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Experiment Number (4)

The Performance of Radial Fan

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Abstract

In this experiment we examined the performance of a radial flow rotor (a mechanical device which is powered by an electrical motor) in air over wide range of operating conditions for impeller with radial blades, there are two types of impellers which differ in blade shape. First, forward curved fan, where the air exits tangentially from the circumference of the fan (which gives higher efficiency). Second backward curved fan, which the air exits in a radial direction. During this experiment we used the forward curved impeller fan. We found that the highest efficiency is considered at 100% speed.

no need

ok

this is apparatus discription.

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Results

cross sectional area =6.361725 * 10^{-3} m^2.

At speed 100%

Table (1): raw data at speed 100%

position	fan speed	dP_N (pa)	dP_f(pa)	T_1(°C)	T_1(K)	$P_{electrical}$ (W)	$P_{ambient}$ (mbar)
0	3300	0.2111	320.0820	26.5	299.65	44.7	904
0.5	3300	1.5363	322.3026	26.5	299.65	45.4	904
1	3300	12.7936	316.3392	26.4	299.55	55.2	904
1.5	3300	75.5252	429.6112	26.3	299.45	82.6	904
2	3300	165.5456	426.1501	26.3	299.45	125.6	904
2.5	3300	240.4032	396.7378	26.3	299.45	161.8	904

Table (2): calculated data at speed 100%

density(kg/m^3)	air velocity u (m/s)	volumetric flow rate(vs)in (m^3/s)	volumetric flow rate(vs) in (m^3/h)	P_{hyd} (w)	efficiency
1.0518	0.6336	0.004031	14.5099	1.2901	2.8861%
1.0518	1.7092	0.010873	39.1434	3.5044	7.7190%
1.0522	4.9314	0.031372	112.9390	9.9242	17.9786%
1.0525	11.9796	0.076211	274.3602	32.7412	39.6382%
1.0525	17.7360	0.112832	406.1945	48.0833	38.2829%
1.0525	21.3731	0.135970	489.4917	53.9444	33.3402%

At speed 90%

Table (3): raw data at speed 90%

position	fan speed	dP_N (pa)	dP_f(pa)	T_1(°C)	T_1(K)	$P_{electrical}$ (W)	$P_{ambient}$ (mbar)
0	2970	0.2274	256.9216	26.6	299.75	45.1	904
0.5	2970	1.3017	258.3027	26.5	299.65	46.2	904
1	2970	10.2846	252.1737	26.5	299.65	52.1	904
1.5	2970	57.4531	334.6658	26.4	299.55	59.6	904
2	2970	134.5076	338.9711	26.3	299.45	100.9	904
2.5	2970	187.4613	319.0763	26.2	299.35	120.7	904

Table (4): calculated data at speed 90%

density(kg/m^3)	air velocity u (m/s)	volumetric flow rate(vs)in (m^3/s)	volumetric flow rate(vs) in (m^3/h)	P_{hyd} (w)	efficiency
1.0515	0.6577	0.004184	15.0622	1.0749	2.3835%
1.0518	1.5733	0.010009	36.0309	2.5852	5.5958%
1.0518	4.4222	0.028133	101.2777	7.0943	13.6167%
1.0522	10.4503	0.066482	239.3340	22.2491	37.3308%
1.0525	15.9872	0.101706	366.1412	34.4754	34.1678%
1.0529	18.8704	0.120048	432.1738	38.3046	31.7353%

At speed 80%

Table (5): Raw data at speed 80%

position	fan speed	dP_N (pa)	dP_f(pa)	T_1(°C)	T_1(K)	$P_{electrical}$ (W)	$P_{ambient}$ (mbar)
0	2640	0.3756	201.125	26.6	299.75	39.2	904
0.5	2640	0.8122	199.6053	26.6	299.75	38	904
1	2640	8.4397	197.9492	26.6	299.75	44.2	904
1.5	2640	41.7657	252.5352	26.5	299.65	55.7	904
2	2640	102.9253	265.4316	26.4	299.55	80	904
2.5	2640	145.6819	249.1145	26.3	299.45	92.8	904

Table (6): Calculated data at speed 80%

density(kg/m^3)	air velocity u (m/s)	volumetric flow rate(vs)in (m^3/s)	volumetric flow rate(vs) in (m^3/h)	P_{hyd} (w)	efficiency
1.0515	0.8452	0.005377	19.3578	1.0815	2.7589%
1.0515	1.2429	0.007907	28.4658	1.5783	4.1535%
1.0515	4.0066	0.025489	91.7606	5.0455	11.4152%
1.0518	8.9115	0.056693	204.0939	14.3169	25.7036%
1.0522	13.9872	0.088983	320.3382	23.6189	29.5236%
1.0525	16.6380	0.105846	381.0465	26.3678	28.4136%

