The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1) 0915361

Experiment Number (2)

Positive Displacement Pumps Characteristics

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Done by:

Name	Reg. Number

Instructor:

prof. Khaled Rawjfeh

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Abstract

A pump is a device used to move fluids, such as liquids, gases, or slurries. A pump displaces a volume by physical or mechanical action. Pumps fall into three major groups: direct lift, displacement, and gravity pumps here we have positive displacement pumps with two types: piston pump ana vane pump.

This experiment was done to demonstrate how pumps work and show the performance of a selection of positive displacement pumps at constant and variable speeds. Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Its value is not fixed for a given pump, efficiency is a function of the discharge and therefore also operating head. It found that piston pump is more efficient than vane pump.

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Result

The Effect of Delivery Pressure at Constant Speed.

For Piston Pump (swept volume=7.15 ccm/min):

Table 1:Raw data of Piston pump / constant speed / (dis/rev) = 7.15

Speed (rev/min)	Torque (N.m)	Power (W)	Inlet Pressure (P1) bar	Delivery Pressure (P2) bar	Oil Temp. (° C)	Flow Rate Qv (L/min)
1299	0.6	77	-0.06	2	30	9
1298	0.95	134	-0.12	3	30	9
1298	1.05	146	-0.12	4	30	9
1297	1.19	159	-0.12	5	30	9
1297	1.26	172	-0.12	6	30	9
1297	1.37	186	-0.12	7	30	9
1295	1.47	200	-0.12	8	30	8.8
1298	1.58	217	-0.12	9	30	9
1299	1.71	230	-0.11	10	30	9
1296	1.82	247	-0.11	11	30	9
1295	1.95	264	-0.11	12	30	9
1301	2.09	279	-0.11	13	30	9

Table 2:Parameters for piston pump at constant speed =1297 rev/min

trail no.	ΔP (Pa)	Flow Rate Qv (m^3/s)	Wp	Excepted flow rate (l/min)	Excepted flow rate (m^3/s)	overall efficincy %	volumetric efficincy %
1	2.06E+05	1.50E-04	30.90	9.29	1.55E-04	40	97
2	3.12E+05	1.50E-04	46.80	9.28	1.55E-04	35	97
3	4.12E+05	1.50E-04	61.80	9.28	1.55E-04	42	97
4	5.12E+05	1.50E-04	76.80	9.27	1.55E-04	48	97
5	6.12E+05	1.50E-04	91.80	9.27	1.55E-04	53	97
6	7.12E+05	1.50E-04	106.80	9.27	1.55E-04	57	97
7	8.12E+05	1.47E-04	119.09	9.26	1.54E-04	60	95
8	9.12E+05	1.50E-04	136.80	9.28	1.55E-04	63	97
9	1.01E+06	1.50E-04	151.65	9.29	1.55E-04	66	97
10	1.11E+06	1.50E-04	166.65	9.27	1.54E-04	67	97
11	1.21E+06	1.50E-04	181.65	9.26	1.54E-04	69	97
12	1.31E+06	1.50E-04	196.65	9.30	1.55E-04	70	97

The Effect of Speed at Constant Delivery Pressure.

Table 3:Raw data of Piston pump / constant pressure / (dis/rev) = 7.15

Speed (rev/min)	Torque (N.m)	Power (W)	Inlet Pressure (P1) bar	Delivery Pressure (P2) bar	Oil Temp. (º C)	Flow Rate (L/min)
200	1.72	35	-0.02	10.1	30	1.3
297	1.88	50	-0.03	10	30	2.1
400	1.87	67	-0.04	10.1	30	2.9
505	1.93	86	-0.04	10.1	30	3.8
600	1.03	65	-0.04	10	30	4.1
700	1.93	131	-0.04	10.2	30	5.5
800	1.8	151	-0.06	10.3	30	5.7
902	2.02	162	-0.07	10.4	30	6.7
1005	2.05	189	-0.07	10	30	7.5
1104	2.13	218	-0.08	10.3	30	8.4
1203	2.13	234	-0.09	10.2	30	8.7
1300	2.14	251	-0.1	10.3	30	9.3

Table 4:Parameters for piston pump at constant pressure =10.2 bar

trail no.	ΔP (Pa)	Flow Rate Qv (m^3/s)	Wp	Excepted flow rate (l/min)	Excepted flow rate (m^3/s)	overall efficiency %	volumetric efficiency %
1	1.01E+06	2.16667E-05	21.93	1.43	2.383E-05	63	91
2	1.00E+06	0.000035	35.11	2.12	3.539E-05	70	99
3	1.01E+06	4.83333E-05	49.01	2.86	4.767E-05	73	101
4	1.01E+06	6.33333E-05	64.22	3.61	6.018E-05	75	105
5	1.00E+06	6.83333E-05	68.61	4.29	0.0000715	106	96
6	1.02E+06	9.16667E-05	93.87	5.01	8.342E-05	72	110
7	1.04E+06	0.000095	98.42	5.72	9.533E-05	65	100
8	1.05E+06	0.000111667	116.92	6.45	0.0001075	72	104
9	1.01E+06	0.000125	125.88	7.19	0.0001198	67	104
10	1.04E+06	0.00014	145.32	7.89	0.0001316	67	106
11	1.03E+06	0.000145	149.21	8.60	0.0001434	64	101
12	1.04E+06	0.000155	161.20	9.30	0.0001549	64	100

