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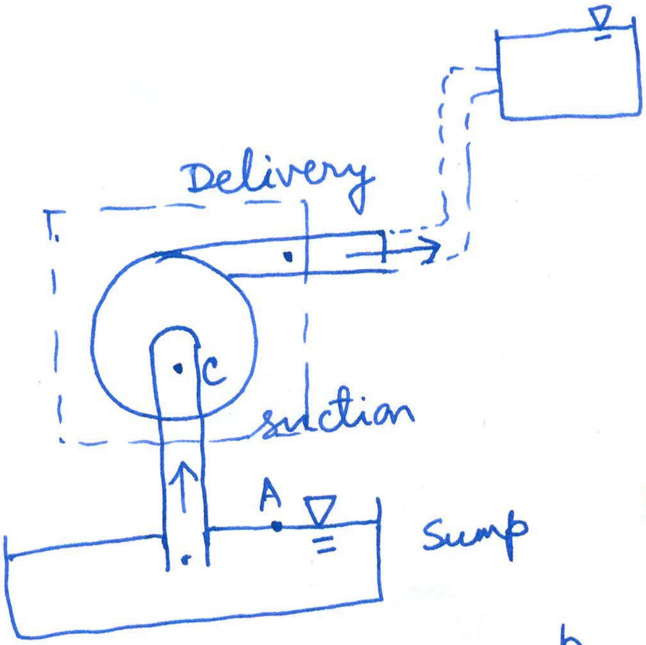


Q

H

$P = \rho Q g H$

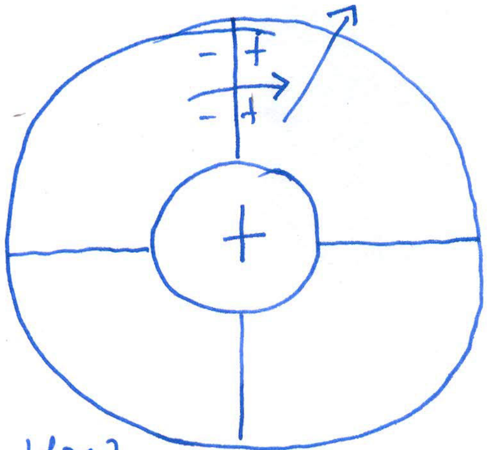
$$\frac{p}{\rho g} + \frac{V^2}{2g} + z = C$$

$$\frac{p_a}{\rho g} = \frac{p_c}{\rho g} + \frac{V_c^2}{2g} + z_c$$

$p_c > p_a$

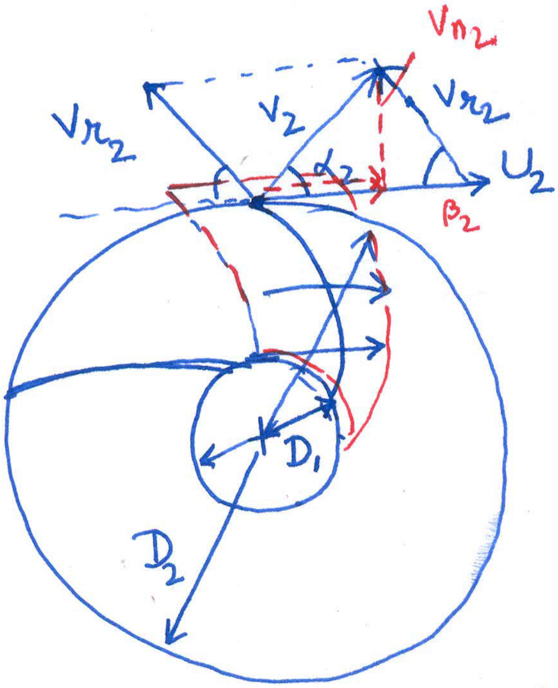
$=$

$< p_a$



$p_c < p_v$

Vane congruent flow



$$U_2 = \frac{\pi D_2 N}{60}$$

$$U_1 = \frac{\pi D_1 N}{60}$$

V_{r_2} = relative velocity

V_2 = absolute "

