Benha University
Faculty of Engineering
Mechanical Engineering Dep.

Fluid and Heat Machinery Technology
2^{nd} year 2015
Final-exam (Code: M 302)

Time: Three Hours ***(attempt all questions)*** ***(assume any missing data)***

Q1 (20 points)

1- 1) Explain the pump cavitation, what are the signs of pump Cavitations and discuss its influence upon runner-dynamic machines?

Solution

Pump cavitation is the formation and subsequent collapse or implosion of vapor bubbles in a pump. It occurs when gas bubbles are formed in the pump due to drop in absolute pressure of the liquid below vapor pressure.

1. Noise 2. Vibration 3. Fluctuating gauges

1. Pitting damage to the impeller
2. Sharp drop in pump head and disharg
3. Sudden drop for the efficiency

1- 2) The characteristics of a single stage single suction centrifugal pump running at a speed of 950 rpm are as follows:

Q (lit/sec)	0	50	100	150	200	250	300
H (m of water)	33.5	35	36	35.5	34	29.5	21
BP (kW)	20.6	36.8	53	67	82.5	95.5	100

On a certain occasion the pump is required to deliver 130 lit/sec against a total head of the pump of 30 m.

Determine:

i) The new speed of the pump.

ii) The corresponding power input.

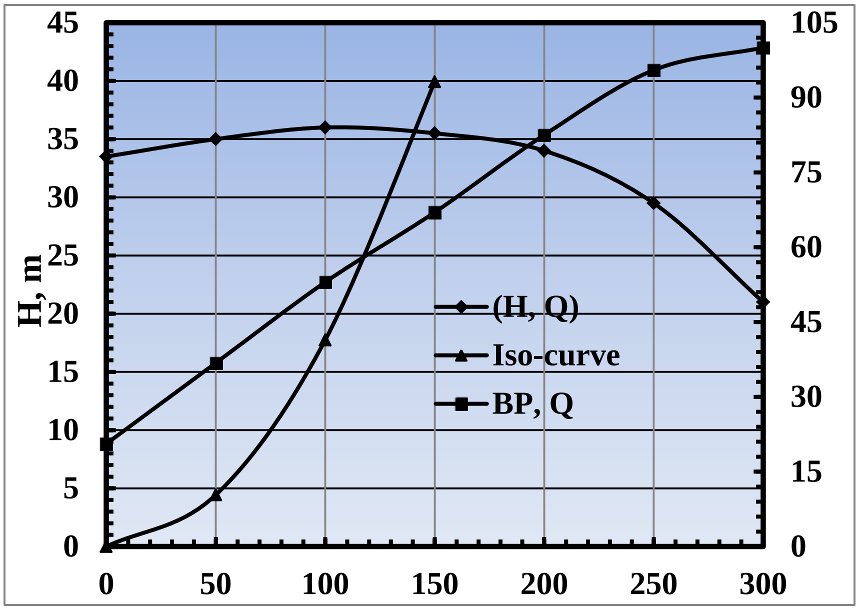
iii) The specific speed of this pump.

iv) Calculate the head coefficient C_H, discharge coefficient C_Q, power coefficient C_p if the pump diameters 30cm.

Solution

i) By Iso-efficiency curve

$$H \, \alpha \, Q^2, \qquad \therefore H = kQ^2, \qquad k = \frac{H}{Q^2} = \frac{30}{130^2} = 0.001775 \frac{m.s^2}{lit^2}$$



From iso-curve and *H-Q* curve.

Q_{P1} = 140 L/s	H_{P1} = 36 m	BP_1 = 68 kW	N_{P1} = 950 rpm
Q_{P2} = 130 L/s	H_{P2} = 30 m	BP_2 = ?? kW	N_{P1} = ?? rpm

$$C_{Q1} = C_{Q2}$$

$$\frac{Q_{p1}}{N_{p1} * D_{p1}^3} = \frac{Q_{p2}}{N_{p2} * D_{p2}^3} \qquad \therefore \frac{Q_{p1}}{N_{p1}} = \frac{Q_{p2}}{N_{p2}}$$

$$N_{p2} = \frac{Q_{p2}}{Q_{p1}} * N_{p1} = \frac{130}{140} * 950 = 882\ rpm$$

$$C_{p1} = C_{p2}$$

$$\frac{BP_{p1}}{N_{p1}{}^3 * \rho * D_{p1}^5} = \frac{BP_{p2}}{N_{p2}{}^3 * \rho * D_{p2}^5} \qquad \therefore \frac{BP_{p1}}{N_{p1}{}^3} = \frac{BP_{p2}}{N_{p2}{}^3}$$

$$BP_{p2} = \frac{BP_{p1}}{N_{p1}{}^3} * N_{p2}{}^3 = \left(\frac{N_{p2}}{N_{p1}}\right)^3 * BP_{p1} = \left(\frac{882}{950}\right)^3 * 68 = 54.4kW$$

$$N_s = \frac{N\sqrt{Q}}{(H)^{3/4}} = \frac{882\sqrt{0.13}}{(30)^{3/4}} = 24.8$$

$$C_{Q1} = \frac{Q_{p1}}{N_{p1} * D_{p1}^3} = \frac{0.14}{\left(\frac{950}{60}\right) * (0.3)^3} = 0.327$$