The Effect of Delivery Pressure at Constant Speed:

For vane Pump (swept volume=6.6 ccm/min):

Table 5:Raw data of Vane pump / constant speed / (dis/rev) = 6.6

Speed (rev/min)	Torque (N.m)	Power (W)	Inlet Pressure (P1) bar	Delivery Pressure (P2) bar	Oil Temp. (° C)	Flow Rate (L/min)
801	0.7	59	-0.05	2	30	6
800	0.72	60	-0.05	2.3	30	6
799	0.81	68	-0.05	3	30	6
797	0.91	76	-0.05	4	30	5.9
796	1.02	85	-0.05	5	30	5.9
803	1.05	88	-0.05	5.1	30	5.9
803	1.14	96	-0.05	6	30	5.9
802	1.26	105	-0.05	7	30	5.8
802	1.23	103	-0.05	6.9	30	5.9
800	1.36	114	-0.05	8	30	5.9
798	1.49	124	-0.05	9	30	5.9
795	1.59	132	-0.05	10	30	5.9

Table 6:Parameters for vane pump at constant speed =800 rev/min

trail no.	ΔP (Pa)	Flow Rate Qv (m^3/s)	Wp	Excepted flow rate (l/min)	Excepted flow rate (m^3/s)	overall efficiency %	volumetric efficiency %
1	2.05E+05	1.00E-04	20.50	5.29	8.811E-05	35	113
2	2.35E+05	1.00E-04	23.50	5.28	0.000088	39	114
3	3.05E+05	1.00E-04	30.50	5.27	8.789E-05	45	114
4	4.05E+05	9.83E-05	39.83	5.26	8.767E-05	52	112
5	5.05E+05	9.83E-05	49.66	5.25	8.756E-05	58	112
6	5.15E+05	9.83E-05	50.64	5.30	8.833E-05	58	111
7	6.05E+05	9.83E-05	59.49	5.30	8.833E-05	62	111
8	7.05E+05	9.67E-05	68.15	5.29	8.822E-05	65	110
9	6.95E+05	9.83E-05	68.34	5.29	8.822E-05	66	111
10	8.05E+05	9.83E-05	79.16	5.28	0.000088	69	112
11	9.05E+05	9.83E-05	88.99	5.27	8.778E-05	72	112
12	1.01E+06	9.83E-05	98.83	5.25	8.745E-05	75	112

The Effect of Speed at Constant Delivery Pressure.

Table 7:Raw data of Vane pump / constant pressure / (dis/rev) = 6.6

Speed (rev/min)	Torque (N.m)	Power (W)	Inlet Pressure (P1) bar	Delivery Pressure (P2) bar	Oil Temp. (° C)	Flow Rate (L/min)
199	1.72	35	-0.02	10.5	30	1.2
306	1.74	54	-0.03	10.1	30	2
396	1.76	73	-0.03	10.2	30	2.8
498	1.81	94	-0.04	10	30	3.5
601	1.81	125	-0.04	10.3	30	4
702	1.82	133	-0.06	10.2	30	5.1
800	1.84	154	-0.07	10.1	30	5.7
900	1.87	176	-0.07	10	30	6.5
1002	1.88	197	-0.08	10	30	7.2
1103	1.95	225	-0.09	10.3	30	7.8
1200	1.95	246	-0.09	10.1	30	8.3
1300	1.98	270	-0.1	10	30	8.9

Table 8:Parameters for vane pump at constant pressure =10.2 bar

trail no.	ΔP (Pa)	Flow Rate Qv (m^3/s)	Wp	Excepted flow rate (l/min)	Excepted flow rate (m^3/s)	overall efficiency %	volumetric efficiency %
1	1.05E+06	0.00002	21.04	1.31	2.189E-05	60	91
2	1.01E+06	3.33333E-05	33.77	2.02	3.366E-05	63	99
3	1.02E+06	4.66667E-05	47.74	2.61	4.356E-05	65	107
4	1.00E+06	5.83333E-05	58.57	3.29	5.478E-05	62	106
5	1.03E+06	6.66667E-05	68.93	3.97	6.611E-05	55	101
6	1.03E+06	0.000085	87.21	4.63	7.722E-05	66	110
7	1.02E+06	0.000095	96.62	5.28	0.000088	63	108
8	1.01E+06	0.000108333	109.09	5.94	0.000099	62	109
9	1.01E+06	0.00012	120.96	6.61	0.0001102	61	109
10	1.04E+06	0.00013	135.07	7.28	0.0001213	60	107
11	1.02E+06	0.000138333	140.96	7.92	0.000132	57	105
12	1.01E+06	0.000148333	149.82	8.58	0.000143	55	104

