CVG 3116 Fall 2017

Hydraulics – Tutorial 3

October 3, 2017

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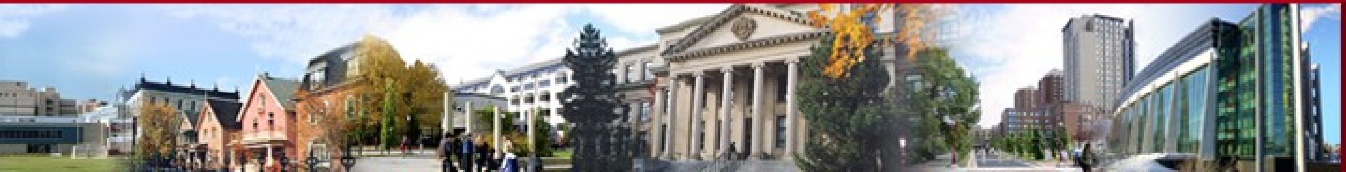
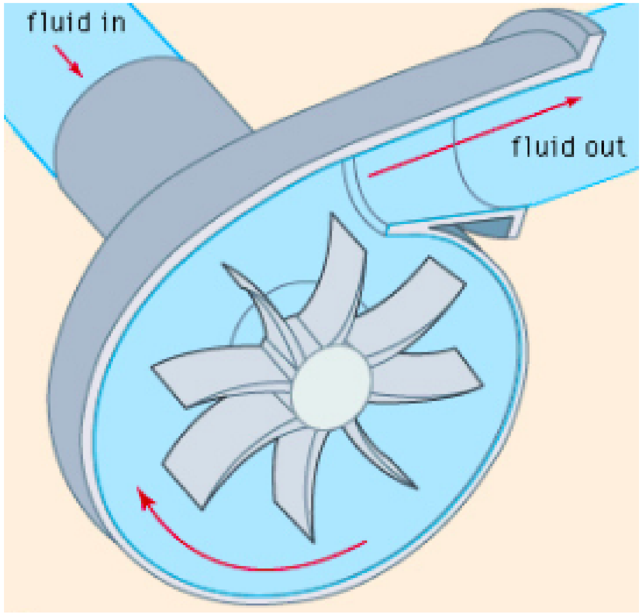
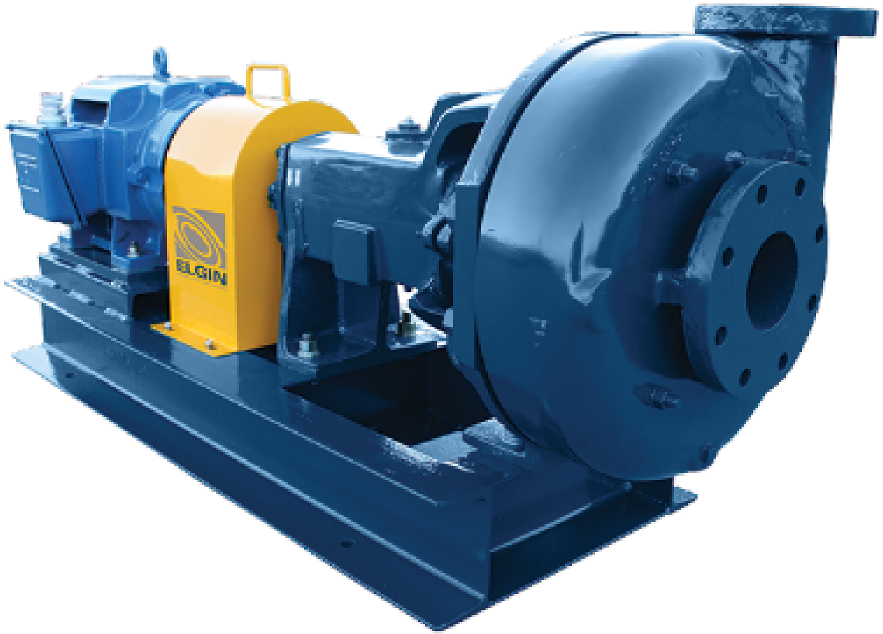


Lecture 4: Centrifugal (radial) pumps





Lecture 4: Centrifugal (radial) pumps

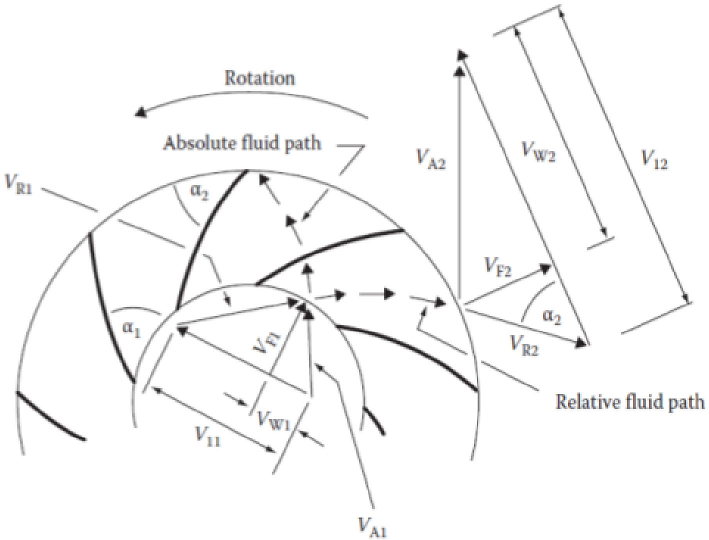


FIGURE 7.2 Velocity diagrams for centrifugal pump.

