ILASS 2008
Sep. 8-10, 2008, Como Lake, Italy

Paper ID ILASS08-1-3

ULTRASONIC ATOMIZATION OF SALT WATER

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ABSTRACT
Ultrasonic atomization of sea water was proposed as a mean of controlling the amount of radiation reaching the earth's surface leading to reduction in the earth's temperature and also solving the global warming problem. The salt crystals will act as cloud condensation nucleus resulting in enhancing more cloud which can reflect more UV radiation. This work has studied characteristics of sprays from the ultrasonic atomizers under difference operating conditions. The effects of supply voltage, operating frequency and types of operating atomizer; continuous and pulsed atomizer, on the spray characteristics have been investigated. A commercial atomizer and the thinner piezo disk atomizer were investigated since the thickness of the piezo disk is one of parameters altering the resonant frequency of the disk which can generate difference droplet size. Particles velocity and size were measured by PDA, the spray images were captured by a high speed camera and the results are presented and discussed.

INTRODUCTION

The idea that global warming can be controlled by means of atomizing sea water is proposed by Latham [1], and is based upon the idea that the number of naturally occurring droplets in the lower atmosphere, especially over oceans, can be increased by artificially increasing the number of smaller droplets, this would lead to an increase in cloud albedo because the overall droplet surface area is changed; thereby reducing the amount of radiation reaching the earth's surface. Also introducing artificial small droplets can increase cloud longevity because normal cloud dispersion by means of droplet coalescence is slowed down. Particles between 0.6 μm and 1.7 μm in diameter are the most effective at acting as nucleus for water vapour condensation, Latham [1] and doubling of maritime cloud cover, on global basis, would be sufficient to compensate for warming due to increased carbon dioxide concentrations, Charlson *et al* [2], slingo [3] and Twomey [4].

Generally, naturally occurring droplets over the oceans are produced from sea water spray; therefore, if sea water can be artificially atomized in a controlled manner, the increasing in droplet concentration over the oceans can be achieved. The size of the droplet is crucial, too large and they fall back to the sea or, if they manage to be swept up into the atmostphere they coalescence to form rain, too small and they evaporate completely. The most suitable device to generate the droplets is an ultrasonic atomizer based on a vibrating high frequency piezo crystal. To obtain the most efficient result, the atomizer should produce mono-sized droplets and consume as less as possible energy.

The current work is aimed at characterizing the piezo disk ultrasonic atomizer by measuring particle size distribution and particle velocity under different operating conditions. The final aim is to maximize the number of droplets in the required diameter range while at the same time minimize power consumption.

EQUIPMENT AND EXPERIMENT

Initially, a low cost readily available ultrasonic atomizer of a type used as a mist generator in tropical aquariums was used as a starting point, Phanphanit [5]. Fig 1 illustrates the commercial atomizer components.

Figure 1 The ultrasonic atomizer and its components; Author, 2005

The atomizer is based upon a piezo transducer made from a Lead Zirconate Titanate (PZT) disk, such transducers work upon the principle that a voltage applied along the axis of the disk cause it to expand and contract at a frequency given by

$$f_s = \frac{N_3^D}{h} \quad \textbf{(1)}$$

where N_3^D is the thickness mode frequency constant of the piezo material for PZT this has a value of 1850, and h is the thickness of the disk. When submerged in a fluid at a given depth the oscillation of the piezo disk causes ultrasonic waves to be produced, at the surface of the fluid, these waves produce a ‘fountain’ of liquid which then break up into droplets, the mean diameter of which is given by

$$d = 0.73\left(\frac{T}{\rho f^2}\right)^{\frac{1}{3}} \quad \textbf{(2)}$$

Where T is the surface tension of the fluid and ρ is the density. For the transducer used in a previous study f_s = 1.45 MHz while d = 2.38 μm for distilled water and 2.36 μm for salt water.

