Chemical Engineering 512

Nuclear Reactor Transient Modeling

Lecture 9

Pump Curves

Spiritual Thought

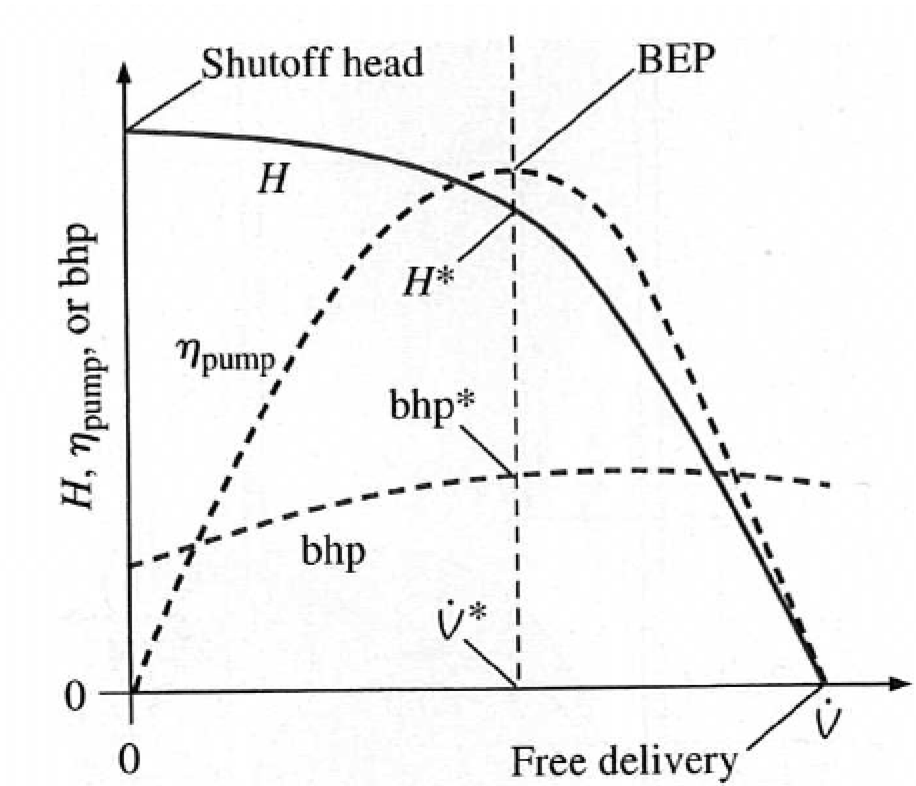
"If it was right when you prayed about it and trusted it and lived for it, it is right now. Don't give up when the pressure mounts… Don't give in. *Certainly don't give in to that being who is bent on the destruction of your happiness.* He wants everyone to be miserable like unto himself. Face your doubts. Master your fears. "Cast not away therefore your confidence.""

-Elder Jeffery R. Holland

Objectives

- Pumps/Pump Curves
- Homologous Pump curve practice

Pump Curve Schematic

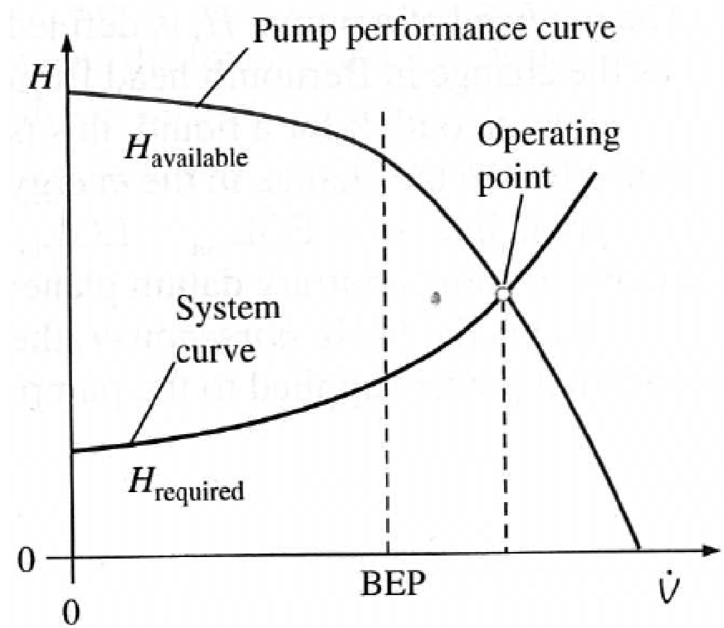


Pump Operation Curves

- Piping system requires a given **V** and a given H.

