

Homework 1

Question 1: A tractor is traveling at 5 mph while pulling a ripper that exerts a force of 10000 lb.

(a). Calculate the drawbar power.

$$\begin{aligned}
 P_{db} &= \text{Force} * \text{velocity} \\
 &= \{ 10000 \text{ lb} * [5 \text{ (mph)} * (5280 \text{ ft/mile}) / 60 \text{ (min/hr)}] \} / 33000 \text{ (ft.lb/min per HP)} \\
 &= \underline{\underline{133.33' \text{ Hp.}}}
 \end{aligned}$$

(b). If 65% of the power available at engine flywheel is available at the drawbar, determine the Engine Brake Power required to pull this ripper under these conditions.

$$\begin{aligned}
 0.65 &= P_{db} / P_b \Rightarrow \\
 P_b &= P_{db} / 0.65 \\
 &= 133.33 \text{ (Hp)} / 0.65 \\
 &= \underline{\underline{205.13 \text{ Hp}}}
 \end{aligned}$$

(c). If the mechanical efficiency of the engine is 0.75 and indicated thermal efficiency of the engine is 0.55, determine the fuel consumed operating 8 hours in the field under these conditions. (You may assume $H_g = 19000$ BTU/lb fuel)

$$\begin{aligned}
 e_m &= P_b / P_i \Rightarrow \\
 P_i &= P_b / e_m \\
 &= 205.13 \text{ (Hp)} / 0.75 \\
 &= 273.50 \text{ Hp}
 \end{aligned}$$

$$\begin{aligned}
 e_{it} &= P_i / P_{fe} \Rightarrow \\
 P_{fe} &= P_i / e_{it} \\
 &= 273.50 \text{ (Hp)} / 0.55 \\
 &= \underline{\underline{497.28 \text{ Hp}}}
 \end{aligned}$$

$$\begin{aligned}
 P_{fe} &= \{ M_r \text{ (lb/hr)} * HV \text{ (BTU/lb)} * 778 \text{ (ft.lb/BTU)} / 60 \text{ (min/hr)} \} / 33000 \text{ (ft.lb/min per HP)} \Rightarrow \\
 M_r &= P_{fe} \text{ (Hp)} * 33000 \text{ (ft.lb/min per HP)} * 60 \text{ (min/hr)} / \{ HV \text{ (BTU/lb)} * 778 \text{ (ft.lb/BTU)} \} \\
 &= 497.28 \text{ (Hp)} * 33000 \text{ (ft.lb/min per HP)} * 60 \text{ (min/hr)} / \{ 19000 \text{ (BTU/lb)} * 778 \text{ (ft.lb/BTU)} \} \\
 &= 66.61 \text{ (lb/hr)} \\
 &= 66.61 \text{ (lb/hr)} * 8 \text{ (hr/day)} \\
 &= \underline{\underline{532.87 \text{ lb/day}}}
 \end{aligned}$$

Question 2: An four-cycle engine is tested on a dynamometer. The engine is running at 2400 rpm and the load torque is 450 N.m. The engine consumes 23 liters/h of fuel. The fuel density is 836 kg/m³ and the higher heating value of the fuel H_g is 45000 kJ/kg.

(a). Calculate the brake power.

$$\begin{aligned}
 P_b &= 2\pi T N / 60000 \\
 &= 2\pi (\text{rad/rev}) * 450 (\text{N.m}) * 2400 (\text{rev/min}) / 60 (\text{s/min}) / 1000 (\text{W/kW}) \\
 &= \underline{\underline{113.1 \text{ kW}}}
 \end{aligned}$$

(b). Determine the fuel equivalent power.

$$\begin{aligned}
 P_{fe} &= M_f (\text{kg/hr}) * HV (\text{kJ/lb}) / 3600 (\text{s/hr}) \\
 &= 23 (\text{l/hr}) * 0.836 (\text{kg/l}) * 45000 (\text{kJ/kg}) / 3600 (\text{s/hr}) \\
 &= \underline{\underline{240.35 \text{ kW}}}
 \end{aligned}$$