Particle velocity and size were measured by means of a Dantec Phase Doppler Anemometer; such systems use a pair of converging laser beams coupled to three photomultipliers to measure the phase differences of laser light scattered from the droplets. A D-Cam HS video camera was used to capture images of the spray. A reduced thickness piezo disk has been used in a new atomizer atilising variable voltage supply and operating frequency. According to the reduction of the piezo disk thickness, the resonant frequency of the disk has changed to 2.31 MHz. The theoretical droplet diameter calculated by Eq. (2) was 1.75 μm for distilled water and 1.74 μm for salt water.

The particle velocity was measured by PDA in both vertical and horizontal planes from the disk centre at different heights above the disk. The particle size was also measured by PDA at the top of the fountain for both distilled water and salt water under the same operating conditions. The new atomizer with thinner piezo disk had been tested with distilled water for different cases. Its operation had been separated into 2 cases; one is using a continuous power supply and the second one is using a pulsing supply this is further divided into high and low frequency rates of pulsing. The supplied voltage and operating frequency have been varied from 48 V to 58 V and 2.23 MHz to 2.36 MHz, respectively. Again the PDA was applied to measure the particle velocity and diameter at the top of the spray. Also the atomizer had been tested in a water flume in order to study the effects of the velocity of the flowing water on the spray.

RESULT AND DISCUSSION

Ultrasonic waves are produced in the fluid over the top of the disk; these waves propagate through the fluid and produce a liquid ‘fountain’ at the surface and then the fountain breaks up into droplets as shown in Fig 2 which was captured by a high speed video camera.

Figure 2 Fluid Fountain and Droplets

Velocity measurements were taken of the flow between the transducer and the fluid surface at different heights across the radius of the atomizer as shown in Fig 3.

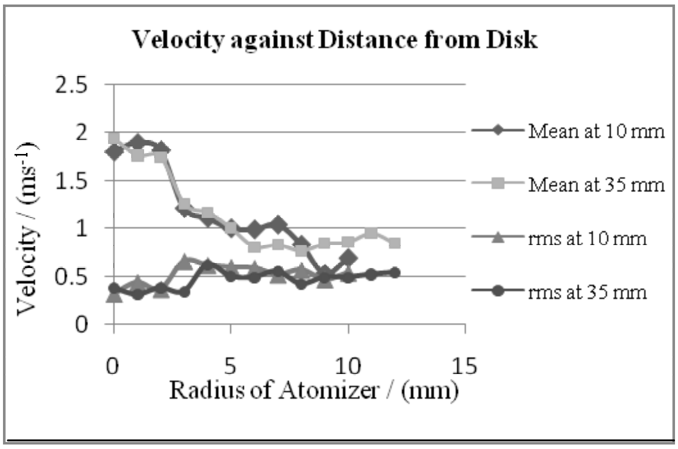

Figure 3 Velocity Profile across Atomizer Radius at 10 and 35 mm from Disk

This showed no measurable difference for distilled water in both heights. The mean velocity at the centre of the disk was approximately 2 m/s and decreased further away from the centre. The RMS velocities are almost the same and constant for both heights. The particle velocity of the new atomizer was measured at the top of the spray and its result shown in Fig 4 which shows the particle velocity against the voltage for both continuous and pulsed atomization.

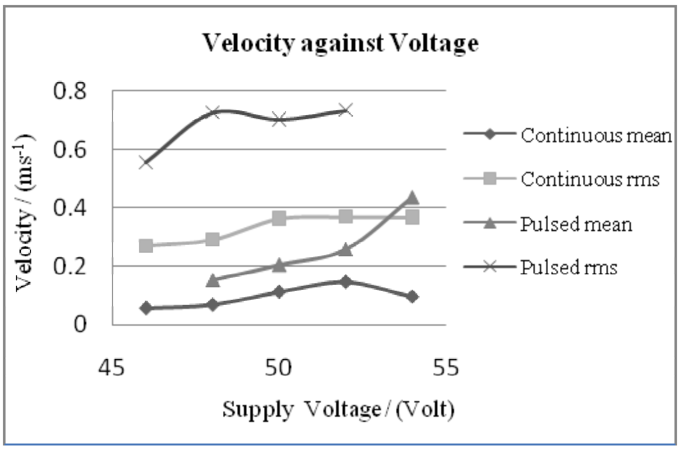

Figure 4 Velocity Profile against Voltage

As can be seen from Fig 4, the pulsed atomizer produced the droplets with higher velocity while the mean velocity was almost constant for the continuous operating case however it gradually increased with an increase in voltage for the pulsed operation.