β_2 = blade angle

α_2 = flow "

$$Q = \pi D_2 b_2 V_{n_2} = \pi D_1 b_1 V_{n_1}$$

V_{u_2} and V_{u_1}

Conservation of angular momentum

$$T = \dot{m}(r_1 V_{u_1} - r_2 V_{u_2}) \qquad \underline{r} \times m\underline{v}$$

$$\frac{P}{\dot{m}} = \frac{\omega T}{\dot{m}}$$

ω = angular velocity

omega $= \frac{2\pi N}{60}$

$$= (\underline{\omega r_1} V_{u_1} - \underline{\omega r_2} V_{u_2})$$

$$\dot{Q} - \dot{W} = \dot{m}\left(h + \frac{v^2}{2} + gz\right)_2 - \dot{m}\left(h + \frac{v^2}{2} + gz\right)_1$$

$$\dot{W} = \dot{m}(h \ldots)_1 - \dot{m}\left(h + \frac{v^2}{2} + gz\right)_2$$

$$w = \frac{P}{\dot{m}} = U_1 V_{u_1} - U_2 V_{u_2}$$

lower case w, specific work.

Euler Turbomachine Theory.

$$V_{r_2}^2 = V_2^2 + U_2^2 - 2 U_2 V_2 \cos\alpha_2$$

$$= V_2^2 + U_2^2 - 2 U_2 V_{u_2}$$

$$U_2 V_{u_2} = \frac{V_2^2 + U_2^2 - V_{r_2}^2}{2}$$

$$w = \frac{(V_1^2 - V_2^2) + (U_1^2 - U_2^2) - (V_{r_1}^2 - V_{r_2}^2)}{2}$$

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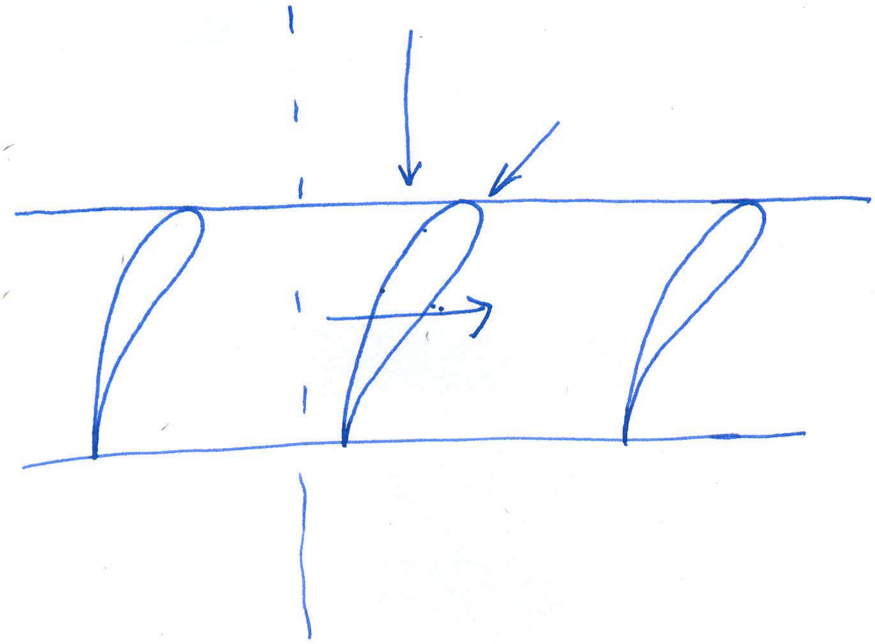
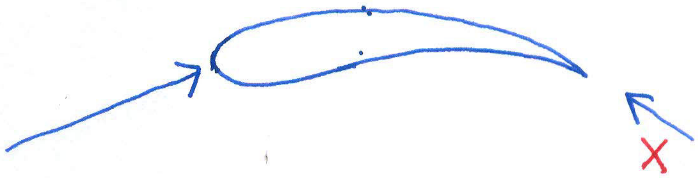
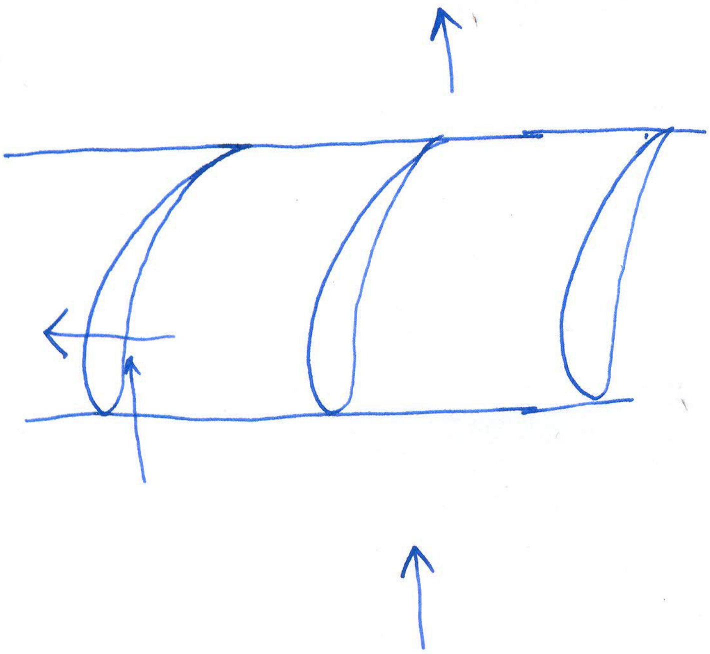
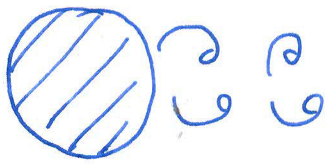








