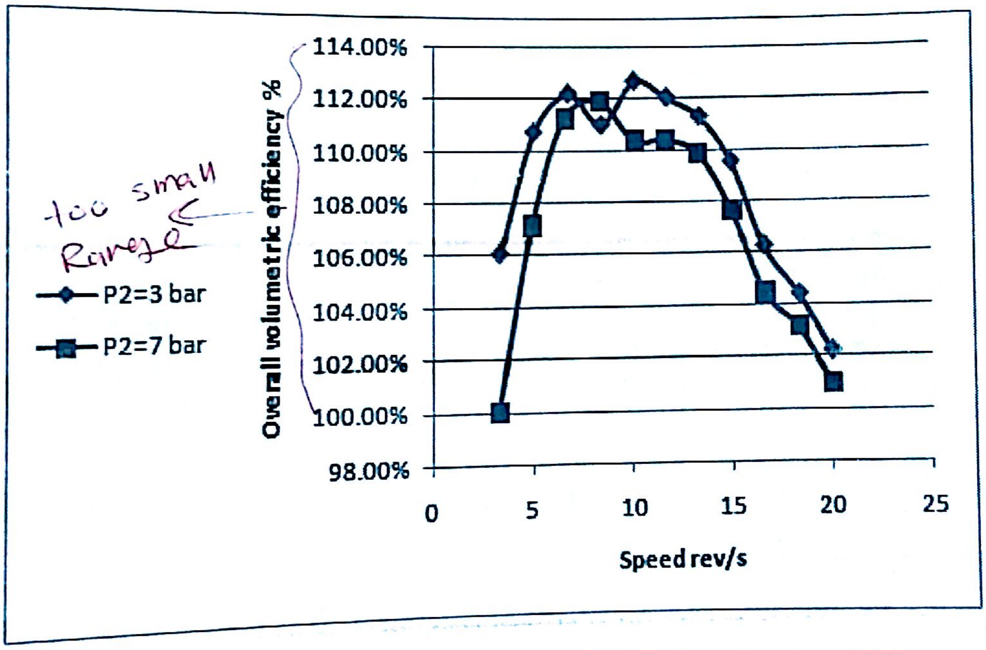


Figure 8 : Overall volumetric efficiency against speed for 2 values of pressure: 3 , 7 bar.

Discussion

Part 1 : The Effect of Delivery Pressure at Constant Speed.

The rotary vane pump is a positive displacement pump that is ideally deliver a fixed quantity of fluid with each revaluation of the pump rotor or drive shaft,the pump performs differently for a range of delivery pressure at constant speed.

At constant speed =7 rev/s and 18 rev/s ,if the pressure difference increases then the flow rate starts to decrease that is shown in the figure(1),but when the speed is higher the flow rate also raises at constant pressure difference.

From the figure(2),when the pressure difference increases the work done to rotate a shaft connected to the system(shaft power) increases. At constant high speed, the shaft power is much higher than low one.
From figure (3)
The best volumetric efficiency for the speed =7 rev/s is 116.55% when the pressure difference is 4.05*10^5 pa .
The best volumetric efficiency for the speed =18 rev/s is 108.72% when the pressure difference is 5.05*10^5 pa
The volumetric efficiency effect by flow rate so that the flow rate increase the volumetric efficiency increase with constant Vs. and constant speed ,then the pressure difference start to decrease. Also, the low speed values have a greater volumetric efficiency.

The overall pump efficiency affected by hydraulic power (that is affected positively by pressure difference between delivery and suction, and affected positively with flow rate) and shaft power. Increasing the flow rate will decrease the pressure difference, so that the most effective term is shaft power. If the shaft power is low then we get high overall pump efficiency
From graph(4),low speed help the pump to have higher efficiency.

Part 2 : The Effect of Speed at Constant Delivery Pressure.

At constant delivery pressure 3 bar and 7 bar, as shown in figure() and figure() , if the speed increases the flow rate also increases.

It is noticed form figure(5) that increasing of flow rate with increasing speed at constant delivery pressure (3 bar and 7 bar) is the same, so the value of delivery pressure does not affect very much when the increasing of flow rate is desired ,but the speed of the pump is important.