At speed 70%

Table (7): Raw data at speed 70%

position	fan speed	dP_N (pa)	dP_f(pa)	T_1(°C)	T_1(K)	$P_{electrical}$ (W)	$P_{ambient}$ (mbar)
0	2310	0.0490	150.5711	26.69	299.84	34.8	904
0.5	2310	0.8711	152.431	26.60	299.75	36.2	904
1	2310	5.6503	148.6195	26.50	299.65	38.9	904
1.5	2310	32.4966	192.5109	26.40	299.55	46.0	904
2	2310	81.9389	199.1589	26.40	299.55	61.3	904
2.5	2310	107.3173	186.9336	26.30	299.45	70.2	904

Table (8): Calculated data at speed 70%

density(kg/m^3)	air velocity u (m/s)	volumetric flow rate(vs)in (m^3/s)	volumetric flow rate(vs) in (m^3/h)	P_{hyd} (w)	efficiency
1.0512	0.3053	0.001942	6.9929	0.2925	0.8405%
1.0515	1.2872	0.008189	29.4799	1.2482	3.4482%
1.0518	3.2778	0.020852	75.0682	3.0991	7.9667%
1.0522	7.8594	0.049999	179.9976	9.6254	20.9248%
1.0522	12.4800	0.079394	285.8201	15.8121	25.7946%
1.0525	14.2801	0.090846	327.0469	16.9822	24.1912%

Diagrams:

