

Lectures

8th Semester B. Tech. Mechanical Engineering

Subject: Internal Combustion Engines

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Topic: Engine Design And Operating Parameters Continued

The Engine Operating Parameters Further Include:

1. Brake Torque And Power

The power P and torque T developed by the engine at the crank shaft are related by the equation:

$$P = 2\pi NT$$

Where N is the crankshaft rotational speed.

In SI units:

$$P(\text{KW}) = 2\pi N(\text{rev/sec})T(\text{Nm}) * 10^{-3}$$

2. Indicated Work Per Cycle

This work is the work done by the gas within the cylinder on the piston over one complete cycle.

The terms indicated refer to the quantities available at the linearly moving piston and not at the rotating crankshaft.

With earliest technology – the engine indicators - the in-cylinder pressure and the corresponding in-cylinder volumes between the top center and the bottom center of the engine cylinder were recorded by means of plotters as indicator diagrams. These indicated diagrams are known as P-V diagrams or pressure versus volume diagrams in thermodynamics.

Now computerized data acquisition is used to create the p-V diagrams by involving the use of piezo electric pressure transducers mounted in cylinder head to measure the in-cylinder pressure and the crank angle encoders mounted on the engine crankshaft to measure the corresponding crank angle.

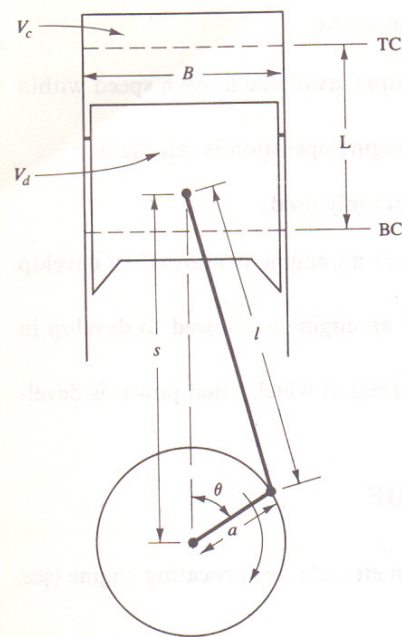


FIGURE 2-1

Geometry of cylinder, piston, connecting rod, and crankshaft where B = bore, L = stroke, l = connecting rod length, a = crank radius, θ = crank angle.

By using the following engine geometrical property based relationship between the crank angle and the corresponding cylinder volume, the software loaded in the computer helps in generating the needed p-V diagram.

$$V = V_c + \frac{\pi B^2}{4} (l + a - s) - (l^2 - a^2 \sin^2 \theta)$$

Where s is as given under:

$$s = a \cos \theta + ((l^2 - a^2 \sin^2 \theta)^{\frac{1}{2}})$$

Where V is the instantaneous cylinder volume and V_c is the clearance volume of the cylinder.

θ is the instantaneous crank angle of the engine crank shaft during each cycle.

B is the cylinder bore or diameter.

l is the length of the connecting rod of the engine.

a is the crank radius of the engine crankshaft.

The crank radius is related to the stroke of the engine cylinder L by the relationship:

$$L = 2a$$

As per the concepts of thermodynamics the area enclosed by the p-V diagram gives the work done. It is possible that the work could be done by the gas on the piston or else by the piston on the gas.

The indicated work per cycle per cylinder is obtained by integrating around the curve to obtain the area enclosed on the diagram.

$$W_{c,i} = \oint_{V_c+V_D}^{V_c} p \cdot dV$$

For Two Cycle Engines:

For two stroke cycle engine this integration is done over one revolution of crankshaft only which covers the piston movement from bottom center to top center and back. That is the integration limits are (V_C+V_D) and V_C

For Four Stroke Cycle Engines:

This integration is done over the two revolutions of crank shaft which on a p-V diagram involves the four processes of compression, expansion, exhaust and intake for the volume based limits between bottom center and top center only. That is the integration limits are (V_C+V_D) and V_C .

The one complete cycle integration process is convertible to 0 to 720 crank angle degrees with integration limits of four strokes as 0 to 180; 180 to 360; 360 to 540; and 540 to 720.

Two definitions of indicated output in common use are:

Gross indicated work per cycle $W_{c,ig}$: Work delivered to the piston over the compression and expansion strokes only.

Net indicated work per cycle $W_{c,in}$: Work delivered to the piston over the entire four-stroke cycle.

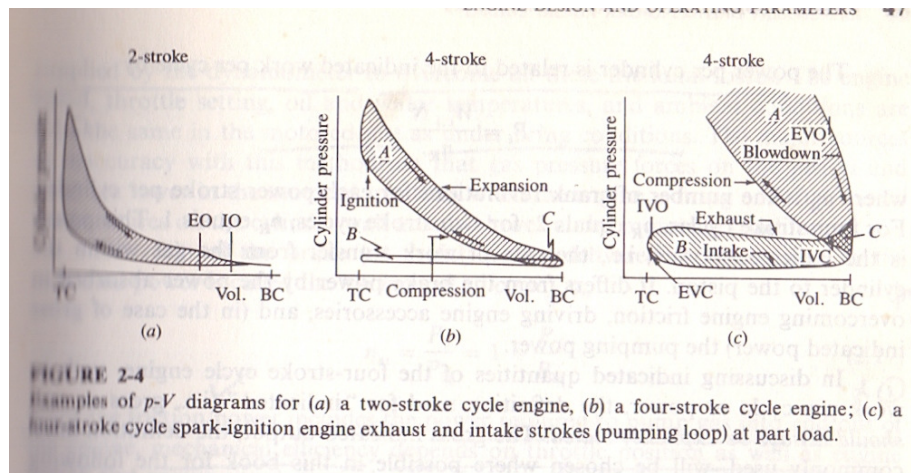
Pumping Work W_p : The work transfer between the piston and cylinder gases during the inlet and exhaust strokes.

The pumping work transfer will be **to the cylinder gases** if the pressure during the intake stroke is less than the pressure during the during the exhaust stroke. This is the situation with **naturally aspirated engines**.

The pumping work transfer will be from the cylinder gases **to the piston** if the exhaust stroke pressure is lower than the intake pressure. This is normally the case with highly loaded **turbocharged engines**.

This becomes clear if the **sign convection** that movement of piston **from TC to BC** creates a curve on p-V graph giving **positive work** done on the piston.

And the movement of piston **from BC to TC** creates a curve on the p-V graph giving **negative work** done on the gas.



The power per cylinder is related to the indicated work per cycle by:

$$P_i = \frac{W_{c,i}N}{n_R}$$

Where n_R is the number of crank revolutions for each power stroke per cylinder.

For four-stroke cycles, n_R equals 2; for two-stroke cycles, n_R equals 1.

This indicated power is the rate of work transfer from the gas within the cylinder to the piston.

By subtracting the power required to overcome engine friction, driving engine accessories, and the pumping power from the gross indicated power developed at piston we get the **brake power** developed at the crankshaft. This is true for **naturally aspirated engine**.

However when we use sign convention, for a **turbo-charged engine** we get:

Brake power = Indicated power – (power required to overcome engine friction + power required to drive engine accessories) + pumping power.

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Text Book:
Internal Combustion Engine Fundamentals
By John B Heywood
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