Objective

Discuss the differences between fixed speed pump operation and variable speed pump operation.

- Overview of system curves
- VS pump performance
- Interaction with systems
- Reduced maintenance cost
- System reliability
- Energy savings

Changing Speed

The operating point of a centrifugal pump is always determined by the interaction of:

The pump head-capacity curve
System resistance curve

In general:

Increase in speed results in an increase in pump flow and head
Decrease in speed results in a decrease in pump flow and head

Common misconception

Variable speed operation allows you to control head and flow at the same time.
Hydraulic System

Static Head

Frictional Head

a.k.a Dynamic Head Loss

\[ H_f = f \frac{L}{d} \frac{V^2}{2g} + K \frac{V^2}{2g} \]

Pipe Friction

Component Friction

Dynamic Head Curve
Dynamic Head Curve

System Curve
Static Plus Frictional Head Effects

Operating Point
Intersection of Pump Curve and System Curve
Static Head
...not always "static"

Static Head
Adding Back Pressure

Control Valve Operation
Changing System Curve with Valve Position
Variable Speed Performance

Affinity Laws

Affinity laws are used to estimate pump performance with changes in operating speed or impeller trim.

\[
\begin{align*}
\frac{Q_1}{Q_2} &= \left( \frac{D_1}{D_2} \right) \quad \frac{Q_1}{Q_2} &= \left( \frac{N_1}{N_2} \right)^\frac{1}{2} \\
\frac{H_1}{H_2} &= \left( \frac{D_1}{D_2} \right)^2 \quad \frac{H_1}{H_2} &= \left( \frac{N_1}{N_2} \right)^2 \\
\frac{P_1}{P_2} &= \left( \frac{D_1}{D_2} \right)^3 \quad \frac{P_1}{P_2} &= \left( \frac{N_1}{N_2} \right)^3
\end{align*}
\]

Pump Performance Factored for Speed
Variable Speed Operation

Reduced Speed Implications
Reduced Speed Implications

High static head applications: constant pressure

Some applications have a very high static head in relation to the dynamic head curve.

- Pumping against high elevations
- Pumping into pressurized vessels
- Pumping systems with multiple demands off a header

Reliability

Reliability Index

\[ RI = F_r \times F_d \times F_q \]

- \( F_r \) - RPM factor
- \( F_d \) - Impeller diameter factor
- \( F_q \) - Best Efficiency Point Factor

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Reliability

- Reduced pump and system wear due to reduced fluid velocity and system pressure
- Protection against process upsets (dry run, dead head and run-out)
- Reduced system damage from hydraulic hammer effect during start up and shut down
- Heat, noise and vibration reduction due to right sizing and demand control

Estimating Energy Savings

Information required to estimate energy savings
- System curve data
  - rated operating point and static head, or
  - two points on system curve
- Time operating at a given rating (hours)
- Pump performance curve at known speed
- Knowledge of current control method
- Cost per energy unit (typically $/kWh)

Optional data

Valve loss coefficients for estimating savings at maximum rated condition

### Energy Saving Calculation

<table>
<thead>
<tr>
<th>Rating</th>
<th>Fixed Speed HP</th>
<th>VS RPM</th>
<th>Variable Speed HP</th>
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<tbody>
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<td>3600</td>
<td>22</td>
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<table>
<thead>
<tr>
<th>Rating</th>
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<th>Fixed Speed $</th>
<th>Variable Speed $</th>
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</thead>
<tbody>
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<td>1438</td>
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Total: $3,450 $2,300

Difference: $1,150

Western Dry Kiln Association 8 May, 2005