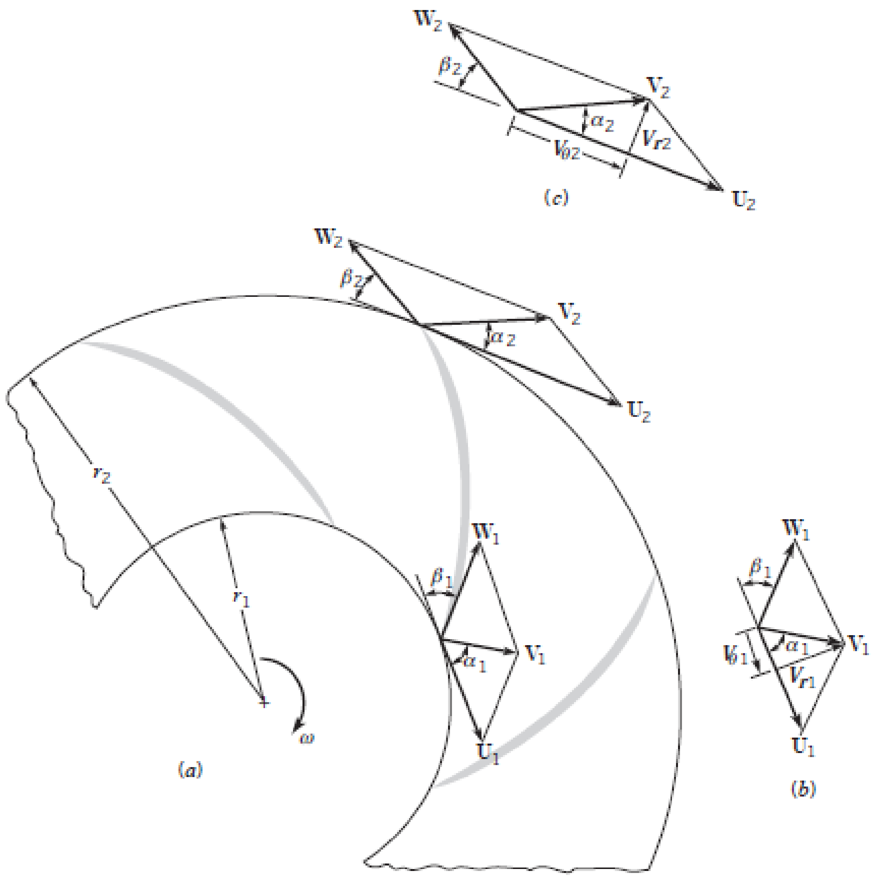
EXERCISE 302a:

Water is pumped at the rate of 1400 gpm through a centrifugal pump operating at a speed of 1750 rpm. The impeller has a uniform blade height, *b*, of 2 in. with $r1 = 1.9$ in. and $r2 = 7.0$ in, and the exit blade angle β2 is 23°. Assume ideal flow conditions and that the tangential velocity component, $V\theta 1$, of the water entering the blade is zero ($\alpha 1$ = 90°).

Determine (a) the tangential velocity component at the exit, (b) the ideal head rise, (c) the power transmitted to the fluid, and (d) the motor efficiency if the electrical power is 125 hp. Discuss the difference between ideal and actual head rise.



AXIAL FLOW FAN

Fans are classified as axial flow low pressure compressor. They operate at a pressure equal to or below 7 kPa. One of the functions of fan is to circulate air through ducts of an air-conditioning unit. It is also used for handling fuel gases, light materials and furnace gases.

In the design of fans, the terms often used for power input and power output are brake power and total air power respectively.

$$\eta_f = \frac{TAP}{BP} \times 100\% = \frac{\gamma Q h_t}{BP} \times 100\%$$

$$\eta_s = \frac{SAP}{BP} \times 100\% = \frac{\gamma Q h_s}{BP} \times 100\%$$

$$\eta_m = \frac{BP}{EP} \times 100\%$$

$$EP = \frac{TAP}{\eta_m \eta_f}$$

$$H_s + h_t = H_d + h_l$$

$$h_t = H_d - H_s + h_l$$

$$h_t = \left[\frac{p_d}{\gamma_a} + z_d + \frac{V_d^2}{2g}\right] - \left[\frac{p_s}{\gamma_a} + z_s + \frac{V_s^2}{2g}\right] + h_l$$

$$h_t = \frac{p_d}{\gamma_a} + \frac{V_d^2}{2g}$$

PROBLEM 309a:

A manufacturer rates his fan at 120 cu.m/min with air static pressure of 15 cm of water and fan speed of 1500 rpm. The air temperature is 25°C and 760 mm Hg barometric pressure of 75% static efficiency. Determine the flow, static pressure and shaft power at 1800 rpm considering that the air temperature and barometric pressure readings are 50°C and 700 mm Hg, respectively.

