Theory of machinery

Chapter eight

Static balancing

By

Laith Batarseh

Static balancing

Theory of machinery

❑Imbalance is inherited in any rotating machinery due to the un symmetry in the material or the shape of the machine

❑The main problem of imbalance is the generation of unbalanced centrifugal forces rotates with the machine which produce shaking and vibration issue in the system.

❑Unless the vibration is required, the unbalanced machine will suffer from excessive fatigue stresses.

❑To eliminate unbalance, we perform a process called balancing

❑Balancing can be static or dynamic

❑Static balance is sometimes called **single plane balancing.**

❑ dynamic balance is sometimes called **multi plane balancing.**

Static balancing

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- In static balancing the main condition is: ∑F –ma =0
- In dynamic balancing the main conditions are: ∑F = 0 and ∑M=0.
- static balance is applied when the inertia is distributed radialy rather than axially (i.e. has a large radius compared to the thickness). For example, single slim gear or pulley or fly wheel or single turbine blade disc can be balanced using static balancing.
- When the ratio between the radius and the thickness become small. or when there are multi discs on the same shaft, dynamic balancing is applied

Static balancing

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Procedures for static balancing

1. Represent the mass distribution as a concentrated point mass (m) located at the center of gravity of that mass (C.G).
2. Measure the distances between the concentrated masses (i.e. C.Gs) to the center of rotation. Call this distance R.
3. Assume angular velocity (ω).
4. Assume that there is a balance mass (m_b) located from the center of rotation by R_b.
5. Apply the static balance condition : ∑F –ma =0

$$\left.\begin{aligned} -m_1\vec{R}_1\omega^2 - m_2\vec{R}_2\omega^2 - .... - m_n\vec{R}_n\omega^2 - m_b\vec{R}_b\omega^2 &= 0 \\ \Rightarrow -m_1\vec{R}_1 - m_2\vec{R}_2 - .... - m_n\vec{R}_n - m_b\vec{R}_b &= 0 \end{aligned}\right\} --Eq.1$$

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Procedures for static balancing

6. Rearrange Eq.1: $m_b\vec{R}_b = -\left(m_1\vec{R}_1 + m_2\vec{R}_2 + ... + m_n\vec{R}_n\right) --- Eq.2$

7. Resolve E.2 to its rectangular components

$$\left.\begin{aligned} m_b\vec{R}_{b,x} &= -\left(m_1\vec{R}_{1,x} + m_2\vec{R}_{2,x} + ... + m_{n,x}\vec{R}_{n,x}\right) \\ m_b\vec{R}_{b,y} &= -\left(m_1\vec{R}_{1,y} + m_2\vec{R}_{2,y} + ... + m_n\vec{R}_{n,y}\right) \end{aligned}\right\} --Eq.3$$

8. Drive expressions for R_b and θ_b:

$$\theta_b = \tan^{-1}\left[\frac{m_b\vec{R}_{b,y}}{m_b\vec{R}_{b,x}}\right] = \tan^{-1}\left[\frac{-\left(m_1\vec{R}_{1,y} + m_2\vec{R}_{2,y} + ... + m_n\vec{R}_{n,y}\right)}{-\left(m_1\vec{R}_{1,x} + m_2\vec{R}_{2,x} + ... + m_{n,x}\vec{R}_{n,x}\right)}\right] --- Eq.4$$

$$R_b = \sqrt{\left(\vec{R}_{b,x}\right)^2 + \left(\vec{R}_{b,y}\right)^2} \Rightarrow m_bR_b = \sqrt{\left(m_b\vec{R}_{b,x}\right)^2 + \left(m_b\vec{R}_{b,y}\right)^2} --- Eq.5$$

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Procedures for static balancing

As you can see, we can find the angle θ_b directly from Eq.4 but to find the values of m_b and R_b we have single equation (5). So, the product of distance and mass m_b and R_b can be found and according to that you can design the balancing system