The droplet size distributions of the commercial atomizer are shown in Fig 5 and Fig 6 for distilled water and salt water, respectively and the graph shows the number of droplets as a percentage of the total number of droplets produced by the atomizer against the droplet size. The mean droplet diameter obtained from salt water shows a significant reduction in size, 2.76 µm compared to 4.29 µm although the number of droplets for a given size fell slightly. It is thought that this difference is due to salt crystals acting as a nucleus for cavitation so that there are two, distinct modes, of droplet production. The piezo disk thickness was then reduced so that it resonated at 2.31 MHz and then measurements were repeated for the continuous and pulsed operation. The results are shown in Fig 7 and Fig 8.

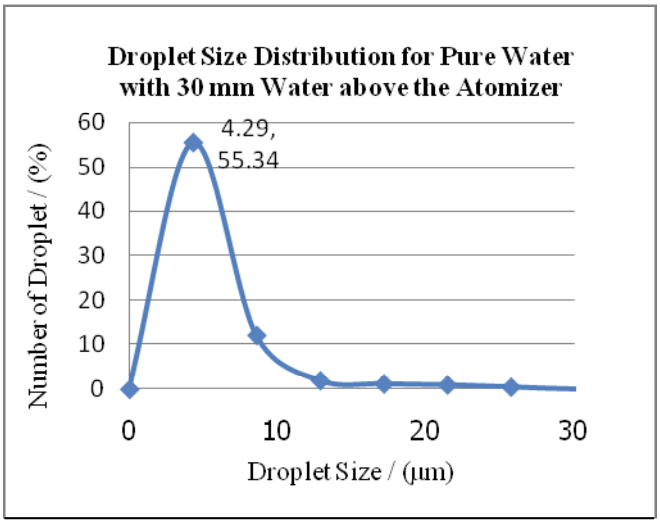

Figure 5 Droplet Size Distribution for Pure Water from the Commercial Atomizer

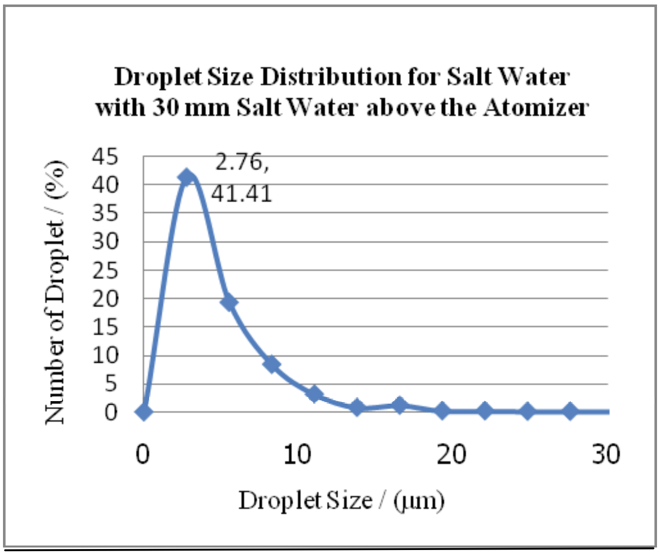

Figure 6 Droplet Size Distribution for Salt Water from the Commercial Atomizer

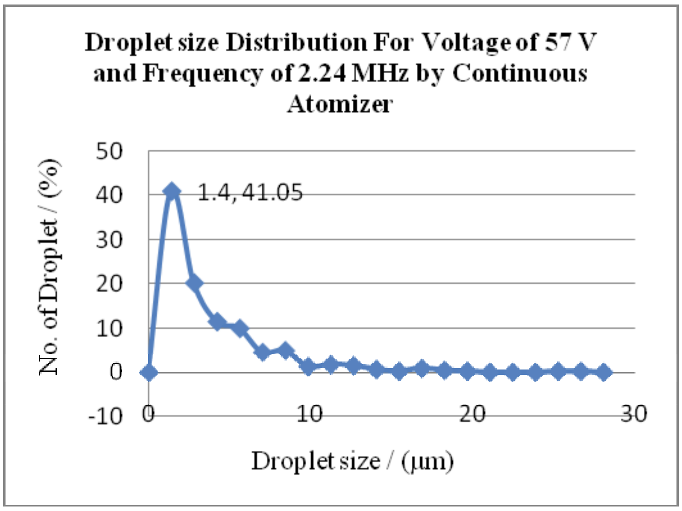

Figure 7 Droplet Size Distribution from the Continuous Atomization with thinner disk

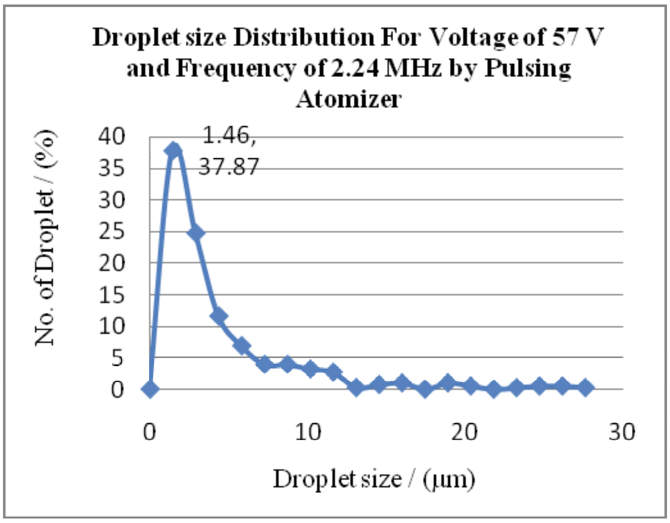

Figure 8 Droplet Size Distribution from the Pulsed Atomization with the thinner disk

It was found that the mean particle diameter reduced, as expect, however the total number of droplets increased considerably. At a voltage of 57 V and a frequency of 2.24 MHz, the atomizer produced the most number of droplets and also the smallest droplet mean diameter. As can be seen from fig 6 and fig 7, the mean diameter reduced to 1.4 µm and 1.46 µm for the continuous and pulsed