A shown in figure (6), as the speed increases, the shaft power also increases.
As shown in table (7) and table (8) The hydraulic power is also increases with increasing speed, and that can be explained by the relationship between hydraulic power and flow rate, hydraulic power affected by delivery pressure-suction and volumetric flow rate, so when the delivery pressure is constant and the speed is increasing, the flow rate will also increase so that the hydraulic power will increase.
From figure (7), it is noticed that the major trend of Overall pump efficiency curve is decreasing with increasing speed.

The overall volumetric efficiency affected by flow rate (direct relationship) and speed of the pump (inverse relationship)
, it is clear from figure (8), that the best Overall volumetric efficiency achieved at P2=3 bar is112.70% at a speed of 10.08 rev/s,
And the best Overall volumetric efficiency achieved at P2=7 baris 111.90% at a speed of 8.35 rev/s. ??
Before these values the major trend of efficiency curve is increasing with increasing speed, but after these values the major trend of efficiency curve is decreasing with increasing the value of speed.

Conclusion

Part 1 : The Effect of Delivery Pressure at Constant Speed.

-For the vane pump, increasing flow rate will affect the pressure difference between delivery and suction decreasingly.
-There is a lot of factors that help us to select a positive displacement pump at constant speed: Flow rate, pressuredifference, volumetric and overall efficiencies.
- At constant speed, if working under low speed conditions is achieved then the overall pump efficiency will raise.

Part 2 : The Effect of Speed at Constant Delivery Pressure.

-The rate of increasing flow rate with increasing speed is the same at a different constant delivery pressure.

-There is a lot of factors that help us to select a positive displacement pump at delivery pressure:

Flow rate,speed,volumetric and overall efficiencies.

-Increasing speed keeping higher constant value of delivery pressure yields to higher overall pump efficiency.

-Increasing speed keeping lower constant value of delivery pressure yields to higher overall volumetric efficiency.

References

Chemical Engineering Laboratory (1) (6th ed.). (2016). Amman: University of Jordan.

Appendix

Taking the first row from each table:

At constant speed =400 rev/min

$\Delta P = P_2 - P_1$

$= (2-(-0.05)) = 2.05$ bar $= 2.05*10^5$ Pa ✓

- $Q_v\ (m^3/s) = Q_v\ (L/min) * (\frac{1}{60*1000})$

  $= 3.1*\frac{1}{60*1000} = 5.17*10^{-5} m^3/s$ ✓ see your table no. 3

- $W_p = \Delta P * Q_v$

  $= 2.05*10^5 * 5.17*10^{-5} = 10.59$ W ✓

- N_P Speed (rev/s) = speed (rev/min) / 60

  = 404 (rev/min) / 60 = 6.73 rev/s

- Expected flow rate = $V_S * N_P$

  V_S $= 6.6*10^{-6}*6.73 = 4.44*10^{-5} m^3/s$

- Overall pump efficiency : $\eta p = (\frac{WP}{WD})*100$

  $= \frac{10.59}{28}*100\% = 37.83\%$ ✓

- Volumetric efficiency : $\eta v = (\frac{Qv}{VS * NP})*100$

  $\frac{5.17*10^{-5}}{4.44*10^{-5}}*100\% = 116.4\%$ ✓

Expected Flow Rate = $\frac{404 * 6.6}{1000}$ (rev/min, cc/rev) = 2.67 L/min ⇕ 4.44×10^{-5} m3/s ✓

At constant speed =1100 rev/min

$\Delta P = P_2 - P_1$

$= (2-(-0.11)) = 2.11$ bar $= 2.11*10^5$ Pa ✓

cont'

