MŰEGYETEM 1782

Budapest University of Technology and Economics

Department of Fluid Mechanics

Fluid Mechanics Laboratory Practice M12

Task D

<u>Laboratory practice conducted by:</u>

Camille Marie Cardoze (Y3GTYB) - Leader

Oluwalemi Adewole Oyeyele (HDVNX1) - Leader

Danara Nurmukhanova (PCUFSG) - Helper

Maxim Mintus (HU1ZQL) - Helper

Verification Code:

HDVNX1-M12-7-4.44-21.1-1345-0.095-0.12182-580bb6357fc8ebb6e15526d8f1235b45

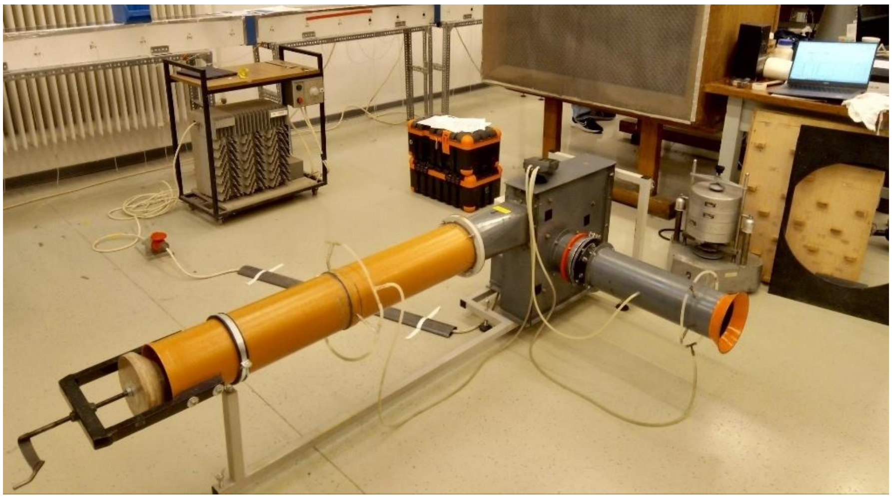
Date: 25.11.2024

Contents of the report

1. Goal and Description of the Measurement

The goal of this measurement was to determine the main characteristics of a radial fan, namely the total pressure change across the fan as a function of its volumetric flow rate, as well as its effective power curve. We conducted our measurements for different RPM settings and air inlet angles approaching the fan.

The fan was connected to a flow tube on its inlet and outlet side respectively, with the inlet tube having a trumpet-like orifice at the mouth, as well as adjustable turning vanes. These vanes ensured the oncoming air approached the fan at a particular preset angle. The outlet tube had an adjustable choke at the end, allowing us to precisely control the volumetric flow rate at the exit of the tube. Both tubes had static pressure probes compatible with our digital manometer, allowing for the recording of pressure differences. The RPM value could be adjusted using a thyristor on the 3-phase motor unit powering the fan.



Prior to and following each measurement, the ambient pressure and temperature (p_0 and T_0 respectively) was recorded using the Fischer barometer and the liquid-in glass thermometer.

We started off by calibrating our digital manometer using the Betz manometer; we recorded various static pressure value points (the pressure changed using a syringe) using both instruments. Following this, we plotted the corresponding measured values of each instrument against each other on a graph with a regression line (shown in figure 1). This gave the digital manometer's future recorded values a set of reference values to be compared to, which are from a far more accurate instrument.

We then proceeded with our main measurement task. For each of the 13 data points of every combined RPM and angle setting, we used the choke to reduce the volumetric flow rate by 10% from a maximum value, recording the pressure difference between the inlet orifice and the atmosphere (Δp_{io}), as well as the pressure change across the inlet and outlet tube of the fan (Δp_t). Caution had to be exercised in order not to allow the fan speed to deviate much from its set value, as it has a tendency to climb when lowering the volumetric flow rate value. To correct for this, we periodically had to reset the fan RPM using the thyristor. Moreover, we found that the air outlet of the wind tunnel used in a measurement adjacent to ours was blowing air into the inlet orifice of our fan, interfering with the results. We subsequently moved the fan and started our measurement over.

The instruments used to carry out the measurement were the following:

- EMB-001 Digital manometer [02]
- Liquid-in-glass thermometer
- M12 Measuring tape
- ARA _BETZ-05 Betz Manometer [6989]
- Fischer 103 Barometer [8906781]
- M12 Angle measuring tool

2. The Sub-Tasks

Our sub-task was task *D,* which instructed us to initially set the inlet guide vanes to a zero angle, measuring the characteristic curves for two different RPM values while taking measurements in at least ten evenly distributed operating points for each curve. Afterwards, we set the guide vanes to a negative angle of attack and repeated the measurement of the characteristic curves for both of the RPM values that have already been investigated. Besides this, we noted down the ambient pressure and temperature before and after carrying out the measurement.

To achieve this, we first set the fan's RPM to a chosen value, and wrote down the first reading of the manometer (between the inlet side and the atmosphere, while the choke is fully open). Then, with this initial pressure difference we were to calculate an initial Qv, and obtain 9 more measuring points by decreasing the Qv by 10% for each. With our new Qv values, we calculated the pressure values that would make them possible, and matched them to our measuring system manually with the help of the manometer and choking mechanism. Then, for each point we switched to channel 2 of our manometer after matching the calculated pressure difference to channel 1, and wrote down the readings for the difference between the inlet and outlet pipes. With these values we calculated the total pressure difference, from which we also obtained all other calculated data. For the other three measurements, the process was the same, only the RPM and the angle of attack changed. To change the angle, we had to unscrew the inlet side of the fan and manually reposition each blade with the help of an angle measuring tool.