operating, respectively; however, the number of droplets produced are not that much different. Although the pulsed atomizer produced less droplets than the continuous, the percentage of the droplets in the required range compared to the total number of droplets generated from each case are almost the same, 37.87 % and 41.05 %.

All these tests were undertaken with stagnant water over the atomizer; however some tests were taken in a water flume using flowing water. It was found that as the horizontal flow velocity of the water increased, so the atomization process decreased until it stopped completely when the flow velocity exceeded the vertical velocity of the ultrasonic waves at the water surface, which was approximately 0.7 m/s.

CONCLUSION

The atomizer running at 1.45 MHz could produce 4.29 μm diameter water droplets and 2.76 μm diameter salt water droplets; however, they are far too large to be able to stay in the atmosphere. Since the size of droplet depends on the frequency and the frequency depends on the thickness of the piezo disk, therefore the thinner piezo disk which gives the higher resonant frequency, 2.31 MHz, had been used and it produced smaller droplets with 1.4 μm diameter, as expected. Although it produces the droplets in the required range, the range is still very wide thus it needs to be studied further in order to generate more mono-sized droplets and to also maximize the number of droplets while minimizing the energy consumption.

NOMENCLATURE

Symbol	Quantity	SI Unit
d	Diameter	m
f	Frequency	Hz
f_s	Resonance Frequency	Hz
h	Thickness	m
N_3^D	Thickness Frequency Constant	Hz·m
T	Surface Tension	N/m
	Density	kg/m^3

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