PROBLEM 309a:

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Solution:

a) Use Affinity Laws considering the same fan diameters.

$$\frac{Q_1}{n_1 D_1^3} = \frac{Q_2}{n_2 D_2^3}$$

$$Q_2 = Q_1\left[\frac{n_2}{n_1}\right]$$

$$Q_2 = 120\frac{\text{m}^3}{\text{min}}\left[\frac{1800}{1500}\right]$$

$$Q_2 = 144\frac{\text{m}^3}{\text{min}}$$

$$\frac{gh_1}{n_1^2 D_1^2} = \frac{gh_2}{n_2^2 D_2^2}$$

$$h_2 = h_1\left[\frac{n_2}{n_1}\right]^2$$

$$h_2 = 0.15\,\text{m}\left[\frac{1800}{1500}\right]^2$$

$$h_2 = 0.216\,\text{m}$$

b) Use Ideal Gas Equation of State to find the mass density of air.

$$\rho_1 = \frac{p_1}{RT_1} = \frac{(101.325\,\text{kPa})}{(0.287\,\text{kJ/kg - K})(25 + 273.15)\text{K}}$$

$$\rho_1 = 1.184\,\text{kg/m}^3$$

$$\rho_2 = \frac{p_2}{RT_2} = \frac{\left(700\,\text{mm Hg} \times \frac{101.325\,\text{kPa}}{760\,\text{mmHg}}\right)}{(0.287\,\text{kJ/kg - K})(50 + 273.15)\text{K}}$$

$$\rho_2 = 1.0063\,\text{N/m}^3$$

PROBLEM 309a:

Solution:

c) Calculating the brake power at point 1

$$\eta_s = \frac{SAP_1}{BP_1} \times 100\%$$

$$BP_1 = \frac{\gamma_1 Q_1 h_1}{\eta_s} = \frac{(9.80665\ \text{kN/m}^3)(2.0\ \text{m}^3/\text{s})(0.15\ \text{m H}_2\text{O})}{0.75}$$

$$BP_1 = 3.923\ \text{kW}$$

$$\frac{BP_1}{\rho_1 n_1^3 D_1^5} = \frac{BP_2}{\rho_2 n_2^3 D_2^5}$$

$$BP_2 = BP_1\left[\left(\frac{\rho_2}{\rho_1}\right)\left(\frac{n_2^3}{n_1^3}\right)\right]$$

$$BP_2 = 3.923\ \text{kW}\left[\left(\frac{1.0063\ \text{N/m}^3}{1.184\ \text{N/m}^3}\right)\left(\frac{1800}{1500}\right)^3\right]$$

$$BP_2 = 5.762\ \text{kW}$$

PROBLEM 309b:

Find the air horsepower of an industrial fan that delivers 25.98 cu.m/s of air through a 0.915 m by 1.22 m duct. Pressure is 127 mm water with air temperature and barometric pressure readings of 21°C and 760 mm Hg, respectively. If the motor and total fan efficiencies are 92% and 70%, find EP.

PROBLEM 309b:

Find the air horsepower of an industrial fan that delivers 25.98 cu.m/s of air through a 0.915 m by 1.22 m duct. Pressure is 127 mm water with air temperature and barometric pressure readings of 21°C and 760 mm Hg, respectively. If the motor and total fan efficiencies are 92% and 70%, find EP.

Solution:

a) Calculate the total air power, TAP.

$$TAP = \gamma Q h_t$$

where,

$$h_t = \frac{p_d}{\gamma_a} + \frac{V_d^2}{2g} = \frac{\gamma_w h_s}{\gamma_a} + \frac{1}{2g}\left(\frac{Q}{lw}\right)^2$$

Also, using Ideal Gas Equation of State yields

$$\gamma_a = \frac{pg}{RT} = \frac{(101.325\ \text{kPa})(9.80665\ \text{m/s}^2)}{(0.287\ \text{kJ/kg - K})(21 + 273.15)\text{K}} = 11.7703\ \text{N/m}^3$$

Thus,

$$h_t = \frac{(9.80665\ \text{kN/m}^3)(0.127\ \text{m of H}_2\text{O})}{11.7703\ \text{N/m}^3} + \frac{1}{2(9.80665\ \text{m/s}^2)}\left(\frac{25.98\ \text{m}^3/s}{1.22\ \text{m} \times 0.915\ \text{m}}\right)^2 = 133.43\ \text{m}$$

Finally,

$$TAP = \gamma_a Q h_t$$

$$TAP = (11.7703\ \text{N/m}^3)(25.98\ \text{m}^3/s)(133.43\ \text{m})$$

$$TAP = 40{,}801.51\ \text{W} \times \frac{1\ \text{kW}}{1{,}000\ \text{W}} = 40.802\ \text{kW}$$

PROBLEM 309b:

Solution:

b) Calculating the electrical power, EP yields

$$EP = \frac{TAP_t}{\eta_m \eta_f}$$

$$EP = \frac{40.802\ \text{kW}}{0.92 \times 0.70} = 63.36\ \text{kW}$$