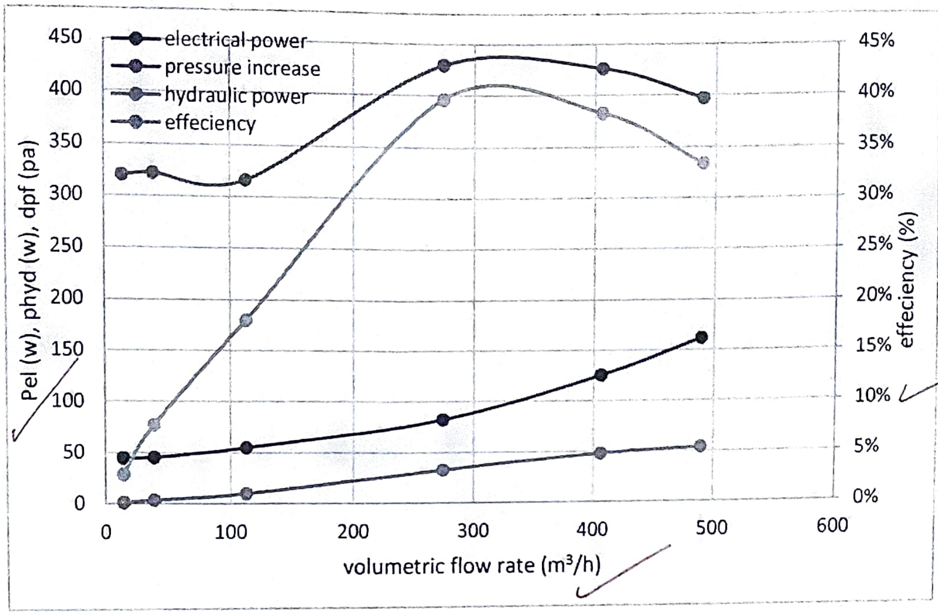

Figure (1): Fan Characteristics vs volumetric flow rate at 100%

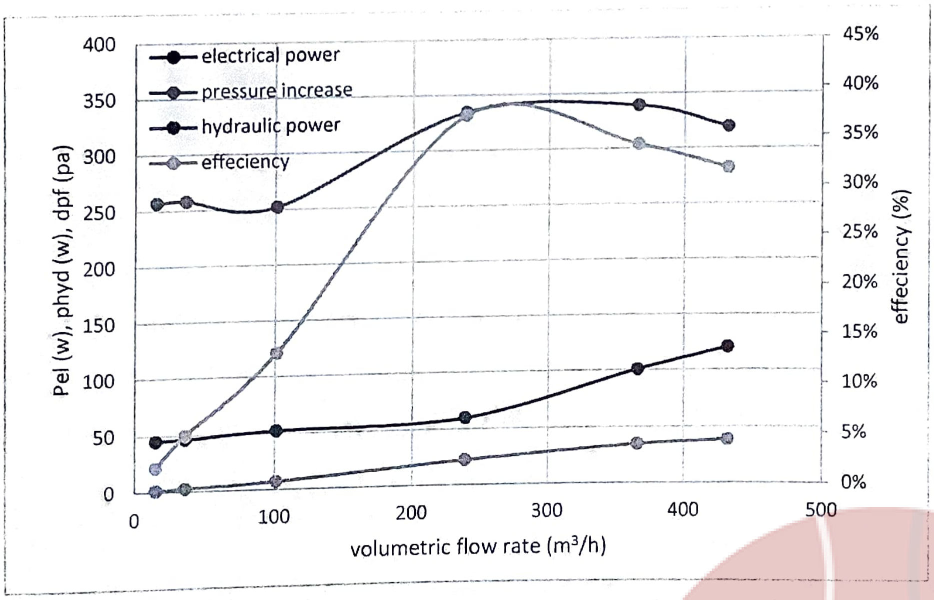

Figure (2): Fan Characteristics vs volumetric flow rate at 90%

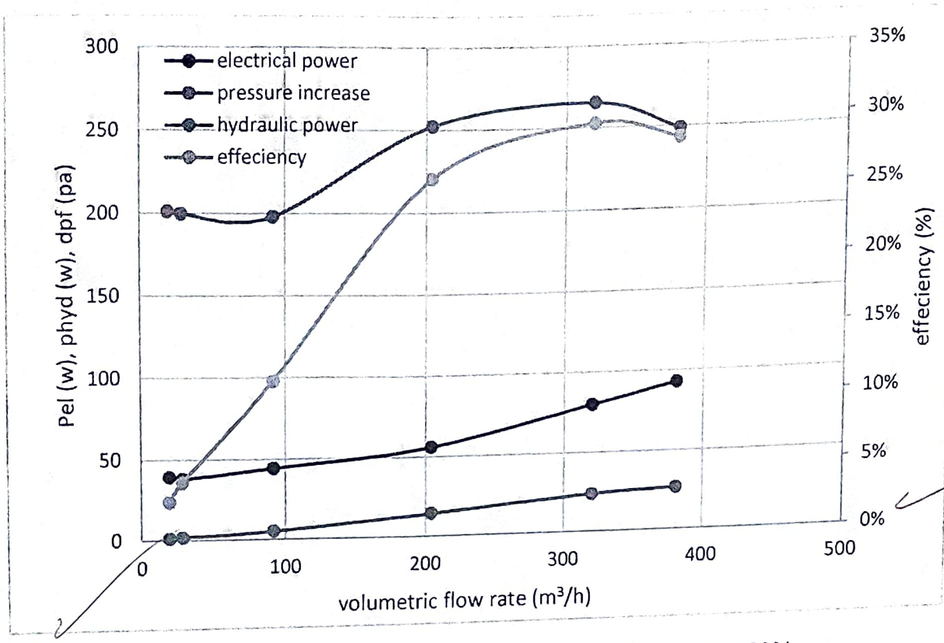

Figure (3): Fan Characteristics vs volumetric flow rate at 80%

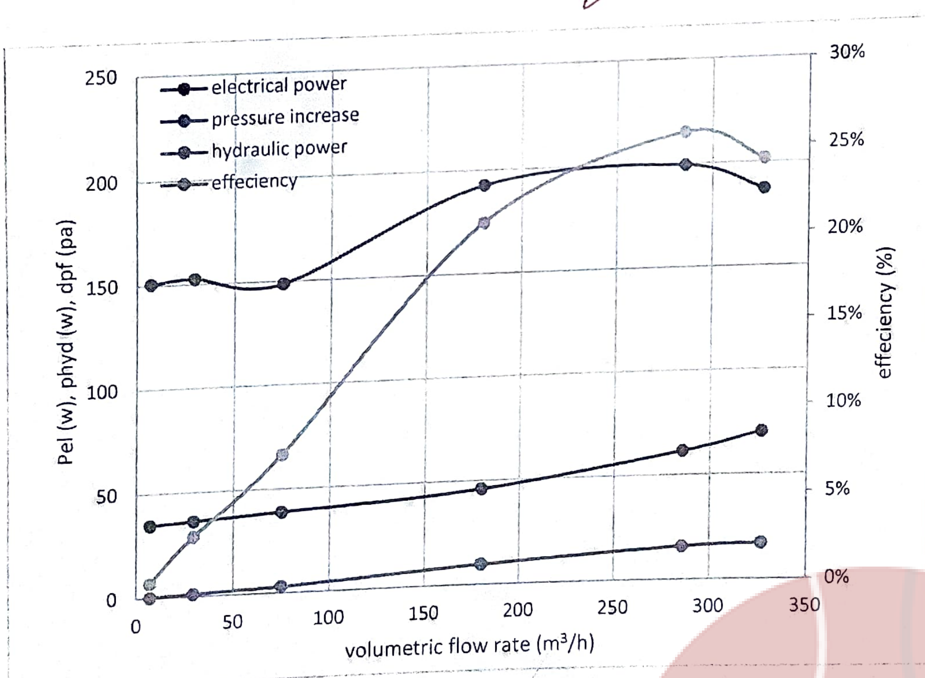

Figure (4): Fan Characteristics vs volumetric flow rate at 70%

Discussion of the Results:

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

Efficiency increases with increasing volumetric flow rate reaching the peak value then decreasing. It reaches the maximum efficiency at speed 100% with the value of 39.6382% as shown in table (2), figure (1).

Hydraulic and electrical power are directly proportional to volumetric flow rate as shown in all figures above they both increase with increasing volume flow.

Hydraulic power depends on pressure increase and suction volume, direct relationship.

Electrical power has higher vales the hydraulic power.

As we can see in table (2), the efficiency increases as increasing the opening of the valve, the efficiency when the throttling valve is fully closed is (2.8861%), while the efficiency when the throttling valve is fully open is (33.3402%).

We cannot use this type of fan test to predict the performance of a geometrically similar pump as fan is used for gases while pump is used to rise liquids.

Conclusion and Recommendation

- Because a pump is used for liquid instead of gas, we cannot use this test to forecast how well a pump with identical geometry will function.
- Efficiency rises when the delivery pip's throttle valve opens wider.
