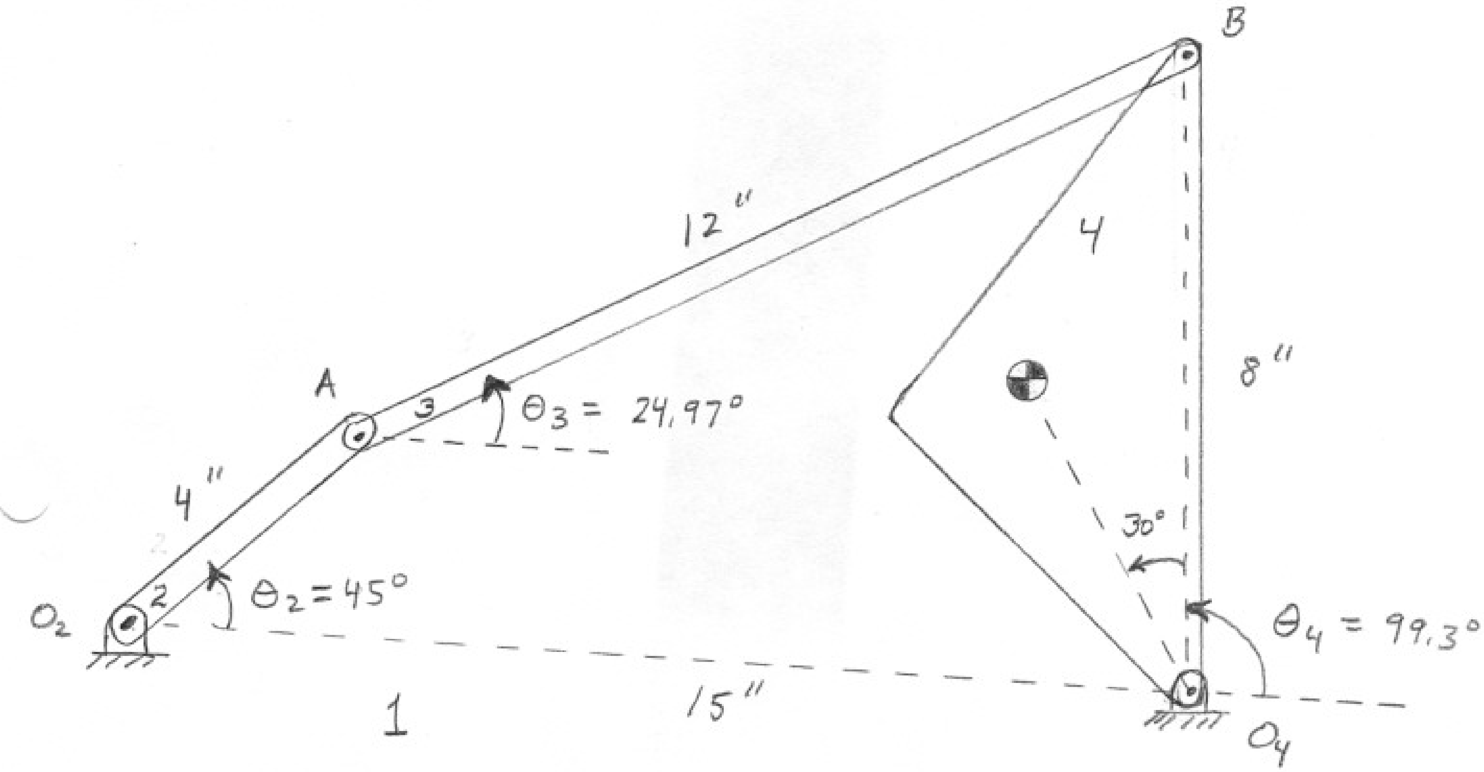
Example

For the fourbar linkage shown, calculate the size and angular locations of the counterbalance mass-radius products needed on link 2 and 4 to completely force balance the linkage by the Method of Berkof and Lowen.



$l_2 = 4''$, $l_3 = 12''$, $l_4 = 8''$, $l_1 = 15''$, $\theta_1 = 0°$

Mass: $m_2 = 0.002$ blob, $m_3 = 0.02$ blob $m_4 = 0.1$ blob

$I_{G2} = 0.1$ blob in^2 $I_{G3} = 0.2$ blob in^2 $I_{G4} = 0.5$ blob in^2

Center of Mass: $b_2 = 2''$, $\phi_2 = 0°$, $b_3 = 5''$, $\phi_3 = 0°$

$b_4 = 4''$, $\phi_4 = 30°$

Solution: To solve for mass-radius product needed on link 2 and 4 we need to use the equations shown on page 20-5

