NAME: SHUIAB, Khalifa Yaqub

MATRIC Nº.: 18/ENG05/056

DEPARTMENT: Mechatronics Engineering

COURSE: ENG 214

SHUAIB, Khalifa Yaqub
18/ENG05/1056
Mechatronics Engineering
ENG214 (Fluid Power Assignment)

1.) ~~(i.) Volumetric Efficiency (VE);~~
~~VE = Actual Flow~~

1.) Actual Flow Rate $= 10 dm^3/min$
$= \left(\frac{10}{60000}\right) m^3/s$
$\simeq 0.00167 m^3 s^{-1}$

Pressure $= 12$ bar $= 12 \times 10^5 Nm^{-2}$

Speed $= 1500$rpm $= 25$rps

Displacement $= 10cm^3/rev = 10^{-5} m^3/rev$

(T) Torque input $= 12.5 Nm$

(i.) Volumetric Efficiency (VE);

$$VE = \frac{\text{Actual Flow Rate}}{\text{Ideal Flow Rate}} \times 100\%$$

~~Idea~~ Ideal Flow Rate = Speed × Disp.
$= 25 \times 10^{-5} m^3 s^{-1}$

$$\therefore VE = \frac{0.000167}{25 \times 10^{-5}} \times 100\%$$
$\simeq 66.67\%$

(ii.) Fluid Power (P_F);

~~P_F = Pressure × Speed~~
~~$= 12 \times 10^5 \times 25$~~

P_F = Pressure × Actual Flow Rate
$$= 12 \times 10^5 \times \frac{10}{60000}$$

$P_F = 200W$

(iii.) Shaft Power $= T \times W$
$W = 2\pi \times$ Speed
$= 2\pi \times 25$
$= 50\pi$ rad/sec

$T = 12.5 Nm$
Shaft Power $= 12.5 \times 50\pi$
$= 1963.495W$

(iv) Overall Efficiency
$$= \frac{\text{Fluid Power}}{\text{Shaft Power}} \times 100\%$$
$$= \frac{200}{1963.495} \times 100$$
$\simeq 10.19\%$

2.) Actual Flow Rate $= 35 dm^3/min$
$= \left(\frac{35}{60000}\right) m^3/sec$
$\simeq 5.833 \times 10^{-4} m^3 s^{-1}$

Pressure $= 100$bar $= 100 \times 10^5 Nm^{-2}$

Overall Efficiency $= 87\%$

$$\text{Overall Efficiency} = \frac{\text{Fluid Power}}{\text{Shaft Power}} \times 100\%$$

~~2)~~ $\therefore$ Shaft Power $= \left(\dfrac{\text{Overall Efficiency}}{P_F \times 100\%}\right)^{-1}$

P_F = Pressure × Actual Flowrate

$\therefore$ Shaft Power $= \left(\dfrac{\text{Overall Efficiency}}{\text{Pressure} \times \text{Actual Flowrate} \times 100\%}\right)^{-1}$

$= \left(\dfrac{87\%}{100 \times 10^5 \times 5.833 \times 10^{-4} \times 100\%}\right)^{-1}$

Shaft Power $= \dfrac{100 \times 10^5 \times 5.833 \times 10^{-4} \times 100\%}{87\%}$

$\simeq 6704.98\ W$

$\simeq 6.705\ KW$

3.) Displacement $= 50\,cm^3/rev = 5 \times 10^{-5}\ m^3/rev$

Pressure $= 100\,bar = \cancel{10} \times 10^7\ Nm^{-2}$

Shaft Power $= 15\ KW$

Actual Flowrate $= 35\,dm^3/min = \left(\dfrac{35}{60000}\right) m^3 s^{-1}$

$= 5.833 \times 10^{-4}\ m^3 s^{-1}$

Speed $= 850\,rpm = \left(\dfrac{850}{60}\right) rps$

$\simeq 14.167\,rps$

(i) Overall Efficiency $= \dfrac{\text{Fluid Power}}{\text{Shaft Power}} \times 100\%$