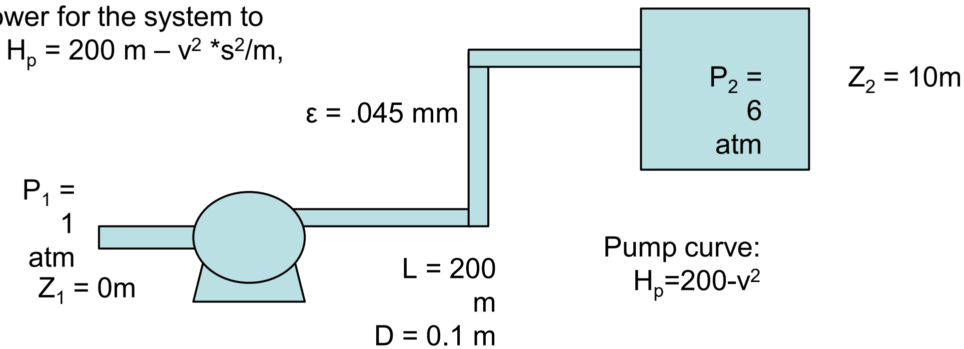
$$H_{req} = \frac{P_2 - P_1}{\rho g} + \frac{v_2^2 - v_1^2}{2g} + (z_2 - z_1) + H_{loss}$$

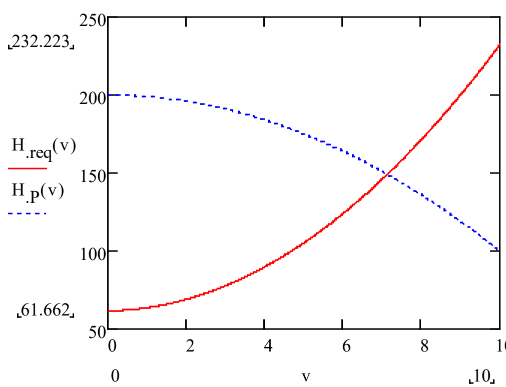
  - H_{loss} is friction and minor losses, etc.
- Pump has a corresponding **V** and H.
- These **must match**, forming the operating point.
  - This may not be the best efficiency.
- Select a pump so that the best efficiency point (BEP) occurs at the operating point.
- Generally oversize the pump a bit
  - higher flow for given H_{req}
  - or Higher H_{avail} for given flow
  - Add a valve after pump → raises H_{req} to match H_{avail} for given flow
  - Somewhat wasteful, but offers control.
  - Also may increase efficieny. (But higher efficieny may not compensate for extra work wasted in the valve (see example 14.2)



Example

Find the flow rate and required pumping power for the system to the right. The pumping curve is defined by H_p = 200 m – v^2 *s^2/m, with a pump efficiency of 90%.





Operating Point is at intersection of two lines:

