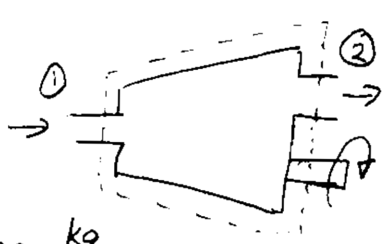
7.2 GIVEN: STEAM TURBINE

WITH: $h_1 = 3062 \frac{kJ}{kg}$, $V_1 = 10 \frac{m}{s}$,

$h_2 = 2621 \frac{kJ}{kg}$, $V_2 = 50 \frac{m}{s}$

$\dot{Q} = -10 \; kJ/hr$, AND $\dot{m} = 4000 \frac{kg}{hr}$



FIND: SHAFT POWER

$$\dot{Q} - \dot{W}_s = \underbrace{\cancel{\frac{d}{dt}\int_{CV}\left(\frac{V^2}{2} + gz + u\right)\rho \, d\forall}}_{0 \text{ STEADY PROCESS}} + \int_{CS}\left(\underbrace{\frac{p}{\rho} + u}_{h} + \frac{V^2}{2} + \underbrace{\cancel{gz}}_{0 \text{ NEGLECT ELEVATION CHANGE}}\right)\rho \underline{V} \cdot d\underline{A}$$

$$\dot{Q} - \dot{W}_s = \dot{m}_{OUT}\left(\frac{V_2^2}{2} + h_2\right) - \dot{m}_{IN}\left(\frac{V_1^2}{2} + h_1\right)$$

$$\dot{m}_{OUT} = \dot{m}_{IN} = \dot{m}$$

$$\dot{W}_s = \dot{Q} + \dot{m}\left(\frac{V_1^2}{2} - \frac{V_2^2}{2} + h_1 - h_2\right)$$

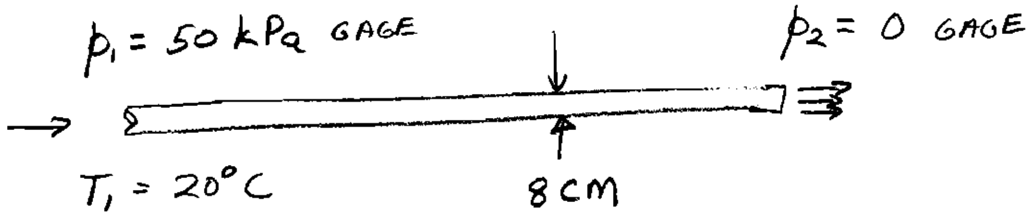
$$\dot{W}_s = -10{,}000 \frac{J}{h} + 4000 \frac{kg}{h}\left(50 \frac{m^2}{s^2} - 1250 \frac{m^2}{s^2} + 3.062 \times 10^6 \frac{m^2}{s} - 2.621 \times 10^6 \frac{m^2}{s^2}\right)$$

$$\dot{W}_s = -10{,}000 \frac{J}{h} + 1.759 \times 10^9 \frac{J}{h} = 1.759 \times 10^9 \frac{J}{h}$$

$$\dot{W}_s = 4.887 \times 10^5 \text{ WATTS} = 488.7 \text{ kW}$$

7.5

GIVEN:



AIR FLOW IN PIPE WITH $\dot{m} = 0.5$ kg/s.

$h = 1.004\ T$ $\qquad \dot{Q} = \dot{W}_S = 0$

$\left[\frac{kJ}{kg}\right] \qquad [K]$

FIND: T_2 AND V_2

SOLUTION: CONSERVATION OF ENERGY

$$\cancel{\dot{Q}} - \cancel{\dot{W}_S} = \cancel{\frac{d}{dt}\int_{CV}(\ )\rho\, d\forall} + \int_{CS}\left(\frac{p}{\rho} + \frac{V^2}{2} + gz + u\right)\rho \underline{V}\cdot d\underline{A}$$

$0 \qquad 0$

$$\dot{m}_1\left(\frac{p_1}{\rho_1} + \alpha_1\frac{V_1^2}{2} + \cancel{gz_1} + u_1\right) = \left(\frac{p_2}{\rho_1} + \alpha_2\frac{V_2^2}{2} + \cancel{gz_2} + u_2\right)\dot{m}_2$$