P_F = Pressure × Actual Flowrate

$\therefore E = \dfrac{\text{Pressure} \times \text{Actual Flowrate}}{\text{Shaft Power}} \times 100\%$

$= \dfrac{10^7 \times 5.833 \times 10^{-4}}{15000} \times 100$

$E \simeq 38.89\%$

~~4)~~ (ii) Volumetric Efficiency (VE);

$VE = \dfrac{\text{Actual Flowrate}}{\text{Ideal Flowrate}} \times 100\%$

Ideal Flowrate = Displacement × Speed

$= 5 \times 10^{-5} \times 14.167$

$\simeq 7.083 \times 10^{-4}\ m^3 s^{-1}$

$VE = \dfrac{5.833 \times 10^{-4}}{7.083 \times 10^{-4}} \times 100\%$

$\simeq 82.35\%$

4.) Water level $(z) = 24000\ m$

$= 240\ m$

Volumetric Flowrate $(Q) = 13L/sec$

$= 1.3 \times 10^{-2}\ m^3 s^{-1}$

Jet Velocity $= 66\ ms^{-1}$

$\rho_{water} = 1000\ Kgm^{-3}$

(i) Since the jet is issuing from the nozzle, ~~P = atmosc~~ and if is at datum level,

$P = 0$, and $z = 0$

(i) recall,

$P = P \cdot Q + \dfrac{\rho \cdot Q \cdot V^2}{2} + \rho g Q z$

since $P = z = 0$,

$P = \dfrac{\rho Q V^2}{2}$

$= \dfrac{1000 \times 1.3 \times 10^{-2} \times 66^2}{2}$

$P = 28314\,W$
$= 28.314\,KW$

(ii) Power Supplied from reservoir,
This implies that $P = V = 0$

recall,
$$P = p \cdot Q + \frac{\rho Q V^2}{2} + \rho g Q z$$

substitute for P and V
$$P = \rho g Q z$$
$$= 1000 \times 9.81 \times 1.3 \times 10^{-2} \times 240$$
$$= 30607.2\,W$$
$$= 30.6072\,KW$$

(iii) Power loss in Transmission
= Power of Reservoir − Power of Jet
$= (30.6072 - 28.314)\,kW$
$= 2.2932\,KW$

(iv) Head used to overcome losses (h)
$$= \frac{\text{Power loss in transmission}}{\rho g Q}$$
$$= \frac{2.2932 \times 1000}{1000 \times 9.81 \times 1.3 \times 10^{-2}}$$
$h \simeq 17.982\,m$

(iv) Efficiency of pipeline and nozzle in transmitting operation (E);
$$E = \frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100\%$$

$$E = \frac{28.314}{30.6072} \times 100$$
$\simeq 92.51\%$

5.) $S_{oil} = 0.89$
$z = 30000\,cm = 300\,m$
$Q = 220\,L s^{-1} = 0.22\,m^3 s^{-1}$
$V = 7\,ms^{-1}$

(i) Power of Jet
From jet, $P = z = 0$
$$\therefore P = \frac{\rho Q V^2}{2}$$
$$= \frac{890 \times 0.22 \times 7^2}{2}$$
$= 4797.1\,W$
$= 4.7971\,KW$

(ii) Power Supplied from reservoir;
This implies that $P = V = 0$
$\therefore P = \rho g Q z$
$= 890 \times 9.81 \times 0.22 \times 300$
$= 576239.4\,W$
$= 576.2394\,kW$

(iii) Head used to overcome losses (h)
$$h = \frac{\text{Power loss in transmission}}{\rho g Q}$$
$$= \frac{\text{Power of Reservoir} - \text{Power of Jet}}{\rho g Q}$$

$$h = \frac{(576.2394 - 4.7971) \times 1000}{890 \times 9.81 \times 0.22}$$

$$= \frac{571442.3}{1920.798}$$

$$\approx 297.503\,m$$

(iv) Efficiency in pipeline and nozzle in transmitting operation (E);

$$E = \frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100\%$$

$$= \frac{4797.1}{576239.4} \times 100$$

$$E \approx 0.832\%$$

6.) $V = ?$

$d = 10\,cm = 0.1\,m$; $h = 20\,m$

$A = \frac{\pi}{4}(d)^2 = \frac{\pi}{4}(0.1)^2 = 0.00785\,m^2$

(Assuming pipe is cylindrical)

