Chemical Engineering 512

Nuclear Reactor Transient Modeling

Lecture 9

Pump Curves

Spiritual Thought

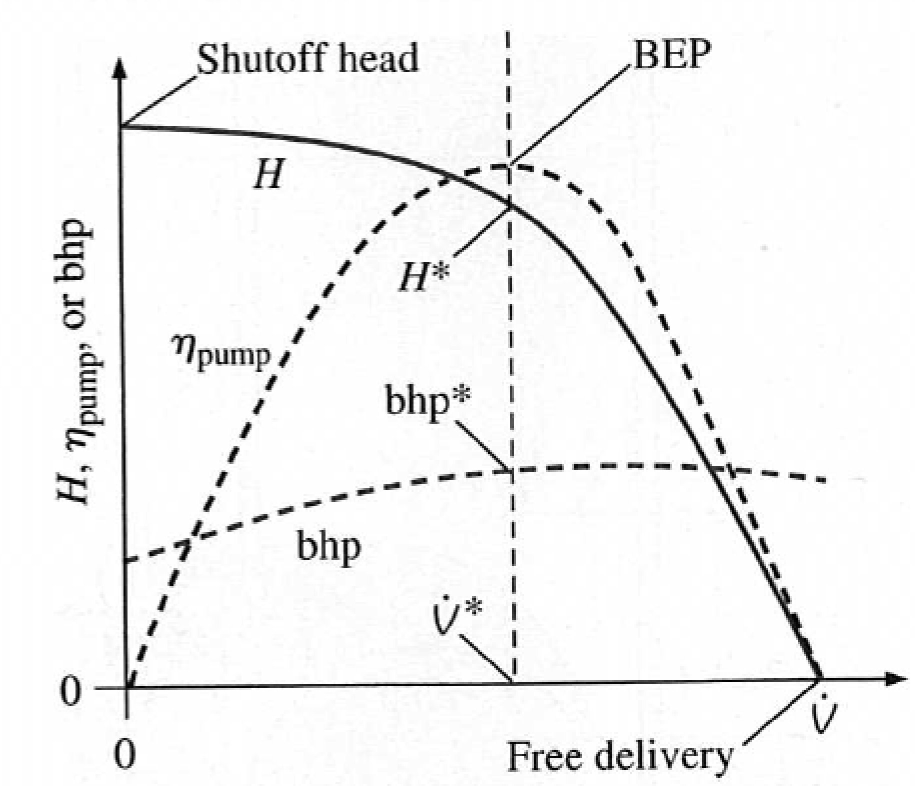
“We must lay on the altar and sacrifice whatever is required by the Lord. We begin by offering a ‘broken heart and a contrite spirit.’ We follow this by giving our best effort in our assigned fields of labor and callings. We learn our duty and execute it fully. Finally we consecrate our time, talents, and means as called upon by our file leaders and as prompted by the whispering of the Spirit. In the Church … we can give expression to every ability, every righteous desire, every thoughtful impulse. … And in the end, we learn it was no sacrifice at all.”