Figures

Analysis 1: Parameter against pressure difference at constant speed

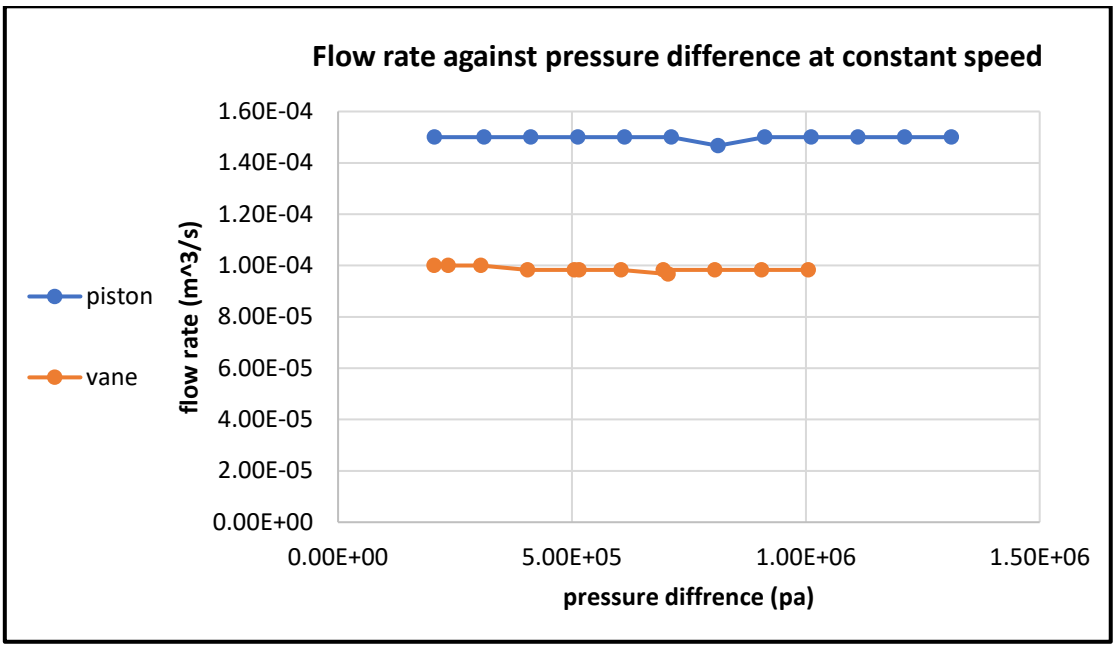

Figure 1 :Flow rate against pressure difference at constant speed

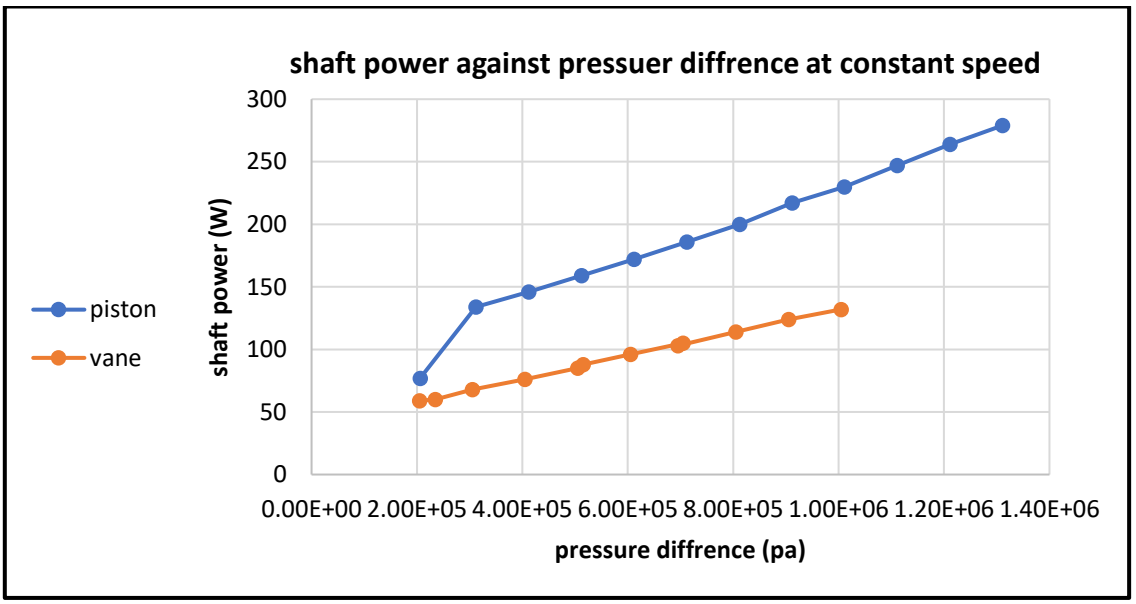

Figure 2:shaft power against pressuer difference at constant speed

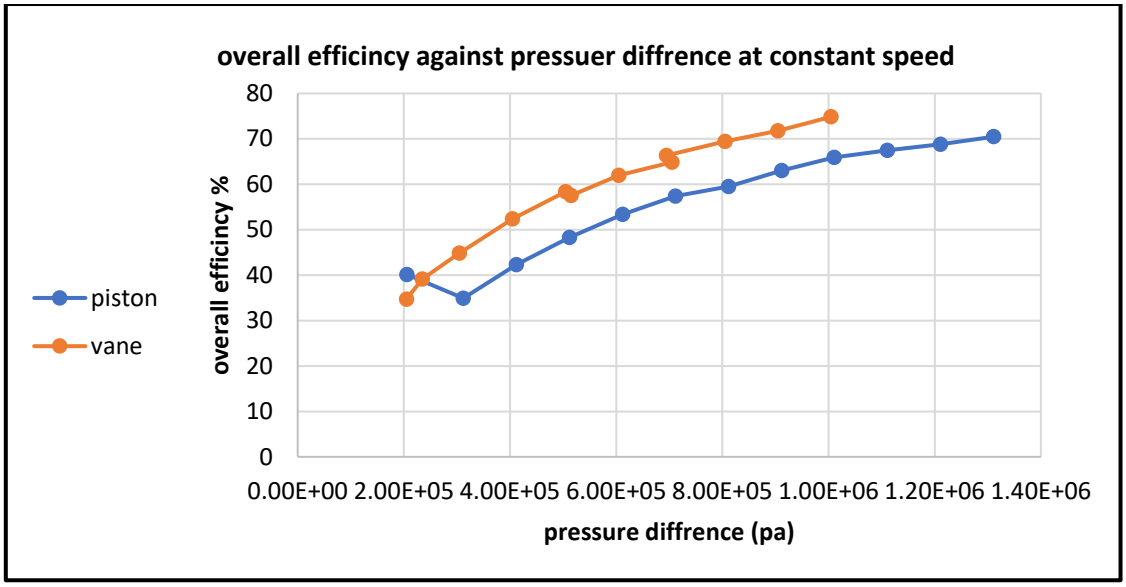

Figure 3:overall efficincy against pressure difference at constant speed

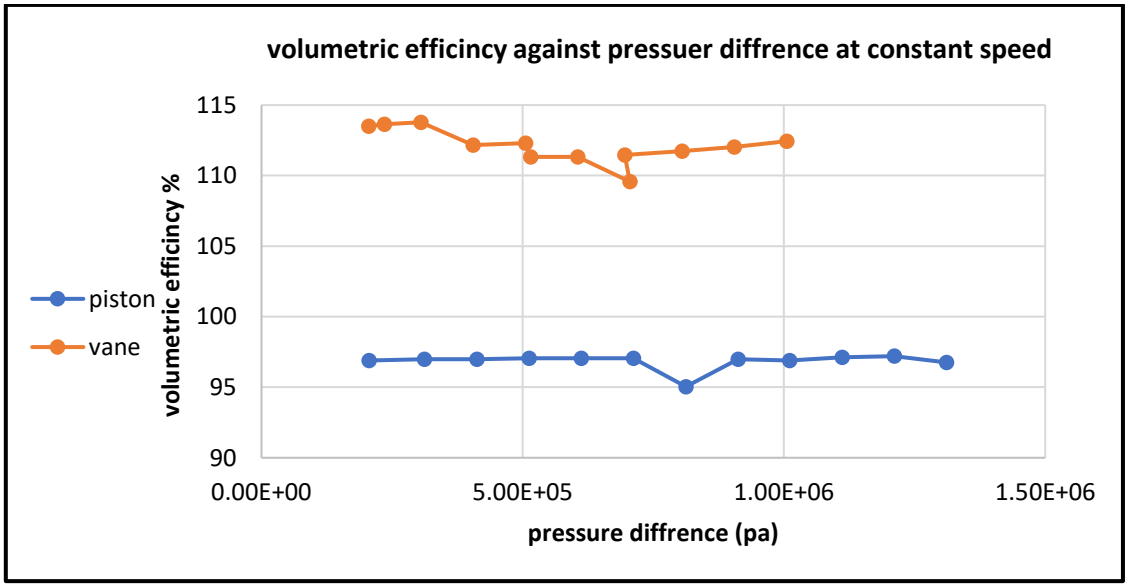

Figure 4:volumetric efficincy against pressure difference at constant speed

Analysis 2: Parameter against pump speed at constant pressure

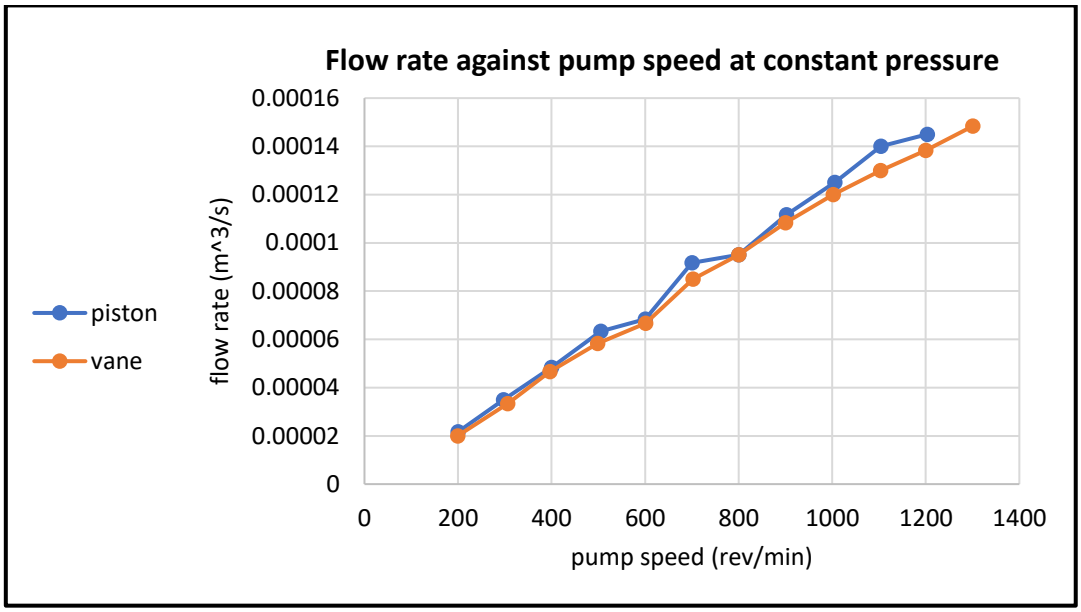

Figure 5:Flow rate against pump speed at constant pressure

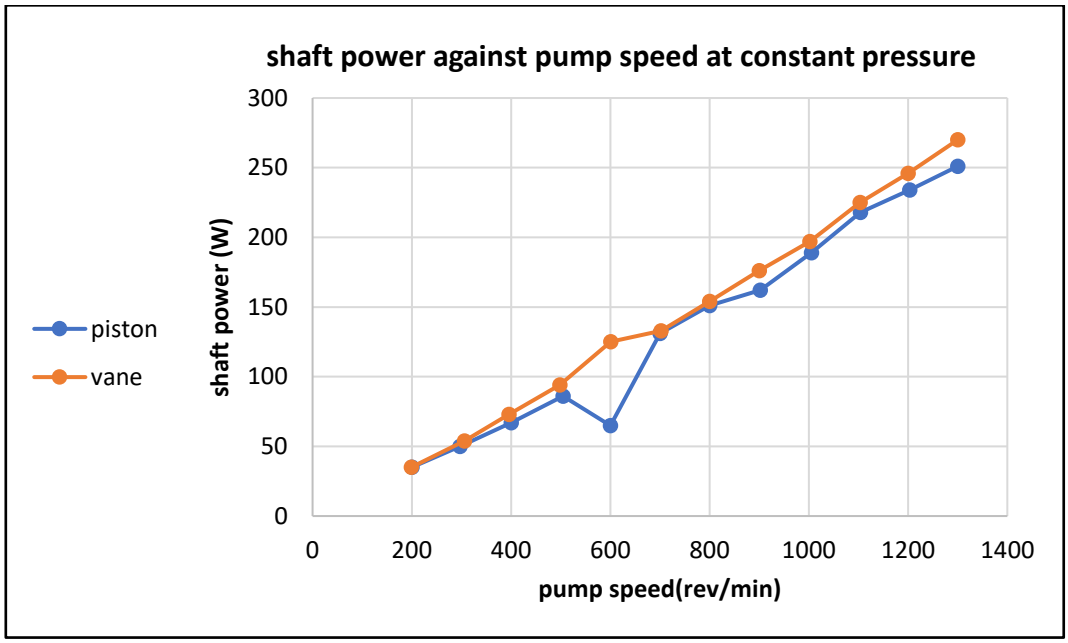

Figure 6:Shaft power against pump speed at constant pressure

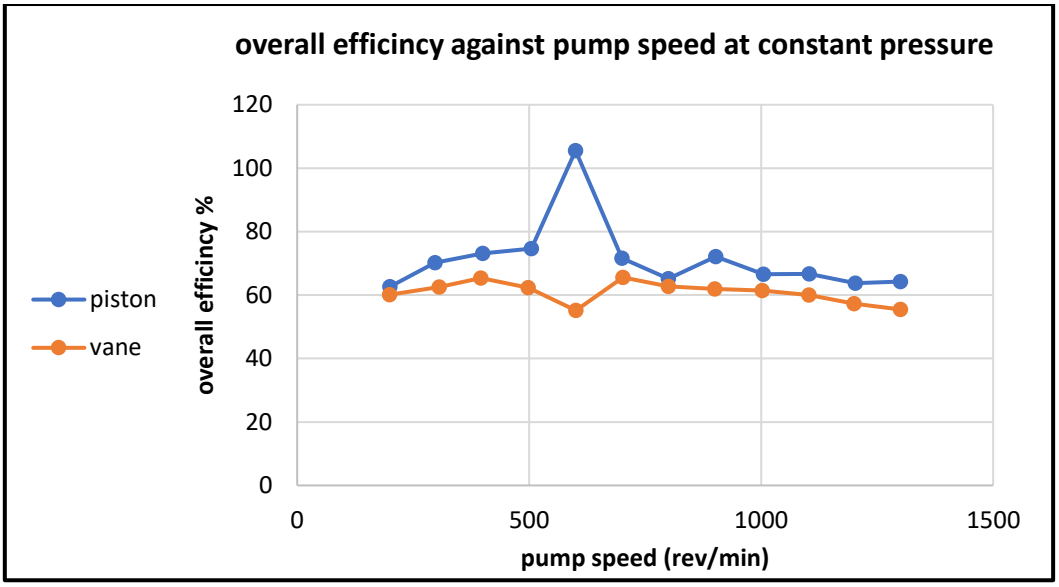

Figure 7:Overall efficincy against pump speed at constant pressure

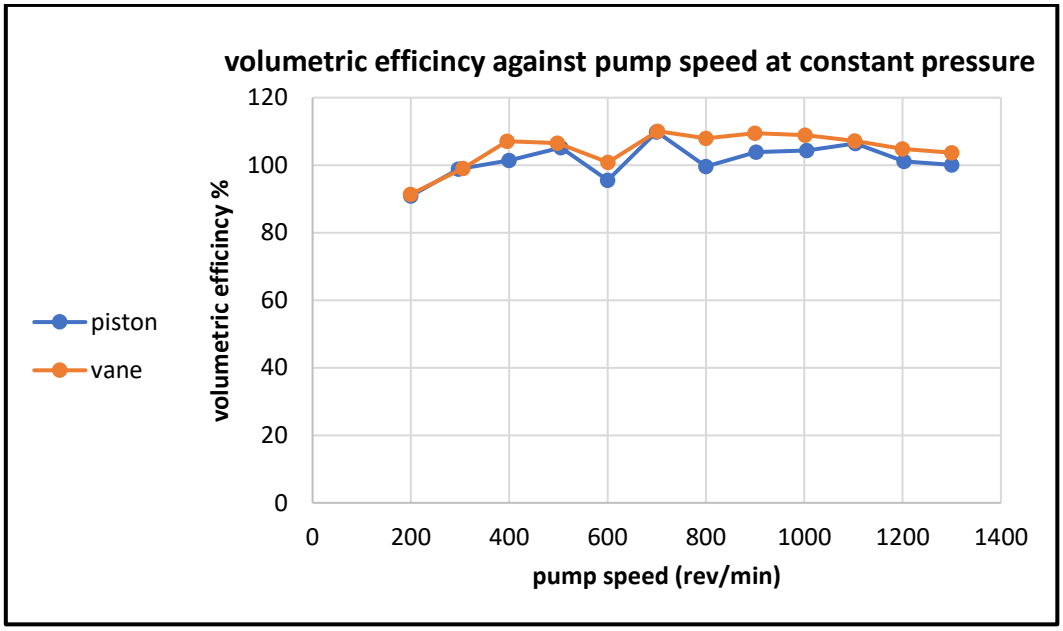

Figure 8:Volumetric efficincy against pump speed at constant pressure

