Lab Report

Engineering Experiments (Me) (Nanyang Technological University)

RESULTS AND DISCUSSION

1. P_a = 100.7 kPa, T_a = 27.8ºC = 300.95 K

$$\rho = \frac{P_a}{RT_a}$$, ρ = 100700/(287 x 300.95) = **1.1659 kg/m^3**

2. Heating value of kerosene is generally from 43.1MJ/kg to 46.2 MJ/kg. The density of kerosene is generally at 804 kg/m^3.

3.

50k RPM

	T1 (C)	T2 (C)	T3 (C)	T4 (C)	T5 (C)	P1 (kPa)	P2 (kPa)	P3 (kPa)	P4 (kPa)	P5 (kPa)	Fuel Flow (L/hr)	N1 (RPM)	Thrust (N)
	34.43	75.46	522.38	495.95	368.28	2.04	50.35	51.90	7.89	5.28	11.91	50007.11	15.99
	34.47	79.17	525.59	500.45	377.44	2.07	50.46	52.00	7.73	5.48	11.15	49990.24	15.71
	34.51	80.62	525.55	502.88	380.46	2.09	50.54	52.09	7.82	5.53	11.86	50016.97	16.12
	35.31	82.83	529.26	505.35	385.24	2.12	50.33	51.93	7.83	5.42	11.70	49995.44	21.43
Average	34.68	79.52	525.69	501.16	377.85	2.08	50.42	51.98	7.82	5.43	11.66	50002.44	17.31
Average T in Kelvin	307.83	352.67	798.84	774.31	651.00								
Absolute Pressure						102.78	151.12	152.68	108.52	106.13			
Entropy	1.73	1.76	2.57	2.64	2.47								

60k RPM

	T1 (C)	T2 (C)	T3 (C)	T4 (C)	T5 (C)	P1 (kPa)	P2 (kPa)	P3 (kPa)	P4 (kPa)	P5 (kPa)	Fuel Flow (L/hr)	N1 (RPM)	Thrust (N)
	34.91	109.79	588.07	517.43	399.19	3.46	78.54	80.09	11.73	9.32	14.92	60001.78	38.84
	35.10	115.25	581.86	514.95	398.93	3.52	78.31	79.92	11.87	9.03	14.65	60001.35	37.45
	35.29	116.14	583.81	519.16	398.77	3.52	78.42	79.97	11.85	9.10	13.82	59998.52	30.37
	35.53	117.98	583.04	518.13	398.93	3.56	78.12	79.68	11.56	9.07	14.10	59998.23	31.07
Average	35.21	114.79	584.20	517.42	398.96	3.51	78.35	79.92	11.75	9.13	14.37	59999.97	34.43
Average T in Kelvin	308.36	387.94	857.35	790.57	672.11								
Absolute Pressure						104.21	179.05	180.62	112.45	109.83			
Entropy	1.73	1.81	2.60	2.65	2.50								

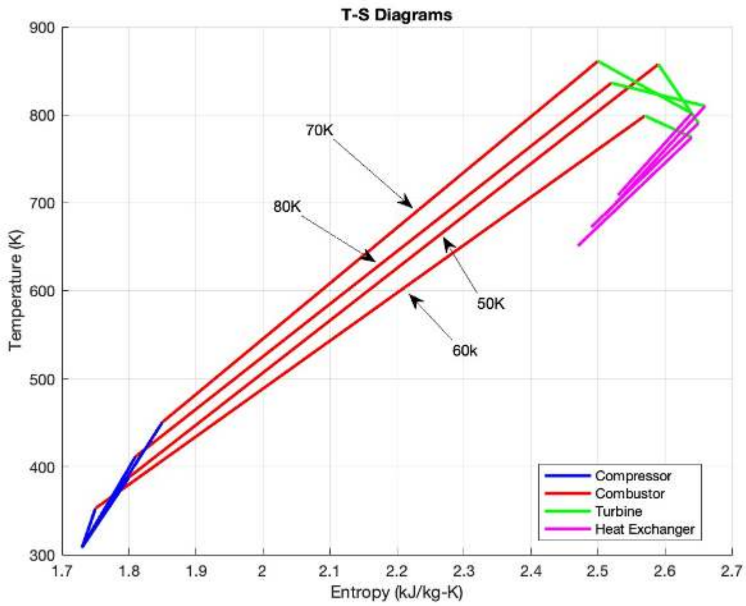
70k RPM

	T1 (C)	T2 (C)	T3 (C)	T4 (C)	T5 (C)	P1 (kPa)	P2 (kPa)	P3 (kPa)	P4 (kPa)	P5 (kPa)	Fuel Flow (L/hr)	N1 (RPM)	Thrust (N)
	35.02	135.04	562.51	534.00	411.60	5.21	116.10	117.75	17.15	13.12	19.61	69818.16	60.76
	35.80	136.32	561.00	534.15	411.82	5.22	115.76	117.59	17.09	13.32	19.17	69817.11	62.52
	35.88	137.92	560.74	536.15	412.37	5.23	115.99	117.71	17.21	13.32	19.22	69811.01	61.10
	35.36	144.27	567.68	542.71	414.95	5.64	123.03	124.69	18.70	13.87	19.65	70895.03	52.96
Average	35.51	138.39	562.98	536.76	412.68	5.33	117.72	119.43	17.54	13.41	19.41	70085.32	59.33
Average T in Kelvin	308.66	411.54	836.13	809.91	685.83								
Absolute Pressure						106.03	218.42	220.13	118.24	114.11			
Entropy	1.73	1.81	2.52	2.67	2.51								

