ID43 ON THE DEVELOPMENT AND APPLICATION OF INTRUSIVE SENSORS FOR TWO-PHASE FLOWS CHARACTERIZATION IN COMPLEX ENVIRONMENTS

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ABSTRACT

Intrusive sensors are widely employed in numerous industrial applications to determine the phase fraction in gas-liquid two-phase flows. Such applications include those in the chemical, nuclear, and oil industries. This study aims to investigate the use of three distinct intrusive sensor topologies, specifically intended for underwater applications, wherein the detailed characterization of the disperse phase is the primary objective. Examples of such applications include aeration diffusers in wastewater treatment plants (WWTPs) and fish farming facilities.

Keywords – Two-phase flow, intrusive sensors, signal processing, aeration processes

INTRODUCTION

Two-phase flows occur in a multitude of scenarios, including both industrial and natural processes. In past decades, their study has primarily focused on topics related to the chemical, nuclear, and petroleum industries. Recently, their use has extended to other areas such as wastewater treatment, aquaculture, and natural water sources regeneration. In all of these cases, detailed characterization of aeration systems is of great utility. Such knowledge allows for the optimization of processes, from both energy efficiency and economic perspectives.

For example, in WWTPs, aeration processes typically require a significant amount of electricity to power the equipment used to generate and distribute air to the biological reactor. Therefore, the energy impact of aeration processes can be substantial, particularly in medium to large WWTPs. However, some aeration processes, such as diffused aeration, can be more energy-efficient than others, such as surface aeration. In the case of intensive marine aquaculture, the correct distribution of dissolved oxygen is one of the most important factors for ensuring the proper growth of fish. When the availability of food and dissolved oxygen is limited, the optimal temperature for fish growth is lower than when feeding and oxygen availability are not limited.

Therefore, monitoring and controlling the level of dissolved oxygen (DO) is necessary but complex in both WWTPs and marine aquaculture facilities, as it depends on multiple factors, including the physical and chemical properties of the water, available transfer area, turbulence of the continuous phase, etc. Having an accurate model of the behavior of gas-phase aeration systems (number and size of generated bubbles, distribution of void fraction, available interfacial area, etc.) is essential for optimizing and controlling these systems.

AVAILABLE INSTRUMENTATION

Instrumentation for measuring gas phase parameters includes local intrusive sensors. These sensors allow the complete characterization of any aeration system throughout local measurements, with high temporal and/or spatial resolution, of the main two-phase flow parameters: void fraction, bubble frequency, local velocity, and available interfacial area, etc. Basically, they identify the present phase in their measurement volume based on differentiating physical characteristics of the present fluids, such as conductivity (resistive or conductive sensors), permittivity (capacitive or impedance sensors), or optical properties (optical sensors). Among the different types, the following stand out:

- Conductivity sensors [1]: These sensors are composed of two or more sensitive tips. Phase discrimination is based on whether or not current passes between the sensitive tips. They allow for obtaining all local flow parameters. However, they require that bubbles pass through the sensor, so there are limitations regarding the minimum size of the bubble and the surface tension of the measured medium. They are widely used in water-air flows.

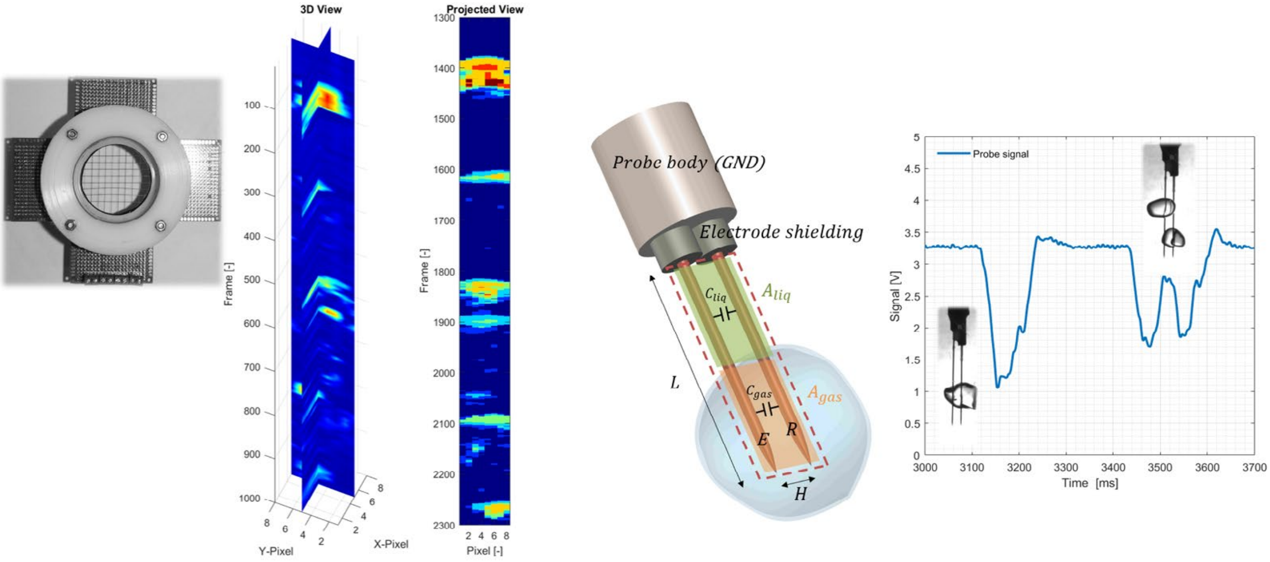
- Capacitive sensors: Phase discrimination is based on the difference in electrical permittivity of the fluid between electrodes (Figure 1). They allow measurements between non-conductive fluids and have no limitations in terms of detectable bubble size. Although similar to conductivity sensors, the signal processing of capacitive sensors is more complex, but their construction can be much more robust.

- Wire-mesh sensors: Unlike the previous sensors, measurements are not local but rather taken in a measurement plane (Figure 1). They allow for high-resolution temporal and spatial measurements. However, since it is a multiplexed system, they do not reach the temporal resolution of the previous sensors. Depending on the measurement circuit, they allow for measurements based on both conductivity [2] and permittivity [3]. The signal processing and electronics are more complex compared to the previous sensors.

The choice of sensor type depends on the measurement conditions and the required data resolution, including the properties of the medium (maximum conductivity, minimum difference in permittivity between phases, viscosity, etc.) and the required sensor robustness.

CONCLUSIONS

Three types of intrusive sensors have been presented that allow for detailed characterization of the dispersed phase behavior in aeration systems. Due to their characteristics, these sensors can be widely applied in various complex environments, such as marine environments or biological reactors in wastewater treatment plants. Furthermore, these sensors can be used for inspection and maintenance activities, such as assessing the state of aeration diffusers.



Wire-mesh 8x8 sensor

Two-needle capacitance probe

Fig 1. Example of a wire-mesh with 8 sensing lines and an example of slug bubble measured passing through the sensor (left). Detail of two-needle capacitive sensor and isolated bubbles measurement example signals (right).

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