Homework 1

Question 1: A tractor is traveling at 5 mph while pulling a ripper that exerts a force of 12000 lb.

(a). Calculate the drawbar power.

P_{db} = Force * velocity

= { 12000 lb * [5 (~~mph~~) * (5280 ft/~~mile~~) / 60 (min/~~hr~~)]} / 33000 (ft.lb/min per HP)

= 160 Hp.

(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.

0.65= P_{db} /P_b ⇨

P_b = P_{db} / 0.65

= 160 (Hp) / 0.65

= 246.15 Hp

(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)

e_m = P_b / P_i ⇨

P_i = P_b / e_m

= 246.15 (Hp) / 0.75

= 328.21 Hp

e_{it} = P_i / P_{fe} ⇨

P_{fe} = P_i / e_{it}

= 328.21 (Hp) / 0.55

= 596.74 Hp

P_{fe} ={ M_f (lb/hr) * HV (BTU/lb) * 778 (ft.lb/BTU) / 60 (min/hr) } / 33000 (ft.lb/min per HP) ⇨

M_f = P_{fe} (~~Hp~~) * 33000(~~ft.lb/min per HP~~) * 60 (~~min~~/hr) / { HV (~~BTU~~/lb) * 778 (~~ft.lb/BTU~~)}

= 596.74 (~~Hp~~) * 33000(~~ft.lb/min per HP~~) * 60 (~~min~~/hr) / { 19000 (~~BTU~~/lb) * 778 (~~ft.lb/BTU~~)}

= 79.93(lb/hr)

= 79.93 (lb/hr) * 8(hr/day)

= 639.45 lb/day

Question 2: An four-cycle engine is tested on a dynamometer. The engine is running at 2400 rpm and the load torque is 600 N.m. The engine consumes 31 liters/h of fuel. The fuel density is 836 kg/m^3 and the higher heating value of the fuel H_g is 45000 kJ/kg.

(a). Calculate the brake power.

P_b = 2π T N / 60000

= 2π (~~rad/rev~~) *600 (N.m)*2400(~~rev/min~~) / 60 (s/~~min~~) / 1000 (W/kW)

=150.8 kW

(b). Determine the fuel equivalent power.

P_{fe} = M_f (kg/hr) * HV (kJ/lb)/ 3600 (s/hr)

= 31 (~~l/hr~~)*0.836 (~~kg/l~~) * 45000 (kJ/~~kg~~)/ 3600 (s/~~hr~~)

= 323.95 kW

(c). Calculate the brake specific fuel consumption.

BSFC = M_f / P_b

= 31 (l/hr)*0.836 (kg/l) / 150.8 (kW)

= 0.172 (kJ/kW.h) (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.

e_{bt} = P_b / P_{fe}

= 150.8 (kW) / 323.95 (kW)

= 0.47 (Note: This is much higher than is expected, Normal range 0.35)

Question 3: In a governed engine test, the following information was collected. Use this information for reference in calculating the requested parameters (4 Stroke Engine).

Brake Torque = 510 Nm (376 ft.lb) Speed = 2400 rpm
Mechanical Efficiency = 0.80 Fuel consumption = 38 liters/hour (10 gal/hr)
Engine displacement = 5.9 liter (360 in^3) Volumetric efficiency = 85%
Fuel heat content = 38000 kJ/liter (136,000 BTU/gal) Air Density = 1.12 kg/m^3 (0.07 lb/ft^3)
Fuel density = 800 kg/m^3 (50 lb/ft^3)

a). Calculate the Brake Power

P_b = 2π T N / 60000
= 2π (~~rad/rev~~) *510 (N.m)*2400(~~rev/min~~) / 60 (s/~~min~~) / 1000 (W/kW)
=128.2 kW

b). Calculate the Brake Mean effective pressure

P_b = BMEP * D * N / [rc * 60* 1000 }
BMEP = P_b *[rc * 60* 1000] /(D * N)
= 128.2 *2*60000/(5.9*2400)
=1086 kPa