is there any page missing

P_2 2-14 bar   Speed ±5   Speed < 400 / 1100

[...] Speed Power P_1 P_2 T_1 F_1

P < 3 / 7

Speed 200-1200 +100

Constant speed = 400 rev/min

Trials	Torque Nm	Speed rev/min	Power W	P_1 bar	P_2 bar	T_1 °C	F_1 l/min
1	0.67 Nm	401	28	-0.05	2	18.2	3.1
2	0.8	405	33	-0.05	3	18.2	3.1
3	0.92	403	39	-0.05	4	18.1	3.1
4	1.07	401	45	-0.05	5	18.2	3
5	1.22	400	51	-0.05	6	18.2	3
6	1.35	398	56	-0.05	7	18.2	3
7	1.52	396	63	-0.04	8	18.1	2.9
8	1.66	~~39~~ 402	~~6~~ 70	-0.054	9	18.2	3
9	1.80	403	76	-0.04	10	18.2	3
10	1.94	401	80	-0.04	11	18.2	2.9
11	2.06	399	86	-0.05	12	18.3	2.7
12	2.19	396	91	-0.05	13	18.4	2.3
13	2.32	~~392~~ 400	~~95~~ 97	-0.05	14	19.7	1.89

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Constant speed = 1100

Trials	Torque Nm	Speed rev/min	Power W	P_1 bar	P_2 bar	T_1 °C	F_1 l/min
1	1.15	1096	133	-0.11	2	18.8	7.7
2	1.30	1102	150	-0.10	3	17.8	7.7
3	1.37	1103	158	-0.10	4	18.9	7.7
4	1.44	1101	167	-0.10	5	19	7.9
5	1.51	1100	173	-0.10	6	19	7.6
6	1.66	1098	191	-0.10	7	19.1	7.5
7	1.78	1097	204	-0.10	8	19.2	7.4
8	1.91	1100 ~~1095~~	219	-0.10	9	19.8	7.4
9	2.00	1100	230	-0.10	10	20	7.5
10	2.12	1097	244	-0.10	11	20	7.3
11	2.24	1095	257	-0.10	12	20	7.1
12	2.33	1097	~~270~~ 268	-0.10	13	~~20.1~~ 22	6.7
13	2.43	~~1089~~ 1097	~~277~~ 280	-0.10	14		

Input pressure:

P = 3 bar

variation of speed

	0.66	200	14	-.02	3.1	21.5	1.4
	0.68	301	22	-0.03	3.0	21.4	2.2
	0.79	405	33	-0.04	3.0	21.6	3.0
4	0.85	505	45	-0.05	3.0	21.5	3.7
5	0.91	605	57	-0.06	3.0	21.1	4.5
6	0.95	703	70	-0.07	3.0	21.4	5.2
7	1.01 ~~0.99~~	803	85	-0.07	3.1	21.5	5.9
8	1.04	899	98	-0.08	3.0	21.5	6.5
9	1.06	998	111	-0.09	3.0	21.5	7.0
10	1.11	1103	128	-0.09	3.0	21.6	7.6
11	1.18	1201	149	-0.10	3.0	21.7	8.1

(B) P = 7 bar

1	1.31	197	27	-0.02	7.1	21.7	1.3
2	1.23	297	38	-0.03	7.0	21.6	2.1
3	1.38	395	57	-0.04	7.0	21.5	2.9
4	1.47	501	77	-0.05	7.1	21.6	3.7
5	1.52	604	97	-0.05	7.1	21.3	4.4
6	1.58	700	113	-0.06	7.0	21.4	5.1
7	1.58	800 ~~799~~	133	-0.07	7.0	21.6	5.8
8	1.61	901	151	-0.08	7.0	22.0	6.4
9	1.61	1001	169	-0.08	7.0	22.0	6.9
10	1.65	1102	192	-0.09	7.0	21.8	7.5
11	1.69	1201	212	-0.10	7.1	22.1	8.0

30/10/2018

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The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1)

Experiment Number: (10)

Experiment title:

The Performance of a Radial Fan

Type of the report: Short Report

Done by

Abstract

Any pumping job can be done with roto-dynamic machines, having rotating elements called impellers. Roto-dynamic machines are classified as radial, mixed (centrifugal) or axial flow. Centrifugal machines are preferred when high pressure differences are required. Very high pressure may be produced by multi-stage radial flow machines. The air compressor for a jet engine is an example of multi-stage fan. The Objective of this experiment is to examine the performance of a radial flow rotor in air over a wide range of operating conditions for impeller with radial blades. The relationships between parameters was plotted. A sample of main results :
At a speed of 1050 rpm and gate opening 100%
Force(N)=1.8
Q (m3/s)= 0.04
delta Ps (Pa)= 9.41
Air power (W)= 3.47
Net efficiency= 0.22

