Lecture 5

3rd Semester M. Tech. Mechanical Systems Design

Mechanical Engineering Department

Subject: Advanced Engine Design

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Topic: Engine Design And Operating Parameters Continued – 29-09-2020

1. **Specific Fuel Consumption: sfc**
   It is defined as the fuel flow rate per unit power output of the engine.
   It measures how efficiently an engine is using the fuel supplied to produce work.
   In engine testing in laboratory we can measure fuel flow rate or fuel consumption rate per unit time on volumetric basis by means of a calibrated glass tube and stop watch as a simple device.
   It is also possible to measure the fuel consumption per unit time on gravimetric basis by using a strain gauge based calibrated load cell with a computerized data acquisition system.

   sfc = $\frac{\dot{m}_f}{P}$

   with units

   sfc(mg/J) = $\frac{\dot{m}_f(\frac{g}{s})}{P(KW)}$ or

   sfc(g/KW.h) = $\frac{\dot{m}_f(\frac{g}{h})}{P(KW)}$

   Low values of sfc are obviously desirable.
   For **SI engines** typical **best values** of brake specific fuel consumption are about **75 μg/J = 270 g/KW.h**
   For **CI engines**, **best values** are lower and in large engines can go below **55 μg/J = 200 g/KW.h**
   Alternative method to relate the engine output say work done per cycle or power to the input fuel consumption rate of engine is by using the dimensionless parameter known as thermal efficiency or fuel conversion efficiency.

2. **Thermal Efficiency or Fuel Conversion Efficiency:**
   It is defined as the ratio of the work produced by the engine per cycle to the energy supplied to the engine per cycle. [cycle basis]
   It is also defined as the ratio of the power produced by the engine to the rate at which energy is supplied to the engine. [unit time basis]

   $\eta_f = \frac{W_c}{m_f Q_{HV}}$ [cycle basis]

   $\eta_f = \frac{(P n_R/N)}{(\dot{m}_f n_R/N) Q_{HV}} = \frac{P}{\dot{m}_f Q_{HV}}$ [unit time basis]

   Where m_f is the mass of fuel inducted per cycle.

Substituting $\frac{P}{\dot{m}_f} = sfc$ from the definition of specific fuel consumption we have

$\eta_f = \frac{1}{sfc\ Q_{HV}}$

with units:

$\eta_f = \frac{1}{sfc\ (\frac{mg}{J}) Q_{HV}\ (\frac{MJ}{Kg})}$

$\eta_f = \frac{1}{sfc(\frac{g}{KWh}) Q_{HV}(\frac{MJ}{Kg})}$

Q_{HV} = heating value of fuel.
For commercial hydrocarbon fuels typical values of Q_{HV} are in the range of 42 to 44 MJ/Kg
The term specific fuel consumption is inversely proportional to fuel conversion efficiency for normal hydrocarbon fuels.

3. **Air/Fuel and Fuel/Air Ratios:**
Air/Fuel ratio is defined as the ratio of the mass flow rate of air inducted into to the engine to the mass flow rate of fuel consumed by the engine.
It is a useful parameter for defining the engine operating condition.

Air/Fuel ratio (A/F) = $\frac{\dot{m}_a}{\dot{m}_f}$

Fuel/Air ratio (F/A) = $\frac{\dot{m}_f}{\dot{m}_a}$

The normal operating range:
For a conventional **SI engine** using **gasoline fuel.**
$12 \le A/F \le 18$
$(0.056 \le F/A \le 0.083)$
For **CI engines** with **diesel fuel.**
$18 \le A/F \le 70$
$(0.014 \le F/A \le 0.056)$

4. **Volumetric Efficiency: η_V**
It is defined as the ratio of volume flow rate of air into the engine to the rate at which volume is displaced by the piston.
In thermodynamics, thermodynamic property volume alone is not sufficient to define the state of air in a system like an engine cylinder.
The volume displaced by the piston in the denominator of the above definition is taken as a reference volume. The other two thermodynamic properties to define the state air corresponding to the volume displaced by the piston are the pressure and temperature of the ambient air from which air is being inducted into the engine.
For the term volume flow rate of air in the numerator of above definition, the two thermodynamic properties to define the state of air completely are the pressure and temperature of air after its induction into the engine cylinder.

During induction process, the resistance to the flow of air in the intake manifold pipes, creates a drop in the pressure of air going into the engine cylinder. So the volume in the numerator is to be considered at lower pressure existing in the engine cylinder towards the end of induction process. The above mentioned pressure drop results in a corresponding decrease in the density of air in the engine cylinder.

In other words the mass of air which actually goes into the engine cylinder is less than the mass which could go into the engine cylinder if calculated as per the ambient conditions.

$\eta_V = \frac{2\dot{m}_a}{\rho_{a,i} V_d N}$

where

$\rho_{a,i}$ = Density of the ambient air.

Alternatively we can also write:

$\eta_V = \frac{m_a}{\rho_{a,i} V_d}$

Typical maximum values of volumetric efficiency for the **naturally aspirated engines** are in the range of **80 to 90 percent.**

The volumetric efficiency for diesel engines is somewhat higher than for SI engines.

For **turbocharged engines** volumetric efficiency is always **more than 100 percent.**

This is because there is actually a rise in both pressure and density of air going into the engine cylinder by using the compressor of the turbocharger in its intake manifold.

The use of compressor in the intake manifold increases the density of ambient air, say from 1.19 kg/m^3 to 1.3 Kg/m^3.

Thus the mass of air which actually goes into the engine cylinder is greater than the mass of air which could go into the engine cylinder under thermodynamic conditions of ambient air.

This turbocharger finally helps to boost the power of the engine with the same displacement volume by changing the thermodynamic conditions of the ambient air.

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In charge Course:

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Text Book:
Internal Combustion Engine Fundamentals
By John B Heywood
Published By: McGraw-Hill Book Company