Balancing of rotating masses.

Whenever a certain mass is attached to a rotating shaft, it excerts some centrifugal force, whose effect is to bend the shaft and to produce vibrations in it. Inorder to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft, at such a position so as to balance the effect of the centrifugal force of the first mass.

The process of providing the second mass inorder to counteract the effect of the centrifugal force of the first mass, is called 'Balancing of rotating masses'.

The following cases are important.

1. Balancing of a single rotating mass by a single mass rotating in the same plane.
2. Balancing of a single rotating mass by two masses rotating in different plane.
3. Balancing of different masses rotating in the same plane.

4. Balancing of different masses rotating in different planes.

Static balancing

"A System of rotating masses is said to be in static balance if the Combined mass centre of the system lies on the axis of rotation."

Fig. shows a rigid rotor revolving with a constant angular velocity of 'ω' rad/s. A number of masses, say three are depicted by point masses at different radii in the same transverse plane.

They may represent different kind of rotating masses such as turbine blades, eccentric discs, etc.

If m_1, m_2 and m_3 are the masses revolving at radii r_1, r_2 and r_3 respectively in the same plane. then each mass produces a centrifugal force acting radially outwards from the axis of rotation.

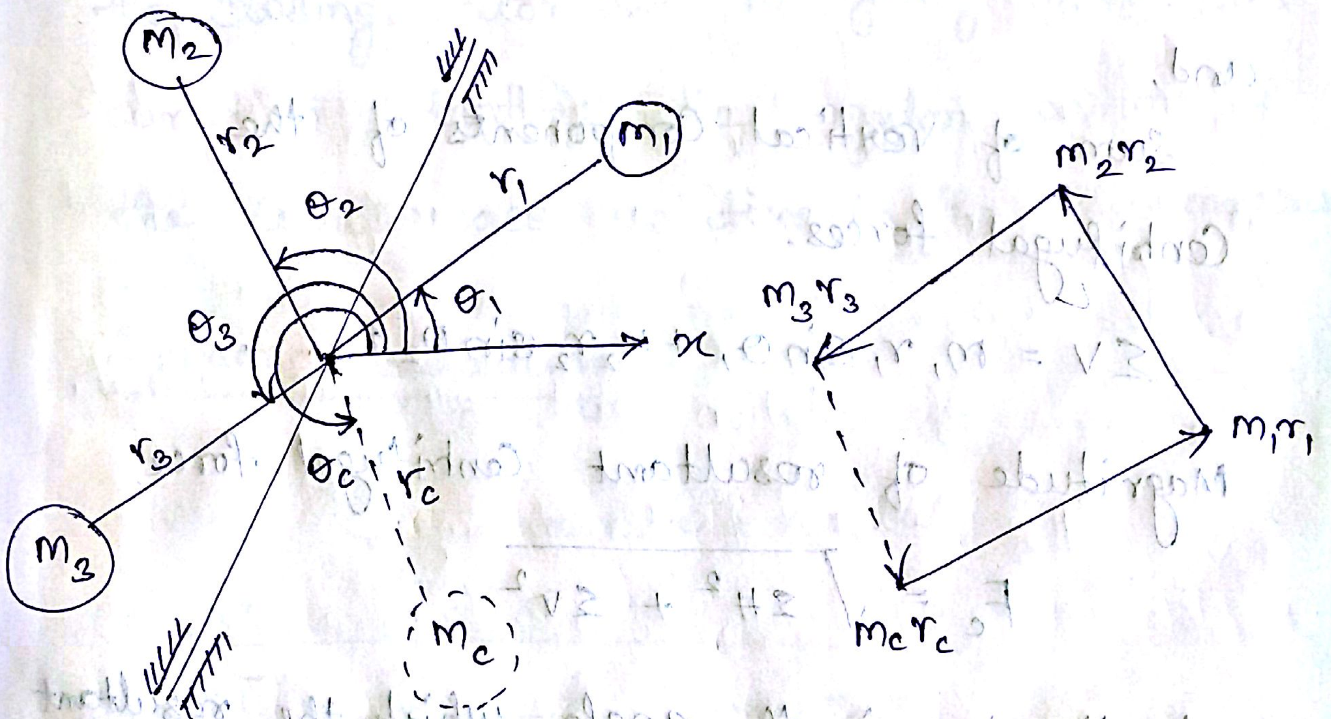
Let 'F' be the Vector Sum of these forces,

$$F = m_1 r_1 \omega^2 + m_2 r_2 \omega^2 + m_3 r_3 \omega^2$$

The rotor is said to be statically balanced if the vector sum F is zero.