Table of Contents

Results

Table 1: Raw data

T(K)	289.15
atm.p (pa)	99500
torque arm(m)	0.179
density	1.199

Table 2: Data and results from experimental work at speed = 1050 rpm

speed (rpm)	1050	rev/s =	17.5	N (rad./s)	110					
gate opening	h1(inlet) mmH2O	-h2 (suction) mmH2O	h3 (discharge) mmH2O	force (N)	h out - h in (cm H2O)	delta Ps (Pa)	Q (m3/s)	Air power (W)	Shaft power (W)	net efficiency
100	5	6	2	0.8	0.80	9.41	0.04	3.47	15.75	0.22
90	5	6	2	0.8	0.80	9.41	0.04	3.47	15.75	0.22
80	5	6	2	0.8	0.80	9.41	0.04	3.47	15.75	0.22
70	5	5	3	0.8	0.80	9.41	0.04	3.47	15.75	0.22
60	4	4	3	0.8	0.70	8.23	0.04	2.72	15.75	0.17
50	4	4	3	0.8	0.70	8.23	0.04	2.72	15.75	0.17
40	3	3	4	0.8	0.70	8.23	0.03	2.35	15.75	0.15
30	2	2	5	0.8	0.70	8.23	0.03	1.92	15.75	0.12
20	1	1	6	0.75	0.70	8.23	0.02	1.36	14.77	0.09
10	1	0	7	0.5	0.70	8.23	0.02	1.36	9.85	0.14

Table 3: Data and results from experimental work at speed = 1520 rpm

speed (rpm)	1520	rev/s =	25.33	N (rad./s)	159.24					
gate opening	h1(inlet) mmH2O	-h2 (suction) mmH2O	h3 (discharge) mmH2O	force (N)	h out - h in (cm H2O)	delta Ps (Pa)	Q (m3/s)	Air power (W)	Shaft power (W)	net efficiency
100	16	18	2	1.1	2.00	23.52	0.08	15.52	31.35	0.49
90	17	18	2	1.1	2.00	23.52	0.08	16.00	31.35	0.51
80	16	17	3	1.1	2.00	23.52	0.08	15.52	31.35	0.49
70	15	16	4	1.1	2.00	23.52	0.08	15.03	31.35	0.48
60	13	15	6	1.1	2.10	24.70	0.07	14.69	31.35	0.47
50	11	12	9	1.1	2.10	24.70	0.07	13.51	31.35	0.43
40	8	9	12	1.1	2.10	24.70	0.06	11.52	31.35	0.37
30	6	7	15	1.1	2.20	25.88	0.05	10.45	31.35	0.33
20	3	4	17	1.1	2.10	24.70	0.03	7.06	31.35	0.23
10	1	2	19	1.1	2.10	24.70	0.02	4.07	31.35	0.13

Table 4 : Data and results from experimental work at speed = 2150 rpm

speed (rpm)	2150	rev/s =	35.83	N (rad./s)	225.24					
gate opening	h1(inlet) mmH2O	-h2 (suction) mmH2O	h3 (discharge) mmH2O	force (N)	h out - h in (cm H2O)	delta Ps (Pa)	Q (m3/s)	Air power (W)	Shaft power (W)	net efficiency
100	29	30	2	2.7	3.20	37.64	0.11	33.43	108.86	0.31
90	28	29	3	2.6	3.20	37.64	0.10	32.85	104.83	0.31
80	27	28	4	2.4	3.20	37.64	0.10	32.26	96.76	0.33
70	25	26	6	2.2	3.20	37.64	0.10	31.04	88.70	0.35
60	21	23	9	2.1	3.20	37.64	0.09	28.45	84.67	0.34
50	18	19	14	2	3.30	38.82	0.08	27.16	80.64	0.34
40	14	15	16	1.9	3.10	36.46	0.07	22.50	76.60	0.29
30	9	11	23	1.6	3.40	39.99	0.06	19.79	64.51	0.31
20	5	6	26	1.5	3.20	37.64	0.04	13.88	60.48	0.23
10	2	2	30	1.4	3.20	37.64	0.03	8.78	56.44	0.16