$$H_p = \eta \frac{2\pi r_2 n \left(2\pi r_2 n - \frac{Q}{A_2} \cot \alpha_2 \right)}{g}$$

Let η be the hydraulic efficiency of the pump.

$$H_p = \eta H_{ideal}$$

$$H_{ideal} = \frac{power}{\rho g Q} = \frac{1}{g}(V_{W2}V_{I2} - V_{W1}V_{I1})$$

$$P = 2\pi n \rho Q (v_{W2} r_2 - v_{W1} r_1)$$

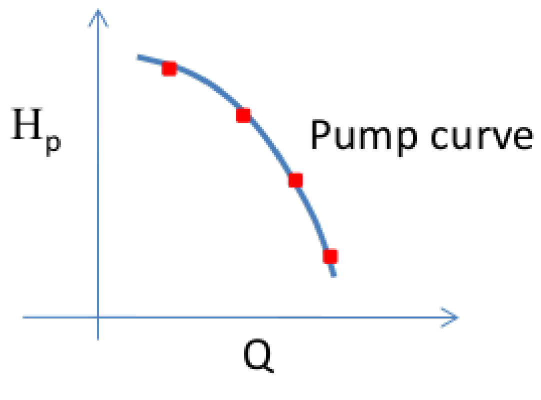
If V_{A1} is in radial direction, then V_{W1} =0 ⇨ $H_{ideal} = \frac{V_{W2}V_{I2}}{g}$

V_R: the relative velocity of the fluid with respect to the impeller
V_I : the tangential velocity of the impeller at radius R : $V_I = 2\pi r n$
V_A: the absolute velocity of fluid at radius r
V_W: the tangential component of V_A ; whirl velocity;
V_F: the radial component of V_A

$$\cot \alpha_2 = \frac{V_{I2} - V_{W2}}{V_{F2}}$$

Lecture 5: Pumps – Pump Curve

$$H_p = \eta \frac{2\pi\, r_2 n \left(2\pi\, r_2 n - \frac{Q}{A_2} \cot \alpha_2 \right)}{g}$$



Assume several values for Q and obtain H_p using the above formula and then plot them

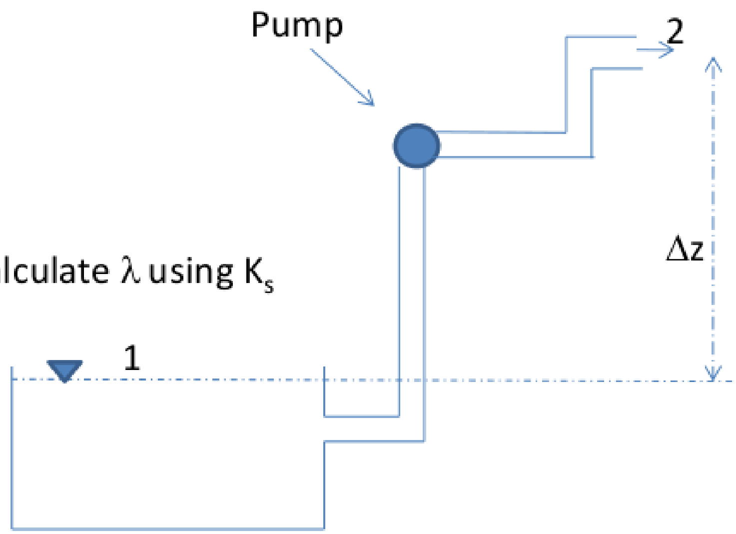
Lecture 5: Pumps – System Curve

When you have a pump in a system, the discharge depends on the pump head. You can calculate the *discharge* based on a given *pump head* using the energy equation.

$$\frac{P_1}{\rho g}+z_1+\frac{V_1^2}{2g}+H_P=\frac{P_2}{\rho g}+z_2+\frac{V_2^2}{2g}+\sum(h_L+h_f)$$

$$P_1=V_1=P_2=0$$

$$z_2-z_1=\Delta z$$



The solution is obtained by iteration:

1- Assume the rough turbulence regime and calculate λ using K_s

2- Calculate velocity

$$H_P=\Delta z+\sum(K_L+\frac{\lambda L}{D})\frac{V_2^2}{2g}$$

3- Correct λ using Re and K_s

4- Recalculate velocity

5- Continue the iteration until convergence obtained.

So you can calculate the discharge if the pump head is given.