Analysis 3: Parameter against the inlet pressure

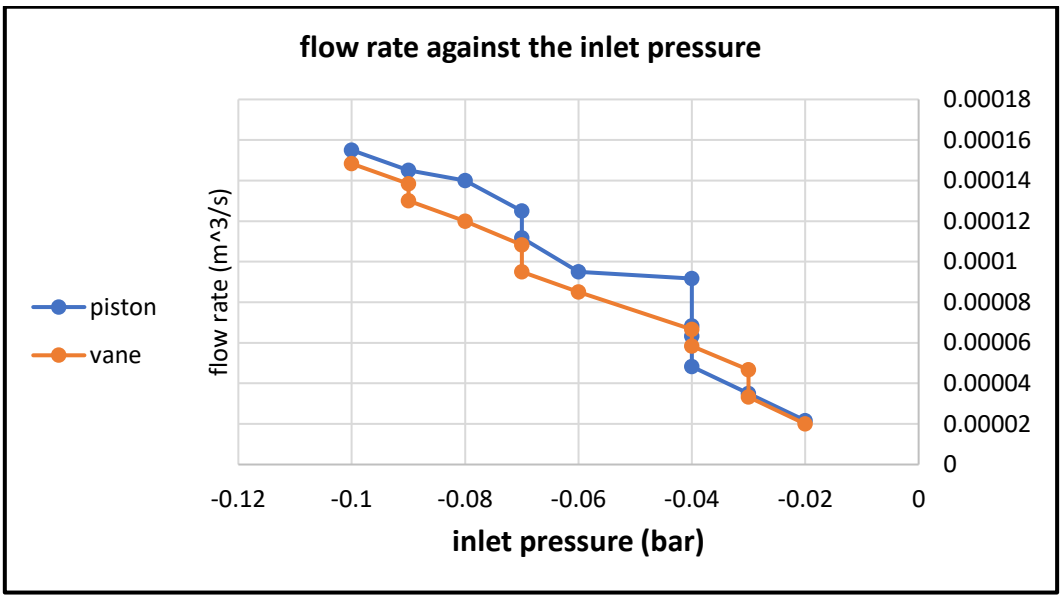

Figure 9:Flow rate against the inlet pressure

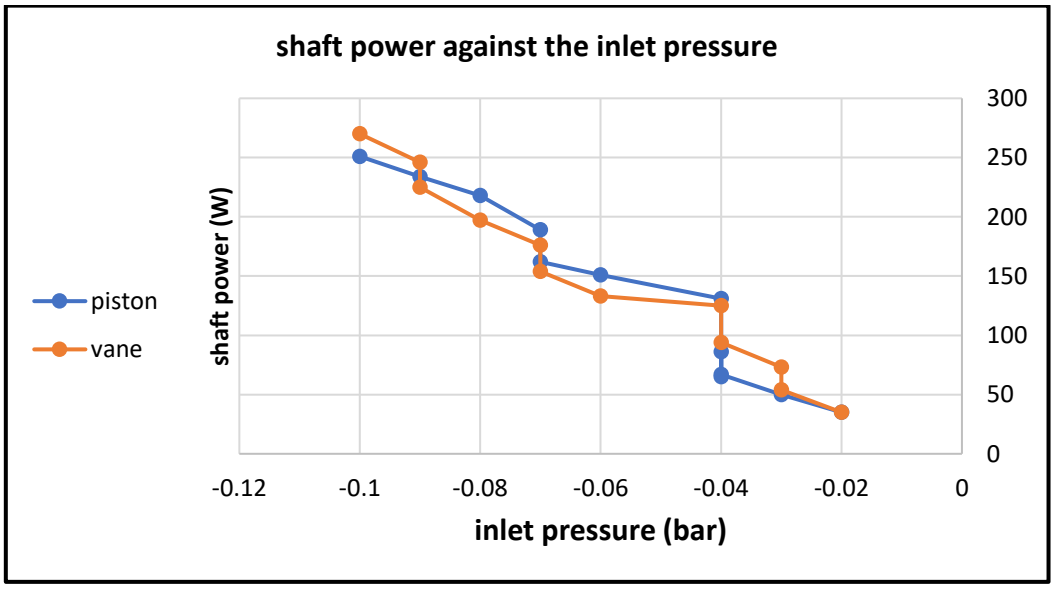

Figure 10:Shaft power against the inlet pressure

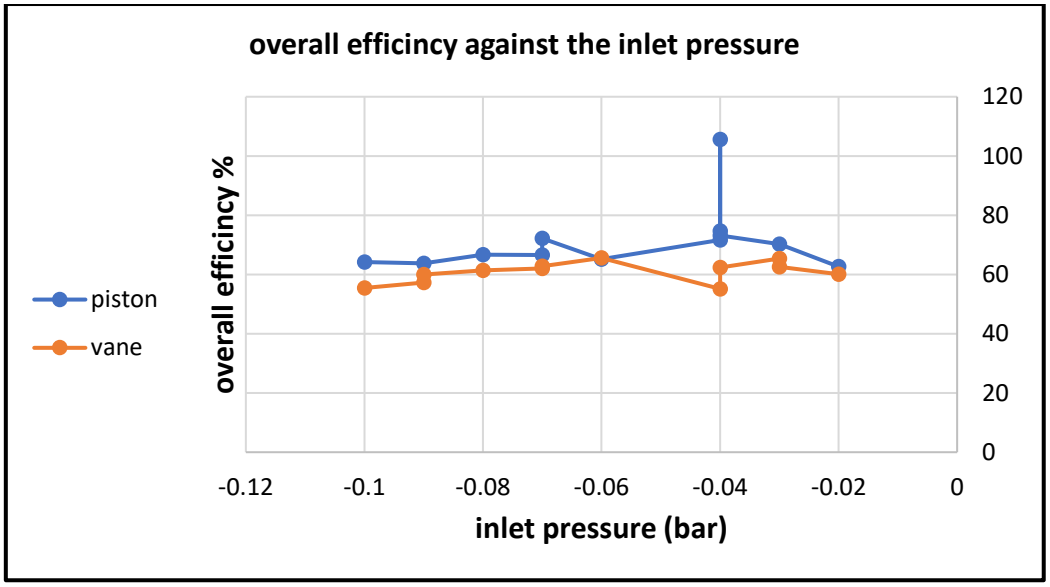

Figure11 :Overall efficincy against the inlet pressure

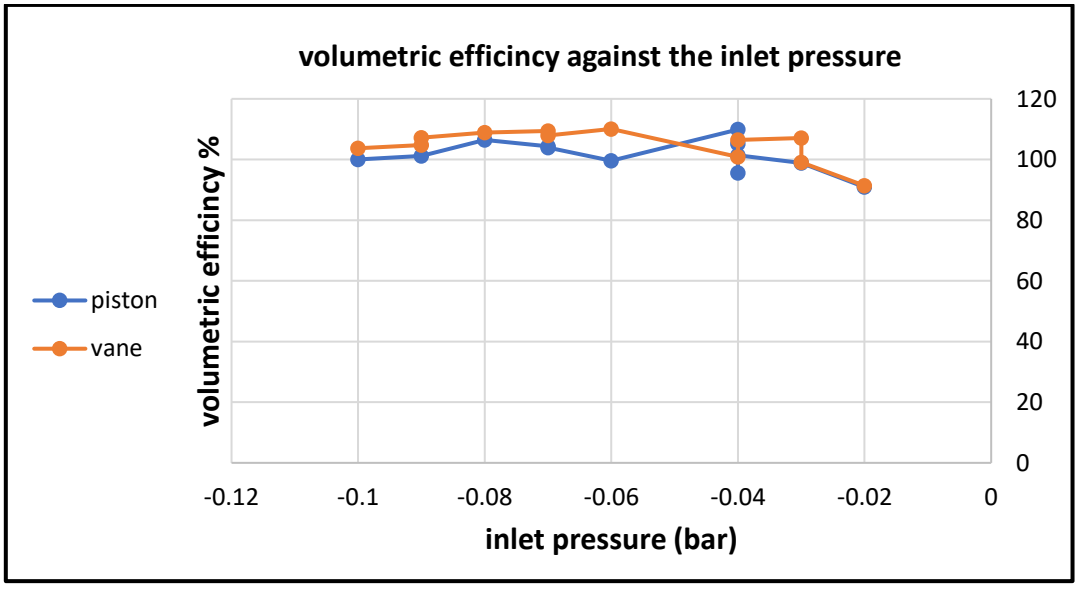

Figure 12:Volumetric efficincy against the inlet pressure

Discussion

By exerting force on a liquid using a mechanical component like a piston or plunger, positive displacement pumps impart energy to a fluid. By reducing the volume containing the liquid, a positive displacement pump raises the liquid's pressure until it is equal to the pressure in the discharge system. In other words, a mechanical compression of the liquid results in a direct increase in potential energy. The majority of positive displacement pumps are reciprocating pumps, where the displacement is produced by the linear motion of a piston or plunger within a cylinder.