$\frac{p}{\rho} + u = h$ AND $\dot{m}_1 = \dot{m}_2 = \dot{m}$

$$\alpha_1\frac{V_1^2}{2} - \alpha_2\frac{V_2^2}{2} + h_1 - h_2 = 0$$

$$h_1 - h_2 = 1004\,(T_1 - T_2)$$

ASSUME TURBULENT FLOW $\alpha_1 = \alpha_2 \approx 1$

$$\frac{V_1^2}{2} - \frac{V_2^2}{2} + 1004\,(T_1 - T_2) = 0$$

$$\rho_1 V_1 A_1 = \dot{m} \qquad \rho_1 = \frac{p_1}{RT_1} = \frac{151{,}000}{(287)(293)}$$

$$V_1 = \frac{\dot{m}}{\rho_1 A_1} = \frac{0.5}{\frac{151{,}000}{(287)(293)}\left(\frac{\pi}{4}\right)(.08)^2}$$

$$V_1 = 55.4 \ \frac{m}{s} \qquad \rho_1 = 1.796 \ \frac{kg}{m^3}$$

$$\overset{\checkmark}{\frac{V_1^2}{2}} - \overset{?}{\frac{V_2^2}{2}} + 1004\,(\overset{\checkmark}{T_1} - \overset{?}{T_2}) = 0$$

1 EQN. WITH 2 UNKNOWNS.

USE CONSERVATION OF MASS.

$$\dot{m}_1 = \dot{m}_2 \qquad \rho_1 V_1 A_1 = \rho_2 A_2 V_2$$

$$A_1 = A_2 \qquad \overset{\checkmark}{\rho_1} \overset{\checkmark}{V_1} = \overset{?}{\rho_2} \overset{?}{V_2} \qquad \rho_2 = \frac{\overset{\checkmark}{p_2}}{R \overset{?}{T_2}}$$

$$\rho_2 = \rho_1 \frac{V_1}{V_2} \qquad \frac{p_2}{RT_2} = \rho_1 \frac{V_1}{V_2} \qquad \frac{T_2 R}{p_2} = \frac{V_2}{\rho_1 V_1}$$

$$T_2 = \frac{p_2}{R\rho_1} \frac{V_2}{V_1}$$

$$\frac{V_1^2}{2} - \frac{V_2^2}{2} + 1004\left[T_1 - \frac{p_2}{R\rho_1}\left(\frac{V_2}{V_1}\right)\right] = 0$$

SOLVE FOR V_2.

$$\underset{a=1}{V_2^2} + \underbrace{\left(2008 \frac{p_2}{R\rho_1 V_1}\right)}_{b} V_2 + \underbrace{\left(-V_1^2 - 2008\, T_1\right)}_{c} = 0$$

$$V_2 = -\frac{b}{2} \pm \frac{1}{2}\sqrt{b^2 - 4ac}$$

$a = 1$

$$b = 2008 \frac{101{,}000}{287\,(1.796)\,55.4} = 7102 \ \frac{m}{s}$$

$$c = -55.4^2 - 2008\,(293) = -5.914 \times 10^5 \ \frac{m^2}{s^2}$$

$$V_2 = -3551 \ \frac{m}{s} \pm 3633 \ \frac{m}{s}$$

$$\boxed{V_2 = 82 \ \frac{m}{s}}$$

$$T_2 = \frac{p_2}{R\rho_1} \ \frac{V_2}{V_1}$$

$$T_2 = \frac{101{,}000}{(287)(1.796)} \left(\frac{82}{55.4}\right)$$

$$T_2 = 290 \ K$$

$$\boxed{T_2 = 17\,^\circ C}$$

7.8

GIVEN: VELOCITY DISTRIBUTIONS AS SHOWN.

FIND: IS $\alpha > 1$, $\alpha = 1$, OR $\alpha < 1$ FOR EACH CASE.

SOLUTION:

FOR AXISYMMETRIC FLOW IN A ROUND PIPE:

$$\alpha = \frac{2}{r_0^2}\int_0^{r_0}\left(\frac{V}{\bar{V}}\right)^3 r\,dr$$

(a) $\frac{V}{\bar{V}} = 1$, $\alpha = 1$

(b) $\alpha = 2$, $\alpha > 1$
(SEE EXAMPLE 7.2)

(c) $\alpha > 1$

(d) $\alpha > 1$

$\alpha > 1$ FOR <u>ALL</u> NONUNIFORM VELOCITY DISTRIBUTIONS. SEE DISCUSSION ON PAGE 255, TEXT