3. Equations

Volume flow rate equation:

$$Qv = k * \frac{d^2\pi}{4} * \sqrt{\frac{2 \triangle Pio}{\rho air}}$$

Velocity equation:

$$v = \frac{Qv}{A}$$

Density equation:

$$\rho = \frac{P_0}{R * T_0}$$

Effective power equation:

$$Peff = Qv * P_{tot}$$

Absolute error of the Effective power:

$$\delta Peff = \sqrt{(\delta Xi * (\frac{\partial Peff}{\partial Xi})^2)}$$

Relative error of the Effective power:

$$\boldsymbol{\delta Peff_{Relative}} = \frac{\boldsymbol{\delta Peff}}{\boldsymbol{Peff}}$$

Total Pressure equation:

$$P_{tot} = (P_{st,pressure} + \frac{\rho_{air}}{2} * v_{pressure}^2) - (P_{st,suction} + \frac{\rho_{air}}{2} * v_{suction}^2)$$

Flow coefficient:

$$\phi = \frac{Qv}{\frac{D^2\pi}{4} * u_2}$$

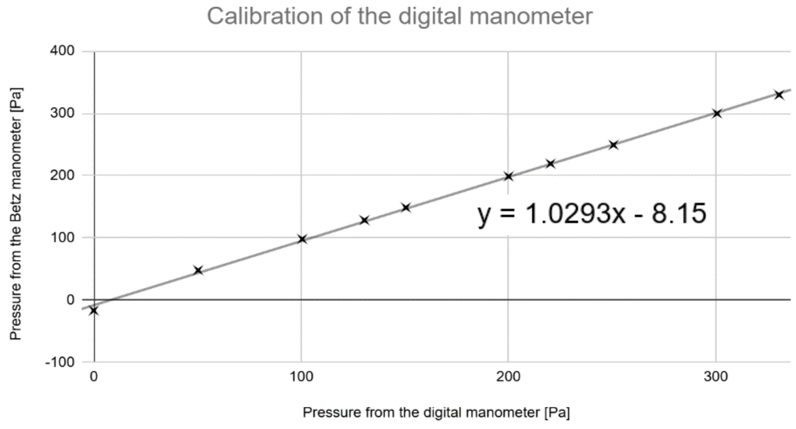
Pressure coefficient:

$$\psi = \frac{\Delta Ptot}{\frac{\rho}{2} * u_2^2}$$

Where:

k =	Experimentally determined, 0.96	[-]
d =	Diameter of the suction tube	[m]
A =	Cross sectional area of the suction tube	[m^2]
R =	Specific gas constant of air (287)	[J/kg*K]
P0 =	Ambient pressure	[Pa]
T0 =	Ambient temperature	[K]
D =	Diameter of the impeller	[m]
u =	Circumferential velocity of the fan	[m/s]
ρ =	Density	[m^3/kg]
ΔPio =	Pressure difference between inlet and atmosphere	[Pa]
Xi =	Evaluated error	[Pa, K]

4. Calibration of the digital manometer



Digital (Pa)	Betz (mm)	Betz (Pa)
-0.05	-1.70	-16.68
50.31	4.90	48.07
100.45	10.00	98.10
130.5	13.10	128.5
150.5	15.15	148.6
200	20.25	198.7
220.25	22.35	219.3
250.65	25.40	249.2
300.6	30.55	299.7
330.5	33.60	329.6

Figure 1: To ensure accurate results, our EMB-001 digital manometer was calibrated by comparing its values to a previously calibrated Betz manometer. The Betz manometer showed a height in mm caused by the static pressure, which we calculated using $p = \frac{\rho * g * h}{1000}$. The resulting graph gives us a regression line which follows the equation y = 1.0293x - 8.15. We could see from the diagram as well as the regression equation that the readings from the Betz manometer have a linear, almost 1:1 relationship with that of its digital counterpart in the data range that we are to work in. This means that the digital manometer is precise enough to reliably take up the role of the more accurate Betz manometer.

5. Measured and Calculated Data

Table 1: Measured Data. Obtained by measuring the ambient pressure with a Barometer, the ambient temperature with a mercury thermometer, and the Suction and Pressure pipes' diameters with a measuring tape. From these values we obtained the cross-sectional areas. All other values were given.

General Data	Meas. value	Unit
K	0.96	-
P	1.204	kg/m^3
D_suction	0.153	m
T_0 - before lab	21.1	C
T_abs	294.25	K
p_0 - before lab	101700	Pa
D_pressure	0.157	m
A_suction	0.0184	m^2
A_pressure	0.0194	m^2
R	287	J/kg K
T_0 - after lab	294.65	K
p_0 - after lab	99500	Pa