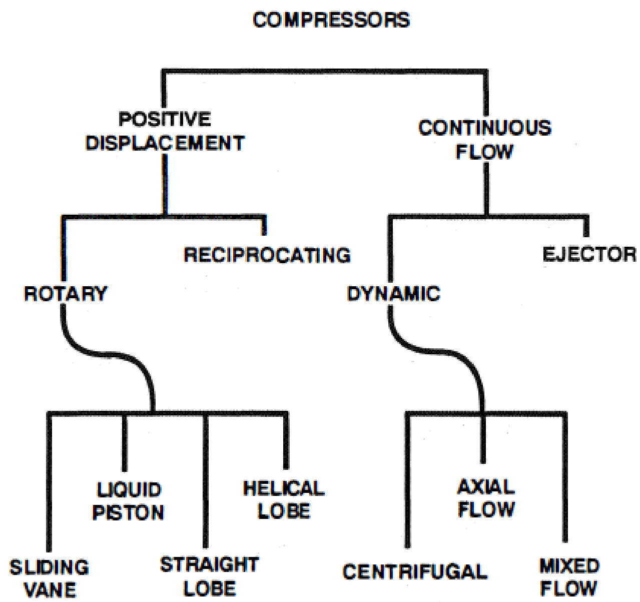
$$C_{H1} = \frac{gH_{p1}}{{N_{p1}}^2 * D_{p1}^2} = \frac{9.81 * 36}{\left(\frac{950}{60}\right)^2 * (0.3)^2} = 15.65$$

$$C_{p1} = \frac{BP_{p1}}{{N_{p1}}^3 * \rho * D_{p1}^5} = \frac{68 * 1000}{1000 * \left(\frac{950}{60}\right)^3 * (0.3)^5} = 0.62$$

Q2 (20 points)

2-1) Explain with sketch different types of compressors?

Solution



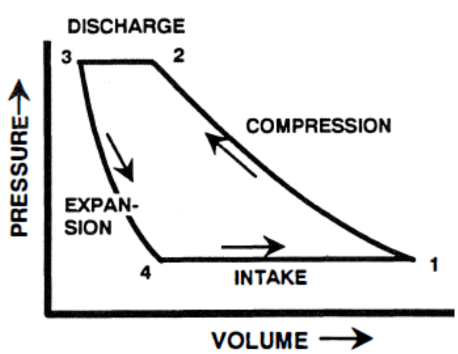
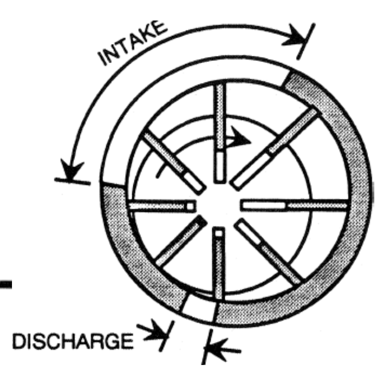


Figure 2. Reciprocating Compressors.



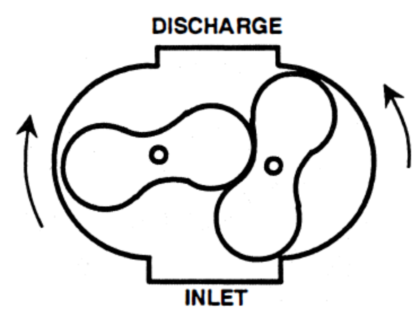


Figure 5. Straight Lobe, Two Rotor Compressor.

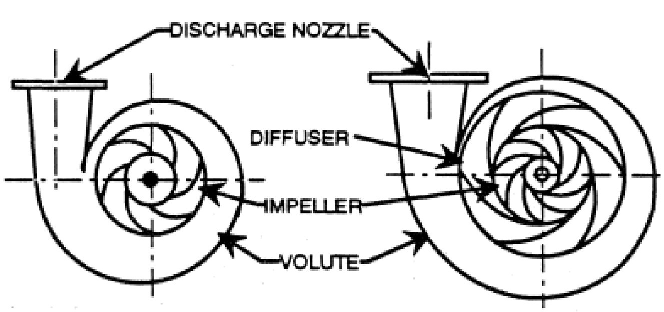


Figure 7. Centrifugal Compressors.

