The University of Jordan

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Experiment Number (2)

Positive Displacement Pumps Characteristics

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Abstract

In this experiment, we compared two pumps, the first was piston pump and the second was vane pump in terms of qualities and efficiency, as well as performance under the same conditions, it was in two steps, In the first step, we changed the speed with constant pressure and vice versa in the second step by using the positive displacement pump module. Also, and we used the oil as the working fluid in this apparatus. We found that piston is more efficient.

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Result

Part (1): The effect of Delivery pressure at constant speed.

For Piston Pump (swept volume=7.15 cm^3/min)

Table 1: Raw data of varying pressure at constant speed=400 rev/min for piston pump.

Speed (rev/min)	Torque (N.m)	Shaft power (w)	Inlet pressure (bar)	Delivery pressure (bar)	Oil Temperature (°c)	Volumetric flow rate (L/min)	volumetric flow rate (m^3/s)
		(W_D)	(P_1)	(P_2)	(T)	(Q_V)	(Q_V)
400	0.32	13	-0.03	1	23.5	3.1	5.17E-05
400	0.44	18	-0.03	2	23.6	3.2	5.33E-05
400	0.59	24	-0.03	3	23.6	3.2	5.33E-05
400	0.75	31	-0.03	4	23.6	3.2	5.33E-05
400	0.89	36	-0.03	5	23.6	3.2	5.33E-05
400	1.04	46	-0.03	6	23.6	3.3	5.50E-05
400	1.22	51	-0.04	7	23.7	3.3	5.50E-05
400	1.33	55	-0.04	8	23.7	3.3	5.50E-05
400	1.53	63	-0.05	9	23.8	3.2	5.33E-05
400	1.69	68	-0.05	10	23.8	3.0	5.00E-05

Table 2: Parameters at constant speed =400 rev/min for piston pump.

Trail No.	Δ pressure	Wp	Expected flow rate	Expected flow rate	Overall efficiency	Volumetric efficiency
	(pa)	(kw)	(L/min)	(m^3/s)	(%)	(%)
1	1.03E+05	5.32E-03	2.86	4.77E-05	41%	108%
2	2.03E+05	1.08E-02	2.86	4.77E-05	60%	112%
3	3.03E+05	1.62E-02	2.86	4.77E-05	67%	112%
4	4.03E+05	2.15E-02	2.86	4.77E-05	69%	112%
5	5.03E+05	2.68E-02	2.86	4.77E-05	75%	112%
6	6.03E+05	3.32E-02	2.86	4.77E-05	72%	115%
7	7.04E+05	3.87E-02	2.86	4.77E-05	76%	115%
8	8.04E+05	4.42E-02	2.86	4.77E-05	80%	115%
9	9.05E+05	4.83E-02	2.86	4.77E-05	77%	112%
10	1.01E+06	5.03E-02	2.86	4.77E-05	74%	105%

For Vane Pump (swept volume=6.6 cm^3/min)

Table 3: Raw data of varying pressure at constant speed=400 rev/min for vane pump.

Speed (rev/min)	Torque (N.m)	Shaft power (w)	Inlet pressure (bar)	Delivery pressure (bar)	Oil Temperature (°c)	Volumetric flow rate (L/min)	volumetric flow rate (m^3/s)
		(W_D)	(P_1)	(P_2)	(T)	(Qv)	(Qv)
400	0.45	18	-0.03	1	24.8	3.0	5.00E-05
400	0.59	24	-0.03	2	24.8	3.0	5.00E-05
400	0.74	30	-0.03	3	24.9	3.0	5.00E-05
400	0.91	37	-0.03	4	24.9	2.9	4.83E-05
400	1.05	44	-0.03	5	24.9	2.9	4.83E-05
400	1.19	49	-0.03	6	24.9	2.9	4.83E-05
400	1.34	55	-0.03	7	24.9	2.9	4.83E-05
400	1.46	61	-0.03	8	24.9	2.9	4.83E-05
400	1.59	66	-0.03	9	24.9	2.9	4.83E-05
400	1.72	71	-0.03	10	24.9	2.8	4.67E-05

Table 4: Parameters at constant speed =400 rev/min for vane pump.

Trail No.	Δ pressure (pa)	Wp (kw)	Expected flow rate (L/min)	Expected flow rate (m^3/s)	Overall efficiency (%)	Volumetric efficiency (%)
1	1.03E+05	5.15E-03	2.64	4.40E-05	29%	114%
2	2.03E+05	1.02E-02	2.64	4.40E-05	42%	114%
3	3.03E+05	1.52E-02	2.64	4.40E-05	51%	114%
4	4.03E+05	1.95E-02	2.64	4.40E-05	53%	110%
5	5.03E+05	2.43E-02	2.64	4.40E-05	55%	110%
6	6.03E+05	2.91E-02	2.64	4.40E-05	59%	110%
7	7.03E+05	3.40E-02	2.64	4.40E-05	62%	110%
8	8.03E+05	3.88E-02	2.64	4.40E-05	64%	110%
9	9.03E+05	4.36E-02	2.64	4.40E-05	66%	110%
10	1.00E+06	4.68E-02	2.64	4.40E-05	66%	106%

Part (2): The effect of Speed at constant Delivery pressure.

For Piston Pump (swept volume=7.15 cm^3/min)

Table 5: Raw data of varying speed at constant pressure=5 bar for piston pump.