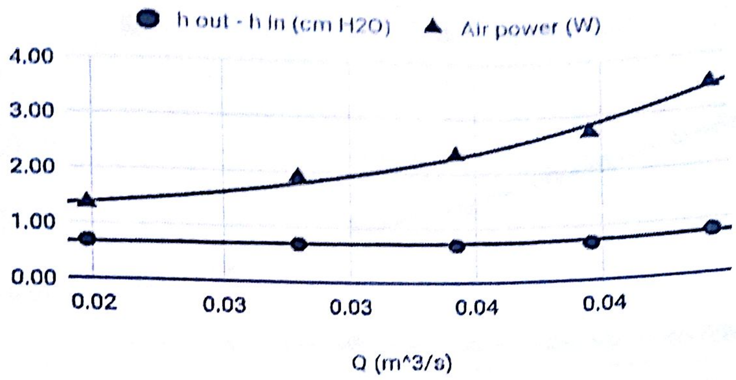

Figure 1 : (hout - hin), total air power, against (Q) at speed = 1050 rpm

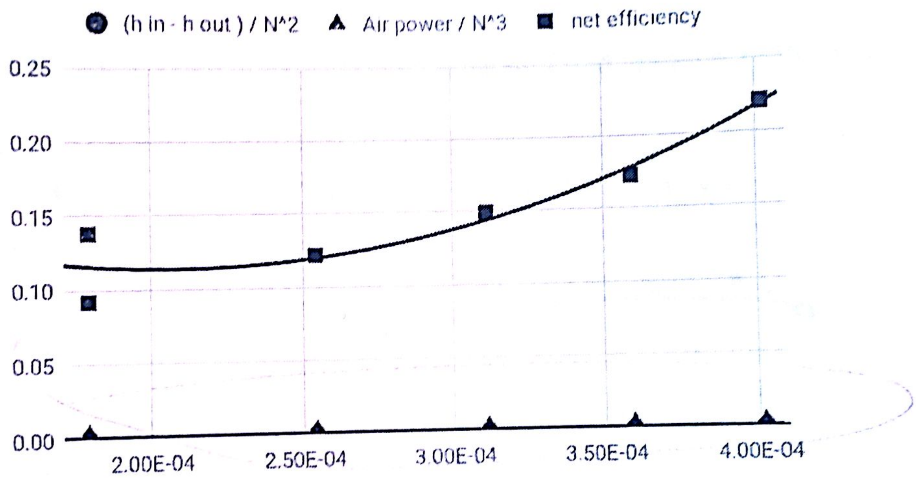

Figure 2 : (hout - hin)/N2, total air power /N3, and (η) against (Q/N) at speed = 1050 rpm.

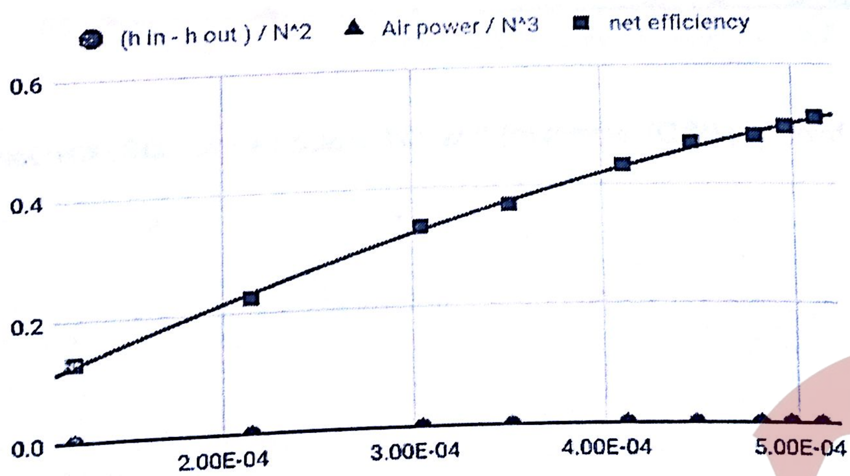

Figure 4 : (hout - hin)/N2, total air power /N3, and (η) against (Q/N) at speed = 1520 rpm.

