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Microbubble Characterisation for Ballast Water Treatment on Ships over Indonesian Exclusive Economic Zones

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Abstract - *In generally, the vessel takes on ballast water as it unloads cargo and discharges ballast water as it loads cargo. It is estimated that approximately 7 billion tons of ballast water is transferred globally each year. The total volume of ballast water onboard a ship can be in excess of 5,000 m3. The organisms and pathogens in the water are not necessarily evenly distributed i.e. there may be patches with higher densities. Int his research, we implement micronbubble technology for Ballast Water Treatment. Principally, bubble could be developed in liquid or gas form. The micro term in microbubble reflects to the proportion which is usually in micrometer of its diameter size. Smaller bubble size is expected to give wider surface area as well as affected to greater mass transfer between its surface and interfacial area. Microbubble characterisation was conducted by using high speed camera for bubble size determination. Moreover, a fluidic oscillator was attached into the system to study the efficacy of bubble distribution within ceramic diffuser.*

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1. Introduction

Ballast Water is water used by the ships for maintaining its balance and stability strength. Generally, the vessel takes on ballast water as it unloads cargo and discharges ballast water as it loads cargo [1-5].

At any one time ballast water can naturally contain an estimated 7000 different species of organisms comprising of plankton (microscopic plants and animals), bacteria and viruses. Over 80% of the world's commodities are being moved by shipping, calling for speedy and efficient vessel movement. It is estimated that approximately 7 billion tons of ballast water is transferred globally each year [6].

The total volume of ballast water onboard a ship can be in excess of 5,000 m^3. The organisms and pathogens in the water are not necessarily evenly distributed i.e. there may be patches with higher densities. Concentrations of organisms and pathogens can also vary over time as they replicate and regenerate. This makes the task of obtaining representative samples very difficult. It is estimated that some 57,000 ships will need to comply with the BWMC. The experts have estimated that the whole process from selecting a BWM system to installing the system takes from a minimum of six months up to a year. Figure 1 shows the mechanism of Ballast Water Management on the ships. BWM systems can be very complex with biological, chemical and physical parts [7-9].

It is essential to provide technology for Ballast Water Treatment [10]. This influence the stability of ecosystem in the ocean, including in Indonesia Territory [11]. Some considerations are in need when assessing the treatment management [12]. In this research, we propose the application of microbubble for ballast water treatment technology.

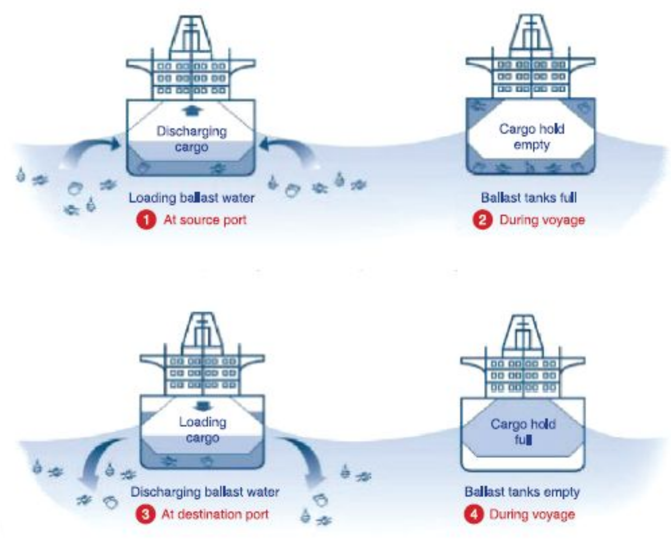


Figure 1. Ballast Water Cycle on the Ship [13].

Microbubbles is a novel technology which is well known by its benefits. This technology has effective impact to some emerging issues. Figure 2 describe mechanism of bubble acts in comparison to macrobubble and microbubble. Li and Tsuge [14] mentioned about evaluation of mass transfer efficiency between gas phase and liquid phase of ozone by using liquid phase volumetric mass transfer coefficient, k_La.

