HYDRAULIC UPGRADE OF HOT WATER CIRCULATION PUMPS IN A DISTRICT HEATING SYSTEM

CASE STUDY P9
Contents

• Introduction
  – Particulars
  – Objective

• First Design
  – Design Details
  – Hydraulic Performance
  – Onsite Vane Pass Vibration

• Second Design
  – Design Details
  – Hydraulic Performance

• Concluding Remarks
District heating circulation pumps (2 blocks):

- Single stage
- Double suction
- Between bearing
- Radial split casing
  (API 610 BB2)
- Side-side nozzles
- Variable speed
  (1000 – 1500 r/min)
Introduction - Particulars

Conditions of service:

• Pre-upgrade: 500 – 1500 m³/h @ 60 m
• Requested for upgrade: 720 – 2400 m³/h @ 80 m

↓

Normal duty: 1750 m³/h @ 35 m (1000 r/min)

Max. (design) duty: 2400 m³/h @ 80 m (1490 r/min)

• Fluid: Hot pressurized water (70 – 140 °C)
• Suction pressure: 6.9 – 11 bar
Introduction - Particulars

Pre-upgrade max. coverage

New window(s) of planned operation; beyond existing max. coverage

Capacity, [m³/h]

Head, [m]
Objective / Scope of supply:
1. Re-rate existing pumps with new hydraulic end, keeping existing shaft.
2. Replace existing DC speed controlled motors with VFD driven asynchronous motors
3. Replace existing conventional packing with mechanical seal

Hydraulic Options:
• New impeller and new diffuser (→ First design iteration) vs.
• New impeller and volute insert (→ Second design iteration)
Proposal curve for the hydraulic upgrade
(@ max. duty \( N_{s,\text{design}} = 2350 \))

CSP9 – Hydraulic Upgrade of Hot Water Circulation Pumps
First Design

Existing pump

Impeller/diffuser in single volute casing

Existing diffuser (4 vanes)
First Design

- New high capacity impeller
  - 8 vanes
  - $D_{2,\text{max}}$ 21½” (546.1 mm)

- New diffuser (6 vanes)
First Design

First Test Result:
- Failed to make the head
- Efficiency too low
- Power too high
- BEP at too low capacity

Suspected Cause:
- Choking flow at casing outlet (narrowing throat passage)

1490 r/min
D₂: 546 mm
First Design

Second Test Result:
(After opening up casing area)
- Head picked-up
- Efficiency improved
- BEP shifted to higher capacity

BUT, pump still not making expected performance

Suspicion:
- Incorrect diffuser design?!?

1490 r/min
D₂: 546 mm

Test Floor NPSHA issue

Second Hydraulic Option: Volute insert

Diffuser throat area laid out too small

CSP9 – Hydraulic Upgrade of Hot Water Circulation Pumps
First Design

- While developing volute insert and manufacturing parts, the pump was shipped to site.
- At site, an **8X vane pass vibration** issue @ PIH emerged when running **around 1200 r/min**.*

* Shop tests were @ 1500 r/min.
First Design

Onsite vibration measurement

Order Tracking

1000 – 1420 r/min

- PIH: 7.3 mm/s
  @ 1236 r/min
  (8X, or 165 Hz)

Bump Test:

- 169 Hz resonance frequency (Hor.)

CSP9 – Hydraulic Upgrade of Hot Water Circulation Pumps
First Design

Elevated vibration levels due to:

- 8X vane passing excitation forces @165 Hz
- Natural (resonance) frequency in horizontal plane @169 Hz.
- Very small impeller tip ("Gap B") clearance, causing strong vane passing excitation forces

\[(D_3 - D_2) / D_2 = 553 - 546 / 546\]

= 0.013 or 1.3% (!)
Second Design

- Keep new high capacity impeller
- Replace diffuser with (dual) volute insert
- Increase impeller tip clearance
Second Design

Final test result:

- Head okay
- Efficiency okay
- Power okay
- Tip clearance (Gap B) okay:

\[
\frac{D_3 - D_2}{D_2} = \frac{578.2 - 515}{515} = 0.123 \text{ or } 12.3\%
\]

- 8X vane pass vibration issue resolved

(1490 r/min  
D₂: 515 mm)
Second Design

- Shop test with VFD demonstrated strong reduction in vibration response.
- 8X Vibration response not peaking up anymore
- Overall vibration level below 3 mm/s (RMS)
Concluding Remarks

• Pumps have been upgraded with new hydraulic internals for **60% increase in design capacity**.

• **First design iteration** with new impeller and new diffuser was **not successful**:
  - Hydraulic performance failure
  - Vibration issue (at intermediate running speed)

• **Second design iteration** with same new impeller and volute insert **proved to be successful**.
Concluding Remarks

• First design iteration was unsuccessful because of:
  - Diffuser throat area was designed too small
  - Impeller tip clearance (Gap B) was much too small

• Particulars of second design iteration:
  - Sufficient volute (cutwater) throat area
  - Ample impeller tip clearance (Gap B) solved the PIH vibration response without having to introduce structural modifications.

• Pumps with new impeller and volute insert have been installed at site, and are in operation for more than 2 years now.
Thank you for your attention

Questions?