c). Calculate the Brake Thermal Efficiency

P_{fe} = M_f (kg/hr) * HV (kJ/lb)/ 3600 (s/hr)
= 38 (~~l/hr~~)* 38000 (kJ/~~kg~~)/ 3600 (s/~~hr~~)
= 401 kW

e_{bt} = P_b / P_{fe}
= 128.2 (kW) / 4-01 (kW)
= 0.32

d). Calculate the Indicated Power

e_m = P_b / P_i
P_i = P_b / e_m
= 128.2 (kW) / .8
= 160 kW

e) Calculate the Indicated Mean effective pressure

P_b = BMEP * D * N / [rc * 60* 1000 }
BMEP = P_b *[rc * 60* 1000] /(D * N)
= 160 *2*60000/(5.9*2400)
=1357 kPa

f). **Actual Mass flowrate** of air entering engine

M_{at} = D (l/cylc)* N(rev/min) 60 (min/hr) / [rc(rev/cycle) * 1000 (l/m^3)] * ρ_a (kg/m^3)
= 5.9 (l/cycle)* 2400 * 60 (min/hr) / [2(rev/cycle) * 1000 (l/m^3)] * 1.12 (kg/m^3)
= 475.776 kg/hr

M_a = M_{at} *e_v
= 475.776 kg/hr* .75
= 356.83 kg/hr

Question 4: 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 = IMEP * D * N / [rc * 60* 1000 }

= 1000 (kPa) * 10.445 (l/cylce) * 2100 (rev/min) / [2 (rev/cycle) * 60 (s/min) * 1000 (l/m^3)}

= 183.0 kW

(b). Calculate the brake power.

P_b = 2π T N / 60000

= 2π (~~rad/rev~~) *670 (N.m)*2100(~~rev/min~~) / 60 (s/~~min~~) / 1000 (W/kW)

=147.3 kW

(c). Calculate the friction power.

P_f =P_i - P_b

= 182.8 - 147.3 kW

=35.6

(d). Determine indicated mean effective pressure.

IMEP = 1000kPa (Given in question)

(e). Determine brake mean effective pressure.

P_b = BMEP * D * N / [rc * 60* 1000 } ⇨

BMEP = P_b (kPa) * 60(s/min) *1000 (l/m^3) * rc (rev/cycle) / [D(l/cycle * N(rev/min)]

= 147.3 (kPa) * 60(s/min) *1000 (l/m^3) * 2 (rev/cycle) / [10.455(l/cycle * 2100(rev/min)]

= 805.3 kPa

(f). Determine friction mean effective pressure.

FMEP = P_f (kPa) * 60(s/min) *1000 (l/m^3) * rc (rev/cycle) / [D(l/cycle * N(rev/min)]

= 35.4 (kPa) * 60(s/min) *1000 (l/m^3) * 2 (rev/cycle) / [10.455(l/cycle * 2100(rev/min)]

= 194.7 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 reasons.

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

P_i = IMEP * D * N / [rc * 60* 1000 }

= 1000 (kPa) * 10.445 (l/cylce) * 2100 (rev/min) / [1 (rev/cycle) * 60 (s/min) * 1000 (l/m^3)}

= 365.9 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 5: During a test, a four-cycle engine with a displacement of 955 in^3, 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.

P_{fe} ={ M_f (lb/hr) * HV (BTU/lb) * 778 (ft.lb/BTU) / 60 (min/hr) } / 33000 (ft.lb/min per HP)
= { M_f (gal/hr)*7(lb/gal) * HV (BTU/lb) * 778 (ft.lb/BTU) / 60 (min/hr) } / 33000 (ft.lb/min per HP)
= { 19 (gal/hr)*7(lb/gal) * 19500 (BTU/lb) * 778 (ft.lb/BTU) / 60 (min/hr) } / 33000 (ft.lb/min per HP)
= 1019.1 kW

(b). Calculate the indicated power.
(See Below after calculation of Brake & Friction Power

(c). Calculate the brake power.

P_b = 2π T N / 33000
= 2π (~~rad/rev~~) *870 (ft.lb)*2100(~~rev/min~~) / 33000 (ft.lb/min per HP)
=347.9 Hp

(d). Calculate the friction power.

