Introduction

Agenda:
• Experimental Loop
• Single-Phase Pump Performance
• Two-Phase Flow Pump Characterization

Partially Shrouded Open Impeller
• Pressure distribution
• Optical inspection of flow

\[ D_1 = 10'' \]
\[ D_2 = 3.38'' \]
\[ \beta_1 = 71^\circ \]
\[ \beta_2 = 17^\circ \]
Two Phase Flow Pump Characterization

Two-Phase Flow Experiment Loop (Schematic)

PUMP TWO PHASE EXPERIMENT (Lillibridge Engr. Lab. ISU)
Experimental Loop

Secondary Separator Tank

Primary Separator Tank

Air Pipe

Loop Pump

Mixer

Pump Suction Pipe
Test Pump Instrumentation

- Pump
- Torque & Speed Meter
- 6 beam Densitometer
- Optical Probes
- DP Cells
Test Pump Instrumentation

Optical Probe Ports

Pressure Probe Ports
• Followed the line bisecting the distance between two vanes
• 0.03” hypodermic tubes (filtered pressure oscillation)
Test Pump Instrumentation

6-Beam low gamma & x-Ray attenuation densitometer

Schematic of 6-Beam Densitometer
Fluid pressure measurement arrangement through the pump flow passages.
Pump Single Phase Pressure Distribution

1. S-P Pump Curve, N=500
   - Head [kPa]
   - Q [LPM]

2. S-P Vane Pressure Rise, N=500
   - Vane DP [kPa]
   - Q [LPM]

3. S-P Pump Efficiency, N=500
   - Pump Efficiency [%]
   - Q [LPM]

4. S-P Volute Pressure Rise, N=500
   - Volute DP [kPa]
   - Q [LPM]

5. S-P Pump Torque, N=750
   - Pump Torque [Nm]
   - Q [LPM]

6. S-P Volute Pressure Rise, N=750
   - Volute DP [kPa]
   - Q [LPM]

TEST matrix: N, Q
S-P Pump Models
Pump Single Phase Calculation

Input:
- Impeller geometry: $r_1 \text{ [m]}, r_2 \text{ [m]}, \beta$'s
- Suction pipe diameter: $d_{\text{pipe}} \text{ [m]}$
- Volumetric flow rate: $Q \text{ [liter/minute]}
- Water density ($\rho_{sp}$)

Pump Single-Phase Flow Performance Prediction.
Two-phase flow mass flux effect
N=1250 rpm, $p_{\text{suction}}=130$ [kPa]

Preliminary Test Result:
Void Fraction
Pump Suction Pressure

The effect of different suction pressure on pump head.

Test Matrix:
$N, Q_W, Q_{\text{air}}, P_{\text{suction}}$
Pump Two Phase Flow Pump Performances

Flow number versus Pressure Number

Inlet Diffuser -> 1.5
Impeller     -> 1.05
Volute       -> 0.75
Two Phase Flow Pump Performances

1. Different inlet fluid pressure

2. Data
   ○ Prediction

3. $p_{suction} = 160$ kPa

4. $p_{suction} = 185$ kPa
Pump Two Phase Flow Performances

1. T-P Pump Curve, N=1250 [RPM]  T-P Vane Pressure Rise, N=1250 [RPM]
   Head [KPa]  Vane DP [KPa]
   alpha [%]  alpha [%]

2. T-P Pump Curve, N=1500 [RPM]  T-P Volute Pressure Rise, N=1500 [RPM]
   Head [KPa]  Volute DP [KPa]
   alpha [%]  alpha [%]

3. T-P Pump Curve, N=1750 [RPM]  T-P Vane Pressure Rise, N=1750 [RPM]
   Head [KPa]  Vane DP [KPa]
   alpha [%]  alpha [%]

   Head [KPa]  Volute DP [KPa]
   alpha [%]  alpha [%]

+ Data
○ Prediction
Two Phase Flow Pump Performances

Input:
Suction Pressure: $p_{suction}$ [kPa]
Two-Phase Flow Quality: $x$
S-P Water Flow Rate: $m$ [kg/sec]
S-P pump pressure Distribution:
- Inlet Diffuser
- Pump Vane
- Pump Volute

Pump Two-Phase Flow Performance Prediction

- $p_{suction} = 101:150$
- $X = 2.5 \times 10^{-5}:1.2 \times 10^{-3}$

- $p_{suction} = 200:300$
- $X = 4.5 \times 10^{-5}:4.5 \times 10^{-3}$
**CONCLUSION**

- Two-phase flow regime in the vane flow passage versus void fraction.

- Pressure distribution along the vane flow passage versus void fraction.

- Two mechanism:
  - Low Void fraction: chapping effect of Vane
  - High void fraction: Intensive centrifuge field
CONCLUSION

• Single & Two Phase Flow Experiment
• Single & Two-Phase Models Were Developed
• Compared Them With Experimental Data Point

Recommendation:
More experimental work needed to develop more accurate models to predict pump two-phase flow pump performance for both condensable and un-condensable fluids.