Speed (rev/min)	Torque (N.m)	Shaft power (w)	Inlet pressure (bar)	Delivery pressure (bar)	Oil Temperature (°c)	Volumetric flow rate (L/min)	volumetric flow rate (m^3/s)
		(W_D)	(P_1)	(P_2)	(T)	(Q_v)	(Q_v)
200	0.85	18	-0.03	5	24.2	1.6	2.67E-05
300	0.84	26	-0.03	5	24.2	2.4	4.00E-05
400	1.01	41	-0.04	5	24.2	3.3	5.50E-05
500	1.03	53	-0.05	5	24.2	4.1	6.83E-05
600	1.08	67	-0.05	5	24.3	4.8	8.00E-05
700	1.11	82	-0.06	5	24.3	5.5	9.17E-05
800	1.20	100	-0.07	5	24.4	6.3	1.05E-04
900	1.18	112	-0.07	5	24.4	7.0	1.17E-04
1000	1.28	135	-0.08	5	24.5	7.6	1.27E-04
1100	1.29	150	-0.08	5	24.4	8.1	1.35E-04

Table 6: Parameters at constant pressure=5 bar for piston pump.

Trail No.	Δ pressure (pa)	Wp (w)	Expected flow rate (L/min)	Expected flow rate (m^3/s)	Overall efficiency (%)	Volumetric efficiency (%)
1	5.03E+05	1.34E-02	1.43	2.38E-05	75%	112%
2	5.03E+05	2.01E-02	2.145	3.58E-05	77%	112%
3	5.04E+05	2.77E-02	2.86	4.77E-05	68%	115%
4	5.05E+05	3.45E-02	3.575	5.96E-05	65%	115%
5	5.05E+05	4.04E-02	4.29	7.15E-05	60%	112%
6	5.06E+05	4.64E-02	5.005	8.34E-05	57%	110%
7	5.07E+05	5.32E-02	5.72	9.53E-05	53%	110%
8	5.07E+05	5.92E-02	6.435	1.07E-04	53%	109%
9	5.08E+05	6.43E-02	7.15	1.19E-04	48%	106%
10	5.08E+05	6.86E-02	7.865	1.31E-04	46%	103%

For Vane Pump (swept volume=6.6 cm^3/min)

Table 7: Raw data of varying speed at constant pressure=5 bar for vane pump.

Speed (rev/min)	Torque (N.m)	Shaft power (w)	Inlet pressure (bar)	Delivery pressure (bar)	Oil Temperature (°c)	Volumetric flow rate (L/min)	volumetric flow rate (m^3/s)
		(W_D)	(P_1)	(P_2)	(T)	(Q_v)	(Q_v)
200	0.91	19	-0.02	5	24.8	1.5	2.50E-05
300	0.87	27	-0.02	5	24.8	2.2	3.67E-05
400	1.03	41	-0.03	5	24.8	2.9	4.83E-05
500	1.08	56	-0.04	5	24.8	3.7	6.17E-05
600	1.13	71	-0.05	5	24.9	4.5	7.50E-05
700	1.14	83	-0.05	5	25.0	5.3	8.83E-05
800	1.18	98	-0.06	5	25.0	5.9	9.83E-05
900	1.22	115	-0.07	5	25.0	6.7	1.12E-04
1000	1.23	129	-0.08	5	25.1	7.4	1.23E-04
1100	1.25	142	-0.08	5	25.1	8.3	1.38E-04

Table 8: Parameters at constant pressure=5 bar for vane pump.

Trail No.	Δ pressure (pa)	Wp (kw)	Expected flow rate (L/min)	Expected flow rate (m^3/s)	Overall efficiency (%)	Volumetric efficiency (%)
1	5.02E+05	1.26E-02	1.32	2.20E-05	66%	114%
2	5.02E+05	1.84E-02	1.98	3.30E-05	68%	111%
3	5.03E+05	2.43E-02	2.64	4.40E-05	59%	110%
4	5.04E+05	3.11E-02	3.3	5.50E-05	56%	112%
5	5.05E+05	3.79E-02	3.96	6.60E-05	53%	114%
6	5.05E+05	4.46E-02	4.62	7.70E-05	54%	115%
7	5.06E+05	4.98E-02	5.28	8.80E-05	51%	112%
8	5.07E+05	5.66E-02	5.94	9.90E-05	49%	113%
9	5.08E+05	6.27E-02	6.6	1.10E-04	49%	112%
10	5.08E+05	7.03E-02	7.26	1.21E-04	49%	114%

Diagrams:

At constant speed=400rev/min:

