ME 410 Day 32

- Volumetric Efficiency - Engine Flow Processes
- Intake Tuning - Simple
- Performance Maps

Volumetric Efficiency

Recall definition

$$\eta_v = \frac{m_a}{\rho_{ao} V_d}$$

or alternatively

$$\eta_v = \frac{m_a}{\rho_{ai} V_d}$$

where

m_a is the air actually inducted per cycle

V_d is the displaced volume

ρ_{ao} is the atmospheric air density - gives overall volumetric efficiency

ρ_{ai} is the intake air density - gives overall volumetric of the cylinder assembly

Factors

1. Fuel Properties
2. Mixture temperature
3. Ratio of exhaust / inlet pressure
4. compression ratio
5. engine speed
6. manifold and port design
7. IV and EV geometry, lift and timing

Fuel Properties

- The presence of the fuel vapor limits the amount of air you can push through. The effect is more noticeable at higher equivalence ratios. (SI)

- Fuels like gasoline - liquid fuels - not much of a problem since the fuel air ratio is small. But for gaseous fuels (esp. hydrogen) the volumetric efficiency is pulled down. (SI)

Mixture and Air Temperature

- Anything that cools the mixture or air is good. Heating the mixture or air drags down volumetric efficiency.

- The evaporation of the fuel (SI) in the mixture cools it. This offsets the fuels presence (as above)

- Volumetric efficiency varies like

$$\left[\frac{T_{ao}}{T_i}\right]^{\frac{1}{2}}$$

T_i is the inlet temperature
T_{ao} is the ambient air temperature

Ratio of Pressures P_e / P_i and Compression Ratio

These quantities work together. The problem is that the presence of residual gas takes up room and lowers the volumetric efficiency.

- See Figure 6-4. Higher compression ratios suffer less loss of volumetric efficiency as the pressure ratio increases.

- Of course as the pressure ratio decreases the lower compression ratio engines see a higher % increase in volumetric efficiency.

Frictional Losses

Pressure drops take place across obstructions in the flow path of the intake air and mixture. For example the throttle. (SI).

And other components such as air filter, manifold, inlet port and valve. Here's the pressure drop

$$\Delta p = \xi \rho v^2$$

where

ξ is a resistance coefficient (like a drag coefficient) for the component

ρ is density

v is speed of the fluid at the component. This speed is directly proportional to mean piston speed.

Mean piston speed is directly proportional to engine speed.

- Therefore volumetric efficiency is penalized by flow friction at higher engine speeds.
- Losses in the exhaust side drive up the exhaust pressure

Ram Effect

- Inertia (velocity) of the gas in the intake drives more air into the cylinder aiding volumetric efficiency.

- More pronounced at high speed.

- Inlet valve left open for 40^o to 60^o after BC to take advantage of this effect

Reverse flow into the intake

- IV closes after BC. See above. This allows for reverse flow out of the cylinder at the beginning of compression. Hurts vol efficiency, esp at low engine speed.

Tuning

- Pressure waves can be set up in the intake system, as in the exhaust.

- Want the geometry of the system to be such that a compression wave arrives at inlet during the end of the intake process. Really helps vol. eff.

Valve Timing and Lift

- IVO 10^o - 25^o BTC. Not so important in performance
- IVC 40^o - 60^o ATC. Very important. Determines backflow and aids ram effect.
- EVO 50^o - 60^o BBC. Want to have blowdown remove more exhaust gas. Very important. Determines expansion ratio and thereby effects fuel conversion efficiency.
- EVC 8^o-20^o ATC. Some importance in determining residual fraction.

Lift. Low lift hurts volumetric efficiency. Smaller flow area. Higher lift can help but only up to a point.

Major Limitation - Choking

When the flow through the valve reaches Mach 1, we get choking. This really puts the brakes on volumetric efficiency.