~97%

3%

Review Questions

1. What is a vane-congruent flow? By means of neat sketches, show the vane-congruent flow for at least two types of radial flow blades and one type of axial flow blades. *(Refer Section 3.2.3)*
2. What is the purpose of air foil shapes for blades? *(Refer Section 3.2)*
3. Derive the Euler turbine equations. Do the equations hold good for pumps/compressors? *(Refer Section 3.3)*
4. Distinguish between impulse and reaction processes in turbomachines. Give examples. *(Refer Section 3.5)*
5. Explain the term utilization factor. *(Refer Section 3.6)*
6. Prove that $\in = \dfrac{V_1^2 - V_2^2}{V_1^2 - RV_2^2}$ *(Refer Section 3.6)*
7. Prove that $\phi = \dfrac{\cos \alpha_1}{2(1-R)}$ *(Refer Section 3.7)*
8. Compare the impulse and reaction ($R = 0.5$) machines. *(Refer Section 3.7)*

Exercises

(For the sake of practice, nonstandard speeds are also used in problems.)

1. The rotor of a radial flow machine has the inlet diameter of 40 cm and outlet diameter of 90 cm. At the outlet, the blades are radial. The speed of the rotor is 8000 rpm. The fluid enters the rotor in a radial direction. Calculate the inlet blade angle, absolute velocity of fluid at the outlet, and the specific work, if the inlet fluid velocity is 150 m/s. The velocity of flow remains constant in the rotor. Also find the angle of outlet velocity.
2. The blade angles at the entry and exit of an axial flow turbine rotor are 25° each. The blades have a mean diameter of 60 cm and the speed is 3000 rpm. The absolute velocity of fluid at the outlet is axial. Calculate the absolute velocities at the inlet and outlet, angle of inlet velocity, specific work, degree of reaction, and utilization factor. The velocity of flow remains constant in the rotor.