(c). Calculate the brake specific fuel consumption.

$$\begin{aligned}
 \text{BSFC} &= M_f / P_b \\
 &= 23 (\text{l/hr}) * 0.836 (\text{kg/l}) / 113.1 (\text{kW}) \\
 &= \underline{\underline{0.17 (\text{kJ/kW.h})}}
 \end{aligned}$$

(Note: This is much lower than expected, Normal range 0.27 kg/kW.h)
The fuel consumption value given in the example is rather low.

(d). Determine the brake thermal efficiency.

$$\begin{aligned}
 e_{bt} &= P_b / P_{fe} \\
 &= 113.1 (\text{kW}) / 240.35 (\text{kW}) \\
 &= \underline{\underline{0.47}}
 \end{aligned}$$

(Note: This is much higher than is expected, Normal range 0.35)

Question 3: An four cycle engine with a displacement of 10.455l produces 670 N.m of torque at a speed of 2100 rpm.
A pressure transducer was used to measure the indicated mean effective pressure which was 1000 kPa.

(a). Calculate the indicated power.

$$P_i = \text{IMEP} * D * N / [rc * 60 * 1000 \text{ } \} \\ = 1000 \text{ (kPa)} * 10.445 \text{ (l/cylce)} * 2100 \text{ (rev/min)} / [2 \text{ (rev/cycle)} * 60 \text{ (s/min)} * 1000 \text{ (l/m}^3\text{)}] \\ = \underline{\underline{183.0 \text{ kW}}}$$

(b). Calculate the brake power.

$$P_b = 2\pi T N / 60000 \\ = 2\pi \text{ (rad/rev)} * 670 \text{ (N.m)} * 2100 \text{ (rev/min)} / 60 \text{ (s/min)} / 1000 \text{ (W/kW)} \\ = \underline{\underline{147.3 \text{ kW}}}$$

(c). Calculate the friction power.

$$P_f = P_i - P_b \\ = 182.8 - 147.3 \text{ kW} \\ = \underline{\underline{35.6}}$$

(d). Determine indicated mean effective pressure.

$$\text{IMEP} = 1000 \text{ kPa (Given in question)}$$

(e). Determine brake mean effective pressure.

$$P_b = \text{BMEP} * D * N / [rc * 60 * 1000 \text{ } \Rightarrow \\ \text{BMEP} = P_b \text{ (kPa)} * 60 \text{ (s/min)} * 1000 \text{ (l/m}^3\text{)} * rc \text{ (rev/cycle)} / [D \text{ (l/cycle)} * N \text{ (rev/min)}] \\ = 147.3 \text{ (kPa)} * 60 \text{ (s/min)} * 1000 \text{ (l/m}^3\text{)} * 2 \text{ (rev/cycle)} / [10.455 \text{ (l/cycle)} * 2100 \text{ (rev/min)}] \\ = \underline{\underline{805.3 \text{ kPa}}}$$

(f). Determine friction mean effective pressure.

$$\text{BMEP} = P_b \text{ (kPa)} * 60 \text{ (s/min)} * 1000 \text{ (l/m}^3\text{)} * rc \text{ (rev/cycle)} / [D \text{ (l/cycle)} * N \text{ (rev/min)}] \\ = 35.4 \text{ (kPa)} * 60 \text{ (s/min)} * 1000 \text{ (l/m}^3\text{)} * 2 \text{ (rev/cycle)} / [10.455 \text{ (l/cycle)} * 2100 \text{ (rev/min)}] \\ = \underline{\underline{194.7 \text{ kPa}}}$$

(g). Consider if a two-cycle engine was used instead of the four-cycle engine. If the indicated mean effective pressure was identical at 2100 rpm. Would the two-cycle engine indicated power be twice or half that of the four-cycle engine? Give your reason.