	Angle = 0	deg									
	n = 1345 RPM										
Percentage of original q_v value	Δp_t [Pa]	Δp_io [Pa]	q_v [m^3/s]	v_t [m/s]	v_io [m/s]	ΔP_tot [Pa]	E. Power [W]	Abs. Error	Rel. error	Pressure Coef	Flow Coeff.
100.0	131.25	81.8	0.2057	10.626	11.189	123.86	25.48	0.518011	0.020331	0.3588	0.0946
90.0	114.4	66.26	0.1851	9.564	10.070	108.41	20.07	0.479738	0.023901	0.3140	0.0852
81.0	129.5	53.67	0.1666	8.607	9.063	124.65	20.77	0.512048	0.024653	0.3611	0.0766
72.9	128.2	43.47	0.1500	7.747	8.157	124.27	18.64	0.524252	0.028130	0.3600	0.0690
65.6	122.4	35.21	0.1350	6.972	7.341	119.22	16.09	0.531511	0.033032	0.3453	0.0621
59.0	118.7	28.52	0.1215	6.275	6.607	116.12	14.11	0.551580	0.039103	0.3364	0.0559
53.1	112.1	23.10	0.1093	5.647	5.946	110.01	12.03	0.565056	0.046981	0.3187	0.0503
47.8	109.7	18.71	0.0984	5.083	5.352	108.01	10.63	0.601335	0.056583	0.3129	0.0453
43.0	107.25	15.16	0.0886	4.574	4.817	105.88	9.38	0.643647	0.068647	0.3067	0.0407
38.7	105.2	12.28	0.0797	4.117	4.335	104.09	8.30	0.694393	0.083703	0.3015	0.0367
34.9	100.7	9.94	0.0717	3.705	3.901	99.80	7.16	0.734097	0.102546	0.2891	0.0330
31.4	99.1	8.06	0.0646	3.335	3.511	98.37	6.35	0.798941	0.125806	0.2850	0.0297
28.2	95	6.52	0.0581	3.001	3.160	94.41	5.49	0.848727	0.154726	0.2735	0.0267

n = 2050 RPM										
Δp_t [Pa]	Δp_io [Pa]	q_v [m^3/s]	v_t [m/s]	v_io [m/s]	ΔP_tot [Pa]	E. Power [W]	Abs. Error	Rel. error	Pressure coeff.	Flow coeff.
230.0	255.00	0.363	18.762	19.756	206.95	75.17	0.795163	0.010578	0.2581	0.1096
256.0	206.55	0.327	16.886	17.780	237.33	77.58	0.766395	0.009878	0.2959	0.0987
293.5	167.31	0.294	15.197	16.002	278.35	81.89	0.778973	0.009512	0.3471	0.0888
301.5	135.52	0.265	13.677	14.402	289.25	76.59	0.786264	0.010266	0.3607	0.0799
318.0	109.77	0.238	12.310	12.962	308.08	73.42	0.831484	0.011325	0.3842	0.0719
321.3	88.91	0.214	11.079	11.666	313.26	67.19	0.877008	0.013053	0.3906	0.0647
300.0	72.02	0.193	9.971	10.499	293.49	56.65	0.881962	0.015568	0.3660	0.0583
314.3	58.34	0.174	8.974	9.449	309.03	53.69	0.988272	0.018408	0.3853	0.0524
299.8	47.25	0.156	8.076	8.504	295.53	46.21	1.029914	0.022289	0.3685	0.0472
272.8	38.27	0.141	7.269	7.654	269.34	37.90	1.031651	0.027220	0.3359	0.0425
284.7	31.00	0.127	6.542	6.888	281.93	35.71	1.180917	0.033074	0.3515	0.0382
277.4	25.11	0.114	5.888	6.200	275.13	31.36	1.270663	0.040519	0.3431	0.0344
272.5	20.34	0.103	5.299	5.580	270.66	27.77	1.381241	0.049747	0.3375	0.0310

	Angle = -15	deg									
	n = 1345 RPM										
Percentage of original q_v value	Δp_t [Pa]	Δp_io [Pa]	q_v [m^3/s]	v_t [m/s]	v_io [m/s]	ΔP_tot [Pa]	E. Power [W]	Abs. Error	Rel. error	Pressure Coef	Flow Coeff.
100.0	116.5	69.90	0.1902	9.823	10.343	110.18	20.95	0.485677	0.023179	0.3192	0.0875
90.0	118.4	56.62	0.1712	8.841	9.309	113.28	19.39	0.485395	0.025035	0.3281	0.0787
81.0	123.5	45.86	0.1540	7.957	8.378	119.35	18.38	0.506625	0.027557	0.3457	0.0709
72.9	112.3	37.15	0.1386	7.161	7.540	108.94	15.10	0.492831	0.032632	0.3156	0.0638
65.6	104.6	30.09	0.1248	6.445	6.786	101.88	12.71	0.491163	0.038639	0.2951	0.0574
59.0	98.9	24.37	0.1123	5.800	6.108	96.70	10.86	0.499287	0.045982	0.2801	0.0517
53.1	104.5	19.74	0.1011	5.220	5.497	102.72	10.38	0.563633	0.054296	0.2975	0.0465
47.8	98.7	15.99	0.0910	4.698	4.947	97.25	8.85	0.582540	0.065854	0.2817	0.0418
43.0	99.8	12.95	0.0819	4.229	4.452	98.63	8.07	0.644640	0.079843	0.2857	0.0377
38.7	97.5	10.49	0.0737	3.806	4.007	96.55	7.11	0.693951	0.097555	0.2797	0.0339
34.9	99.1	8.50	0.0663	3.425	3.607	98.33	6.52	0.778697	0.119430	0.2848	0.0305
31.4	97.7	6.88	0.0597	3.083	3.246	97.08	5.79	0.850094	0.146738	0.2812	0.0275
28.2	96.3	5.58	0.0537	2.774	2.921	95.80	5.15	0.929052	0.180570	0.2775	0.0247