$\cancel{V^2 = 2gh}$ $Q = AV$

$\cancel{V^2 = 2}$ $= 0.00785 \times V$

$V^2 = 2gh$

$V = \sqrt{2gh}$

$\therefore Q = 0.00785\sqrt{2gh}$

$= 0.00785\sqrt{2 \times 9.81 \times 20}$

$Q \approx 0.00785 \times 19.809$

$Q \approx 0.1556\,m^3 s^{-1}$

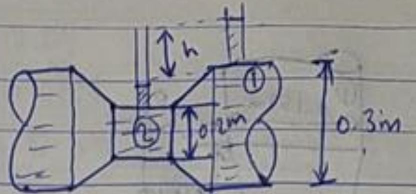
$P = \rho g Q h$

$= 1000 \times 9.81 \times 0.1156 \times 20$

$P \approx 30524.839\,W$

$\approx 30.525\,KW$

7.)



$d_1 = \cancel{0.3m}\ 0.3\,m$

$d_2 = 0.2\,m$

$A_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4}(0.3)^2 \approx 0.0707\,m^2$

$A_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4}(0.2)^2 \approx 0.0314\,m^2$

$y = 0.06\,m$

$$h = y\left(1 - \frac{S_{water}}{S_{gas}}\right)$$

$$= 0.06\left(1 - \frac{1}{19.62}\right)$$

$h \approx 0.05694$ of gas

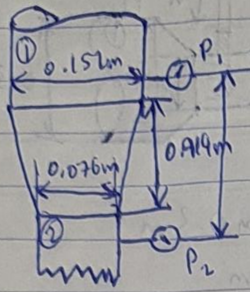
$$Q = \frac{C_d \cdot A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$= \frac{0.96 \times 0.0707 \times 0.0314\sqrt{2 \times 9.81 \times 0.05694}}{\sqrt{(0.0707)^2 - (0.0314)^2}}$$

$$= \frac{0.0022526}{0.06335}$$

$$Q \approx 0.036\,m^3 s^{-1}$$

8.)



$S_L = 0.8 = 0.8 \times 1000$
$= 800\ kgm^{-3}$

$d_1 = 0.152\ m$

$A_1 = \frac{\pi}{4}(0.152)^2 \simeq 0.01815 m^2$

$d_2 = 0.076 m$

$A_2 = \frac{\pi}{4}(0.076)^2 \simeq 0.00454 m^2$

$\Delta Z = 0.914 m$

(i.) Pressure guages read the same;

$\therefore P_1 = P_2$

$P_2 - P_1 = 0 Nm^{-2}$

From Bernaulli's Equation,

$$\frac{P_1 - P_2}{\rho g} + \Delta Z = \frac{V_2^2 - V_1^2}{2g}$$

$$\Delta Z = \frac{V_2^2 - V_1^2}{2g}$$

$$0.914 = \frac{V_2^2 - V_1^2}{2g} \quad - ①$$

recall, from Continuity equation,

$A_1 V_1 = A_2 V_2$

$$\therefore V_2 = \frac{A_1 V_1}{A_2} = \frac{\frac{\pi}{4}(0.152)^2 \times V_1}{\frac{\pi}{4}(0.076)^2}$$