2-2) The velocity of steam at inlet to a simple impulse turbine is 1000 m/s, and the nozzle angle is 20˚. The blade speed is 400 m/s and the blades are symmetrical. ***Determine*** the blade angles if the steam is to enter the blades without shock. If the friction effects on the blade are negligible, calculate:

i) Input power and the diagram power for a mass flow of 0.75 kg/s.
ii) The axial thrust and the diagram efficiency.
iii) Speed ratio and the speed of rotation if the mean diameter of the wheel is 500 mm.
iv) The output power at maximum diagram efficiency and the maximum diagram efficiency if the absolute velocity remains constant.

Solution

- ✓ For symmetrical blades then $\beta_i = \beta_e$
- ✓ For friction effects on the blade are negligible then $Cr_i = Cr_e$

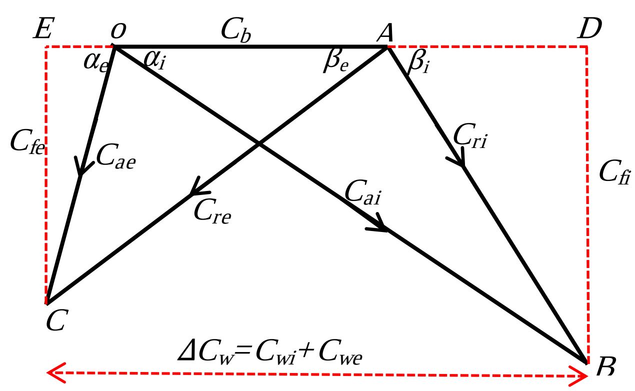
i) Applying the cosine rule to triangle OAB

$C_{ri}^2 = C_{ai}^2 + C_b^2 - 2\, C_{ai}\, C_b \cos \alpha i$

$C_{ri}^2 = 1000^2 + 400^2 - (2*1000*400*\cos 20)$

$C_{ri}^2 = 40.8*10^4$

$C_{ri} = 639$ m/s $= Cr_e$



and by using sine rule in OAB

$$\frac{C_{ai}}{\sin OAB} = \frac{C_{ri}}{\sin \alpha i}$$

Also sin OAB = sin (180 – βi) = sin βi

$$\therefore \frac{C_{ai}}{\sin \beta i} = \frac{C_{ri}}{\sin \alpha i}$$

$$\therefore \sin \beta i = \left(\frac{C_{ai}}{C_{ri}}\right) \sin \alpha i = \frac{1000 * \sin 20}{639} = 0.535$$

$\beta i = 32.3 = \beta e$

AD = $C_{ri} \cos \beta i$ = 639 cos 32.3= 540 m/s

AE = $C_{re} \cos \beta e$ = 639 cos 32.3= 540 m/s

ΔCw = 540 + 540 = 1080 m/s

$$Input\ Power = \dot{m}\ \frac{C_{ai}^2}{2} = 0.75 * \frac{1000^2}{2} = 375\ kw$$

$$diagram\ Power = \dot{m}\ C_b \Delta C_w = 0.75 * 400 * 1080 = 324\ kw$$

$$diagram\ Efficiency = \frac{diagram\ Power}{Input\ Power} = \frac{324}{375} = 86.4\%$$

$C_{fi} = C_{ri} \sin \beta i$ = 639 sin 32.3 = 341.4 m/s

$C_{fe} = C_{re}\, sin\beta_e$ = 639 sin 32.3 = 341.4 m/s

$\Delta Cf = C_{fi} - C_{fe} = 0$

Axial thurst = 0

Speed ratio = C_b / C_{ai} = 400/1000 = 0.4

$C_b = (\pi DN/60)$

speed of rotation = N = 60*400/ (π*0.5) = 15278.8 *rpm*

max.

$$max.diagram\ Power = \dot{m}\left(\frac{cos\alpha i}{2}\right) C_{ai}\Delta C_w = 0.75 * \frac{0.9}{2} * 1080 * 1000$$

$$= 380kw$$

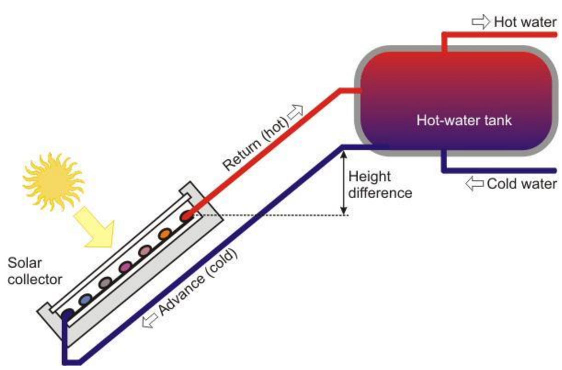
$$max.diagram\ effici. = cos\alpha i = cos20 = 94\%$$

Q3 (20 points)

3-1) Explain briefly with the aid of sketch the different types of solar water collectors?

