Lecture 13

3rd Semester M Tech. Mechanical Systems Design

Mechanical Engineering Department

Subject: Advanced Engine Design

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Lecture 13 – Balancing of Mechanical Forces in I C Engines
Topic: Vibration Fundamentals as applied to Internal Combustion Engines – 14-10-2020

Vibration: --- A body vibrates about some mean position

Vibration is defined as the **response** resulting from any **force repeatedly applied** to a **body.** The **repeated force** may be random, or a force of given **magnitude** may be applied at some constant **frequency**.

In the case of **forces** generated within an **engine**, the **magnitude** will be **constant** at any **given engine speed and load**.

The **magnitude** will **change** either **with engine speed**, for example in the case of **mass based reciprocating and rotating forces**.

The reciprocating force is associated with the piston. The rotary force is associated with the crank shaft.

The reciprocating force F_R associated with the piston having a mass m and acceleration a can be written in terms of the Newton's second law of motion as under:

F_R = m*a

$F_R = m*\frac{d(dS)}{dt(dt)}$

Where

S = instantaneous distance of the piston pin from the centre of the crankshaft.

Mean Piston Speed Sp is written as

Sp = 2LN

The centrifugal force F_C associated with the crankshaft due to a mass m rotating at its crank position with an angular velocity ω corresponding to crankshaft rotational speed N is as under:

$F_C = m*\omega^{2*}r$

We know

$\omega = 2\pi N$

Therefore we can write

$F_C = m*(2\pi N)^2 r$

The **magnitude will also change** by changing **speed and load (gas pressure forces)**

Load external to the engine:

Passengers in bus

Cement bags in Truck

Electrical load on the DG set

Load external to the engine – has to be matched with load internal to the engine

Load internal to the engine:

Throttle position – controlled by accelerator and governor

[variable speed governor for automotives and constant speed governor for electrical power generation]

Air-Fuel Ratio – Rich or Lean – **more fuel or less fuel**

On one cycle basis – more load could mean more fuel – less load means less fuel

The consumption of the higher mass of fuel – results in the development of more higher Peak pressure – this will apply more higher force at piston top which gets transmitted to the crank of the crankshaft. The higher magnitude based force applied at the crank will develop higher torque to balance the load.

The **frequency of the forces causing vibrations – the repetition of the force - in internal combustion engines depends on the crankshaft rotational speed of the engine.**

The **frequency of the forces** on **number of crankshaft revolution basis** gives rise to the term **vibration order** which is defined as follows:

First Order Vibration:

A first order vibration occurs by **forces generated once** every crankshaft **revolution**.

First Order Vibration may be important in engines operating on a **two-stroke cycle** –

For example, the **gas pressure force** applied at one cylinder is repeated over a cycle of one crankshaft revolutions.

Half Order Vibration:

Half order vibration occurs by **forces generated once** every **two crankshaft revolution.**

4 Stroke Cycle

Half orders may be important in engines operating on a four-stroke cycle –

For example, the **gas pressure force** applied at one cylinder is repeated over a cycle of two crankshaft revolutions.

Second Order Vibration:

A second-order vibration occurs by **forces generated twice** every crankshaft **revolution**.

Third Order Vibration:

A third-order vibration occurs by **forces generated thrice** every crankshaft **revolution**.

Fourth Order Vibration:

A fourth-order vibration occurs by **forces generated four times** every crankshaft **revolution**.

And so on ----

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Text Book:
Vehicular Engine Design
By Kevin L. Hoag
Published By: SAE International USA