part 1: The impact of delivery pressure at constant speed

Figure 1 illustrates how lowering flow rates in both vane and piston pumps are caused by rising delivery pressure, which also increases the volumetric efficiency of both pumps.

to a certain threshold, after which it begins to decline, as illustrated in figure (4).

Figure (2) illustrates how increasing the delivery pressure at constant speed leads in higher shaft power and overall efficiency (3).

Part 2: The impact of speed at constant pressure

Figures (5) and (6) illustrate how increasing the speed at constant delivery pressure caused the flow rate in both vane and piston pumps to increase as well as how increasing the shaft power in both pumps resulted in reduced overall efficiency (7).

Figure (8) illustrates how up to a certain threshold, increasing the speed at constant delivery pressure causes the volumetric efficiency to increase.

Conclusion

Part 1: The impact of constant speed delivery pressure

1) As the pressure differential widens, the shaft power for both vane and piston pumps rise, but piston power increases more than vane pump power do.
2) Quantitative effectiveness
3) volumetric efficiency for a vane is higher than a piston since it increases with flow rate at constant speed, low speed values having higher mechanical power than a piston.
4) Low speed aids in improving pump efficiency.
5) A positive displacement pump at constant speed can be chosen based on a variety of parameters, including flow rate, pressure differential, volumetric efficiency, and overall effectiveness.
6) if the working under low speeds condition is met at continuous speeds, the over pump

Part2: How speed affects delivery pressure at a steady rate

1) Since the flow rate increases at the same rate regardless of the increase in speed, the value of the delivery pressure has no impact when the flow rate is to be increased at a different constant deliver pressure.