80k RPM

	T1 (C)	T2 (C)	T3 (C)	T4 (C)	T5 (C)	P1 (kPa)	P2 (kPa)	P3 (kPa)	P4 (kPa)	P5 (kPa)	Fuel Flow (L/hr)	N1 (RPM)	Thrust (N)
	35.45	177.34	587.08	528.84	434.95	7.71	164.63	166.22	26.02	18.94	27.18	79347.99	84.48
	35.30	177.18	587.20	526.88	435.33	7.69	164.63	166.47	26.31	18.31	27.50	79317.85	81.91
	35.98	177.98	587.31	528.99	435.40	7.67	164.49	166.48	25.93	18.97	27.29	79285.46	87.48
	35.28	177.50	589.67	529.78	436.20	7.68	164.25	166.20	26.07	18.85	27.15	79302.44	85.04
Average	35.50	177.50	587.82	528.62	435.47	7.69	164.50	166.35	26.08	18.77	27.28	79313.43	84.73
Average T in Kelvin	308.65	450.65	860.97	801.77	708.62								
Absolute Pressure						108.39	265.20	267.05	126.78	119.47			
Entropy	1.73	1.85	2.50	2.64	2.54								

4.



The T-s cycles appear accurate overall except for one anomaly. In comparison to the 80k RPM graph, the 50k RPM graph displays a greater exit temperature and more entropy at the combustor's end. An increase in starting RPM should raise the temperature and pressure prior to combustion, which could increase the entropy change. But compared to 80k RPM, 50k RPM shows lesser values. This could be due to defective temperature sensors, such as sensor drift or fatigue, where prolonged exposure to high temperatures wears the sensors down and produces inaccurate readings.

5. The assumptions made are as follows:

1. Ideal gas
2. Steady state process
3. Fuel density used in calculation is 804 kg/m^3
4. Averaged values are used

$$M = \frac{u}{a} = \frac{u}{\sqrt{\gamma R T}} \quad \text{since} \quad \frac{P_0}{P} = \left(1 + \frac{\gamma-1}{2} M^2\right)^{\gamma/\gamma-1}$$

sub M into P_0/P:

$$P_0/P = \left[1 + \frac{\gamma-1}{2}\left(\frac{U^2}{\gamma R T}\right)\right]^{\gamma/\gamma-1}$$

$$\boxed{\therefore U = \sqrt{\left[\left(\frac{P_0}{P}\right)^{\gamma-1/\gamma} - 1\right]\left(\frac{2\gamma R T}{\gamma-1}\right)}}$$

$$\boxed{\dot{m}_a = \rho_a U A = \left(\frac{P}{RT}\right)_a U A, \quad \dot{m}_f = \dot{V}_f \rho_f}$$

Sample calculation for 50kRPM:

$P_o = P_s = 106.13\,kPa$ $\quad P = P_a = 100.7\,kPa$ $\quad \gamma = 1.4$ $\quad R = 287\,J/kgK$ $\quad T = T_s = 651K$ $\quad \dot{V}_f = 11.66\,L/hr = 3.2389 \times 10^{-6}\,m^3/s$ $\quad \rho_f = 804\,kg/m^3$

$$U_{out} = \sqrt{\left[\left(\frac{106.13}{100.7}\right)^{0.4/1.4} - 1\right]\left(\frac{2(1.4)(287)(651)}{0.4}\right)} = 140.62\,m/s$$

$$\dot{m}_a = \left(\frac{100.7}{0.287(651)}\right)(140.62)(0.0025) = 0.189\,kg/s$$

$$\dot{m}_f = (3.2389 \times 10^{-6})(1.1659) = 0.026\,kg/s$$

$$\therefore F_{T,50k} = [(\dot{m}_a + \dot{m}_f)U_{out} - \dot{m}_a U_{in}] + \cancel{A_{out}(P_{out} - P_{in})} \quad 0,\ P_{out} = P_{in}$$