$$(m_2 b_2)_x = m_3 \left(b_3 \frac{l_2}{l_3} \cdot \cos(\phi_3) - l_2 \right)$$

$$(m_2 b_2)_x = 0.02 \left(5\left(\frac{4}{12}\right) \cos(0) - 4 \right) = -0.0467 \text{ in-blob}$$

$$(m_2 b_2)_y = m_3 \left(b_3 \frac{l_2}{l_3} \sin(\phi_3) \right)$$

$$(m_2 b_2)_y = 0.02 \left(5\left(\frac{4}{12}\right) \sin(0) \right) = 0$$

$$(m_4 b_4)_x = - m_3 b_3 \frac{l_4}{l_3} \cos \phi_3$$

$$(m_4 b_4)_x = - 0.02 (5)\left(\frac{8}{12}\right) \cos(0) = -0.0667 \text{ in-blob}$$

$$(m_4 b_4)_y = - m_3 b_3 \frac{l_4}{l_3} \sin \phi_3$$

$$(m_4 b_4)_y = -0.02 (5)\left(\frac{8}{12}\right) \sin(0) = 0$$

Note: These equations provide the components of the mass radial product needed to force balance the linkage. If the linkages (2 and 4) have an existing imbalance, then we need to take the existing imbalance into account. Therefore for this problem, we need to subtract the existing imbalance that exists to determine the amount of the counter weights, to balance the linkage.

- The total mR product for link 2 and 4 is given by the equations above, now let's compute the additional mR product to add to the existing links

$$mR_{2x} = (m_2 b_2)_x - m_2 b_2 \cos \phi_2$$

$$mR_{2x} = -0.0467 \text{ in blob} - (0.002)(2)\cos(0) = -0.0507 \text{ in blob}$$

$$mR_{2y} = (m_2 b_2)_y - m_2 b_2 \sin\phi_2$$

$$= 0 \text{ in blob} - (0.002)(2)\sin(0) = 0 \text{ in blob}$$

$$mR_{4x} = (m_4 b_4)_x - m_4 b_4 \cos\phi_4$$

$$= -0.0667 \text{ in blob} - (0.1)(4)\cos(30) = -0.4131 \text{ in blob}$$

$$mR_{4y} = (m_4 b_4)_y - m_4 b_4 \sin\phi_4$$

$$= 0 \text{ in blob} - (0.1)(4)\sin(30) = -0.2 \text{ in blob}$$

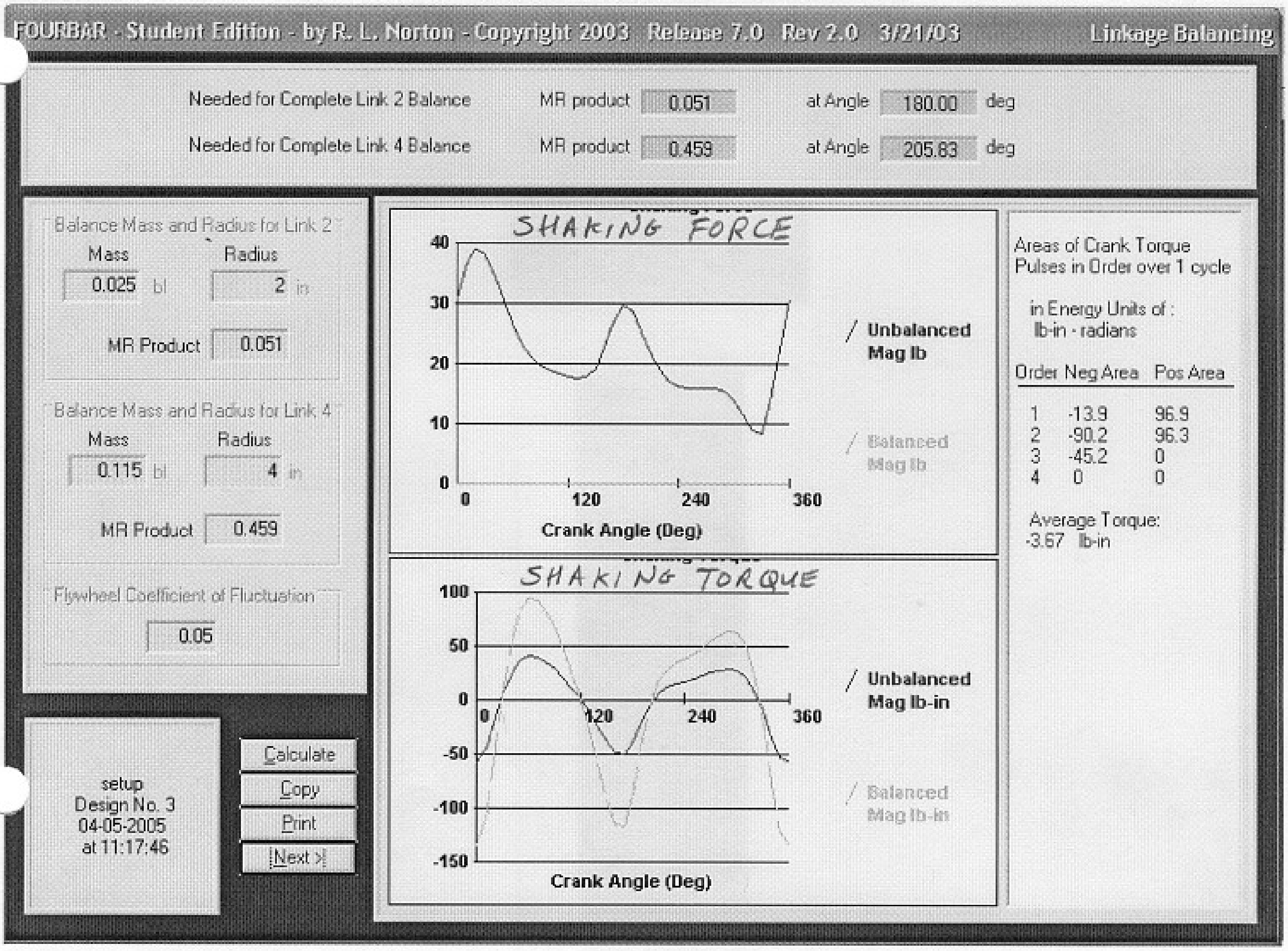
Now solve for the position angle and the additional mass-radius product required

