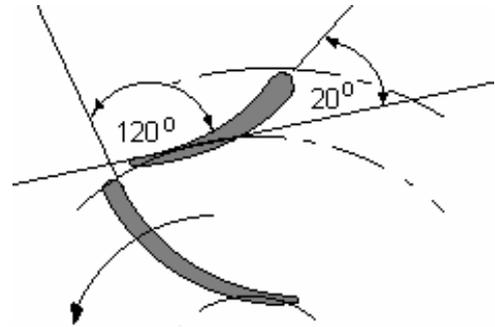


FLUID MECHANICS D203 Q10 1998

The runner (rotor) of a Francis turbine has a blade configuration as shown. The outer diameter is 0.45 m and the inner diameter is 0.3 m. The vanes are 62.5 mm high at inlet and 100 mm at outlet. The supply head is 18 m and the losses in the guide vanes and runner are equivalent to 0.36 m. The water exhausts from the middle at atmospheric pressure. Entry is shock less and there is no whirl at exit. Neglecting the blade thickness, determine:

- i. The speed of rotation.
- ii. The flow rate.
- iii. The output power given a mechanical efficiency of 90%.
- iv. The overall efficiency.
- v. The outlet vane angle.



INLET

Useful head is $18 - 0.36 = 17.64$ m

$$m u_1 v_{w1} = m u_2 v_{w2}$$

$$u_1 v_{w1} = u_2 v_{w2}$$

$$(u_1 v_{w1}/g) = \Delta H = 17.64$$

sine rule $(v_1/\sin 60) = (u_1/\sin 100)$

$$v_1 = 0.879 u_1$$

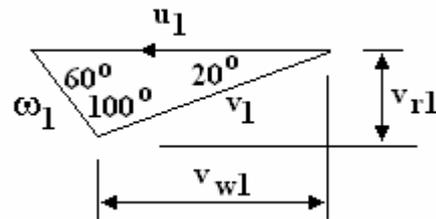
$$(v_{r1}/v_1) = \sin 20 \quad v_1 = 2.923 v_{r1}$$

Equate $0.879 u_1 = 2.923 v_{r1} \quad v_{r1} = 0.3 u_1$

$$v_{w1} = v_{r1}/\tan 20 = 0.824 u_1$$

$$17.64 = u_1 \times 0.824 u_1 / g \quad u_1^2 = 210 \quad u_1 = 14.5 \text{ m/s}$$

$$v_{r1} = 0.3 u_1 = 4.35 \text{ m/s}$$



EXIT

$$u = \pi N D \quad N = u_1 / \pi D_1 = u_2 / \pi D_2$$

$$u_2 = u_1 D_1 / D_2 = 14.5 \times 300/450 = 9.67 \text{ m/s}$$

$$N = u_1 / \pi D_1 = 14.5 \times 60 / (\pi \times 0.45) = 615 \text{ rev/min}$$

$$v_r = Q/\pi D h$$

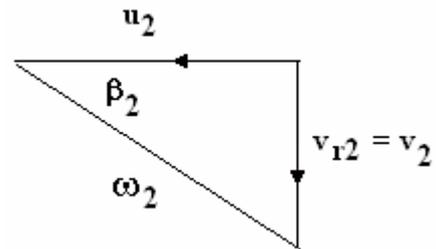
$$v_{r1} = 4.35 = Q/\pi D_1 h_1 = Q/(\pi \times 0.45 \times 0.0625)$$

$$Q = 0.384 \text{ m}^3/\text{s}$$

$$v_{r2} = Q/\pi D_2 h_2 = Q/(\pi \times 0.3 \times 0.1) = 10.61 \text{ m/s} \quad Q = 4.08 \text{ m}^3/\text{s}$$

$$4.08/9.67 = \tan \beta_2$$

$$\beta_2 = 22.8^\circ$$



$$P = m g \Delta H = 384 \times 9.81 \times 17.64 = 66.45 \text{ kW}$$

$$\text{Output Power} = 66.45 \times 90\% = 59.8 \text{ kW}$$

$$\text{Overall efficiency} = 59800 / (m g \Delta H) = 59800 / (384 \times 9.81 \times 18) = 88.2 \%$$