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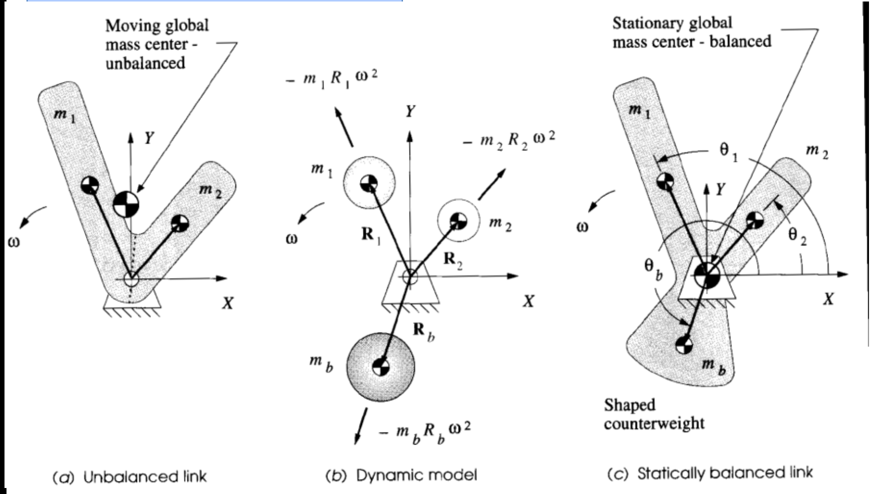
Procedures for static balancing



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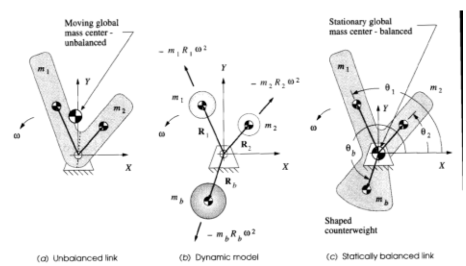
Example



$m_1 = 1.2$ kg

$m_2 = 1.8$ kg

$R_1 = 1.135$ m @$\angle 113.4°$

$R_2 = 0.822$ m @$\angle 48.8°$

$\omega = 40$ rad/sec

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Example

Solution:

1 Resolve the position vectors into *xy* components in the arbitrary coordinate system associated with the freeze-frame position of the linkage chosen for analysis.

$$R_1 = 1.135 @ \angle 113.4°; \quad R_{1_x} = -0.451, \quad R_{1_y} = 1.042$$
$$R_2 = 0.822 @ \angle 48.8°; \quad R_{2_x} = +0.541, \quad R_{2_y} = 0.618 \qquad (a)$$

2 Solve equations 12.2c.

$$m_b R_{b_x} = -m_1 R_{1_x} - m_2 R_{2_x} = -(1.2)(-0.451) - (1.8)(0.541) = -0.433$$
$$m_b R_{b_y} = -m_1 R_{1_y} - m_2 R_{2_y} = -(1.2)(1.042) - (1.8)(0.618) = -2.363 \qquad (b)$$

3 Solve equations 12.2d and 12.2e.

$$\theta_b = \arctan \frac{-2.363}{-0.433} = 259.6°$$
$$m_b R_b = \sqrt{(-0.433)^2 + (-2.363)^2} = 2.402 \text{ kg-m} \qquad (c)$$

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Example

4 This mass-radius product of 2.402 kg-m can be obtained with a variety of shapes appended to the assembly. Figure 12-1c shows a particular shape whose *CG* is at a radius of R_b = 0.806 m at the required angle of 259.6°. The mass required for this counterweight design is then:

$$m_b = \frac{2.402 \text{ kg-m}}{0.806 \text{ m}} = 2.980 \text{ kg} \qquad (d)$$

at a chosen *CG* radius of:

$$R_b = 0.806 \text{ m} \qquad (e)$$