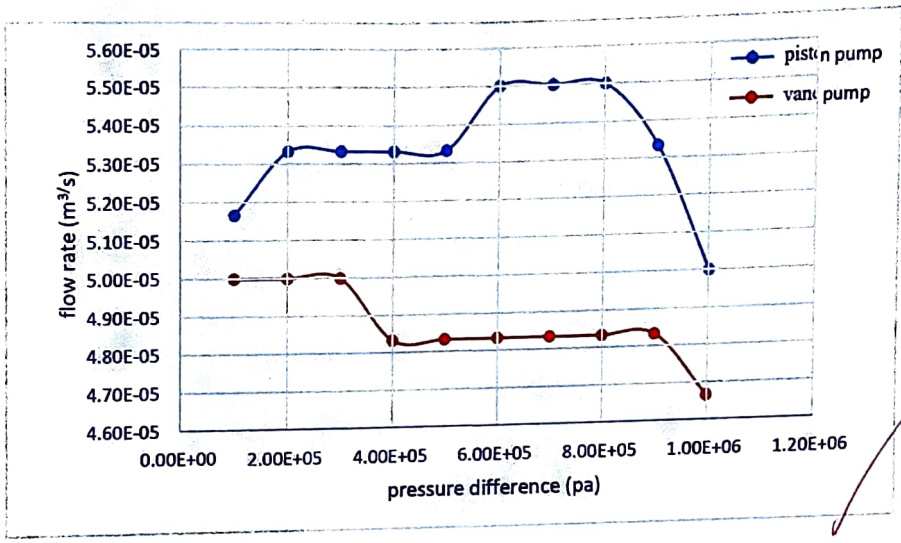

Figure 1: Flow rate vs. Pressure difference at constant speed of different pumps.

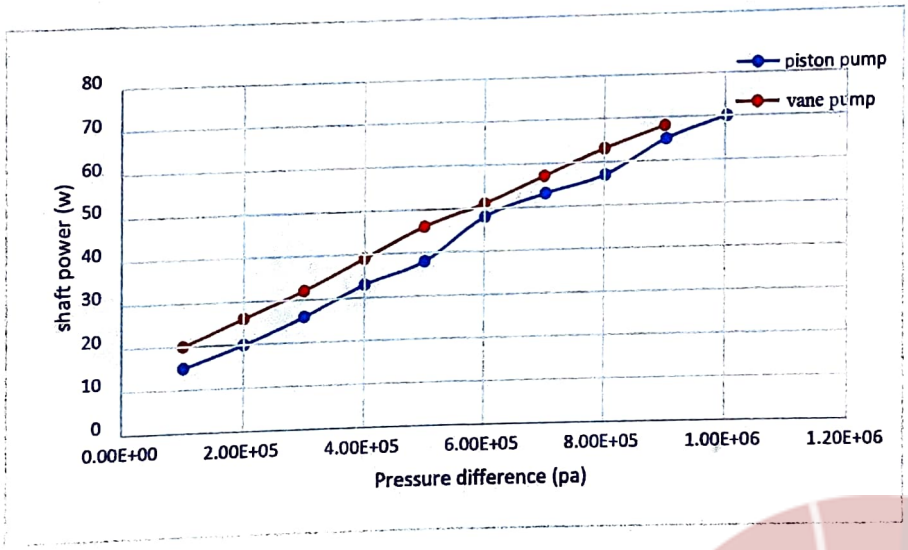

Figure2 : Shaft power vs. Pressure difference at constant speed of different pumps.

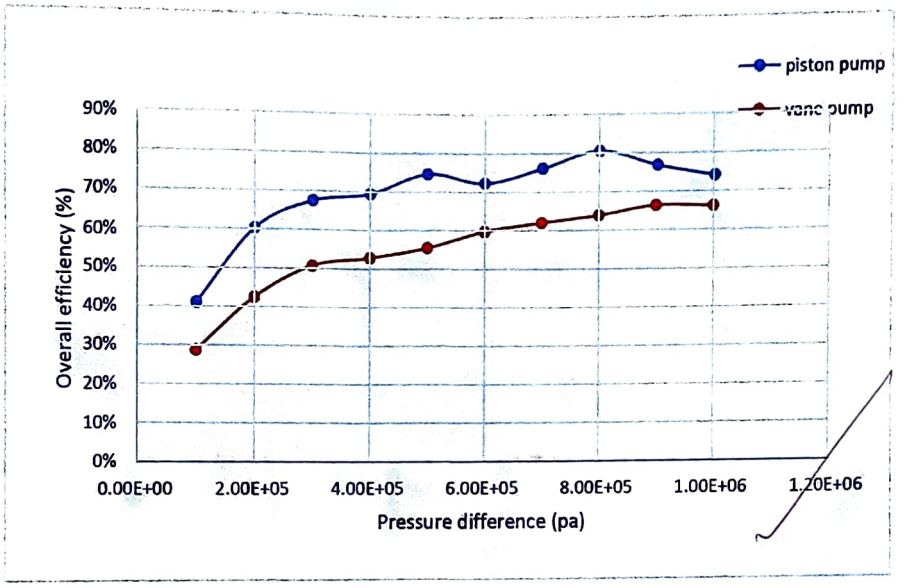

Figure 3: Overall efficiency vs. Pressure difference at constant speed of different pumps.