-Spencer W. Kimball

Objectives

- Pumps/Pump Curves
- Homologous Pump curve practice

Pump Curve Schematic

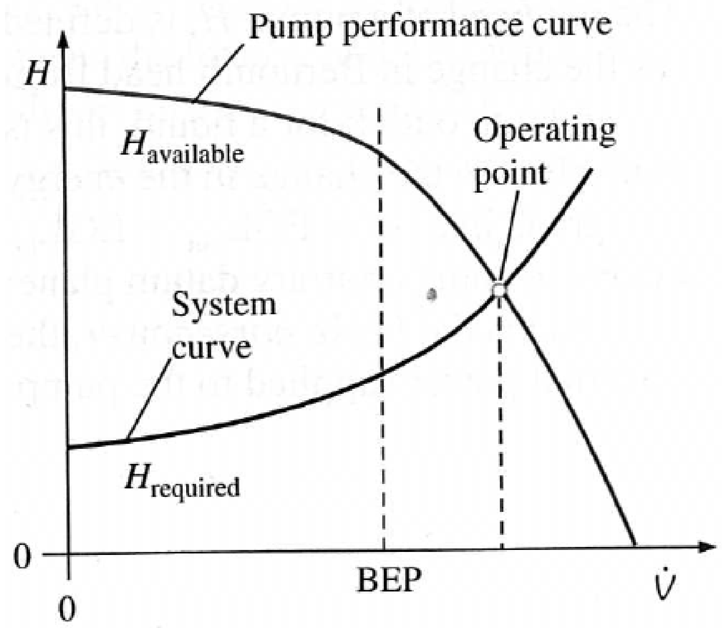


Pump Operation Curves

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

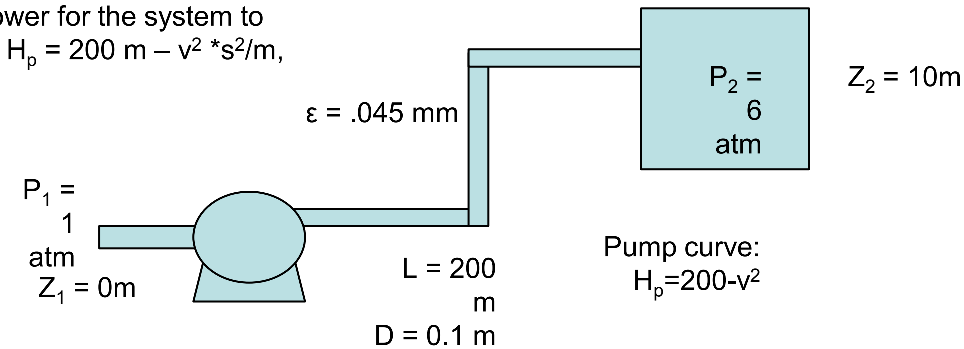
$$H_{req} = \frac{P_2 - P_1}{\rho g} + \frac{v_2^2 - v_1^2}{2g} + (z_2 - z_1) + H_{loss}$$

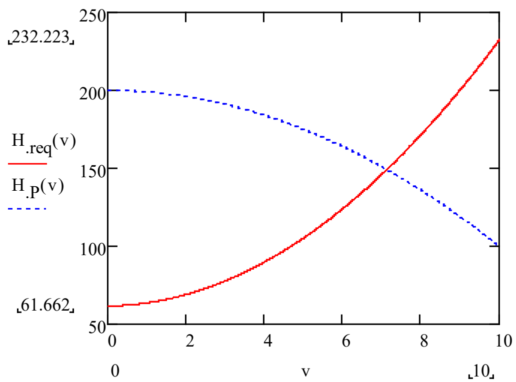
  - H_{loss} is friction and minor losses, etc.
- Pump has a corresponding **V** and H.
- These **must match**, forming the operating point.
  - This may not be the best efficiency.
- Select a pump so that the best efficiency point (BEP) occurs at the operating point.
- Generally oversize the pump a bit
  - 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