Summary

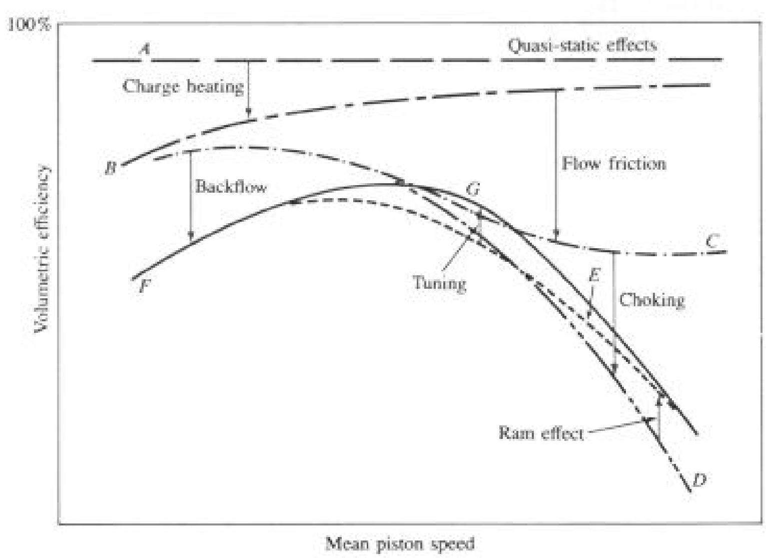
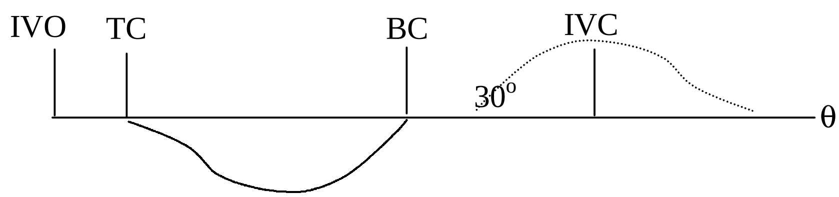


FIGURE 6-9
Effect on volumetric efficiency of different phenomena which affect the air flow rate as a function of speed. Solid line is final η_v versus speed curve.

Tuning Problems

Intake Stroke

a = 1200 ft/sec, speed of sound in the gas



Find the appropriate L (length to reflection) for

- 5000 RPM
- 7500 RPM
- 10000 RPM

Solution

- 5000 RPM L = ________________ft
- 7500 RPM L = ________________ft
- 10000 RPM L = ________________ft

Performance Maps.

See Ch. 15

I will pass one out.

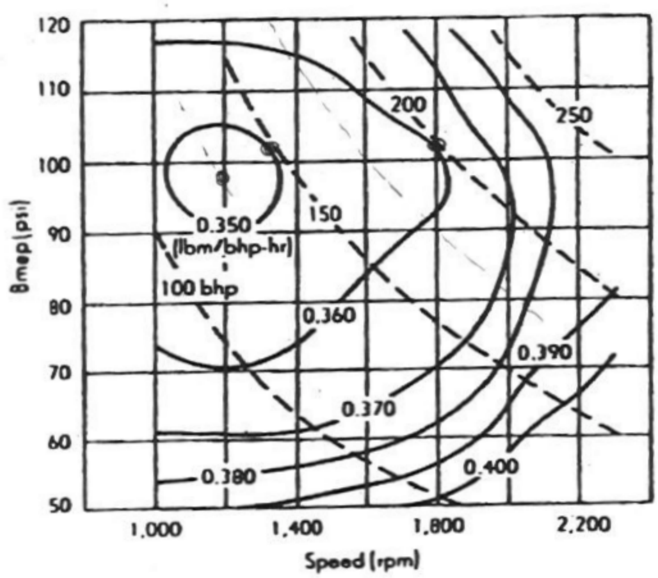


FIG. 2-25. Performance map of Mack Truck's Model END 864 diesel (V-8, 5 × 5½ in., 864 in.^{3}, open chamber).

- At a bmep of 70 psi and 1800 RPM what would the bsfc be?
- What would be the bsfc at 200 hp and 1800 RPM? What would the bmep be?
- At about what bmep and RPM could you get the lowest possible bsfc?
- Say you want to operate the engine at 150 hp. What RPM would you want the engine to operate at?
- In the previous question, suppose that the tire diameter was 3 feet, and the speed was 60 miles/ hr = 88 ft/sec. What overall gear ratio (OGR) would be required?

- Suppose the fuel had a density of 7.3 lbm / gal. Calculate the mileage, ie. miles/gal.

Answers to last questions

```
> r := 1.5;
                    r := 1.5
> v := 88.;
                    v := 88.
> omega := v/r;
                    ω := 58.66666667
> RPM_wheel := evalf( omega/(2*Pi) * 60);
                    RPM_wheel := 560.2253995
> RPM_engine := 1320.;
                    RPM_engine := 1320.
> OGR := RPM_engine/RPM_wheel;
                    OGR := 2.356194491
> bsfc := 0.35;
                    bsfc := .35
> HP := 150;
                    HP := 150
> fuel_flow := HP * bsfc;
                    fuel_flow := 52.50
> gal_hr := fuel_flow / 7.3;
                    gal_hr := 7.191780824
> mil_hr := 60;
                    mil_hr := 60
> mileage := mil_hr / gal_hr;
                    mileage := 8.342857140
>
```