n = 2050 RPM										
Δp_t [Pa]	Δp_io [Pa]	q_v [m^3/s]	v_t [m/s]	v_io [m/s]	ΔP_tot [Pa]	E. Power [W]	Abs. Error	Rel. error	Pressure coeff.	Flow coeff.
236.2	174.95	0.3009	15.541	16.364	220.39	66.30	0.720721	0.010870	0.2748	0.0908
251.9	141.71	0.2708	13.986	14.727	239.09	64.74	0.717687	0.011086	0.2981	0.0817
243.8	114.78	0.2437	12.588	13.255	233.42	56.88	0.702319	0.012347	0.2911	0.0735
277.7	92.98	0.2193	11.329	11.929	269.30	59.06	0.779014	0.013190	0.3358	0.0662
275.8	75.31	0.1974	10.196	10.736	268.99	53.10	0.813479	0.015321	0.3354	0.0596
266.1	61.00	0.1777	9.177	9.663	260.59	46.29	0.841938	0.018187	0.3249	0.0536
254.0	49.41	0.1599	8.259	8.696	249.53	39.90	0.871325	0.021839	0.3112	0.0483
249.7	40.02	0.1439	7.433	7.827	246.08	35.41	0.932492	0.026334	0.3068	0.0434
243.4	32.42	0.1295	6.690	7.044	240.47	31.14	0.996470	0.031997	0.2999	0.0391
241.5	26.26	0.1166	6.021	6.340	239.13	27.87	1.087831	0.039030	0.2982	0.0352
238.6	21.27	0.1049	5.419	5.706	236.68	24.83	1.186790	0.047801	0.2951	0.0317
235.2	17.23	0.0944	4.877	5.135	233.64	22.06	1.294777	0.058698	0.2913	0.0285
232.5	13.96	0.0850	4.389	4.622	231.24	19.65	1.418606	0.072200	0.2883	0.0256

Tables 2-5: Measurements 1, 2, 3 and 4, in order. in yellow we have highlighted the data set used to obtain the verification code. In red is the measured data believed to be outliers, due to instrument and human error.

6. Uncertainty

For this measurement, we are to calculate the absolute and relative errors for the calculated values $\delta \boldsymbol{P_{eff}}$, $\delta \boldsymbol{P_{Qv}}$, and $\delta \Delta \boldsymbol{p_{tot}}$. To achieve this, we follow the general absolute error formula:

$$\delta \boldsymbol{P_{eff}} = \sqrt{\sum \left(\boldsymbol{\delta X_i} \frac{\partial \boldsymbol{P_{eff}}}{\partial \boldsymbol{X_i}} \right)^2}$$

And the relative error formula:

$$\frac{\delta \boldsymbol{P_{eff}}}{P_{eff}} = ?$$

Where $\boldsymbol{\delta X_i}$ represents the errors of the pressure measurement, temperature measurement and of the digital manometer used, which are $\delta p_0 = 100Pa$, $\delta T_0 = 1K$, $\delta \Delta p_{io} = 2Pa$, and $\delta p_{tot} = 2\ Pa$, respectively. To be able to calculate the absolute and relative errors, we'll first need to break down the partial derivative equations:

$P_{eff} = Qv * \Delta \boldsymbol{p_{tot}}$, therefore:

$$\frac{\partial P_{eff}}{\partial p_0} = -k * \frac{A}{2} * \sqrt{2 * \Delta p_{io} * R * T_0} * \Delta p_{tot} * \frac{1}{{p_0}^{3/2}}$$

$$\frac{\partial P_{eff}}{\partial T_0} = k * \frac{A}{2} * \sqrt{\frac{2 * \Delta p_{io} * R}{p_0}} * \Delta p_{tot} * \frac{1}{\sqrt{T_0}}$$

$$\frac{\partial P_{eff}}{\partial \Delta p_{io}} = k * \frac{A}{2} * \sqrt{\frac{2 * T_0 * R}{p_0}} * \Delta p_{tot} * \frac{1}{\sqrt{p_{io}}}$$

$$\frac{\partial P_{eff}}{\partial p_{tot}} = Qv$$

δp_{tot} *is given* $(2Pa)$.

With these formulas, we were able to calculate the following error values:

Error calculation meas. 1					
δp0*(dP/dp0)	δT0*(dP/dT0)	δp_io*(dP/p_io)	δp_tot*(dP/dp_tot)	δP_eff abs	δ P_eff rel
-0.0125	0.0433	0.3115	0.4114	0.5180	0.0203
-0.0099	0.0341	0.3029	0.3703	0.4797	0.0239
-0.0102	0.0353	0.3870	0.3333	0.5120	0.0247
-0.0092	0.0317	0.4287	0.2999	0.5243	0.0281
-0.0079	0.0273	0.4570	0.2699	0.5315	0.0330
-0.0069	0.0240	0.4946	0.2429	0.5516	0.0391
-0.0059	0.0204	0.5206	0.2187	0.5651	0.0470
-0.0052	0.0181	0.5679	0.1968	0.6013	0.0566
-0.0046	0.0159	0.6186	0.1771	0.6436	0.0686
-0.0041	0.0141	0.6757	0.1594	0.6944	0.0837
-0.0035	0.0122	0.7198	0.1435	0.7341	0.1025
-0.0031	0.0108	0.7884	0.1291	0.7989	0.1258
-0.0027	0.0093	0.8407	0.1162	0.8487	0.1547