H_{op} = 149.149 m

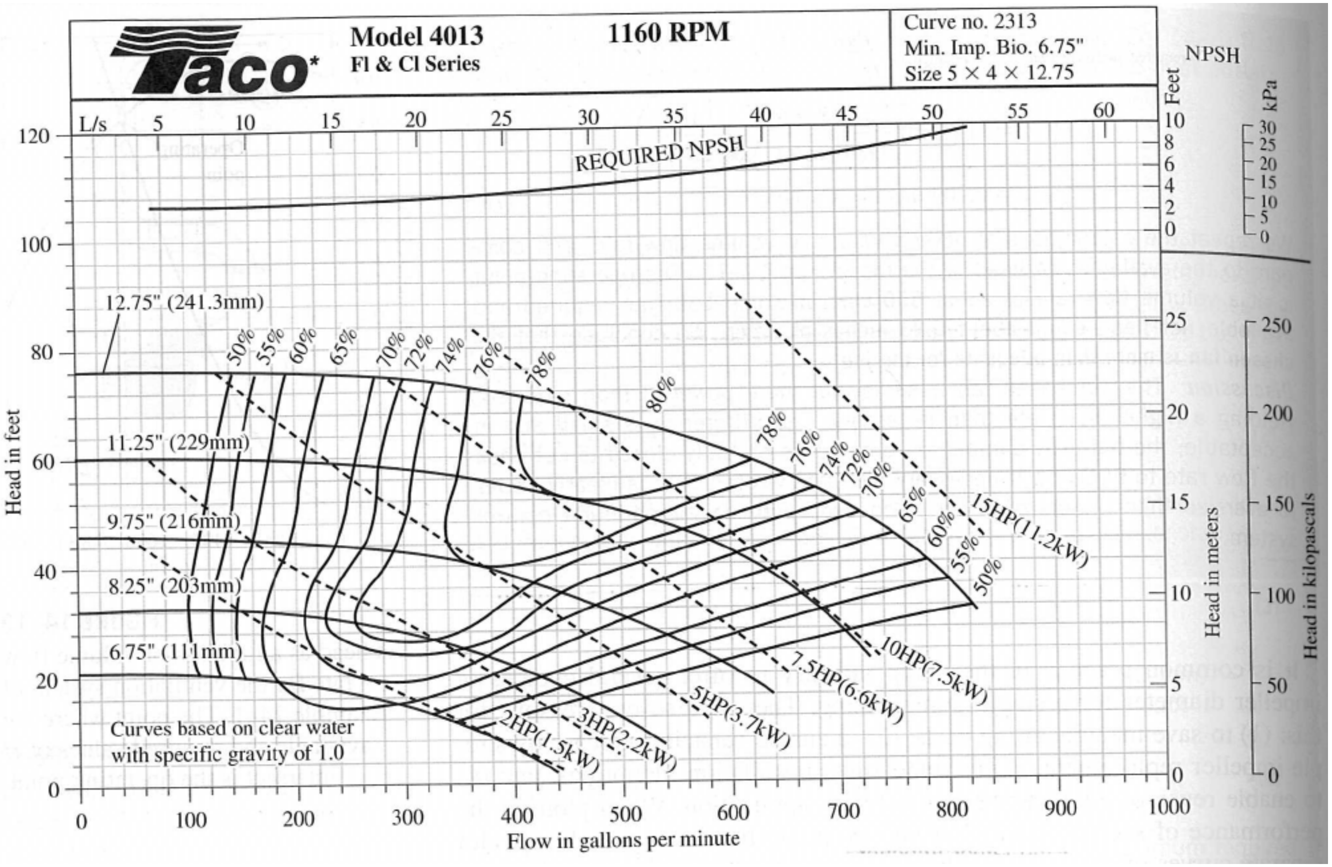
v_{op} = 7.131 m/s

$\dot{v}_{op}$ = 0.055 m³/s

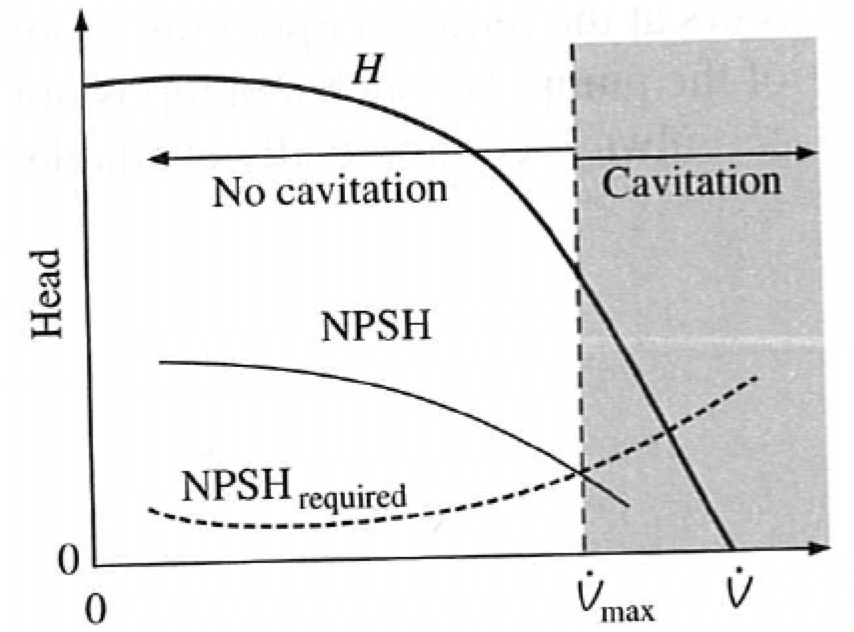
$$bhp = \frac{\rho g H \dot{V}}{\eta}$$

$$bhp = 89.35\ kW$$

Pump Performance Curves

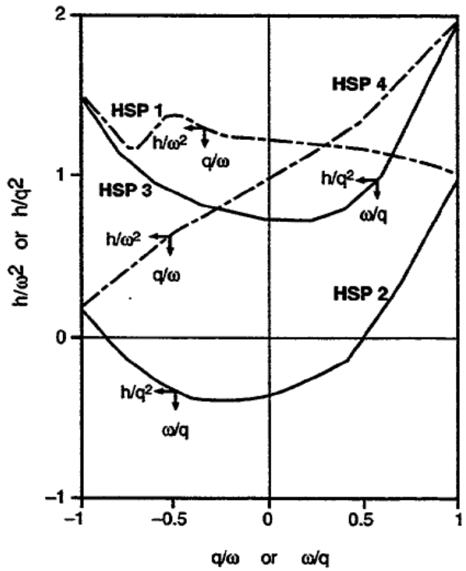


NPSH


H
No cavitation
Cavitation
Head
NPSH
NPSH required
0
0
$\dot{V}_{max}$
$\dot{V}$

Homologous Pump Curves

- Non-dimensionalized (variable divided by rated variable)
  - i.e. v/v_{ref}, τ/τ_{ref}, ω/ω_{ref}, H/H_{ref}
- Contain all information about pump operation
- 4 regimes:
  - positive $\dot{V}$, positive ω
  - negative $\dot{V}$, positive ω
  - positive $\dot{V}$, negative ω
  - negative $\dot{V}$, negative ω
- Can alter pump operation in-situ



Pump Curve Practice

- $\alpha = \frac{\omega}{\omega_R}$
- $v = \frac{Q}{Q_R}$
- $h = \frac{H}{H_R}$
- $\beta = \frac{\tau}{\tau_R}$
- $\tau = \frac{P \cdot Q}{\omega \cdot \eta}$

Regime number	Regime mode ID name	α	v	v/α	Independent variable[a]	Dependent[a] variable head	Dependent[a] variable torque
1	HAN BAN Normal pump	>0	≥ 0	≤ 1	v/α	h/α^2	β/α^2
2	HVN BVN Normal pump	>0	≥ 0	>1	α/v	h/v^2	β/v^2
3	HAD BAD Energy dissipation	>0	<0	≥ -1	v/α	h/α^2	β/α^2
