Appendix– IV

Sample Calculations

The following sample calculations are done for test run no. II – 15.1.

IV.1 Data

Engine speed, N= 1500 rpm

Brake force, W= 24 kg at 2.0 Amp.

Diesel fuel consumption rate, $\dot{m}_f$ = 779.53 × 10^{-6} kg/sec = 4.065×10^{-3} mole /sec

Net caloric value of diesel fuel, CV_{diesel} = 42.5 × 10^6 kJ/kg

Hydrogen Density, ρ_{H_2} = 0.0838 kg/m^3

Hydrogen induction mass flow rate, m_{H_2} = 0 kg/sec = 0 mole/ sec

Net caloric value of hydrogen fuel, CV_{H_2} = 119.93 × 10^6 kJ/kg

Atmospheric pressure P_a = 99.60 kN/m^2

Gas constant =287 J/kg.K

Atmospheric temperature = 25.19 + 273.15 = 298.34 K

Pressure head in term of water, h_w= 177× 10^{-3} m

Water Densityρ_w, assume =1000 kg/m^3

Coefficient of orifice, C_d = 0.6 (constant)

Cross sectional area of orifice which has diameter 25 mm, A= 490.63×10^{-4} m^2

Acceleration due to gravity, g = 9.81 m/s^2

Engine cylinder diameter, d= 89 × 10^{-3} m

Engine cylinder stroke, L= 73×10^{-3} m

Hydrogen / air stoichiometric ratio =0.42 (based on molecular weight)

Diesel / air stoichiometric ratio = 0.012 (based on molecular weight)

Exhaust temperature, $T_{exh.}$ = 252.89 °C

IV.2 Brake Thermal Efficiency

The eddy current dynamometer gives formula to calculate the brake power in terms of speed and break force.

$$BP = \frac{N \times W}{4234} \qquad \text{AIV.1}$$

BP= 8502.60 J/sec = 8.50 kW

The brake thermal efficiency is calculated by using the following formula [91]:

$$\eta_{B.Th} = \frac{BP}{IP} \times 100 \qquad \text{AIV.2}$$

IP is the input power which is equal to:

$$IP = \dot{m}_f \times CV_{diesel} + m_{H_2} \times CV_{H_2} \qquad \text{AIV.3}$$

$$IP = 779.53 \times 10^{-6} \times 42.5 \times 10^{6} + 0 \times 119.93 \times 10^{6}$$

IP = 33129.86111 = 33.13 kW

Then;

$$\eta_{B.Th} = \frac{8.5}{33.13} \times 100$$

$\eta_{B.Th}$= 25.66 %

IV.3 Volumetric Efficiency ($\eta_{Vol.}$)

The volumetric efficiency is calculated by using the following formula [91]:

$$\eta_{Vol.} = \frac{V_{actual}}{V_{swept}} \quad \text{AIV.4}$$

The head pressure in term of air is calculated from ideal gas equation:

$$P_a V_a = m_a R T_a \quad \Rightarrow \quad \rho_a = \frac{P_a}{RT_a} \quad \text{AIV.5}$$

ρ_a = (99.60)/(273×298.34)= 1.16 kg/m^3

$$h_a \rho_a = h_w \rho_w \Rightarrow h_a = \frac{h_w \rho_w}{\frac{P_a}{RT_a}}$$

h_a= 177×10-3×1000/1.16= 152.16 m

Actual volume is calculated from,

V_{actual}=$Q_a = C_d A \sqrt{2gh_a}$

Va = 0.6 × 490.63×10^{-4} ×(2×9.81×152.16)$^{1/2}$ = 16096.58 × 10^{-6} m^3

$$V_s = \text{swept volume} = 4 \times \frac{\left(\frac{\pi d^2}{4} \times L \times N\right)}{120}$$

V_s= 4×((22/7)/4)×((0.073)^2)×(0.0889)×1500/120=18611.53×10^{-6} m^3

$\eta_{Vol.}$ =16096.58 × 10^{-6}/18611.53×10^{-6}×100 = 86.49 %

$\dot{m}_a = Q_a \rho_a$= 16096.58 × 10^{-6} × 1.16 = 18.73 ×10^{-3} kg/sec

IV.4 Equivalence Ratio (ϕ)

The equivalence ratio equation for hydrogen – diesel duel fuel is presented in eq. IV.6, [92]:

$$\emptyset = \left[\frac{\frac{\dot{m}_f}{m_a - \frac{m_{H_2}}{\left(\frac{H_2}{m_a}\right)_{stoch.}}}}{\left(\frac{\dot{m}_f}{m_a}\right)_{stoch.}}\right] \qquad \text{AIV.6}$$

$$\emptyset = \left[\frac{\frac{4.065\times10-3}{0.52-\frac{0}{(0.42)_{stoch.}}}}{(0.012)_{stoch.}}\right] = 0.65$$

IV.5 Brake Specific Energy Consumption (BSEC)

BSEC= (diesel energy + hydrogen energy)/BP

$= (779.53 \times 10^{-6} \times 42.5 \times 10^{6} + 0 \times 119.93 \times 10^{6}) / 8502.60 = 3.896$ J/Wh

$=3.896*3600/1000=14.03$ MJ/kWh