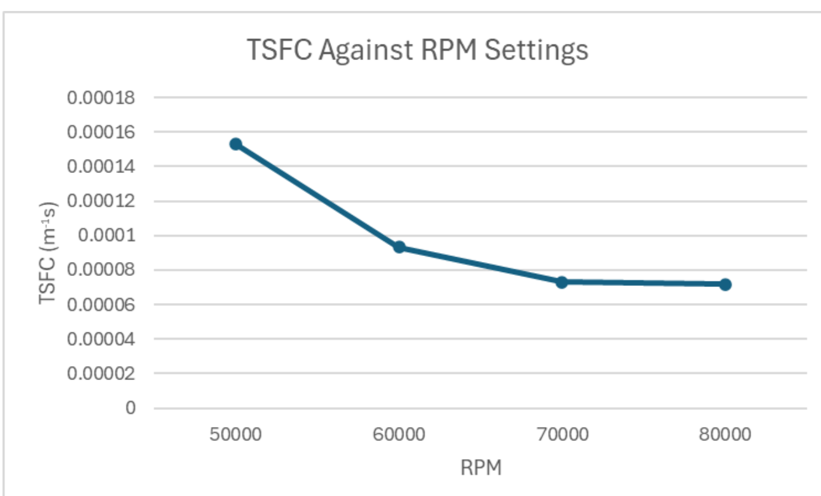
$$= [(0.189 + 0.0026)140.62] = 26.94\,N$$

RPM	50,000	60,000	70,000	80,000
U_{out} (m/s)	140.62	184.12	223.84	266.92
M_a (kg/s)	0.189	0.240	0.286	0.330
M_f (kg/s)	0.002641	0.003209	0.004335	0.006092
$F_{thrust,theoretical}$ (N)	26.94	44.78	64.99	89.71
$F_{thrust,experiment}$ (N)	17.31	34.43	59.33	84.73

7.

TSFC = mf/ F, thrust

RPM	**Measured $\dot{m}_f$ (kg/s)**	**Measured thrust (N)**	**TSFC ($m^{-1}s$)**
50000	0.002641	17.311	0.000153
60000	0.003209	34.432	0.0000932
70000	0.004335	59.333	0.0000731
80000	0.006092	84.727	0.0000719



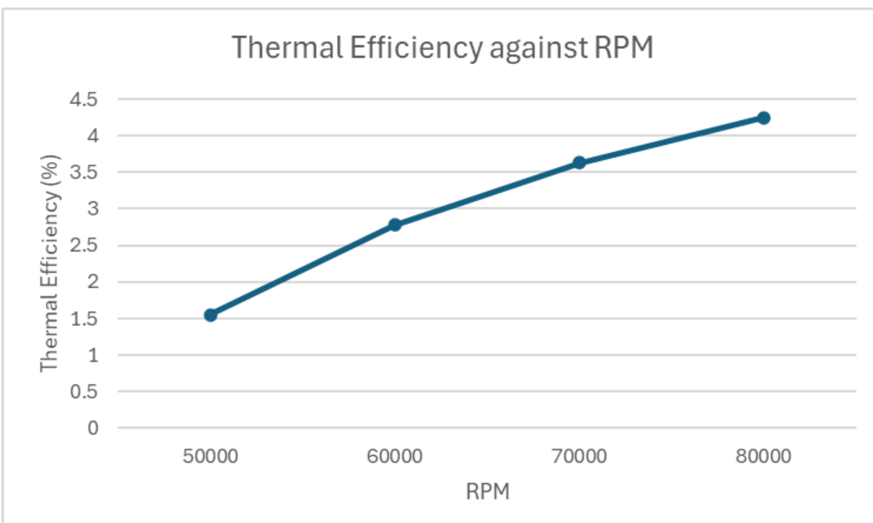
As shown in the graph above, thrust specific fuel consumption (TSFC) decreases as RPM increases. TSFC represents how efficiently a jet engine converts fuel into thrust. One reason for this decrease could be the improved engine efficiency at higher RPMs, where fuel is burned more effectively, reducing the amount required per unit of thrust. Additionally, higher RPMs result in increased airflow and compression, as the compressors spin faster and pull in more air, enhancing the overall airflow through the engine and improving both compression and combustion efficiency.

8.

$$\eta_{\text{th}} = \frac{\Delta \dot{E}_k}{\dot{Q}_{\text{in}}} = \frac{\frac{1}{2}\left[(\dot{m}_a + \dot{m}_f)U_{\text{out}}^2 - \dot{m}_a U_{\text{in}}^2\right]}{\dot{m}_f q_{\text{HV}}}$$

Kerosene Higher Heating Value (HHV) = q_{HV} = 46.2 MJ/kg

RPM	**U_f (m/s)**	**$\dot{m}_a$ (kg/s)**	**Measured $\dot{m}_f$ (kg/s)**	**Thermal Efficiency (%)**
50000	**140.616**	**0.189**	0.002641	**1.55**
60000	**185.775**	**0.24**	0.003209	**2.78**
70000	**223.840**	**0.286**	0.004335	**3.63**
80000	**266.921**	**0.33**	0.006092	**4.25**



9. The calculated thermal efficiency is considered reasonable, as there is a clear trend between TSFC and RPM. The trend shows that TSFC decreases as RPM increases. However, errors might occur due to problems such as calibration issues with the equipment. To minimize these errors, we could calibrate and verify the sensors and equipment before starting the experiment. Additionally, taking multiple readings and averaging them would help ensure the data collected are as accurate as possible.