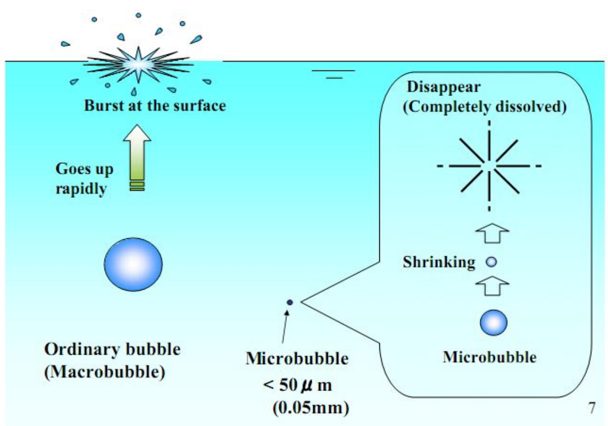


Figure 2. Illustration of microbubble in water [15]

Nowadays, investigation of microbubble using ultrasound technique has been conducted by researcher in some other field of study [16]. Moreover, bubble characterization could be done by high speed camera or another method which is optical micromanipulation [17]. Furthermore, Zimmerman et al proposed fluidic oscillator use in microbubble generation which can condition the bubble size. A fluidic oscillator is shown in Figure 3 below.

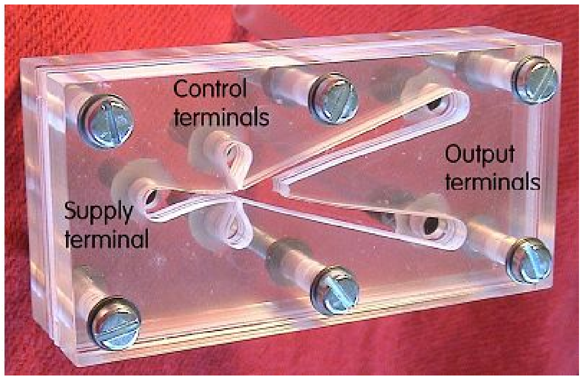


Figure 3. Model of fluidic oscillator [18]

2. Materials and Methods

The methods for this experiments are adopted from [19]. The microbubbles (MBs) generation was performed with application of a bespoke setup attached downstream to the fluidic oscillator (FO), Figure 4. The gas flow through the system was controlled by pressure regulator (Norgren, 0-6 bar) and the flow controller (Key Instruments 0-140 slpm). The FO at a given flow rate is oscillated at known frequency. Flow down to diffuser was controlled by bleeding line with control valves installed. The inlet flow rate to FO was controlled so that it can be compared to non oscillatory flow.

The ceramic mesoporous membrane was tested as diffuser. The experimentation has been done by bubbling air to the water with flow rate through diffuser varied at 0.5 – 3 L/min with oscillation frequency at 284 Hz. The diffuser system was adopted from [20]. The ceramic plate has averaged pore size 20 m and made from 80% alumina : 20% silica (w/w).

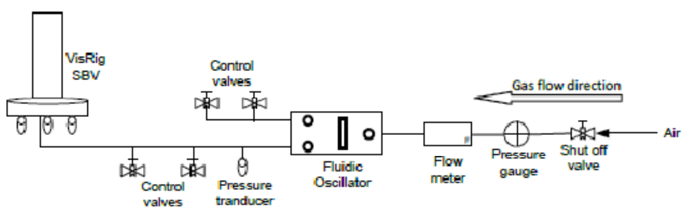


Figure 4. A schematic diagram of the experimental set up.

To characterise bubble cloud dynamics, a high speed photography is typically used [21-23]. For our work the FastCam HS3 Photron camera equipped with Nikon AF Lens was used to collect the bubble size distribution. The camera was computer controlled by the PFV PhotronFastcam software.

3. Results and discussion

3.1 Characterization of catalysts

One of the key elements in characterization reactor is bubble size investigation. Bubble size differs in various flow rates. According to Figure 5, bubble size distribution without oscillator has smaller size in lower flow rate. This bubble size is increased in consequent to flow rate rises. On the other hand, Figure 6 explains bubble size distribution when a fluidic oscillator is applied to the process.