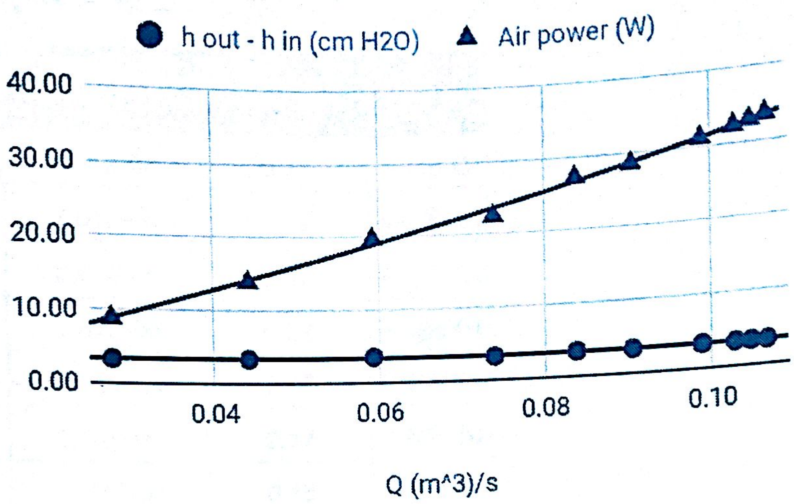

Figure 5 : (hout - hin), total air power, against (Q) at speed = 2150 rpm.

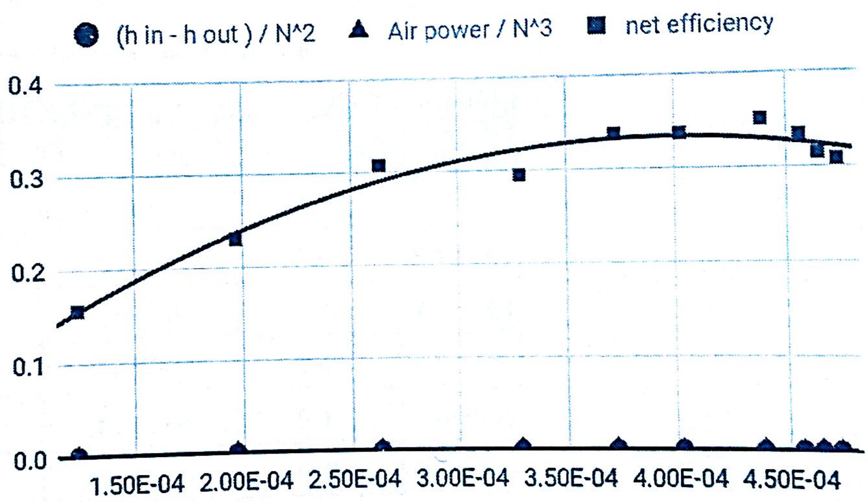

Figure 6 : (hout - hin)/N2, total air power /N3, and (η) against (Q/N) at speed = 2150 rpm.

Table 5:Calculated parameters for speed 1050 rpm

(h in - h out) / N^2	Air power / N^3	net efficiency	Q/N
6.49E-04	2.61E-06	0.22	4.02E-04
6.49E-04	2.61E-06	0.22	4.02E-04
6.49E-04	2.61E-06	0.22	4.02E-04
6.49E-04	2.61E-06	0.22	4.02E-04
5.68E-04	2.04E-06	0.17	3.60E-04
5.68E-04	2.04E-06	0.17	3.60E-04
5.68E-04	1.77E-06	0.15	3.11E-04
5.68E-04	1.44E-06	0.12	2.54E-04
5.68E-04	1.02E-06	0.09	1.80E-04
5.68E-04	1.02E-06	0.14	1.80E-04

Table6: Calculated parameters for speed 1520 rpm

(h in - h out) / N^2	Air power / N^3	net efficiency	Q/N
7.74E-04	3.84E-06	0.49	4.97E-04
7.74E-04	3.96E-06	0.51	5.12E-04
7.74E-04	3.84E-06	0.49	4.97E-04
7.74E-04	3.72E-06	0.48	4.81E-04
8.12E-04	3.64E-06	0.47	4.48E-04
8.12E-04	3.35E-06	0.43	4.12E-04
8.12E-04	2.85E-06	0.37	3.51E-04
8.51E-04	2.59E-06	0.33	3.04E-04
8.12E-04	1.75E-06	0.23	2.15E-04
8.12E-04	1.01E-06	0.13	1.24E-04