Error calculation meas. 2					
δp0*(dP/dp0)	δT0*(dP/dT0)	δp_io*(dP/p_io)	δp_tot*(dP/dp_tot)	δP_eff abs	δ P_eff rel
-0.0370	0.1277	0.2948	0.7264	0.7952	0.0106
-0.0381	0.1318	0.3756	0.6538	0.7664	0.0099
-0.0403	0.1392	0.4895	0.5884	0.7790	0.0095
-0.0377	0.1301	0.5652	0.5296	0.7863	0.0103
-0.0361	0.1248	0.6688	0.4766	0.8315	0.0113
-0.0330	0.1142	0.7557	0.4290	0.8770	0.0131
-0.0279	0.0963	0.7866	0.3861	0.8820	0.0156
-0.0264	0.0912	0.9203	0.3475	0.9883	0.0184
-0.0227	0.0785	0.9779	0.3127	1.0299	0.0223
-0.0186	0.0644	0.9903	0.2814	1.0317	0.0272
-0.0176	0.0607	1.1517	0.2533	1.1809	0.0331
-0.0154	0.0533	1.2488	0.2280	1.2707	0.0405
-0.0137	0.0472	1.3650	0.2052	1.3812	0.0497

Tables 6-7

Error calculation meas. 3					
δp0*(dP/dp0)	δT0*(dP/dT0)	δp_io*(dP/p_io)	δp_tot*(dP/dp_tot)	δP_eff abs	δ P_eff rel
-0.0103	0.0356	0.2998	0.3803	0.4857	0.0232
-0.0095	0.0329	0.3424	0.3423	0.4854	0.0250
-0.0090	0.0312	0.4009	0.3081	0.5066	0.0276
-0.0074	0.0257	0.4066	0.2773	0.4928	0.0326
-0.0062	0.0216	0.4225	0.2495	0.4912	0.0386
-0.0053	0.0185	0.4455	0.2246	0.4993	0.0460
-0.0051	0.0176	0.5258	0.2021	0.5636	0.0543
-0.0043	0.0150	0.5532	0.1819	0.5825	0.0659
-0.0040	0.0137	0.6233	0.1637	0.6446	0.0798
-0.0035	0.0121	0.6780	0.1473	0.6940	0.0976
-0.0032	0.0111	0.7672	0.1326	0.7787	0.1194
-0.0028	0.0098	0.8416	0.1194	0.8501	0.1467
-0.0025	0.0087	0.9228	0.1074	0.9291	0.1806

Error calculation meas. 4					
δp0*(dP/dp0)	δT0*(dP/dT0)	δp_io*(dP/p_io)	δp_tot*(dP/dp_tot)	δP_eff abs	δ P_eff rel
-0.0326	0.1127	0.3790	0.6017	0.7207	0.0109
-0.0318	0.1100	0.4568	0.5415	0.7177	0.0111
-0.0280	0.0967	0.4956	0.4874	0.7023	0.0123
-0.0290	0.1004	0.6352	0.4386	0.7790	0.0132
-0.0261	0.0902	0.7050	0.3948	0.8135	0.0153
-0.0228	0.0787	0.7589	0.3553	0.8419	0.0182
-0.0196	0.0678	0.8074	0.3198	0.8713	0.0218
-0.0174	0.0602	0.8848	0.2878	0.9325	0.0263
-0.0153	0.0529	0.9606	0.2590	0.9965	0.0320
-0.0137	0.0474	1.0614	0.2331	1.0878	0.0390
-0.0122	0.0422	1.1673	0.2098	1.1868	0.0478
-0.0108	0.0375	1.2803	0.1888	1.2948	0.0587
-0.0097	0.0334	1.4080	0.1699	1.4186	0.0722

Tables 8-9

Comments: error calculation for the measurements.