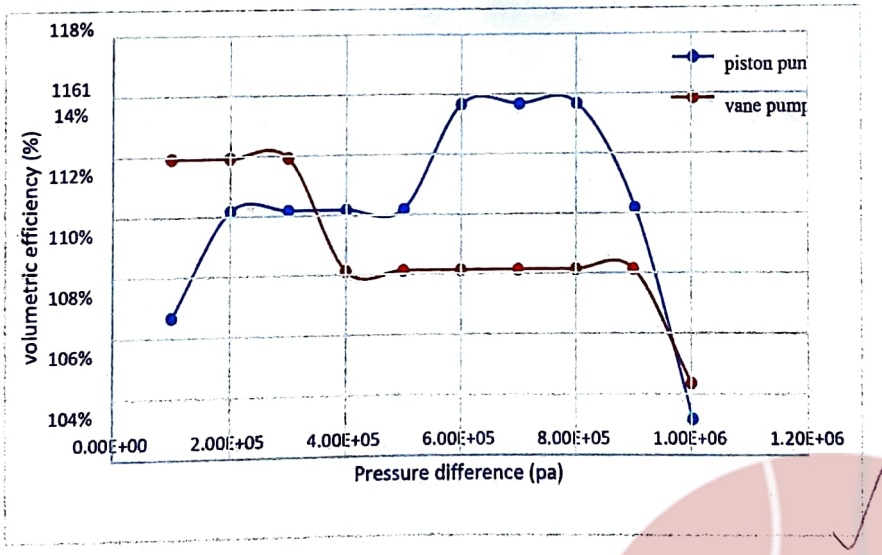

Figure 4: Volumetric efficiency vs. Pressure difference at constant speed of different pumps.

At constant delivered pressure=5 bar:

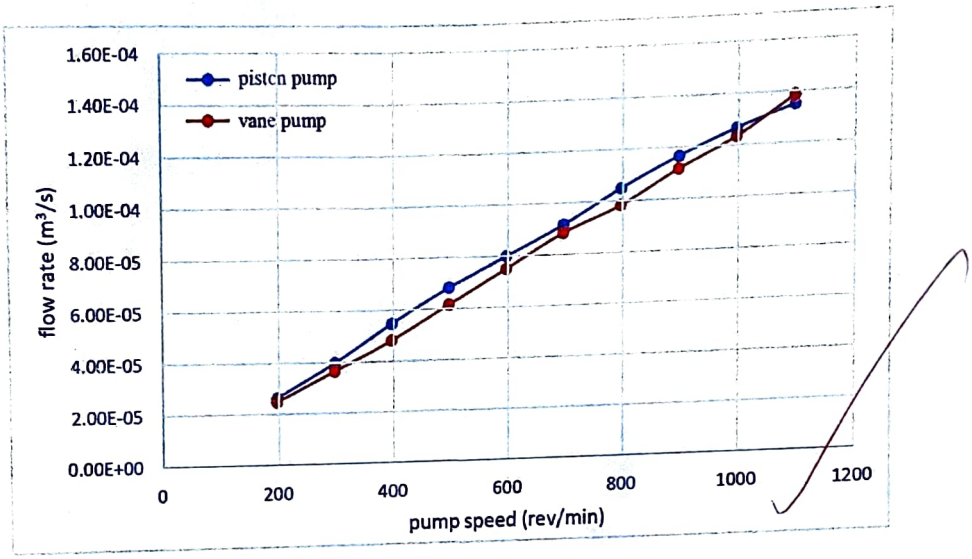

Figure 5: Flow rate vs. pump speed at constant delivery pressure of different pumps.

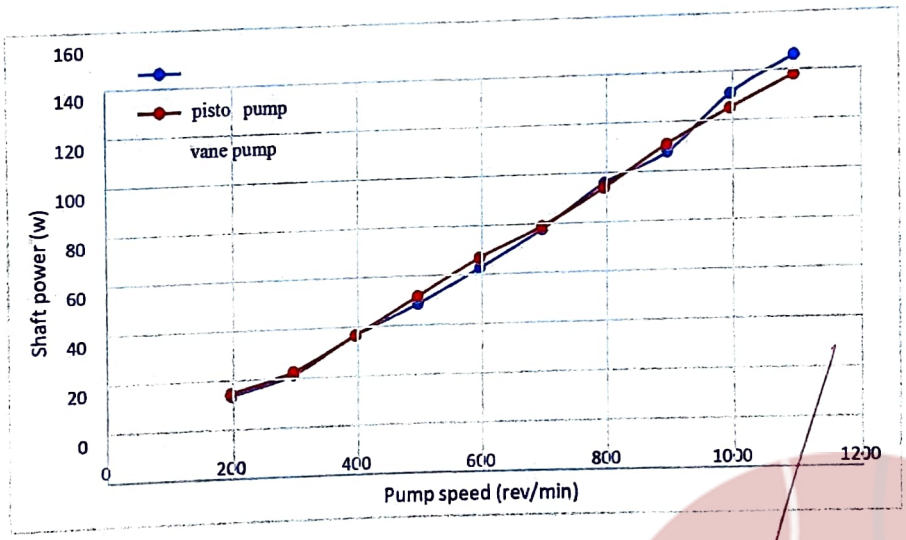

Figure 6: Shaft power vs. pump speed at constant delivery pressure of different pumps.