P_f = 2π T N / 33000
= 2π (~~rad/rev~~) *165 (ft.lb)*2100(~~rev/min~~) / 33000 (ft.lb/min per HP)
=66.0 Hp

P_i = P_b + P_f
=347.9+66.0
=413.8 Hp (Roundoff error)

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

e_{it} = P_i / P_{fe}
= 413.8/1019.1
=0.41

e_m = P_b / P_i
= 347.9/1019.1
=0.84

e_{bt} = P_b / P_{fe} OR e_{bt} = e_{it} * e_m
= 347.9/1019.1 = 0.41*0.84
=0.34 = 0.34

(f). Determine Brake Specific Fuel Consumption.

BSFC = M_f / P_b
= 19 (gal/hr)*7 (lb/gal) / 347.9 (Hp)
= 0.38 (lb/Hp.h)

Question 6: A test to determine the mechanical efficiency of an four-stroke engine was conducted. The following information was gathered during the tests. Use information listed below for reference in calculations below.

General information:

Engine displacement = 226 in^3 (3.7 litres)
4 cylinders, 4 stroke cycle
Fuel gasoline: 122,000 BTU/gal (34,000 kJ/l)

Test results:

Engine speed = 2400 rpm
Brake Mean Effective Pressure =120 psi (825 kPa)
Mechanical Efficiency = 0.75
Fuel consumption = 5 gal/hr (19 l/hr)

a). Determine the Brake Horsepower

P_b = BMEP (psi)* D/12 (in3/cycle) * N (rev/min) / [rc (rev/cycle) * 33000]
= 120 (psi)* 226/12 (in3/cycle) * 2400 (rev/min) / [2 (rev/cycle) * 33000]
= 82.2 Hp

b). Calculate Indicated Power of the engine

e_m = P_b / P_i
P_i = P_b / e_m
= 82.2) / .75
= 109.6 Hp

c). Determine the engine Friction Power of the engine

$P_f = P_i - P_b$
=109.6-82.2
=27.4 HP

d). Calculate the Indicated Mean Effective Pressure

e_m = BMEP / IMEP
IMEP = BMEP / e_m
= 120 / .75
= 160 psi

e). Assuming a volumetric efficiency of 85% at 2400 rpm, calculate the mass flowrate of air into the engine given that the density of air is 0.07 lb/ft^3 (1.12 kg/m^3) (Note: 1 foot = 12 inches)

M_{at} = D (in^3/cyle)* N(rev/min) 60 (min/hr) / [rc(rev/cycle) * 12^3 (in^3/ft^3)] * ρ_a (lb/ft^3)
= 226 (in^3/cyle)* 2400(rev/min) 60 (min/hr) / [2(rev/cycle) * 12^3 (in^3/ft^3)] * 0.07 (lb/ft^3)
= 659 lb/hr

M_a = M_{at} *e_v
= 659 kg/m^3 * .85
= 560 kg/m^3

Question 7: A test to determine the mechanical efficiency of a engine was conducted. The following information was gathered during the tests. Use information listed below for reference in calculations below.

General information:

Engine displacement = 568 in^3 (9.3 litres)
6 cylinders, 4 stroke cycle
Fuel Gasoline 122,000 BTU/gal (34,000 kJ/l)
Indicated thermal Efficiency of the engine = 0.50 (for all cylinders firing)

Test results:

Engine speed = 2400 rpm
6 cylinders firing, Measured Brake Torque = 600 ft.lb (825 N.m)
5 cylinders firing, Measured Brake Torque = 465 ft.lb (640 N.m)

a). Calculate Brake power for this engine at 2400 rpm.

P_b = 2π T N / 33000
= 2π (~~rad/rev~~) *600 (ft.lb)*2400(~~rev/min~~) / 33000 (ft.lb/min per HP)
=274.2 Hp

b). Calculate Indicated power, Ip of the one cylinder at 2400 rpm.