- hydraulic power rises as the volumetric flow rate rises; and electrical power.
- hydraulic power, and hydraulic power all rise as the fan's speed is increased.

References

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Appendix

Sample of calculation

❖ **Taking the first raw of table (2) :(100% speed first trial)**

1.Tempreture (K):

$T_1(K) = T_1(°c) + 273.15 = 26.5 + 273.15 = 299.65$ K.

2.Density:

$$\rho = \rho_0 * \frac{T_0}{T_1} * \frac{P_{amb.}}{P_0} = 1.293 * \frac{273.15}{299.65} * \frac{904}{1013} = 1.0518\ kg/m^3.$$

3.Velocity:

$$u = \sqrt{\frac{2*dP_N}{\rho}} = \sqrt{\frac{2*0.2111}{1.0518}} = 0.6336\ m/s.$$

4.Area:

$$A = \frac{\pi}{4} d_i^{\,2} = \frac{\pi}{4}(90 * 10^{-3})^2 = 6.3617 * 10^{-3} m^2.$$

5.Volumetric flow rate:

$$Vs = u * A = (0.6336) * (6.3617 * 10^{-3}) = 4.031 * 10^{-3}\ m^3/s.$$

$$Vs\ (m^3/h) = 4.031 * 10^{-3} \frac{m^3}{s} * 3600 \frac{s}{h} = 14.5099\ m^3/h.$$

6. Hydraulic power:

$$P_{hyd.} = dP_f * Vs = (320.082) * (4.0305 * 10^{-3}) = 1.2901\ w.$$

7.Efficiency:

$$\eta = \frac{P_{hyd.}}{P_{el}} * 100\% = \frac{1.2901}{44.7} * 100\% = 2.8861\%.$$

❖ **Taking the first raw of table (4) :(90% speed first trial)**

1.Tempreture (K):

$T_1(K) = T_1(°c) + 273.15 = 26.6 + 273.15 = 299.75$ K.

2.Density:

$$\rho = \rho_0 * \frac{T_0}{T_1} * \frac{P_{amb.}}{P_0} = 1.293 * \frac{273.15}{299.75} * \frac{904}{1013} = 1.0515\ kg/m^3.$$

3.Velocity:

$$u = \sqrt{\frac{2*dP_N}{\rho}} = \sqrt{\frac{2*0.2274}{1.0515}} = 0.6577\ m/s.$$

4.Area:

$$A = \frac{\pi}{4} d_i^{\,2} = \frac{\pi}{4}(90 * 10^{-3})^2 = 6.3617 * 10^{-3} m^2.$$