7. Visualisation of results

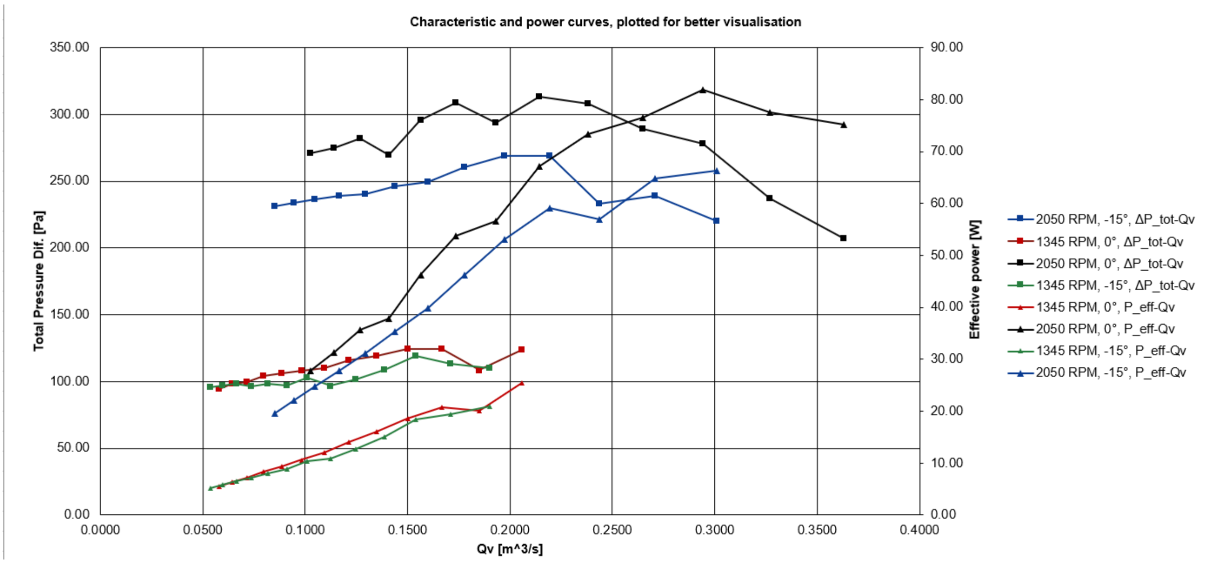
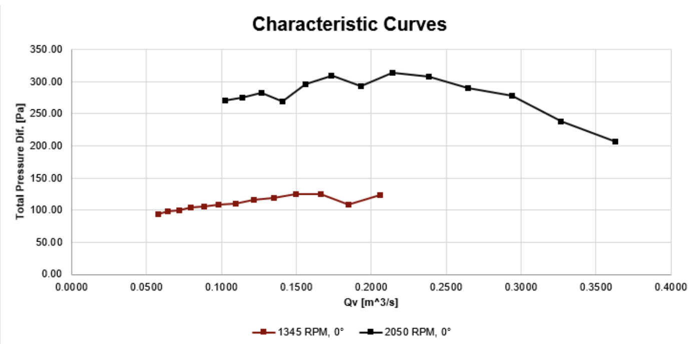
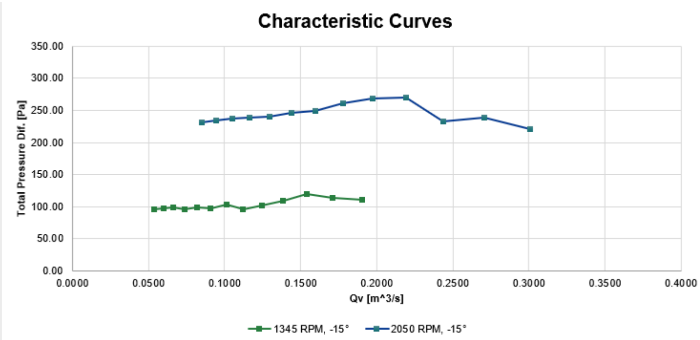
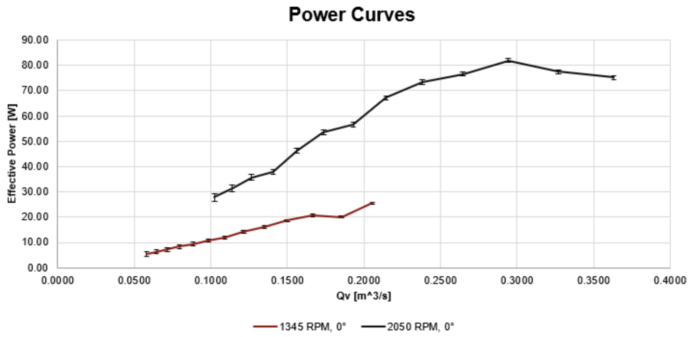


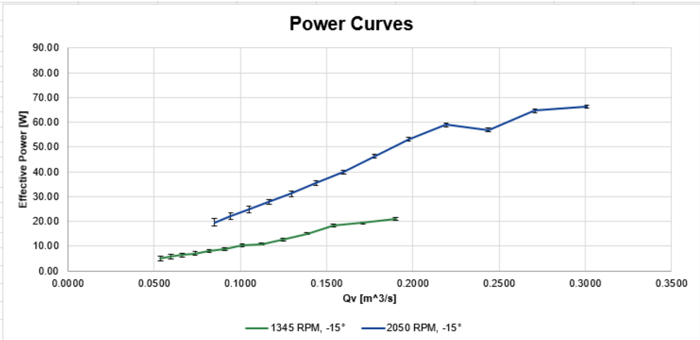
Figure 2: The characteristic and power curves depicted together for easier comparison for each angle and RPM value





Figures 3 & 4: The characteristic curves for each measurement. Due to a mistake we made in the method of picking our data points, only a part of the range of the curve is visible. In an ideal case, there would be a more prominently decreasing trend; as Qv increases, the total pressure decreases. This is due to the fact that as the velocity of a flowing fluid increases, the pressure drops; and with more velocity, more volume per second is being transported. We can also see the initial total pressure difference being higher at higher RPMs; a more powerful fan setting can produce a greater pressure difference between the inlet and the outlet of the system. Additionally, as the angle of the blades of the radial fan is decreased, Qv and the total pressure difference decrease as well.





Figures 5 & 6: Plotted power curves for each measurement, with error bars. We can observe that initially power increases steadily with increasing Qv until it reaches a maximum point. Due to the same mistake in the measurement, we only have a partial curve, but after reaching a maximum point, the power will drop back down; this is the point of the fan's maximum power output, at which the working Qv is optimal. It differs along with RPM and blade angle, as can be seen in the previous graph. Furthermore, the error in the effective power reduces at higher volumetric flow rates because the significance of the 2Pa uncertainty in the digital manometer decreases at higher values.