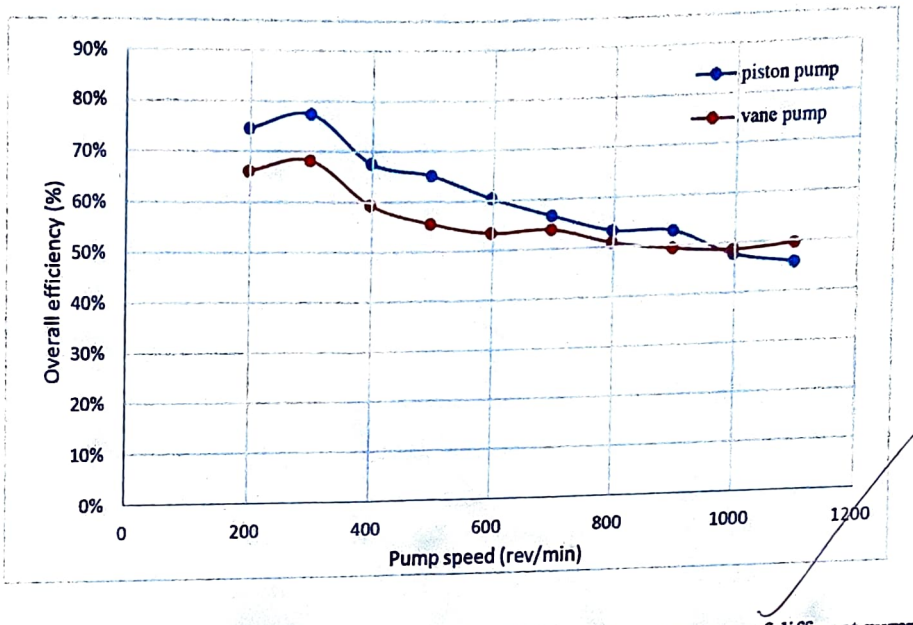

Figure 7: Overall efficiency vs. pump speed at constant delivery pressure of different pumps.

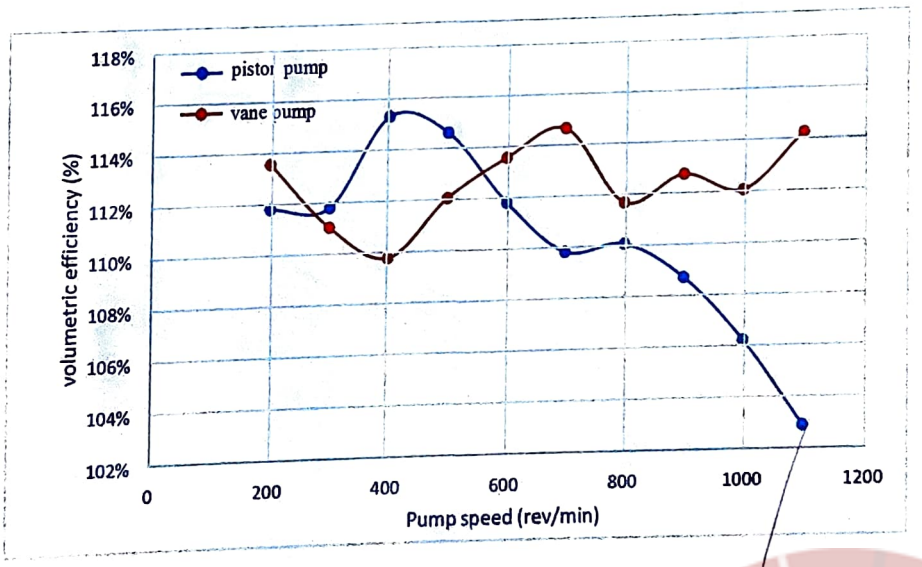

Figure 8: volumetric efficiency vs. pump speed at constant delivery pressure of different pumps

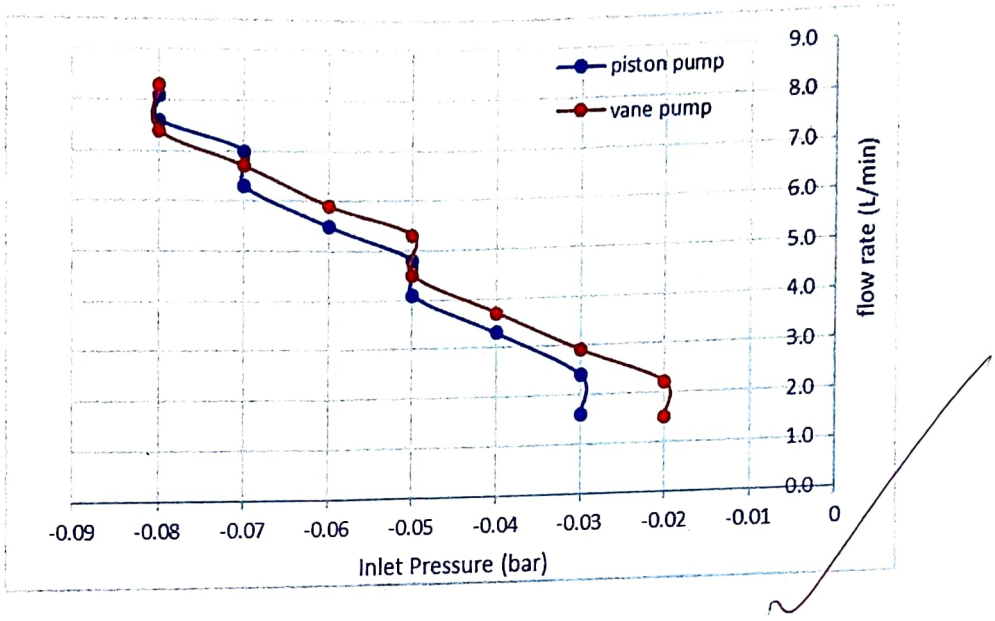

Figure 9: Flow rate vs. inlet pressure at constant delivery pressure of different pumps.