However, in practice, the pump head is not given because it depends on the discharge!
The relation between pump head and discharge is usually provided by the manufacturer in *pump curves*

Lecture 5: Pumps – System Curve

The solution procedure is as follows:

1 - Assume a value for the *discharge, Q*

2 - Calculate the *velocity in the pipe, V_{pipe}* using the continuity equation

3 - Calculate the *relative roughness, k_s/D* and the *Reynolds number, Re*

4 – Determine the *friction factor, λ* from the Moody diagram (or Moody formula)

5 – Calculate *friction losses* in the pipe from the D-W equation

6 – Determine the *system head, H_{SH}* from:

$$H_{SH} = H_S + \left(\sum k_L + \frac{\lambda L}{D}\right)\frac{V_{pipe}^2}{2g}$$

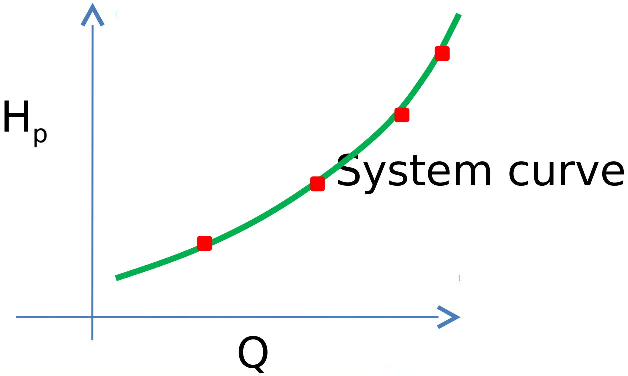
where $H_s = \Delta z$ – is the *static lift*.

7 - Assume another value for the *discharge, Q* and calculate the *system head, H_{SH}* again

8 - Repeat this procedure for several discharges

9 - Using your results, plot the relationship between the *system head, H_{SH} and discharge, Q*.

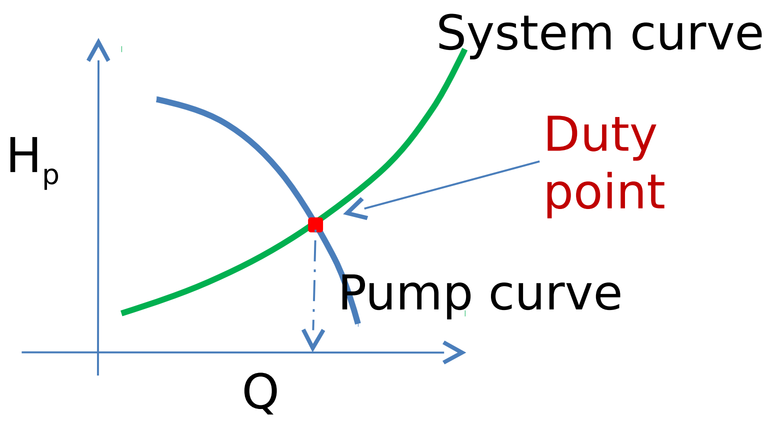
This plot is called the *system curve*.



Lecture 5: Pumps – Duty point

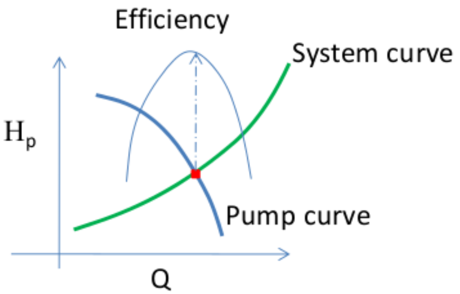
Finally, *the discharge and the head* in the system, are given by the coordinates of the ***intersection point*** (also called ***"duty" point***) of the *pump curve* and the *system curve.*

At the ***duty point*** the head supplied by the pump precisely matches the head requirements of the system at the same discharge.



Lecture 5: Optimal Design

As we saw before, *the efficiency of pumps depends on the discharge*.
In order to have an optimal design, the discharge in the system must be close to the discharge at which the pump has its maximum efficiency:



Pump selection

1- Calculate the *specific speed* N_s, defined as

$$N_s = NQ^{1/2} / H_P^{3/4}$$

N: rotational speed of the impeller (rev/min)
Q: Discharge in m^3/s
H_p: pump head in m

2- Using N_s , we can check if a pump is working close to its optimal efficiency.
i.e., the range of optimal efficiency of pumps could be identified using N_S.
Based on the value of N_s, choose the pump as following

If $10 < N_s < 70$, then choose centrifugal pump
If $70 < N_s < 165$, then choose mixed flow pump
If $110 < N_s$ then choose axial flow

Lecture 5: Cavitation – maximum pump elevation

1- Calculate N_s

$$N_s = NQ^{1/2} / H_P^{3/4}$$

2- Calculate σ_{crit}

$$\sigma_{crit} = \left(\frac{N_s}{191} \right)^{4/3}$$

3- Calculate $NPSH_{crit}$

$$NPSH_{crit} = H_p \sigma_{crit}$$

4- The maximum elevation is given by

$$z < \frac{P_{atm} - P_{vap}}{\rho g} - \frac{V_{inlet}^2}{2g} - \sum \left(h_L + h_f \right) - NPSH_{crit}$$