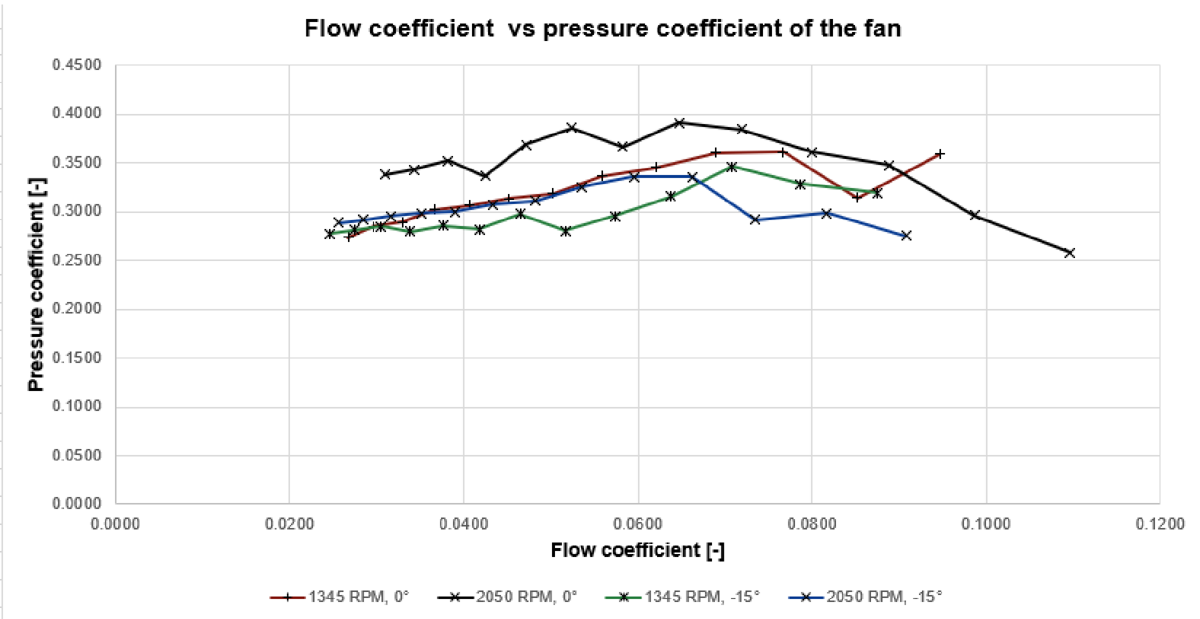


Figure 7: Dimensionless curves, plotted. This diagram allows us to establish a relationship between parameters D, n, μ and ρ, which define the characteristics of the fan (Qv, Δp_{total}, Δp_{st}) while decreasing the number of variables. If the effect of the Reynolds number is neglected, then it can be stated that this representation contains in one curve all the characteristic curves of the machines with different size and revolution. This is because under a

constant fan speed, the flow coefficient is the product of a constant and the volumetric flow rate, while the pressure coefficient is the product of a constant and the total pressure difference.

8. Measurement Conclusion

Despite the erroneous nature of the method of our measurements, some trends are clear. From our characteristic curves, we could observe the that the drop in RPM and change of air approach angle from perpendicular to -15˚ produced an expected drop in pressure difference, though it was intriguing to see that changing the angle produces a much more pronounced pressure difference drop at a high fan speed compared to a low fan speed. This implies that the angle has a much bigger significance on the characteristic curve of the fan at a high-speed setting, therefore when fans for high-speed operations, engineers need pay more attention to this. We observed the same effect of the angle and RPM value on the power curve too.

Interestingly, increasing the fan speed not only increases the power produced by the fan, but also makes the fan produce its peak power at a higher flow rate. If the fan therefore is planned to be used at a set speed, it is important to optimise the flow rate before the fan (i.e. controlling restrictions on its air inlet/outlet side) such that the fan can produce the intended amount of power.

9. Bibliography

1. BME Department of Fluid Mechanics. “M12 Measurement Guide - Investigation of a radial fan.” *BME ARA website*, http://simba.ara.bme.hu/oktatas/tantargy/NEPTUN/BSc_LABOR/ENGLISH/Measurement%20guidelines/BSc_M12_EN.pdf. Accessed 08 11 2024
2. BME Department of Fluid Mechanics. “BSc M12 assignments.” *BME ARA website*, http://simba.ara.bme.hu/oktatas/tantargy/NEPTUN/BSc_LABOR/ENGLISH/Measurement%20assignments/BSc_M12_assignments.pdf. Accessed 08 11 2024
3. BME Department of Fluid Mechanics. “Pre-measurement guide (premeas1, premeas2).” *BME GPK Moodle*, 2022, https://edu.gpk.bme.hu/course/view.php?id=416. Accessed 08 11 2024.

10. Appendix

Measurement title: M12

Investigation of a Radial fan.

Personal Task: D

- Note the atmospheric pressure and temperature in the laboratory before and after the measurement
- Check the setting on the inlet guide vanes.
- Set the angle of the inlet guide vane to zero angle of attack.
- Measure the characteristic curve ($\Delta p_t - q_v$) of the fan for two different RPM settings, taking measurements in at least ten evenly distributed operating points for each curve.
- With the help of the templates, set the inlet guide vane grid to a negative angle of attack and repeat the measurement of the characteristic curves for both of the RPM values that have already been investigated.
- Note the atmospheric pressure and temperature in the laboratory before and after the measurement.

Measurement Group:

Group 4

Mintus Maxim	HU1ZQL	HELPER
Normukhanova Danara	PCUFSG	HELPER
Oyeyele Oluwaleni Adewole	HOVNX1	LEADER
Cardoze Camille Marrie	Y3GTYB.	LEADER

Signature.