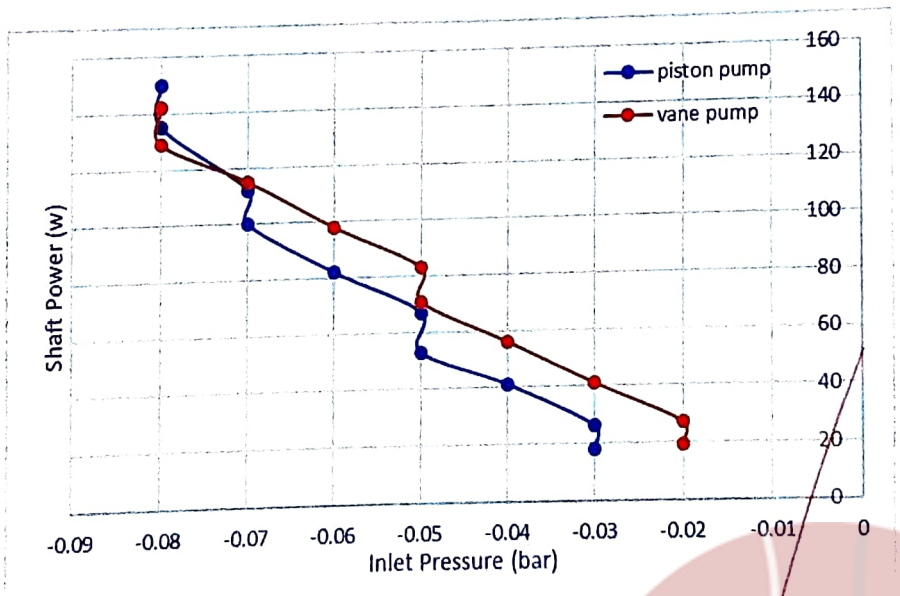

Figure 10: Shaft power vs. inlet pressure at constant delivery pressure of different pumps.

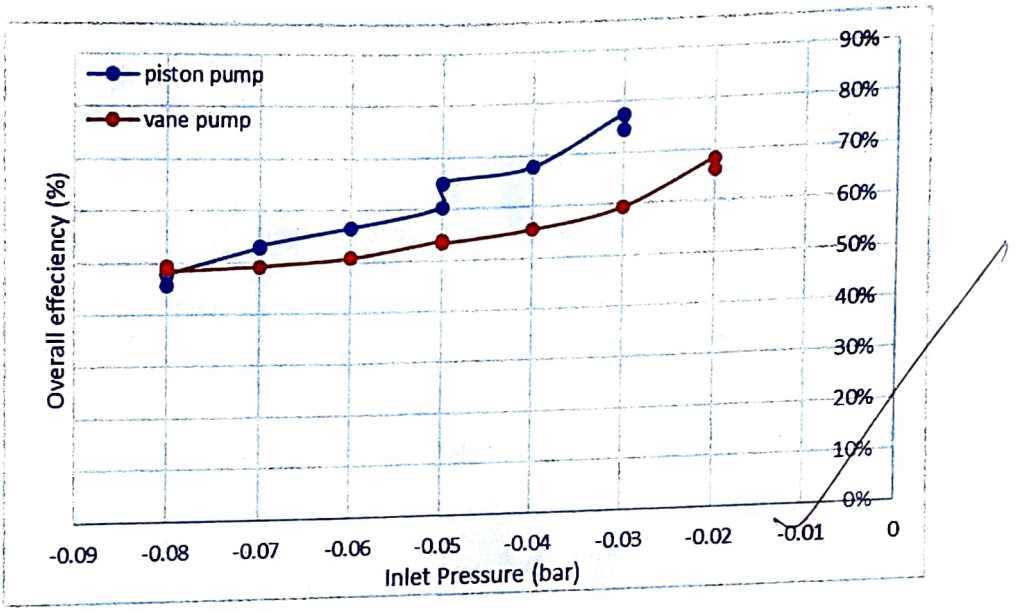

Figure11: Overall efficiency vs. inlet pressure at constant delivery pressure of different pumps.

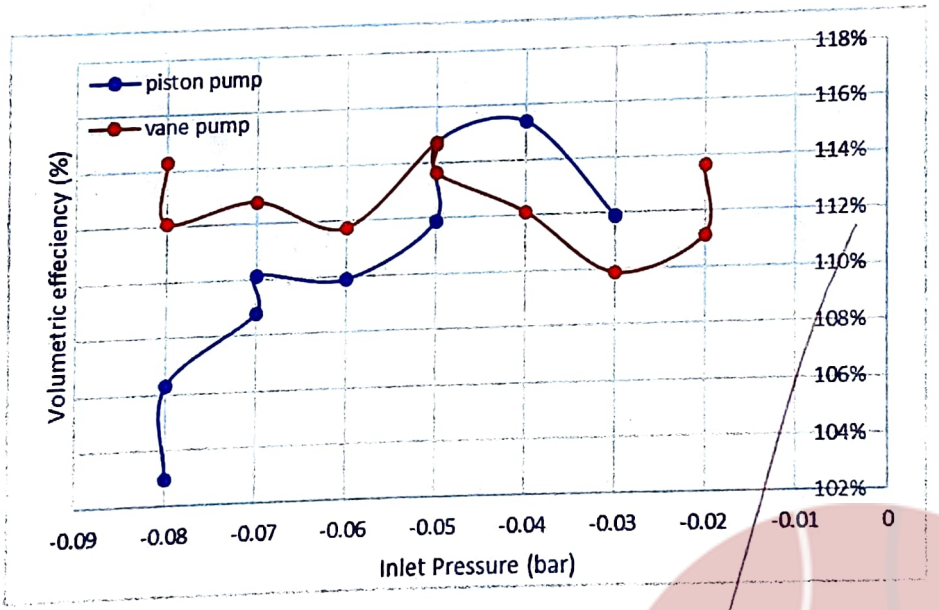

Figure 12: Volumetric efficiency vs. inlet pressure at constant delivery pressure of different pumps.