The Indicated Power would be **twice** that of a four stroke engine, because $rc=1$.

$$P_i = \text{IMEP} * D * N / [rc * 60 * 1000 \text{ } \} \\ = 1000 \text{ (kPa)} * 10.445 \text{ (l/cylce)} * 2100 \text{ (rev/min)} / [1 \text{ (rev/cycle)} * 60 \text{ (s/min)} * 1000 \text{ (l/m}^3\text{)}] \\ = \underline{\underline{365.9 \text{ kW}}}$$

(h). For the following parameters which can be physically measured and which can only be calculated from other measured parameters; indicated power, brake power, friction power, indicated mean effective pressure, brake mean effective pressure and friction mean effective pressure.

Physically Measured: brake power, friction power, indicated mean effective pressure,

Conceptual Values: indicated power, brake mean effective pressure and friction mean effective pressure.

Question 4: During a test, a four-cycle engine with a displacement of 955 in³, consumes 19 gal/h of diesel fuel while running at 2100 rpm, producing a torque of 870 ft.lb. Then a motoring dynamometer was used turn the engine at 2100 rpm, without the engine firing. The torque required to turn the engine was 165 ft.lb. Given that the fuel density was 7 lb/gal and the heating value of the fuel was 19500 BTU/lb.

(a). Calculate the fuel equivalent power.

$$\begin{aligned}
 P_{fe} &= \{ M_f (\text{lb/hr}) * HV (\text{BTU/lb}) * 778 (\text{ft.lb/BTU}) / 60 (\text{min/hr}) \} / 33000 (\text{ft.lb/min per HP}) \\
 &= \{ M_f (\text{gal/hr}) * 7 (\text{lb/gal}) * HV (\text{BTU/lb}) * 778 (\text{ft.lb/BTU}) / 60 (\text{min/hr}) \} / 33000 (\text{ft.lb/min per HP}) \\
 &= \{ 19 (\text{gal/hr}) * 7 (\text{lb/gal}) * 19500 (\text{BTU/lb}) * 778 (\text{ft.lb/BTU}) / 60 (\text{min/hr}) \} / 33000 (\text{ft.lb/min per HP}) \\
 &= \mathbf{1019.1 \text{ kW}}
 \end{aligned}$$

(b). Calculate the indicated power.

(See Below after calculation of Brake & Friction Power)

(c). Calculate the brake power.

$$\begin{aligned}
 P_b &= 2\pi T N / 33000 \\
 &= 2\pi (\text{rad/rev}) * 870 (\text{ft.lb}) * 2100 (\text{rev/min}) / 33000 (\text{ft.lb/min per HP}) \\
 &= \mathbf{347.9 \text{ Hp}}
 \end{aligned}$$

(d). Calculate the friction power.

$$\begin{aligned}
 P_f &= 2\pi T N / 33000 \\
 &= 2\pi (\text{rad/rev}) * 165 (\text{ft.lb}) * 2100 (\text{rev/min}) / 33000 (\text{ft.lb/min per HP}) \\
 &= \mathbf{66.0 \text{ Hp}}
 \end{aligned}$$

$$\begin{aligned}
 P_i &= P_b + P_f \\
 &= 347.9 + 66.0 \\
 &= \mathbf{413.8 \text{ Hp}} \quad (\text{Roundoff error})
 \end{aligned}$$

(e). Calculate the indicated thermal efficiency, the mechanical efficiency and the brake thermal efficiency.

$$\begin{aligned}
 e_{it} &= P_i / P_{fe} \\
 &= 413.8 / 1019.1 \\
 &= \mathbf{0.41}
 \end{aligned}$$

$$\begin{aligned}
 e_m &= P_b / P_i \\
 &= 347.9 / 413.8 \\
 &= \mathbf{0.84}
 \end{aligned}$$

$$\begin{aligned}
 e_{bt} &= P_b / P_{fe} & \text{OR} & & e_{bt} &= e_{it} * e_m \\
 &= 347.9 / 1019.1 & & & &= 0.41 * 0.84 \\
 &= \mathbf{0.34} & & & &= 0.38
 \end{aligned}$$

