$$\text{Thus}\quad L = -\frac{(1/2)\rho V^2\left(h_2^2 - h_3^2\right)}{\rho V^2 h_1 \sin\theta} = -\frac{\left(h_2^2 - h_3^2\right)}{2h_1 \sin\theta} = -\frac{\mathbf{1}}{\mathbf{2}}\mathbf{h_1 \cot\theta}\quad \textit{Ans.}$$

The latter result follows from the (h_1, h_2, h_3) relations in 3.46. The C.P. is below point O.

3.123 The waterwheel in Fig. P3.123 is being driven at 200 r/min by a 150-ft/s jet of water at 20°C. The jet diameter is 2.5 in. Assuming no losses, what is the horsepower developed by the wheel? For what speed Ω r/min will the horsepower developed be a maximum? Assume that there are many buckets on the waterwheel.

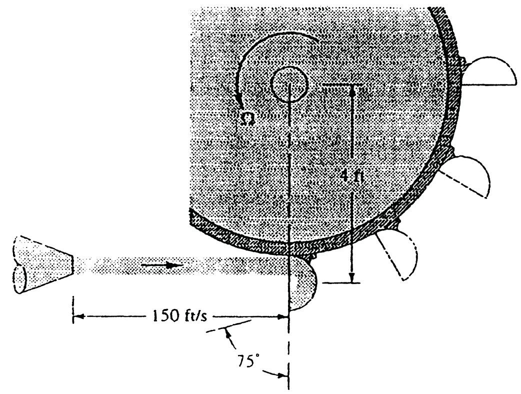

Fig. P3.123

Solution: First convert Ω = 200 rpm = 20.9 rad/s. The bucket velocity = V_b = ΩR = (20.9)(4) = 83.8 ft/s. From Prob. 3.51 of this Manual, if there are many buckets, the entire (absolute) jet mass flow does the work:

$$P = \dot{m}_{jet}V_b(V_{jet} - V_b)(1 - \cos 165°) = \rho A_{jet}V_{jet}V_b(V_{jet} - V_b)(1.966)$$

$$= (1.94)\frac{\pi}{4}\left(\frac{2.5}{12}\right)^2(150)(83.8)(150 - 83.8)(1.966)$$

$$= 108200\ \frac{\text{ft}\cdot\text{lbf}}{\text{s}} \approx \mathbf{197\ hp}\quad \textit{Ans.}$$

Prob. 3.51: Max. power is for $V_b = V_{jet}/2$ = 75 ft/s, or Ω = 18.75 rad/s = **179 rpm** *Ans.*

3.124 A rotating dishwasher arm delivers at 60°C to six nozzles, as in Fig. P3.124. The total flow rate is 3.0 gal/min. Each nozzle has a diameter of $\frac{3}{16}$ in. If the nozzle flows are equal and friction is neglected, estimate the steady rotation rate of the arm, in r/min.

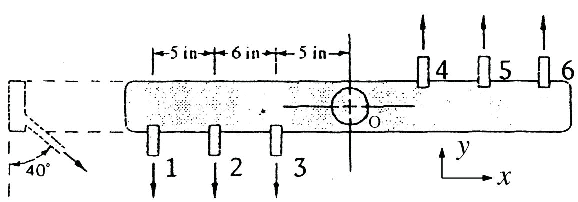

Fig. P3.124