$P_{b(5)}$ = 2π T N / 33000
= 2π (~~rad/rev~~) *465 (ft.lb)*2400(~~rev/min~~) / 33000 (ft.lb/min per HP)
=212.5 Hp

$P_{i(1)} = P_b - P_{b(5)}$
= 274.2-212.5
=61.7 Hp

c). Calculate Indicated power, Ip of the entire engine

$P_i = P_{i(1)}*n$
=61.7(6)
=370 Hp

d). Calculate the Friction Power, Fp of the entire engine

$P_f = P_i - P_b$
=370-212.5
=96.3 HP

e). Calculate the engine mechanical efficiency

$e_m = P_b / P_i$
= 274.2`/370
=0.74

f). Determine the fuel consumption of the engine (gal/hr or l/hr) with all cylinders operating at 2400 rpm.

$e_{it} = P_i / P_{fe}$
$P_{fe} = P_i / e_{it}$
= 370 (Hp) / .5
= 740 Hp

P_{fe} ={ M_f (gal/hr) * HV (BTU/gal) * 778 (ft.lb/BTU) / 60 (min/hr) } / 33000 (ft.lb/min per HP)

M_f (gal/hr) = P_{fe} * 60 (min/hr) *33000 (ft.lb/min per HP)/{HV (BTU/gal) * 778 (ft.lb/BTU)}
= 740 * 60 (min/hr) *33000 (ft.lb/min per HP)/{122000 (BTU/gal) * 778 (ft.lb/BTU)}
= 15.4 gal/h

Question 8: A tractor is used to drive an irrigation pump via the Power Take Off (PTO). The PTO operates at 1000 rpm at an engine speed of 2400 rpm. The PTO torque was found to be 500 N.m (370 lb.f). Assume 95 percent of engine brake horsepower is available at the PTO.

a). Determine the engine Torque and brake power required for this operation.

P_{pto} = 2π T N / 33000
= 2π (~~rad/rev~~) *370 (ft.lb)*1000(~~rev/min~~) / 33000 (ft.lb/min per HP)
=70.44 Hp

P_b = P_{pto} / e_m
= 70.44 / .95
=74.1 Hp

T = P_b(Hp)*33000(ft.lb/min per HP) /2π(~~rad/rev~~) N (~~rev/min~~)
= 74.1(Hp)*33000(ft.lb/min per HP) /2π(~~rad/rev~~) 2400 (~~rev/min~~)
= 162 ft.lb

b). If the brake thermal efficiency of the engine is 0.40, determine the fuel consumption (kg/hr, lb/hr) required for the tractor operating under the conditions described for part a. Given that the diesels fuels higher heating value is 45,000 kJ/kg (19,000 BTU/lb).

E_{bt} = P_b / P_{fe}
P_{fe} = P_b / e_{bt}
= 74.1 (Hp) / .4
= 185 Hp

M_f (gal/hr) = P_{fe} * 60 (min/hr) *33000 (ft.lb/min per HP)/{HV (BTU/gal) * 778 (ft.lb/BTU)}
= 185 * 60 (min/hr) *33000 (ft.lb/min per HP)/{19000 (BTU/lb) * 778 (ft.lb/BTU)}
= 24.7 lb/h

c). Calculate the PTO Specific Fuel Consumption.

(PTO)SFC = M_f / P_{pto}
= 24.7 (lb/hr/ 70.44 (Hp)
= 0.35 (lb/Hp.h)

d). If the speed of the PTO is reduced to 750 rpm while maintaining the same PTO power as in part (a). What is the torque reserve required for the Engine. You may assume that all the efficiencies remain the same.

Pengine = **74.1 Hp (does not change, since same PTO power as before)**

New Engine Speed = 750/1000*2400 = 1800 rpm.

T (new) = P_b(Hp)*33000(ft.lb/min per HP) /2π(~~rad/rev~~) N (~~rev/min~~)
= 74.1(Hp)*33000(ft.lb/min per HP) /2π(~~rad/rev~~) 1800 (~~rev/min~~)
= 216 ft.lb

Torque Reserve = 216 – 162
=54 Hp