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Period of Performance: July 2017-July 2019
Subcontractors: The Ohio State University
Project Goals & Objectives

• The main technical objective of Phase II is to develop a functional Gas-Liquid ECVT demonstration system for real-time imaging and measurement of multiphase flows at high temperature.

Year 1 Milestones:
1. Finalize AECVT sensor design-end of 2\textsuperscript{nd} quarter.
2. Fabricate sensor for gas-liquid applications at for high pressure/temperature applications-end of 3\textsuperscript{rd} quarter.
3. Fabrication of testing chamber-end of 4\textsuperscript{th} quarter.

Year 2 Milestones:
1. Development of reconstruction and feature extraction algorithms- end of 7\textsuperscript{th} quarter.
2. Develop and demonstrate software and GUI-end of 8\textsuperscript{th} quarter.
3. Demonstrate integrated system- end of 8\textsuperscript{th} quarter.
Presentation Outline

• Introduction to ECVT
• Electronic Design
• Sensor
• Software
• Testing
• Schedule
Electrical Capacitive Volume Tomography (ECVT) is a low cost noninvasive imaging technique to find the volumetric dielectric distribution from inter-electrode capacitance measurements.

Electrodes respond differently to the change in permittivity distribution inside the sensing domain. These mutual capacitances are used to reconstruct the dielectric distribution in the sensing domain.

ECVT is used in nondestructive testing, imaging of multiphase flows and for imaging of combustion flames and fluidized beds.
The inter electrode capacitance is computed by

$$C = -\frac{1}{V} \int\int \varepsilon(x,y) \nabla \phi(x,y) \cdot ndS.$$  

The first order linear approximation

$$\Delta C = \frac{d\xi}{d\varepsilon} (\Delta \varepsilon) + O((\Delta \varepsilon)^2)$$

Where \( M = \frac{n(n-1)}{2} \) are the number of independent sensor measurements, \( N \) is the number of pixels in the sensing domain and the sensitivity matrix \( S \) is defined as

$$S_{ij}[n] = \frac{1}{V_i V_j} \int_{v[n]} \nabla \phi_i \cdot \nabla \phi_j d\nu$$
Overview

• Year of 2017 and 2018 to date
• Data Acquisition System (DAS)
• Firmware
• Sensor Design
• Software
• Algorithms
Data Acquisition System

1. Eliminated ghost images in conductive phases
2. Industrial grade enclosure
3. Reducing temperature drift
Channel Selection

- Activate only certain plate pairs during collection
- Increased acquisition speed due to less data
Dual Frequency

- MWS Effect
- 3 Phase
- DCPT Resolution

\[ \cos(\pi f_s t) \sin(2\pi f_R t) \]
Sensor Design

- High Temperature
- High Pressure
- Corrosion
- Abrasion
- Steam
Robust Electrodes

- Simple Conductive Plates
- Electrically Insulative Coating
- Smooth/Laminar Design
- Robust against
  - Heat
  - Pressure
  - Abrasion
  - Corrosion
Minimal Maintenance

- Low Maintenance Parts
  - Non-mechanical
  - Field Removable
  - Field Replaceable

- Minimal Calibration Requirements

- Remote Diagnostics
Installation

- Inline
- Standard Flanges
- Matching ID
- Metal Outer Jacket
- Minimal Space Requirement
Modularity

- Easily modified for various applications
- Exchange plastics, ceramics, and metals for electrode components.

- Adjust based on
  - Temp
  - Press
  - Material in flow
  - Longevity
  - Cost
Software

Firmware Integration
• Dual Frequency
• Channel Selection

Distribution
• Licensing Structure
• Demo License

Imaging
• Image Reconstruction
• Velocimetry

Data
• Normalization
• Calibration
Algorithms

1. Three Phase Decomposition
2. Air-water systems
3. MWS DCPT
4. Velocimetry
Three Phase Decomposition

- Air
- Oil
- Water
Volume Fraction for Air Water Systems
Increased Imaging Resolution for Air-Water Systems
Velocimetry

Model

Image

Velocimetry
Phase II B Schedule

Task 1: Sensor Material Research & Investigation
Task 2: ECVT sensor mechanical design for high temperatures
Task 3: ECVT sensor fabrication
Task 4: Build test chamber
Task 5: Data Acquisition System (DAS) firmware and electronic design
Task 6: Testing
Task 7: Implement image reconstruction algorithm
Task 8: Develop feature extraction
Task 9: System integration and testing in real-time
Task 10: Software interface
Task 11: Finalize demonstration unit
Conclusion

• ECVT for harsh condition gas-liquid applications is under development.

• DAS will be able to operate in Dev 1 environment.

• Advanced feature extraction is under development:
  • Dual frequency
  • MWS-DCPT
  • New normalization
  • Velocimetry

• Software GUI is operational.
QUESTIONS

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