Table7: Calculated parameters for speed2150 rpm

(h in - h out) / N^2	Air power / N^3	net efficiency	Q/N
6.19E-04	2.93E-06	0.31	4.73E-04
6.19E-04	2.87E-06	0.31	4.65E-04
6.19E-04	2.82E-06	0.33	4.56E-04
6.19E-04	2.72E-06	0.35	4.39E-04
6.19E-04	2.49E-06	0.34	4.02E-04
6.38E-04	2.38E-06	0.34	3.72E-04
5.99E-04	1.97E-06	0.29	3.28E-04
6.57E-04	1.73E-06	0.31	2.63E-04
6.19E-04	1.21E-06	0.23	1.96E-04
6.19E-04	7.68E-07	0.16	1.24E-04

Discussion

An impeller is a rotating component of a centrifugal pump which transfers energy from the motor,
Knowing the performance of the impeller in the fan depends on the operating parameters such as gate opening and flow rate, velocity, power,...

For speed 1050 rpm, the more value that affected with flow rate is air power, as shown in figure (1).
As flow rate increase the air power increase, while the change in height of manometer for discharge and suction (hout-hin) is increasing slightly.
If the difference is small that will not driving the flow to increase highly.
Because the air power is function of (hout-hin) and Q. Increasing both of them will increase the work done from the fan.
The volume flow rate per angular velocity, at low velocity(1050 rpm) is a proptionaly parameter for the efficiency of fan that play a significant role in the performance of fan.
See figure(2).

For speed 1520 rpm,also the air power and (hout-hin) is proportionally increasing with flow rate but the values is larger than speed 1050 rpm because increasing the velocity of impeller will increase the difference of (hout-hin),so the flow rate then increase and the air power follow up this increasing. See figure(3).
From figure(4),as a resulting of increasing the flow rate the efficiency of the fan increase much higher than speed 1050 rpm.
The speed of impeller is a proptionaly a parameter that control the performance of the fan.

Also the same results for velocity=2150 rpm, from figure (5, 6).

We cannot use this test to predict the performance of a geometrically similar pump, because pump is used for liquids not gases.

Conclusion

- As volumetric flow rate increases the total air power also increases.

- We cannot use this test to predict the performance of a geometrically similar pump, because pump is used for liquids not gases.

- The force (N) is approximately not affected by changing the gate opening for low speeds.

-The net efficiency decreases as the gate opening decreases.

References

-Laboratory (1) (6th ed.). (2016). Amman: University of Jordan.

Appendix

Sample of calculation (10)

ρ: $The\ density\ of\ air\ (\frac{kg}{m^3})$

Q: $The\ volumetric\ flow\ rate\ (\frac{m^3}{s})$

$Pa = The\ atmospheric\ pressure\ (\frac{N}{m^2})$

$\Delta Ps = Fan\ total\ pressure$ (Pa)

$I = Torque = Load * r$

N: $Angular\ velocity$

K: $Brake\ constant, assuming\ k = 1$

$$density = \frac{pa}{RT}$$

$$\rho = \frac{99500}{289.15 * 287} = 1.199\ kg/m^3$$

1. Speed = 1050 rpm

$$\Delta Ps = \rho . g . (h_{out} - h_{in})$$

$$\Delta Ps = 1.199 * 9.81 * (2 - (-6)) * 9.80665 = 9.41\ Pa$$

$$Q = 1.16(\frac{hT}{Pa})^{\frac{1}{2}}$$

$$Q = 1.116 * \left(\frac{6 * 0.1 * 289.15}{99500}\right)^{\frac{1}{2}} = 0.04\ m^3/s$$