5.Volumetric flow rate:

$$Vs = u * A = (0.6577) * (6.3617 * 10^{-3}) = 4.184 * 10^{-3}\, m^3/s\,.$$

$$Vs\,(m^3/h) = 4.184 * 10^{-3} \frac{m^3}{s} * 3600 \frac{s}{h} = 15.0622\ m^3/h\,.$$

6. Hydraulic power:

$$P_{hyd.} = dP_f * Vs = (256.9216) * (4.184 * 10^{-3}) = 1.0749\, w.$$

7.Efficiency:

$$\eta = \frac{P_{hyd.}}{P_{el}} * 100\% = \frac{1.0749}{45.1} * 100\% = 2.3835\%.$$

- **Taking the first raw of table (6) :(80% speed first trial)**

1.Tempreture (K):

$T_1(K) = T_1(°c) + 273.15 = 26.6 + 273.15 = 299.75$ K.

2.Density:

$$\rho = \rho_0 * \frac{T_0}{T_1} * \frac{P_{amb.}}{P_0} = 1.293 * \frac{273.15}{299.75} * \frac{904}{1013} = 1.0515\, kg/m^3.$$

3.Velocity:

$$u = \sqrt{\frac{2 * dP_N}{\rho}} = \sqrt{\frac{2 * 0.3756}{1.0515}} = 0.8452\, m/s.$$

4.Area:

$$A = \frac{\pi}{4} d_i^{\,2} = \frac{\pi}{4}(90 * 10^{-3})^2 = 6.3617 * 10^{-3} m^2.$$

5.Volumetric flow rate:

$$Vs = u * A = (0.8452) * (6.3617 * 10^{-3}) = 5.377 * 10^{-3}\, m^3/s\,.$$

$$Vs\,(m^3/h) = 5.377 * 10^{-3} \frac{m^3}{s} * 3600 \frac{s}{h} = 19.357\, m^3/h\,.$$

6. Hydraulic power:

$$P_{hyd.} = dP_f * Vs = (201.125) * (5.377 * 10^{-3}) = 1.0815\, w.$$

7.Efficiency:

$$\eta = \frac{P_{hyd.}}{P_{el}} * 100\% = \frac{1.0815}{39.2} * 100\% = 2.759\%.$$

❖ **Taking the first raw of table (8) :(70% speed first trial)**

1.Tempreture (K):

$T_1(K) = T_1(°c) + 273.15 = 26.69 + 273.15 = 299.84$ K.

2.Density:

$$\rho = \rho_0 * \frac{T_0}{T_1} * \frac{P_{amb.}}{P_0} = 1.293 * \frac{273.15}{299.84} * \frac{904}{1013} = 1.0512\ kg/m^3.$$

3.Velocity:

$$u = \sqrt{\frac{2*dP_N}{\rho}} = \sqrt{\frac{2*0.049}{1.0512}} = 0.3053\ m/s.$$

4.Area:

$$A = \frac{\pi}{4} d_i^{\ 2} = \frac{\pi}{4}(90 * 10^{-3})^2 = 6.3617 * 10^{-3} m^2.$$

5.Volumetric flow rate:

$$Vs = u * A = (0.3053) * (6.3617 * 10^{-3}) = 1.942 * 10^{-3}\ m^3/s.$$

$$Vs\ (m^3/h) = 1.942 * 10^{-3} \frac{m^3}{s} * 3600 \frac{s}{h} = 6.9912\ m^3/h.$$

6. Hydraulic power:

$$P_{hyd.} = dP_f * Vs = (150.5711) * (1.942 * 10^{-3}) = 0.2924\ w.$$

7.Efficiency:

$$\eta = \frac{P_{hyd.}}{P_{el}} * 100\% = \frac{0.2924}{34.8} * 100\% = 0.8402\%.$$

Symbol	Meaning	Unit
ρ	The density of the intake air	Kg/m^3
ρ_0	The air density at the reference temperature	Kg/m^3
T_0	The reference temperature	273.15 K
T_1	The temperature of the intake air	K
$P_{amb.}$	The ambient pressure	mbar
P_0	The reference pressure	1013 mbar
u	The air velocity	m/s
P_N	The dynamic pressure	N/m^2, (pa)
dP_N	The differential pressure between ambient static pressure and nozzle static pressure	(pa)
A	Flow cross section	m^2
$\dot{V}s$	Suction volume flow	m^3/s
$P_{hyd.}$	The hydraulic power of the air	W
dP_f	The static pressure	N/m^2, (pa)
η	Efficiency	Unitless
P_{el}	Electrical power	W