3. The rotor of a radial flow machine has its entry and exit diameters as 20 cm and 50 cm, respectively. Its blades are bent backward so that the blade tangent at the outlet makes an angle of 60° with the blade velocity. The fluid velocity at the inlet is radial, without any whirl component. The flow components remain constant at 10 m/s in the rotor. The speed of the rotor is 800 rpm. Draw the velocity triangles at the inlet and outlet of the rotor. Calculate the blade angle at the inlet and the specific work. Also calculate the specific work when the blade outlet angle is 80°, instead of 60°.
4. In an axial flow machine, the mean diameter of the rotor is 50 cm and the speed of the rotor is 10000 rpm. The fluid enters with a velocity of 380 m/s at 25° to the blade velocity. The blade angle at the outlet is 35°. The flow component remains constant in the rotor. Calculate the specific work and degree of reaction. If the machine is turbine, calculate the utilization factor.
5. The mean diameter of the rotor in an axial flow machine is 0.6 m and the speed is 10000 rpm. The fluid enters the rotor in the axial direction at a velocity of 180 m/s. The fluid leaves the rotor at an angle of 35° with the blade velocity. Calculate the blade angles at the inlet and outlet and the specific work. The flow components do not vary in the rotor.
6. The fluid enters the rotor at a velocity of 60 m/s at a diameter of 90 cm at an angle of 30°

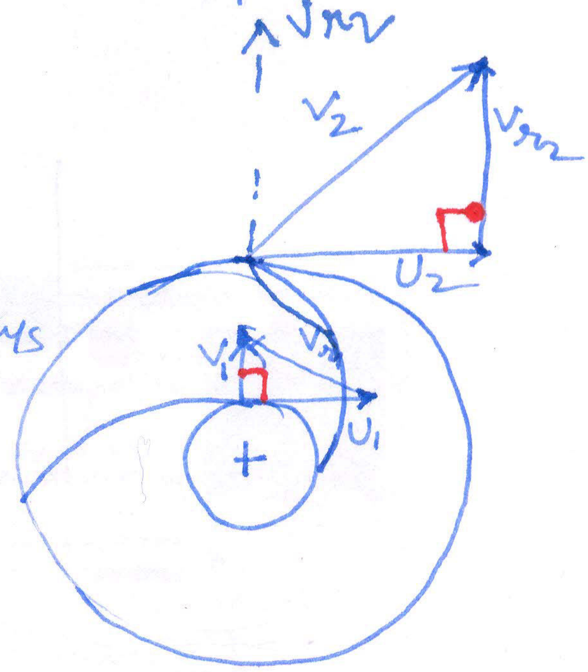
Ex 1

Pai

$D_1 = 40\ cm$; $\alpha_1 = 90^0$ $N = 8000\ rpm.$

$D_2 = 90\ cm$; $\beta_2 = 90^0$

$V_1 = 150\ m/s.$ $V_{n_1} = V_{n_2}$



$$U_1 = \frac{\pi N D_1}{60} = \frac{\pi \times 8000 \times 40}{60 \times 100}\ m/s$$

$$= 167.5\ m/s.$$

$$V_1 = 150\ m/s$$

$$\tan\beta_1 = \frac{V_1}{U_1} = \frac{150}{167.5} = \frac{60}{67}, \quad \underline{\underline{\beta_1 = 41.8^0}}\ ✓$$

$$V_{r_2} = V_{n_1} = V_1 = 150\ m/s = V_{n_2}.$$

$$U_2 = \frac{\pi N D_2}{60} = \frac{\pi \times 8000 \times 90}{60 \times 100}\ m/s = 377\ m/s.$$

$$\tan\alpha_2 = \frac{V_{r_2}}{U_2} = \frac{150}{377} =$$

$$\alpha_2 = 21.7^0\ ✓$$

$$V_2 = \frac{U_2}{\cos 21.7} = 405.7\ m/s.\ ✓$$

$$w = (U_1 V_{t_1} - U_2 V_{t_2})$$

$$= 0 - \cancel{405.7}\ 377^2 / 1000\ kJ/kg$$

$$= \underline{\underline{-\cancel{164.6}\ 142.1\ kJ/kg}}$$