## Lectures

## $8^{th}$ Semester B. Tech. Mechanical Engineering

## Subject: Internal Combustion Engines

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## Chapter: Engine Design – Alternative Fuels

## Topic: Numerical On Ethanol And Petrol Engine Design - 14-05-2020

**Q1.** The following table gives the physic-chemical properties of two fuels; petrol and Ethanol. Comment on the suitability of Ethanol as a renewable alternative fuel for S.I. engines in future.

| Fuel | Formula | Research Octane No | Stoichiometric A/F Ratio | Operating A/F Ratio | Heating Value, MJ/Kg | Volumetric Efficiency |
|---|---|---|---|---|---|---|
| Petrol | $C_8H_{18}$ | 95 | 14.6 | 13.5 | 44 | 0.85 |
| Ethanol | $C_2H_5OH$ | 107 | 9.0 | 8.0 | 26.9 | 0.7 |

**Solution:**

We will use the basic definitions involving relations between various design and operating parameters of I C engines to solve this problem.

**Case I – Petrol Engine**

Given Data:

A/F = 13.5
$Q_{HV}$ = 44 MJ/Kg
Volumetric efficiency = $\eta_v$ = 0.85

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

Assuming
Density of ambient air = $\rho_{a,I}$ = 1.2 $Kg/m^3$
Operating value of A/F ratio = 13.5
Or

$\frac{\dot{m}_a}{\dot{m}_f}$ = 13.5

## Let Us Design With The Following Design And Operating Parameters

Engine Displacement Volume = $V_d$ = 1496 Cc
Number Of Cylinders = 3
Rated Speed, N = 6500 Rpm

## Objective Function = Calculate The Power Output And BSFC Of The Engine ?

From the above definition of volumetric efficiency based equation we can substitute the values of various parameters as written above to get the mass flow rate of air going to the engine.
We have

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

$\eta_v = \frac{\dot{m}_a * 2}{1.2 * 1496 * 6500}$

with proper suitable units, we have

$\eta_v = 0.85 = \frac{\dot{m}_a * 2 * 1000,000 * 60}{1.2 * 1496 * 6500}$

$\dot{m}_a$ = Mass flow rate of air = 0.08265 Kg/sec

Air-Fuel ratio = $\frac{\dot{m}_a}{\dot{m}_f}$ = 13.5

Where
$\dot{m}_f$ = Mass flow rate of fuel

$\frac{0.8265}{\dot{m}_f}$ = 13.5

Or
$\dot{m}_f$ = Mass flow rate of fuel = 0.006122 Kg/sec

Three cylinder engine means three injectors
So mass flow rate of fuel through each injector = 0.006122/3 = 0.00204 Kg/sec
Let the thermal efficiency of the engine be 30%
So heat liberated during combustion of fuel = mass of fuel*Heating value of fuel
Heat Liberated = 0.006122*44 *1000 KJ/sec
Heat Liberated = 0.26939081*1000 KW
Heat Liberated = 269.39 KW
Thermal efficiency = 0.3
So
Brake Power = 269.39/3 - approximately
**Brake Power = 89.79 KW**
Again
Brake Specific Fuel Consumption = Mass flow rate of fuel/Power

Or

BSFC = $\frac{\dot{m}_f}{P}$ = $\frac{0.006122}{87.79}$

With proper units we have

BSFC = $\frac{0.006122*1000*3600}{89.79}$ g/KWh

**BSFC = 245.43 g/KWh**

**Case Ii – Ethanol Engine**

Given Data

A/F = 8.0

$Q_{HV}$ = 26.9 MJ/Kg

Volumetric Efficiency = 0.70

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

$\eta_v = \frac{\dot{m}_a*2}{1.2*1496*6500}$

with proper suitable units, we have

$\eta_v = 0.70 = \frac{\dot{m}_a*2*1000,000*60}{1.2*1496*6500}$

$\dot{m}_a$ = Mass flow rate of air = 0.068064 Kg/sec

Air-Fuel ratio = $\frac{\dot{m}_a}{\dot{m}_f}$ = 8.0

Where

$\dot{m}_f$ = Mass flow rate of fuel

$\frac{0.68064}{\dot{m}_f}$ = 8

Or

$\dot{m}_f$ = Mass flow rate of fuel = 0.008508 Kg/sec

**$\dot{m}_f$ = 0.008508 Kg/sec**

**Three Cylinder Engine** Means **Three Injectors**

So mass flow rate of fuel through each injector = 0.008508/3 = 0.002836 Kg/sec

Let the thermal efficiency of the engine be 30%

So heat liberated during combustion of fuel = mass of fuel*Heating value of fuel

Heat Liberated = 0.008508*26.9 *1000 KJ/sec

Heat Liberated = 0.22886*1000 KW

Heat Liberated = 228.86 KW
Thermal efficiency = 0.3
So
Brake Power = 228.86/3 - approximately
**Brake Power = 76.28 KW**
Again
Brake Specific Fuel Consumption = Mass flow rate of fuel/Power
Or

BSFC = $\frac{\dot{m}_f}{P}$ = $\frac{0.008508}{76.28}$

With proper units we have

BSFC = $\frac{0.008508*1000*3600}{76.28}$ g/KWh

**BSFC = 401.48 g/KWh**

## Further Comparative Design Details

1. In order to develop a power comparable to petrol engine, more fuel is consumed by the ethanol engine with the same displacement volume and same operating speed. Market price of ethanol will however decide it further.
2. Further the comparison of the octane number of petrol = 95 and the octane number of ethanol = 107 shows that the ethanol engine will run with smooth and controlled combustion. Also since the octane number of ethanol is substantially higher than commercial petrol, a higher compression ratio can be used for ethanol engine design which will increase the power of ethanol engine further.
3. Also a comparison of the molecular formulae of the two fuels tells us that since the number of carbon atoms in the ethanol structure is lower than that of petrol so ethanol engine will produce lesser carbon based pollution. Further an oxygen atom in the molecular formula for ethanol will help in combustion and will reduce the pollutants further.

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Text Book:
Internal Combustion Engine Fundamentals
By John B Heywood
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