$V_2 \simeq 4V_1 \quad - ②$

substitute for V_2 in ①

$$0.914 = \frac{(4V_1)^2 - V_1^2}{2g}$$

$$0.914 = \frac{16V_1^2 - V_1^2}{2g}$$

$17.93268 = 15 V_1^2$

$V_1^2 \simeq 1.195512$

$V_1 \simeq 1.0934\ ms^{-1}$

solve for V_2 from ②

$V_2 = 4 \times 1.0934$

$V_2 \simeq 4.3736\ ms^{-1}$

~~soln from Bernaulli's eqn,~~

$\cancel{h = \frac{P}{\rho g}}$

$Q = A_1 V_1$

$= 0.01815 \times 1.0934$

$\simeq 0.0198 m^3 s^{-1}$

(ii.) When $P_1 > P_2$

$P_1 = P_2 + 15170 Nm^{-2}$

$\therefore P_1 - P_2 = 15170 Nm^{-2}$

From Bernoulli's Equation,

$$\frac{P_1 - P_2}{\rho g} + \Delta Z = \frac{V_2^2 - V_1^2}{2g}$$

$$\frac{15170}{800 \times 9.81} + 0.914 = \frac{V_2^2 - V_1^2}{2g}$$

$$1.93298 + 0.914 = \frac{V_2^2 - V_1^2}{2g}$$

$$\frac{V_2^2 - V_1^2}{2g} \simeq 2.846977$$

recall, from continuity eqn

$A_1V_1 = A_2V_2$

$V_2 = 4V_1$

~~It has been established that~~

$\cancel{V_1 = 1.0934 ms^{-1}}$

$15V_1^2 = 2.846977 \times 2g$

$V_1^2 \simeq 3.72385$

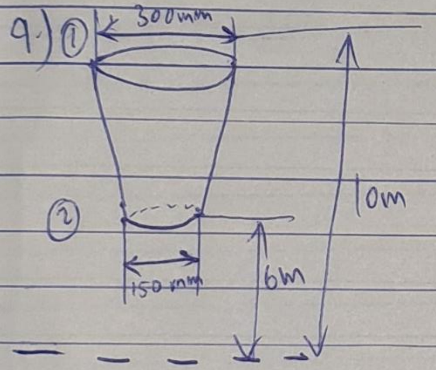
$V_1 \simeq 1.92973 ms^{-1}$

$Q = A_1V_1$

$= 0.01815 \times 1.92973 m$

$Q \simeq 0.035025 m^3 s^{-1}$

9.)



$d_1 = 300mm = 0.3m$

$A_1 = \frac{\pi}{4}(0.3)^2 = 0.0707 m^2$

$d_2 = 150mm = 0.15m$

$A_2 = \frac{\pi}{4}(0.15)^2 = 0.0177 m^2$

$P_1 = 400 kNm^{-2}$

$Q = 40 Ls^{-1} = 0.04 m^3 s^{-1}$

From continuity equation

$Q = A_1V_1 = A_2V_2$

$V_1 = \frac{Q}{A_1}$

$V_1 = \frac{0.04}{0.0707}$

$V_1 \simeq 0.5658 ms^{-1}$

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.0177}$

$V_2 \simeq 2.2599 ms^{-1}$

Recall Bernoulli's equation

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{P_2}{\rho g} = \frac{P_1}{\rho g} + \frac{V_1^2 - V_2^2}{2g} + \Delta Z$$

$$P_2 = \rho g\left(\frac{P_1}{\rho g} + \frac{V_1^2 - V_2^2}{2g} + \Delta Z\right)$$

$$P_2 = 1000\times 9.81\left(\frac{400000}{1000\times 9.81} + \frac{0.3201 - 5.1071}{2\times 9.81} + (10-6)\right)$$

$= 400000 - 2393.45 + 39240$

$P_2 \simeq 436846.55 Nm^{-2}$

$\simeq 436.847 KNm^{-2}$

10.) Manometer Reading $= 170 mmHg$
$= 0.17 mHg$

$S_{Hg} = 13.6$; $S_{seawater} = 1.026$

$$h = y\left(\frac{S_{Hg}}{S_{seawater}} - 1\right)$$

$$h = 0.17\left(\frac{13.6}{1.026} - 1\right)$$

$= 0.17 \times 12.26$

$h \simeq 2.084m$

$$\frac{V^2}{2g} = h$$

$$\therefore V = \sqrt{2gh}$$

$$V = \sqrt{2 \times 9.81 \times 2.084}$$

$$= \sqrt{40.89}$$

$$V \simeq 6.39\ ms^{-1}$$