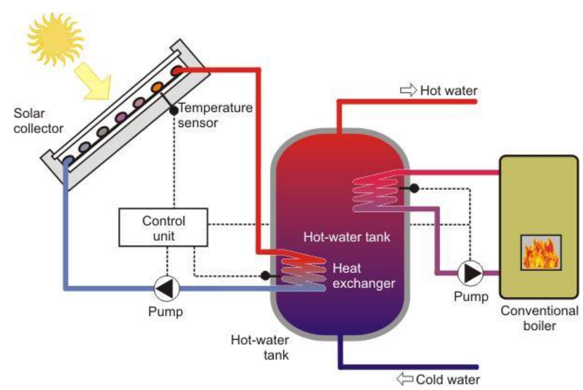
Solution

Thermosyphon systems



The principle of the thermosyphon system is that cold water has a higher specific density than warm water, and so being heavier will sink down.

Forced-circulation systems



In contrast to thermosyphon systems, an electrical pump can be used to move water through the solar cycle of a system by forced circulation. Collector and storage tank can then be installed independently, and no height difference between tank and collector is necessary.

3-2) A 2-shell passes and 4-tube passes heat exchanger is used to heat glycerin from 20°C to 50°C by hot water, which enters the thin-walled 2-cm-diameter tubes at 80°C and leaves at 40°C. The total length of the tubes in the heat exchanger is 60 m. The convection heat transfer coefficient is 25 $W/m^2 \cdot °C$ on the glycerin (shell) side and 160 $W/m^2 \cdot °C$ on the water (tube) side. Draw the heat exchanger and determine the rate of heat transfer in the heat exchanger (a) before any fouling occurs and (b) after fouling with a fouling factor of 0.0006 $m^2 \cdot °C/W$ occurs on the outer surfaces of the tubes. Note take Correction factor F=0.9.

Solution

$$A_s = \pi D L = \pi(0.02 \text{ m})(60 \text{ m}) = 3.77 \text{ m}^2$$

$$\dot{Q} = U A_s F \, \Delta T_{\text{lm}, CF}$$

where F is the correction factor and $\Delta T_{\text{lm}, CF}$ is the log mean temperature difference for the counter-flow arrangement. These two quantities are determined from

$$\Delta T_1 = T_{h,\text{in}} - T_{c,\text{out}} = (80 - 50)°\text{C} = 30°\text{C}$$
$$\Delta T_2 = T_{h,\text{out}} - T_{c,\text{in}} = (40 - 20)°\text{C} = 20°\text{C}$$
$$\Delta T_{\text{lm}, CF} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{30 - 20}{\ln(30/20)} = 24.7°\text{C}$$

(*a*) In the case of no fouling, the overall heat transfer coefficient U is determined from

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}} = \frac{1}{\frac{1}{160 \text{ W/m}^2 \cdot °\text{C}} + \frac{1}{25 \text{ W/m}^2 \cdot °\text{C}}} = 21.6 \text{ W/m}^2 \cdot °\text{C}$$

Then the rate of heat transfer becomes

$$\dot{Q} = U A_s F \, \Delta T_{\text{lm}, CF} = (21.6 \text{ W/m}^2 \cdot °\text{C})(3.77\text{m}^2)(0.91)(24.7°\text{C}) = 1830 \text{ W}$$

(*b*) When there is fouling on one of the surfaces, the overall heat transfer coefficient U is

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o} + R_f} = \frac{1}{\frac{1}{160 \text{ W/m}^2 \cdot °\text{C}} + \frac{1}{25 \text{ W/m}^2 \cdot °\text{C}} + 0.0006 \text{ m}^2 \cdot °\text{C/W}}$$
$$= 21.3 \text{ W/m}^2 \cdot °\text{C}$$

The rate of heat transfer in this case becomes

$$\dot{Q} = U A_s F \, \Delta T_{\text{lm}, CF} = (21.3 \text{ W/m}^2 \cdot °\text{C})(3.77 \text{ m}^2)(0.91)(24.7°\text{C}) = 1805 \text{ W}$$

With best wishes
Dr. Mohamed Ramadan