$$Air\ Power = 9.81\ (h_{out} - h_{in}) \times Q$$

$$Air\ power = 9.81 * (2 - (-6)) * 9.80665 * 0.04 = 3.47\ W$$

$$Shaft\ power = I\frac{N}{K}$$

$$Shaft\ power = 0.179 * 110 * 0.8 = 15.75\ W$$

$$The\ net\ efficiency = \frac{Total\ air\ power}{Impeller\ power}$$

$$The\ net\ efficiency = \frac{3.47}{15.75} = 0.22$$

2. Speed =1520 rmp

$$\Delta Ps = \rho.g.(h_{out} - h_{in})$$

$$\Delta Ps = 1.199 * 9.81 * (2 - (-18)) * 9.80665 = 23.52\ Pa$$

$$Q = 1.16(\frac{hT}{Pa})^{\frac{1}{2}}$$

$$Q = 1.116 * \left(\frac{16 * 0.1 * 289.15}{99500}\right)^{\frac{1}{2}} = 0.08\ m^3/s$$

$$Air\ Power = 9.81\ (h_{out} - h_{in}) \times Q$$

$$Air\ power = 9.81 * (2 - (-18)) * 9.80665 * 0.08 = 15.52W$$

$$Shaft\ power = I\frac{N}{K}$$

$$Shaft\ power = 0.179 * 159.24 * 1.1 = 31.35\ W$$

$$The\ net\ efficiency = \frac{Total\ air\ power}{Impeller\ power}$$

$$The\ net\ efficiency = \frac{15.52}{31.35} = 0.49$$

3. Speed= 2150 rpm

$$\Delta Ps = \rho.g.(h_{out} - h_{in})$$

$$\Delta Ps = 1.199 * 9.81 * (2 - (-30)) * 9.80665 = 23.52\ Pa$$

$$Q = 1.16(\frac{hT}{Pa})^{\frac{1}{2}}$$

$$Q = 1.116 * \left(\frac{2.9 * 289.15}{99500}\right)^{\frac{1}{2}} = 0.11\, m^3/s$$

$$Air\ Power = 9.81\ (h_{out} - h_{in}) \times Q$$

$$Air\ power = 9.81 * (2 - (-30)) * 9.80665 * 0.11 = 33.43W$$

$$Shaft\ power = I\frac{N}{K}$$

$$Shaft\ power = 0.179 * 225.24 * 2.7 = 108.86\ W$$

$$The\ net\ efficiency = \frac{Total\ air\ power}{Impeller\ power}$$

$$The\ net\ efficiency = \frac{33.43}{108.86} = 0.31$$

The Performance of a Radial Fan Data Sheet

Speed: 1250........

Temperature:..................

Atmospheric pressure:...............

Gate opening , %	h_1 Inlet	h_2 Suction (-)	h_3 Discharge	Force
100	5	6	2	0.8
90	5	6	2	0.8
80	5	6	2	0.8
70	5	5	3	0.8
60	4	4	3	0.8
50	4	4	3	0.8
40	3mm	3 mm	4 m	0.8
30	2 mm	2m.	5	0.85
20	1m	1m	6mm	0.75
10	1 m	0	7	0.5

4/12/2018

Instructor signature:

Date:

The Performance of a Radial Fan Data Sheet

Speed: 1520 rpm

Temperature:………………

Atmospheric pressure:……………

Gate opening , %	h_1 Inlet	h_2 Suction (−)	h_3 Discharge	Force
100	16	18	2	1.1
90	17	18	2	1.1
80	16	17	3	1.1
70	15	16	4	1.1
60	13	15	6	1.1
50	11	12	9	1.1
40	8	9	12	1.1
30	6	7	15	1.1
20	3	4	17	1.1
10	1	2	19	1.1

4/12/2018

Instructor signature:
Date

The Performance of a Radial Fan Data Sheet

watts = NewTonse Rev/m / 53.35

Speed: 2150 rpm

Temperature: 16

Torque arm 179 mm

Atmospheric pressure: 995

Gate opening, %	h_1 Inlet	h_2 (−) Suction	h_3 Discharge	Force
100	29	30	2	2.7
90	28	29	3	2.6
80	27	28	4	2.4
70	25	26	6	2.2
60	21	23	9	2.1
50	18	19	14	2
40	14	15	16	1.9
30	9	11	23	1.6
20	5	6	26	1.5
10	2	2	30	1.4

4/12/2016

Instructor signature:

Date: