Engine Design

Chapter 03: Engine Kinematics

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Chapter Description

- Aims
  - To analyse IC engines kinematics.
- Expected Outcomes
  - To conduct the IC engine kinematics analyses.
- References

1. R.L. Norton, 2013. Kinematics and Dynamics of Machinery, McGraw-Hill Education; 2nd edition in SI units.

IC Engine Kinematics

- An internal combustion engine is a heat engine which converts chemical energy from fuel into mechanical energy of the crank-slider mechanism.
- A basic internal combustion engine components is shown in Figure 1-1. During combustion process, the fuel is burnt in the combustion chamber (i.e. the space between the piston and the top of the cylinder).

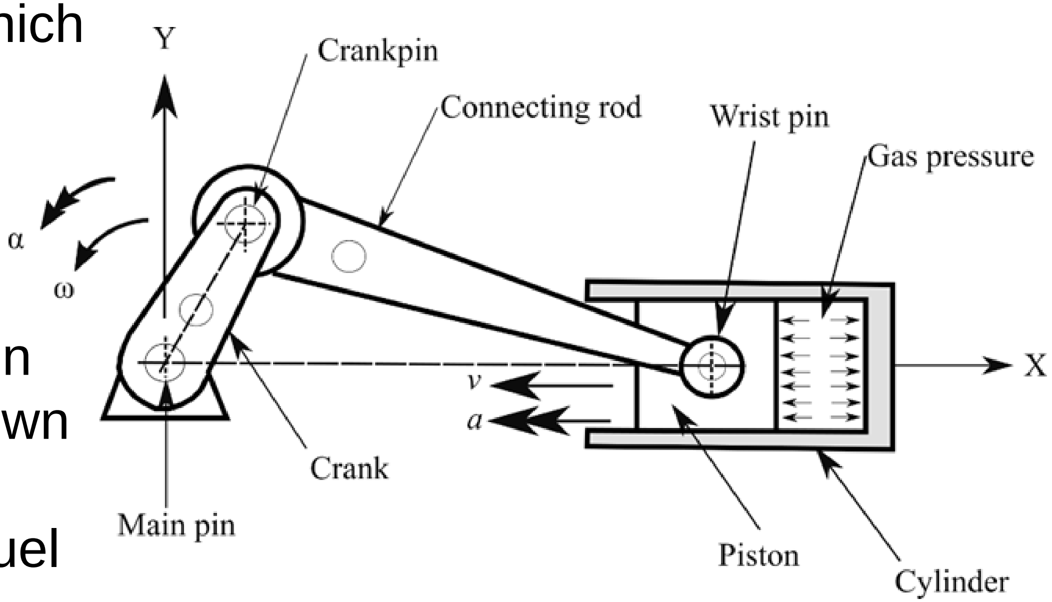

Fig. 3.1 Crank-slider mechanism and single cylinder internal combustion engine components

IC Engine Kinematics

- The combustion process raises the gas temperature and pressure hence pushes the piston along the negative x-axis.
- This linear motion is converted into rotational motion via crank-slider mechanism which consists of wrist pin, connecting rod, crank pin, crank and main pin. The torque resulting from the rotational motion of the crank is transferred to propel vehicles or other devices.

IC Engine Kinematics

- The relationship between the stroke and crank radius is:

$$S = 2a$$

- When the engine is rotating at at engine speed of *N*, the average piston speed is:

$$U_p = 2SN$$

- *N* is generally given in RPM (revolutions per minute), U_p in m/sec, and *B, a* and S in m or cm.
- The piston position, measure between main pin axis to wrist pin axis is given by:

$$x = a\cos\theta + \sqrt{r^2 - a^2\, sin^2\theta}$$

IC Engine Kinematics

- θ is measured from the cylinder centreline and is zero when the piston is at TDC

$$\theta = \omega t$$

- When x is differentiated with respect to time, the instantaneous piston speed U_p is obtained:

$$U_p = \frac{dx}{dt}$$

- The ratio of instantaneous piston speed divided by the average piston speed can then be written as

$$\frac{U_p}{\overline{U}_p} = \left(\frac{\pi}{2}\right) \sin\theta \left[1 + \left(\frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right)\right]$$

- Where:

$$R = \frac{r}{a}$$

- *R* is the ratio of connecting rod length to crank radius.

IC Engine Kinematics

- Displacement, or displacement volume V_d, is the volumes displaced by the piston as it travels from BDC to TDC:

$$V_d = V_{BDC} - V_{TDC}$$

- Clearance volume V_C, is given by:

$$V_c = V_{TDC}$$

$$V_{BDC} = V_c + V_d$$

- The compression ratio of an engine is defined as:

$$r_c = \frac{V_{BDC}}{V_{TDC}} = \frac{(V_c + V_d)}{V_c}$$

- Displacement volume for one cylinder:

$$V_C = \left(\frac{\pi}{4}\right) B^2 S$$

IC Engine Kinematics

- For an engine with N_C cylinders:

$$V_d = N_C \left(\frac{\pi}{4}\right) B^2 S$$

- The cylinder volume V at any crank angle is:

$$V = V_c + (\frac{\pi B^2}{4})(r + a - x)$$

- Another useful formula is in a non-dimensional form is the ratio V to V_c at any crank angle:

$$\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)[R + 1 - cos\theta - \sqrt{R^2 - sin^2\theta}\ ]$$

Summary

- Engine kinematics is looking into the motion of the piston which produce the velocity and acceleration.
- The study is important as the cylinder components design depends on these parameters.

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