(f). Determine Brake Specific Fuel Consumption.

$$\begin{aligned}
 \text{BSFC} &= M_f / P_b \\
 &= 19 (\text{gal/hr}) * 7 (\text{lb/gal}) / 347.9 (\text{Hp}) \\
 &= \mathbf{0.38 (\text{lb/Hp.h})}
 \end{aligned}$$

Question 5: An four-cycle engine with a displacement of 5.866l, consumes 19 kg/h of fuel and 413 kg/h of air running under full load at 2400 rpm. The ambient density of air during the test was 1.22 kg/m³

(a). Calculate the theoretical air consumption.

$$\begin{aligned}
 M_{\text{at}} &= [D * N / rc] * \rho \\
 &= 5.866 \text{ (l/cycle)} * 2400 \text{ (rev/min)} * 60 \text{ (min/hr)} * 1.22 \text{ kg/m}^3 / [2 \text{ (rev/cycle)} 1000 \text{ (l/m}^3\text{)}] \\
 &= \underline{\underline{515.3 \text{ kg/hr}}}
 \end{aligned}$$

(b). Determine the volumetric efficiency.

$$\begin{aligned}
 e_v &= M_{\text{actual}} / M_{\text{theoretical}} \\
 &= 413 \text{ (kg/h)} / 515.3 \text{ (kg/hr)} \\
 &= 0.80
 \end{aligned}$$

(c). The Air to Fuel Ratio.

$$\begin{aligned}
 A/F &= M_{\text{air}} / M_{\text{fuel}} \\
 &= 413 \text{ (kg/h)} / 19 \text{ (kg/hr)} \\
 &= \underline{\underline{21.7}}
 \end{aligned}$$

(d). If you had to guess, do you think this is naturally aspirated (no turbo charger) or turbo charged engine?

Explain your reason.

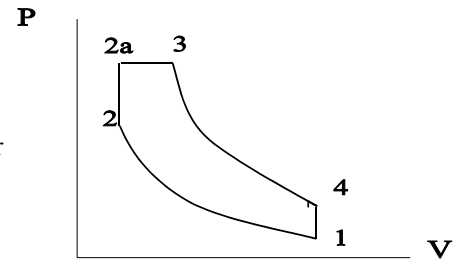
This most likely a naturally aspirated engine since the volumetric efficiency is less than one. If the volumetric efficiency is very much greater than 1 then it would definately be a turbo or supercharged engine.

Consider the dual cycle shown in the figure below. Given:

- $k=1.4,$
- $C_v = 0.719 \text{ kJ/kg}\cdot^\circ\text{K}$
- $T_1 = 25^\circ\text{C}$
- $P_1 = 101 \text{ kPa}$
- Engine Compression Ratio = 15:1

The injection cycle of this diesel engine is such that 500 kJ/kg of energy is added under constant volume and 1000 kJ/kg of additional fuel energy added between point 2a and point 3.

- a). Calculate the temperatures and pressures at all points in the cycle.
- b). Determine fuel cutoff ratio.
- c). Determine the net work for the cycle.
- d). Calculate the indicated thermal efficiency for the cycle.



Solutions

- k 1.4
- C_v 0.719
- C_p 1.0066
- T_1 25
- P_1 101

	CR	Q_{in}	T	P
1			298	101
2	15	500	880.3447278	4475.578063
2a		1000	1575.75502	8010.969313
3	1.630		2569.198294	8010.969313
4	9.2	-546.1	1057.510508	358.4179911

- Q_{in} 1500
- Q_{out} 546.1
- W 953.9
- eit 0.6359