Discussion

Positive displacement pumps add energy to a fluid by applying force to the liquid with a mechanical device such as a piston or plunger. A positive displacement pump decreases the volume containing the liquid until the resulting liquid pressure equals the pressure in the discharge system. That is, the liquid is compressed mechanically, causing a direct rise in potential energy. Most positive displacement pumps are reciprocating pumps in which linear motion of a piston or plunger in a cylinder causes the displacement.

Part 1: The effect of delivery pressure at constant speed

increasing the delivery pressure results to decreasing the flow rate in both vane and piston pumps as shown in figure (1), that also leads to increasing the volumetric efficiency in both pumps as shown in figure (4) to a certain point and then it starts to decrease.

Increasing the delivery pressure at constant speed results to higher shaft power as shown in figure (2), and higher overall efficiency as you can see in figure (3).

Part 2: The effect of speed at constant delivery pressure

increasing the speed at constant delivery pressure led to increasing the flow rate in both vane and piston pumps as shown in figure (5), and increasing the shaft power in both pumps as shown in figure (6), that also leads to lower overall efficiency as shown in figure (7).

As shown in figure (8) increasing the speed at constant delivery pressure results to increasing the volumetric efficiency to a certain point 400 rev/min gives 115% volumetric efficiency in the vane pump, and around 500 rev/min gives around 115% volumetric efficiency in the piston pump, after those speeds increasing the speed decrease the volumetric efficiency.

The flow rate and shaft work decrease as the inlet pressure increase as shown in figure (11) and (12), although the overall and volumetric efficiencies increase shown in figure (13) and (14) .

Conclusion

Part 1: The effect of delivery pressure at constant speed

- When the pressure difference increases the shaft power for vane and piston pumps increase, but the increase power for piston much higher than power of vane pump.
- volumetric efficiency increases with flow rate at constant speed, low speed values have greater volumetric efficiency mechanical power so volumetric efficiency for vane higher than piston.
- low speed help pump to get higher efficiency.
- there is a lot of factors that help us to select a positive displacement pump at constant speed: flow rate, pressure difference, volumetric and overall efficiency.
- at constant speeds if working under low speeds condition is achieved then the over pump efficiency with Raise.

Part 2: The effect of speed at constant delivery pressure

- increasing the flow rate with increasing speed is the same so the value of delivery pressure does not affect very much when increasing the flow rate is desired at different constant deliver pressure.
- the major intent of overall pump efficiency care is decreasing with increasing speed increasing speed keeping higher constant value of delivery pressure yield efficiency.
- increasing speed keeping lower constant value of delivery pressure yield to higher overall volumetric efficiency.
- there is a lot of factors that helped us to select a positive displacement pump at constant delivery pressure: flow rate, speed, volumetric and overall efficiency.

Sources of errors in the experiment:

1. **Personal error**

Uncertainty in reading raw data, errors in calculation.

2. **Experimental error**

Fluctuation in readings, vibration of the system.

References

- Book: Laboratory Manual for "Chemical Engineering Laboratory (1)" by the University of Jordan, version5 2014-15.
- Website : Positive Displacement Pumps - an overview | ScienceDirect Topics
- Website : Different Types of Pumps and Their Working [Explained] PDF (theengineerspost.com)

Appendix

Sample of calculations:

Taking the first row from each table:

At constant speed=400 rev/min from table (1)

$$Q_v = 3.1\frac{L}{min} * \frac{min}{60\,s} * \frac{m^3}{10^3 L} = 5.17 * 10^{-5}\frac{m^3}{s}.$$

1.Pressure difference across the pump:

$$\Delta P = P_{out} - P_{in} = 1 - (-0.03) = 1.03\ bar * 100000 = 1.03 * 10^5\ pa.$$

2.Hydraulic Power (W_P):

$$W_p = \Delta P * Q_v = 1.03 * 10^5 \frac{N}{m^2} * 5.17 * 10^{-5}\frac{m^3}{s} * \frac{1KW}{1000W} = 5.32 * 10^{-3} kw.$$

3.Expected flow rate for the speed:

$$Q_E = V_S * N_p = 7.15\frac{ccm}{rev} * 400\frac{rev}{min} * 10^{-3}\frac{L}{ccm} = 2.86\frac{L}{min} * \frac{min}{60\,s} * \frac{m^3}{10^3 L} = 4.76 * 10^{-5}\frac{m^3}{s}.$$

4.Overall pump efficiency:

$$\eta_P = (W_P / W_D) * 100\% = \frac{5.32 * 10^{-3} kw}{13\,w} * \frac{1000\,w}{kw} * 100\% = 40.9\%$$

