Lecture 14

3rd Semester M Tech. Mechanical Systems Design

Mechanical Engineering Department

Subject: Advanced Engine Design

I/C Prof M Marouf Wani

Lecture 14 – Balancing of Mechanical Forces in I C Engines
Topic: Balancing of Rotary Forces in Internal Combustion Engines - 15-10-2020

Rotating forces and dynamic couples:

The centrifugal force generated at each crankshaft throw is calculated first. These centrifugal forces from multi-cylinder engines only may give rise to unbalanced dynamic couples or moments.

As the crankshaft rotates each element of mass m located at a distance away from the crankshaft centerline generates an outward centrifugal force calculated as

$F_{rotational,} = \frac{Wr\omega^2}{g_c} = mr\omega^2$

Where

W = Weight – Force basically = mass*acceleration = m*g_c

r = radial distance of mass M from the crankshaft centerline

ω = angular velocity of the crankshaft

g_c = gravitational constant or - acceleration due to gravity

The mass m includes:

1. **The mass from the crank of crankshaft and**
2. **The portion of the mass of the connecting rod supposed to be concentrated at crank pin or crank radius.**

The equation for the rotary motion of the crank shaft is:

Torque = mass moment of inertia * angular acceleration

Or

T = I*α

$I = m*r^2$

The term m will firstly decide the **total mass m at the crank radius** and then subsequently The **Possible distribution of this mass** by choosing the suitable **materials, dimensions** including the **cross sections** for various parts of the **connecting rod** and the **crank of the crankshaft** which helps in converting the reciprocating motion of the piston into the rotary motion of the crankshaft.

Methodology for calculations of the rotating mass of the crankshaft:

1. **Earlier** this was done by **graphical methods**.
2. **Now** this is done by **computer aided design (CAD) software** applicable to **engine design.**

Methodology For Balancing The Rotating Forces Or Centrifugal Forces Acting On The Crankshaft Of An Internal Combustion Engine.

1. First step is the calculations for the total displacement volume required for the engine corresponding to a rated power at its rated speed.
2. The second step is the division of the total displacement volume into a multi-cylinder engine based small volumes for each cylinder.
3. The above step tells us the number of cylinders in our engine design.
4. The above step gives us the number of piston and connecting rod arrangements needed for the crankshaft.
5. The above step leads us to the number of crank throws of the crankshaft needed to join the big end of the connecting rod from each cylinder.
6. Next the centrifugal force or the rotating force is computed at each crank throw corresponding to each piston cylinder arrangement.
7. Next the firing order is decided for a multi-cylinder engine design.
8. This firing order helps us in the design of the crankshaft for the multi-cylinder engines.
9. The firing order decides the orientation of the cranks of the crankshaft for each cylinder in the geometrical crank angle degrees with respect to each other.
10. The firing order should ensure that the torque from each cylinder, during one complete engine cycle, is added to the crankshaft in a balanced manner uniformly along its entire length.
11. After getting the final design of the crankshaft along with the orientation of the cranks for various cylinders, the centrifugal forces along with their directions are shown at each crank throw.

12. The crankshaft is now analyzed for the balance of centrifugal forces and corresponding moments acting on it.
13. Finally the rotating forces or the centrifugal forces acting on the crankshaft are balanced by adding a pair of masses known as counterweights for each crank throw or each piston cylinder arrangement.
14. The above concept helps to balance not only the rotating forces acting on the crankshaft but also rules out the possibility of any unbalanced moment to act on the crankshaft.

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Prof M Marouf Wani

I/C Advanced Engine Design
Mechanical Engineering Department
National Institute of Technology
Srinagar, J&K
India – 190006

Text Book:
Vehicular Engine Design
By Kevin L. Hoag
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