(1)

General Data	Measured Value	Unit
K	0,96	–
ρ	1,204	Kg/m^3
$D_{suction}$	0,144	m
T_0 before lab	21,1	C
T_{abs}	294,25	K
p_0 before lab	101700	Pa
$D_{pressure}$	0,157	m
$A_{suction}$	0,0163	m^2
$A_{pressure}$	0,0194	m^2
R	287	J/kgK
T_0 after lab	294,65	K
p_0 after lab	100500	Pa

Table 2. General Data

List of instruments used for the measurement

Instrument	Serial number
EMB-001 Digital manometer	02
ARA_BETZ-05 Betz manometer	6989
Fischer 103 Barometer	8906781
Liquid-in-glass thermometer	—
Tape measure	M12
~~[illegible]~~ Airflow guide vane angle measuring protractor	M12

Angle = 0°

Percentage of original q_v value	n= 1345 RPM ΔP_t	ΔP_{io}	q_v	v_t	v_{io}	ΔP_{tot}	$Power_{eff}$	n= 2050 RPM ΔP_t	Δp_{io}	q_v	v_t	v_{io}	ΔP_{tot}	$Power_{eff}$
100,0	131,25	81,8	0,2057	10,626	11,189	42,06	8,65	230,0	255,00	0,3632	19,762	19,756	-48,05	-17,45
90,0	14,4	66,26	0,1851	9,564	10,070	42,15	7,80	256,0	206,55	0,3269	16,886	17,780	3,978	10,06
81,0	129,5	53,67	0,1666	8,607	9,063	70,98	11,83	293,5	167,31	0,2942	15,197	16,002	111,0	32,67
72,9	128,2	43,47	0,1500	7,747	8,157	80,80	12,12	301,5	135,52	0,2648	13,677	14,402	153,7	40,71
65,6	122,4	35,21	0,1350	6,972	7,341	84,00	11,34	318,0	109,77	0,2383	12,310	12,962	198,31	47,26
59,0	115,7	28,52	0,1215	6,275	6,607	87,60	10,64	321,3	88,91	0,2145	11,079	11,666	224,35	48,12
53,1	112,1	23,10	0,1093	5,647	5,946	86,91	9,50	300,0	72,02	0,1930	9,971	10,499	221,47	42,75
47,8	109,7	18,71	0,0984	5,083	5,352	89,30	8,79	314,3	58,34	0,1737	8,974	9,449	250,69	43,55
43,0	107,25	15,16	0,0886	4,574	4,817	90,72	8,03	299,8	47,25	0,1564	8,076	8,504	248,28	38,82
38,7	105,2	12,28	0,0797	4,117	4,335	91,81	7,32	272,8	38,27	0,1407	7,269	7,654	231,07	32,52
34,9	100,7	9,94	0,0717	3,705	3,901	89,86	6,45	284,7	31,00	0,1266	6,542	6,888	250,93	31,78
31,4	99,1	8,06	0,0646	3,335	3,511	90,32	5,83	277,4	25,11	0,1140	5,888	6,200	250,02	28,50
28,2	95	6,52	0,0581	3,001	3,160	87,89	5,11	272,5	20,34	0,1026	5,299	5,580	250,32	25,68

Table 1. Measured and Calculated Values

	Angle = -15° n = 1345 RPM							n = 2050 RPM						
% of original q_v value	Δp_t	Δp_{io}	q_v	V_t	V_{io}	ΔP_{tot}	Power eff	Δp_t	Δp_{io}	q_v	V_t	V_{io}	ΔP_{tot}	Power eff.
100	116,5	69,90	0,1902	9,823	10,343	40,28	7,66	236,2	174,95	0,3009	15,541	16,364	45,44	13,67
90	118,4	56,62	0,1712	8,841	9,309	56,66	9,70	251,9	141,71	0,2708	13,986	14,727	97,38	26,37
81	123,5	45,86	0,1540	7,957	9,378	73,49	11,32	243,8	114,78	0,2437	12,588	13,255	118,64	28,91
72,9	112,3	37,15	0,1386	7,161	7,540	71,79	9,95	277,7	92,98	0,2193	11,329	11,929	176,32	38,67
65,6	104,6	30,09	0,1248	6,445	6,786	71,79	8,96	275,8	75,31	0,1974	10,196	10,736	193,68	38,23
59	99,9	24,37	0,1143	5,800	6,108	72,32	8,12	266,1	61,00	0,1777	9,177	9,663	199,58	35,46
53,1	104,5	19,74	0,1011	5,220	5,497	82,97	8,39	254,0	49,41	0,1599	8,259	8,696	200,12	32,00
47,8	98,7	15,99	0,0910	4,698	4,947	81,26	7,39	249,7	40,02	0,1439	7,433	7,827	206,06	29,65
43,0	99,8	12,95	0,0819	4,229	4,452	85,68	7,01	243,4	32,42	0,1295	6,690	7,044	208,05	26,94
38,7	97,5	10,49	0,0737	3,806	4,007	86,06	6,34	241,5	26,26	0,1166	6,021	6,340	212,87	24,81
34,9	99,1	8,50	0,0663	3,425	3,607	89,83	5,96	238,6	21,27	0,1049	5,419	5,706	215,41	22,60
31,4	97,7	6,88	0,0597	3,083	3,246	90,19	5,38	235,2	17,23	0,0944	4,877	5,135	216,41	20,43
28,2	96,3	5,58	0,0537	2,774	2,921	90,22	4,85	232,5	13,96	0,0850	4,389	4,622	217,28	18,48

Formulae used:

$$\Delta P_{tot} = \Delta P_{atm} - \Delta P_S = (\Delta p_t - \Delta p_{io}) + \rho \cdot \left(V_t^2 \cdot \frac{1}{2} - V_{io}^2 \cdot \frac{1}{2} \right)$$

$$V_t = \frac{q_v}{A_{pressure}}$$

$$V_{io} = \frac{q_v}{A_{suction}}$$

$$P_{eff} = \Delta P_{tot} \cdot q_v$$