2) The primary goal of total pump efficiency maintenance is speed-related speed reduction Efficiency is improved by increasing speed while maintaining a higher constant value of delivery pressure.
3) Increased volumetric efficiency is achieved by increasing speed while maintaining a lower constant value of delivery pressure.
4) We chose a positive displacement pump at constant delivery pressure based on a variety of parameters, including flow rate, speed, volumetric efficiency, and overall effectiveness.

References

1) F.A. Holland, “Fluid Flow for Chemical Engineers ", Arnold, 1980.
2) J.M. Coulson and FF Richardson," Chemical Engineering" Vol.1, Third Edition, 1980, Pergamon Press.
3) Chemical engineering laboratory “1” (0915361); University of Jordan; faculty of engineering and Technology; Department of Chemical engineering.

Appendices

❖ Sample of calculations:

- **Actual flow rate (m^3/s):**
  Qv=9 $\frac{L}{min} \times \frac{1\,min}{60\,s} \times \frac{1\,m^3}{1000\,l} = 1.5 \times 10^{-4}$ m^3/s

- **Pressure difference(pa):**
  $\Delta P = p2 - p1 = (2 - -0.06) \times 10^5 = 2.06 \times 10^5$ pa

- **Hydraulic power(watt):**
  $Wp = Qv \times \Delta P = 1.5 \times 10^{-4} \times 2.06 \times 10^5 = 30.9\,watt$

- **Excepted flow rate (m3/s):**
  $Qe = \text{VS} \times \text{NP} = 1299 \times 7.15 \times 0.001 = 9.29 \frac{L}{min} \times \frac{1\,min}{60\,s} \times \frac{1\,m^3}{1000\,l} = 1.55 \times 10^{-4}$ m3/s

- **Overall efficiency%:**
  ηp = $\left(\frac{wp}{wD}\right) \times 100 = \left(\frac{30.9}{77}\right) \times 100 = 40\%$

- **Volumetric efficiency%:**
  ηv = $\left(\frac{Qe}{Qv}\right) \times 100 = \left(\frac{1.55}{1.5}\right) \times 100 = 97\%$

  and so on ..

❖ Data

Positive Displacement Pumps Characteristics

Piston pump / constant speed / (dis/rev) = 7.15

Speed (rev/min)	Torque (N.m)	Power (W)	Inlet Pressure (P1) bar	Delivery Pressure (P2) bar	Oil Temp. (° C)	Flow Rate (L/min)
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Vane pump / constant speed / (dis/rev) = 6.6

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