4	HVD BVD Energy dissipation	>0	<0	<-1	α/v	h/v^2	β/v^2
5	HAT BAT Normal turbine	≤ 0	≤ 0	≤ 1	v/α	h/α^2	β/α^2
6	HVT BVT Normal turbine	≤ 0	≤ 0	>1	α/v	h/v^2	β/v^2
7	HAR BAR Reverse pump	≤ 0	>0	≥ -1	v/α	h/α^2	β/α^2
8	HVR BVR Reverse pump	≤ 0	>0	<-1	α/v	h/v^2	β/v^2

a. α = rotational ratio; v = volumetric flow ratio; h = head ratio; and β = torque ratio.

Pump Curve Practice

- Assume the following:
  - Rated Flow Rate = 10000 m^3/hr
  - Density = 1000 kg/m^3
  - Rated Head = 10 kgf/cm^2
  - Rated Efficiency = 0.7
  - Rated Speed = 104.2 rad/s
  - Rated Torque = 31600 N-m
- Calculate the homologous pump data at a speed of 104.2 rad/s and a flow rate of 12000 m^3/hr with a head of 5 kgf/cm^2 and an efficiency of 0.6.

Pump Curve Practice

- What regime is this pump in?
  - 1, HAN BAN, Normal Pump
- What is the head independent variable?
  - $\frac{v}{\alpha} = 1.2$
- What is the head dependent variable?
  - $\frac{h}{\alpha^2} = 0.5$
- What is the torque independent variable?
  - $\frac{v}{\alpha} = 1.2$
- What is the torque dependent variable?
  - $\frac{\beta}{\alpha^2} = 0.7$

Assignment

- Watch DVD Sections 44-52 before Tuesday’s class
- Homework 5 due on Tues (10/14)
- Homework 6 due on Thurs (10/16)