$$\theta_{b2} = \tan^{-1}\left(\frac{mR_{2y}}{mR_{2x}}\right) = \tan^{-1}\left(\frac{0}{-.0507}\right) = 180°$$

$$mR_{b2} = \sqrt{mR_{2x}^2 + mR_{2y}^2} = \sqrt{(-0.0507)^2 + 0^2} = 0.0507 \text{ in blob}$$

$$\theta_{b4} = \tan^{-1}\left(\frac{mR_{4y}}{mR_{4x}}\right) = \tan^{-1}\left(\frac{-0.2}{-0.4131}\right) = -154.16°$$

$$mR_{b4} = \sqrt{mR_{4x}^2 + mR_{4y}^2} = \sqrt{(-0.4131)^2 + (-0.2)^2} = 0.459 \text{ in blob}$$



The maximum positive input Torque without force balancing is 245.7 in.-lb. After force balancing it is 460.7 in.-lb.

- When we balance a link that is in pure rotation, the addition of the counterweight will have the side effect of increasing its mass moment of inertia. Even when the crank is moving at constant angular velocity, the coupler and rocker will have a non constant angular acceleration. Therefore, individually balancing the rockers will tend to increase the required input torque.

- Performing a force balance of an entire linkage increases the mass moment of inertia and unbalances individual links in order to achieve a global linkage balance.
- Balancing the entire linkage can have the side effect of increasing the variation in the required input torque. The peak value of the required input torque has increased in the example we did on p. 20-5 as a result of force-balancing

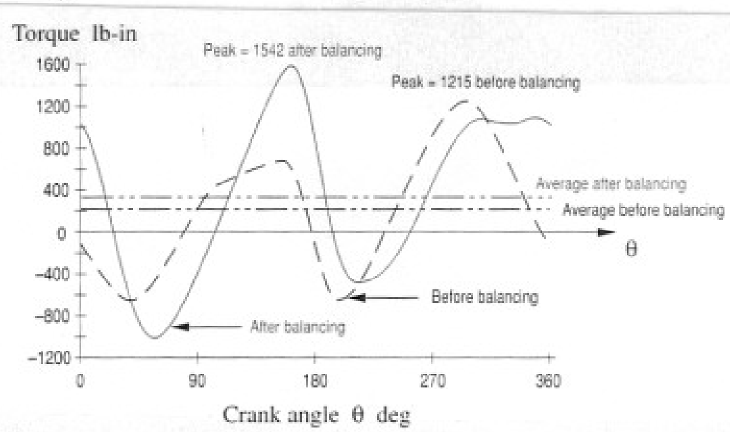


FIGURE 12-8
Unbalanced and balanced input torque curves for the fourbar linkage of Figure 12-5

- The degree of increase in the input torque due to the force-balancing is dependent on the choice of radii at which the balance masses are placed. Placing the balance mass at as small a radius as possible will minimize the increase in input torque. Placing circular counterweights tangent to the link's pivot center provides a good compromise between added mass and increased moment of inertia.

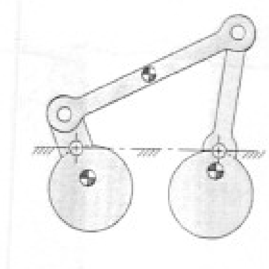


FIGURE 12-9
An inline fourbar linkage (6), (7) with optimally located circular counterweights. (5)