5.Volumetric efficiency:

$$\eta_v = (Q_v / Q_E) * 100\% = \frac{5.17 * 10^{-5}\frac{m^3}{s}}{4.76 * 10^{-5}\frac{m^3}{s}} * 100\% = 108.6\%$$

At constant delivery pressure from table (5)

$$Q_v = 1.6\frac{L}{min} * \frac{min}{60\ s} * \frac{m^3}{10^3 L} = 2.67 * 10^{-5}\frac{m^3}{s}.$$

1.Pressure difference across the pump:

$$\Delta P = P_{out} - P_{in} = 5 - (-0.03) = 5.03\ bar\ * 1.01 * 10\text{^}5 = 5.08 * 10^5\ pa.$$

2.Hydraulic Power (W_P):

$$W_p = \Delta P * Q_v = 5.08 * 10^5 \frac{N}{m^2} * 2.67 * 10^{-5}\frac{m^3}{s} = 13.56\ w$$

3.Expected flow rate for the speed:

$$Q_E = V_S * N_p = 7.15\frac{ccm}{rev} * 200\frac{rev}{min} * 10^{-3}\frac{L}{ccm} = 2.86\frac{L}{min} * \frac{min}{60\ s} * \frac{m^3}{10^3 L} = 2.38 * 10^{-5}\frac{m^3}{s}.$$

4.Overall pump efficiency:

$$\eta_P = (W_P / W_D) * 100\% = \frac{13.56}{18\ w} * 100\% = 75.3\%$$

5.Volumetric efficiency:

$$\eta_v = (Q_v / Q_E) * 100\% = \frac{2.67 * 10^{-5}\frac{m^3}{s}}{2.38 * 10^{-5}\frac{m^3}{s}} * 100\% = 112.2\%$$

Piston

~~Vane~~ pump / Constant speed / (dis/rev) = 7.15 cc/rev

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- Noor Ghassan
- Sajq Alqisi
- laila Alameri

rev/min	Nm	W	bar	bar	K	L/min
Speed	Torque	Power	Inlet Pressure (P1)	Delivery Pressure (P2)	oil temp	Flow Rate
400	0.32 Nm	13 W	−0.03 bar	1 bar	23.5	3.1 L/min
400	0.44	18 W	−0.03	2 bar	23.6	3.2
400	0.59	24 W	−0.03	3 bar	23.6	3.2
400	0.75	31	−0.03	4 bar	23.6	3.2
400	0.89	36	−0.03	5 bar	23.6	3.2
400	1.04	46	−0.03	6 bar	23.6	3.3
400	1.22	51	−0.04	7 bar	23.7	3.3
400	1.33	55	−0.04	8 bar	23.7	3.3
400	1.53	63	−0.05	9 bar	23.8	3.2
400	1.69	68	−0.05	10 bar	23.8	3.0

seen

Piston:

~~Vane~~ pump Constant pressure (dis/rev) = 7.15

Speed	Torque	Power	Inlet Pressure (P1)	Delivery Pressure (P2)	oil temp	Flow Rate
200	0.85	18	−0.03	5 bar	24.2	1.6
300	0.84	26	−0.03	5 bar	24.2	2.4
400	1.01	41	−0.04	5 bar	24.2	3.3
500	1.03	53	−0.05	5 bar	24.2	4.1
600	1.08	67	−0.05	5 bar	24.3	4.8
700	1.11	82	−0.06	5 bar	24.3	5.5
800	1.20	100	−0.07	5 bar	24.4	6.3
900	1.18	112	−0.07	5 bar	24.4	7.0
1000	1.28	135	−0.08	5 bar	24.5	7.6
1100	1.24	150	−0.08	5 bar	24.4	8.1

Ans

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Piston pump / Constant speed / (dis/rev) = 6.6 cc/rev

Speed	Torque	Power	Inlet Pressure (P1)	Delivery Pressure (P2)	oil temp	Flow Rate
400	0.45	18	-0.03	1	24.8	3.0
400	0.59	24	-0.03	2	24.8	3.0
400	0.74	30	-0.03	3	24.9	3.0
400	0.91	37	-0.03	4	24.9	2.9
400	1.05	44	-0.03	5	24.9	2.9
400	1.19	49	-0.03	6	24.9	2.9
400	1.34	55	-0.03	7	24.9	2.9
400	1.46	61	-0.03	8	24.9	2.9
400	1.59	66	-0.03	9	24.9	2.9
400	1.72	71	-0.03	10	24.9	2.8

vane

Piston pump Constant pressure (dis/rev) = 6.6 cc/rev

Speed	Torque	Power	Inlet Pressure (P1)	Delivery Pressure (P2)	oil temp	Flow Rate
rev/m	Nm	W				
200	0.91	19	-0.02	5 bar	24.3	1.5
300	0.87	27	-0.02	5 bar	24.8	2.2
400	1.03	41	-0.03	5 bar	24.8	2.9
500	1.08	56	-0.04	5 bar	24.8	3.7
600	1.13	71	-0.05	5 bar	24.9	4.5
700	1.14	83	-0.05	5 bar	25.0	5.3
800	1.18	98	-0.06	5 bar	25.0	5.9
900	1.22	115	-0.07	5 bar	25.0	6.7
1000	1.23	129	-0.08	5 bar	25.1	7.4
1100	1.25	142	-0.08	5 bar	25.1	8.3

27-7-2022