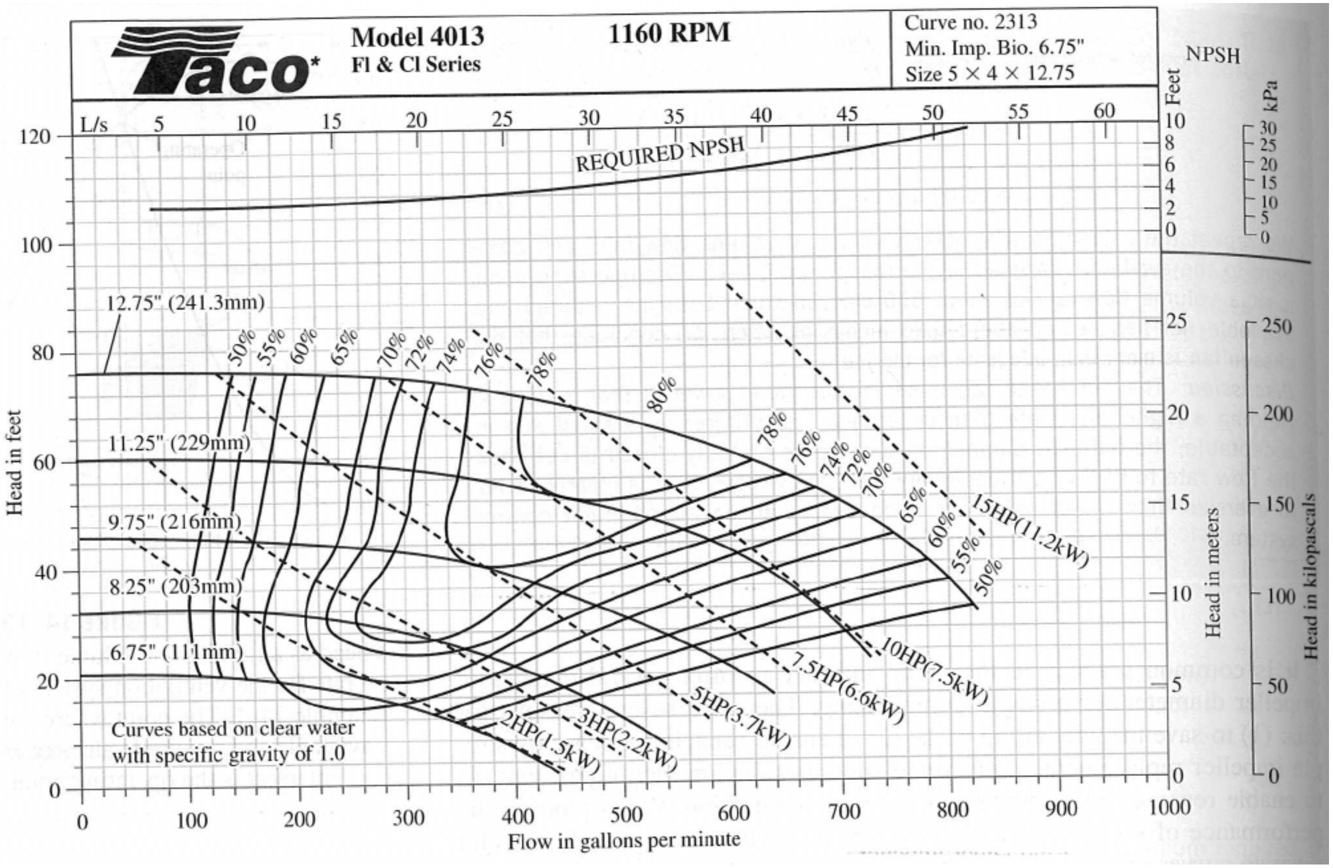
v_{op} = 7.131 m/s

$\dot{v}_{op}$ = 0.055 m^3/s

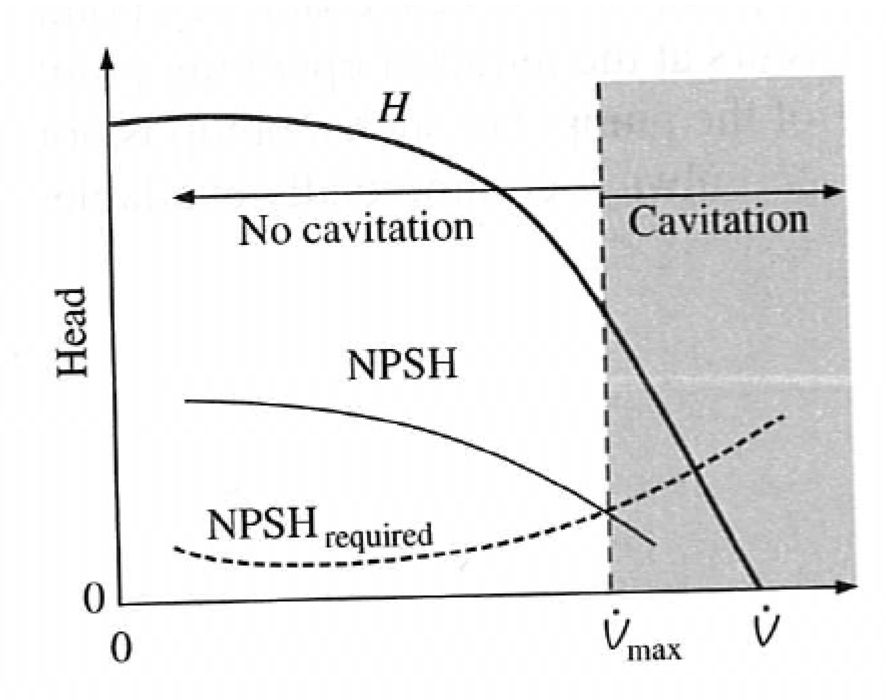
$$bhp = \frac{\rho g H \dot{V}}{\eta}$$

$$bhp = 89.35\ kW$$

Pump Performance Curves



NPSH

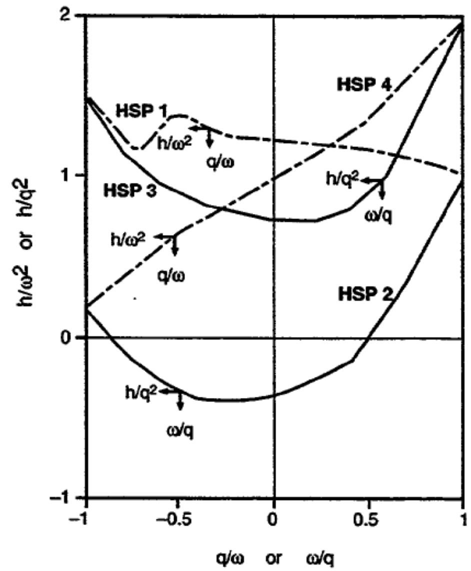

H
No cavitation
Cavitation
Head
NPSH
NPSH required
0
0
$\dot{V}_{max}$
$\dot{V}$

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.

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
  - positive $\dot{V}$, positive ω
  - positive $\dot{V}$, positive ω
  - positive $\dot{V}$, positive ω
- Can alter pump operation in-situ



Pump Curve Practice

- $\alpha = \frac{\omega}{\omega_R}$
- $v = \frac{Q}{Q_R}$
- $h = \frac{H}{H_R}$

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

- 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 (10/10)