If 'F' is not zero, ie. the rotor is unbalanced, then introduce a Counterweight (balance weight) of mass m_c, at radius r_c to balance the rotor so that

$$m_1 r_1 + m_2 r_2 + m_3 r_3 = 0.$$



The magnitude of either m_c or r_c may be selected and of the other can be calculated.

In general, if Σmr is the vector sum of $m_1 r_1$, $m_2 r_2$, $m_3 r_3$, $m_4 r_4$, etc. then,

$$\Sigma mr + m_c r_c = 0.$$

The equation can be solved either mathematically or graphically. To solve it mathematically, divide each force into its x and z components:

Sum of horizontal components of the centrifugal forces.

$$\Sigma H = m_1 r_1 \cos\theta_1 + m_2 r_2 \cos\theta_2 + \ldots$$

and,

Sum of vertical components of the centrifugal forces.

$$\Sigma V = m_1 r_1 \sin\theta_1 + m_2 r_2 \sin\theta_2 + \ldots$$

Magnitude of resultant centrifugal force,

$$F_c = \sqrt{\Sigma H^2 + \Sigma V^2}$$

If the 'θ' is the angle which the resultant force makes with the horizontal, then,

$$\tan\theta = \frac{\Sigma V}{\Sigma H}.$$

The balancing force is then equal to the resultant force, but in opposite direction.

Now, the magnitude of the balancing mass, such that,

$$F_c = m.r.$$

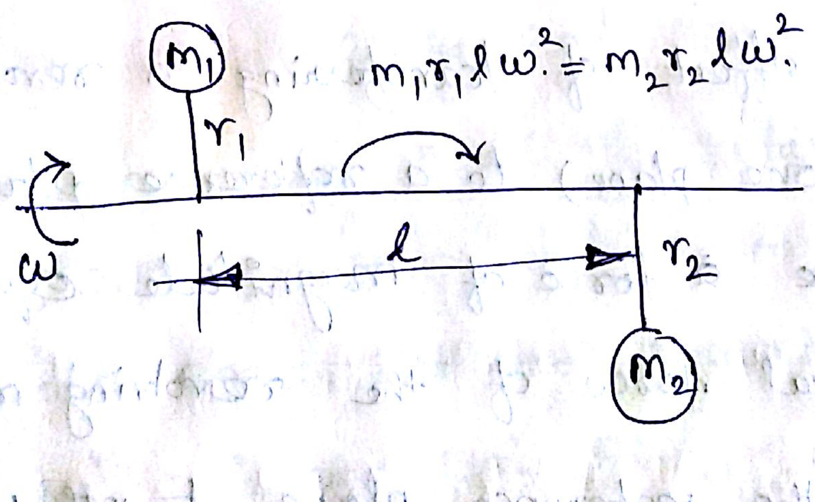
where,

m = Balancing mass and,

r = Its radius of rotation.

In graphical solution, vectors, $m_1 r_1$, $m_2 r_2$, $m_3 r_3$, etc. are added. If they close in a loop, the system is balanced. Otherwise, the closing vector will be giving $m_c r_c$. Its direction identifies the angular position of the countermass relative to the other masses.

Dynamic Balancing



When several masses rotate in different planes, the centrifugal forces, in addition to being out of balance, also form couples. A system of rotating masses is in dynamic balance when there does not exist any resultant centrifugal force as well as resultant couple.

Balancing of several masses rotating in Different planes.

When, several masses revolve in different planes, they may be transferred to a 'reference plane', which may be defined as the plane passing through a point on the axis of rotation and perpendicular to it.

The effect of transferring a revolving mass (in one plane) to a reference plane is to cause a force of magnitude equal to the centrifugal force of the revolving mass to act in the reference plane, together with a couple of magnitude equal to the

Product of the force and the distance between the plane of rotation and reference plane. In order to have a complete balance of the several revolving masses in different planes, the following two conditions must be satisfied.

1. The forces in the reference plane must balance. (i.e) the resultant force must be zero.

2. The couples about the reference plane must balance. (i.e) the resultant couple must be zero.

Problem ①.

Four masses m_1, m_2, m_3 and m_4 are 200 kg, 300 kg, 240 kg and 260 kg respectively. The corresponding radii of rotation are 0.2 m, 0.15 m, 0.25 m and 0.3 m respectively. and the angles between sucessive masses are 45°, 75° and 135°. Find the position and magnitude of the balance mass required, if the radius of rotation is 0.2 m.