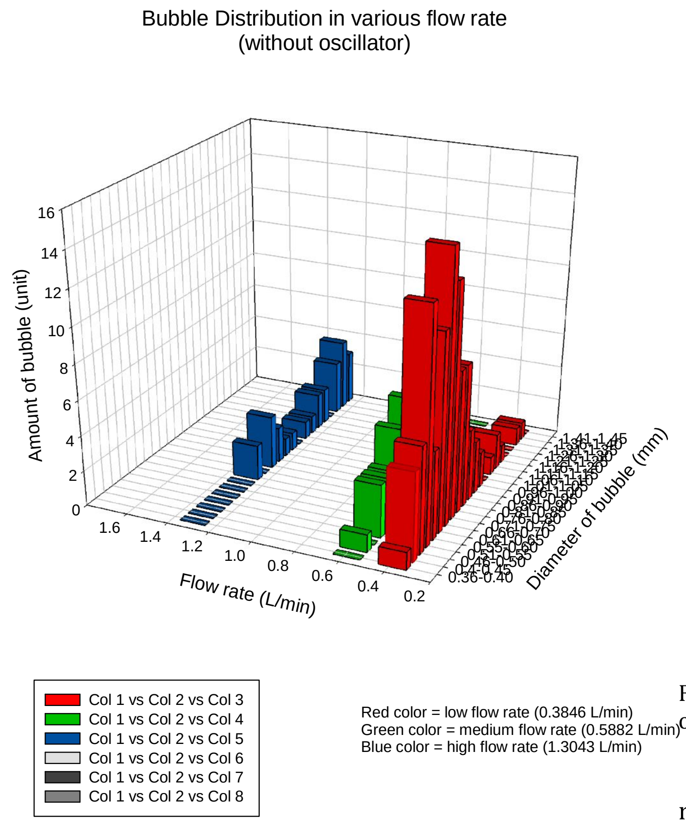


Figure 5. Bubble size distribution in various flow rate (without oscillator)

Bubble characterization in terms of size is taken by high speed camera for imaging then further analysis for its diameter measurement. Calculation of bubble distribution using actual diameter shows quite different profile compared with distribution using image diameter of bubble. Moreover, we should use actual diameter for any measurement (i.e area determination).

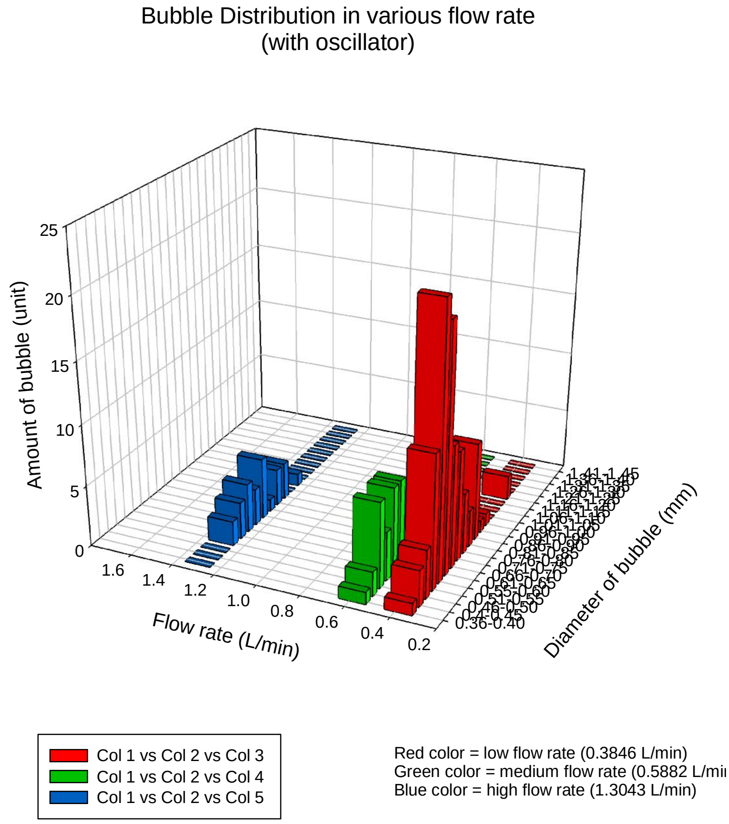
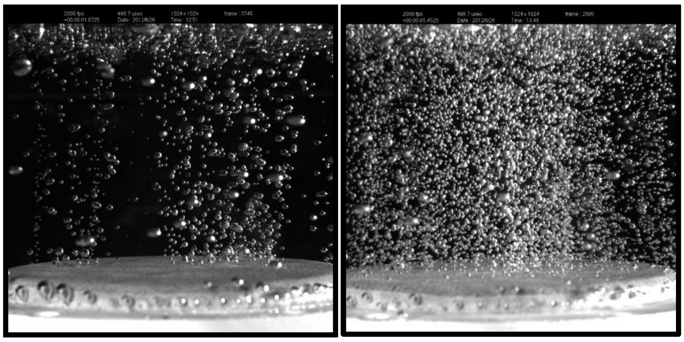


Figure 6. Bubble size distribution in various flow rate (without oscillator)

Figure 7 present images of bubble profiles in low flow rate in comparing of fluidic oscillator application. It is obviously shown that fluidic oscillator lead important influence in bubble size. Bubbles which are produced in absence of fluidic oscillator have bigger size.



(a) (b)

Figure 7. Bubble profile (a) with oscillator and (b) without oscillator in low flow rate

4. Conclusions

The microbubble characterisation showed that bubble size distributions are significantly different when a fluidic oscillator was introduced into the system. Even distribution was achieved on low flow rate both in system with and without a fluidic oscillator.

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