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# EFFECT OF INTERNAL GEOMETRY ON PERFORMANCE OF EFFERVESCENT ATOMIZER-A REVIEW

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**Abstract** — *Effervescent atomizer is one of the most innovative atomizers and has been used in various applications such as gas turbine combustors, consumer products, internal combustion (IC) engines and incinerators due to their advantages such as good atomization and insensitive to liquid viscosity. Performance of an atomizer could be measured by their resultant spray produced by the atomizer. The influence of the geometrical parameters and operating condition towards the spray characteristics of any atomizer is very crucial since the change in the parameter will greatly affect the performance. The factors influencing effervescent atomization are operating parameters and atomizer internal geometry. The purpose of this article is to study the dependence of effervescent spray unsteadiness on Effervescent atomizer internal design.The result shows that the size of the droplets produced decreases with a decrease in the air injection area. This is due to the increase in atomizing air injection velocity that accompanies the decrease in the air injection area, which improves atomization. Short mixing chamber length provides slightly larger SMD and gives wider spray cone half-angle. The spray angle shows increment with the increase of discharge orifice diameter and with the increase of the swirl generating vane angle.It is concluded that Effervescent atomizer is capable of providing a wide range of spray patterns depending upon the application requirement by controlling various geometrical parameters.*

***Keywords***- *Liquid Atomization, Effervescent Atomizer, Spray cone angle, Sauter mean diameter (SMD), Aeration area, discharge orifice diameter, swirl generating vane angle*

## I. INTRODUCTION

Liquid atomization, the process of producing a large number of droplets from bulk liquid, is used in a variety of engineering applications, in pharmaceutical industries, process industries, aerospace, chemical, civil, and mechanical engineering, medicine, agriculture, food, fuel injection in combustion applications, and in agricultural sprays. Liquid atomization is a process of great importance in practical applications. A number of spray devices have been developed for this purpose, and they are generally designated as atomizers or nozzles [2]. Effervescent atomization is a method involving a twin-fluid process that involves bubbling gas within a liquid. The types of atomizers are: Pressure atomizer, Rotary atomizer and Twin-fluid atomizer, Effervescent atomizer. Effervescent atomizer is one of the most innovative atomizers and has been used in various applications such as gas turbine combustors, consumer products, internal combustion (IC) engines and incinerators due to their advantages such as good atomization and insensitive to liquid viscosity. Compared to conventional pressure, rotary and twin-fluid atomizers, the effervescent atomizer offers advantages of smaller drop sizes, reduced injection pressure, lower gas flow, a larger exit orifice, and tolerance for high viscosities.

## II. EFFERVESCENT ATOMIZER

Effervescent atomizer consists of four main components: liquid and gas supply ports, a mixing chamber where the gas is bubbled into the liquid stream, and an exit orifice as shown in Figure 1. Liquid is supplied to the atomizer through a port at the top and flows down inside a perforated central tube to the exit orifice. The atomizing gas supply pressure is slightly higher than that of the liquid. Being at a higher pressure, the gas flows through the perforations in the central tube into the liquid stream, and forms bubbles. The bubbly two-phase mixture forms flows downward and is ejected through the exit orifice. There are four possible flow regimes in the discharge orifice of an effervescent atomizer, including small bubbly flow, larger bubbly flow, slug flow and annular flow. Annular flow pattern is beneficial to obtaining finer droplets. The second step is the resulting two-phase mixture that is discharged from the atomizer orifice. Leaving the nozzle exit, the rapidly expanding gas phase will shatter the liquid into fine droplets, which is called primary atomization. The third domain lies at the downstream of the spray. As the droplets produced by primary atomization are unstable in the turbulent spray, they will undergo a series of events such as collision, breakup and coalescence, and finally the droplets entrained in the gas jet will impinge on the plate or undergo further mass and heat transfer. It is believed that two effects induce atomization in such an First, as both the liquid and the air share the same flow passage in the injector, the liquid is restricted to a smaller available flow area. The reduction in flow area accelerates the liquid, thus, increasing its kinetic energy, which induces fine atomization. Second, the relative motion between the air and the liquid phases produces shear forces at their interface leading to the onset of flow instability at the interface resulting in ligament formation. Furthermore, the shear force strips liquid droplets from the liquid filaments inducing atomization.

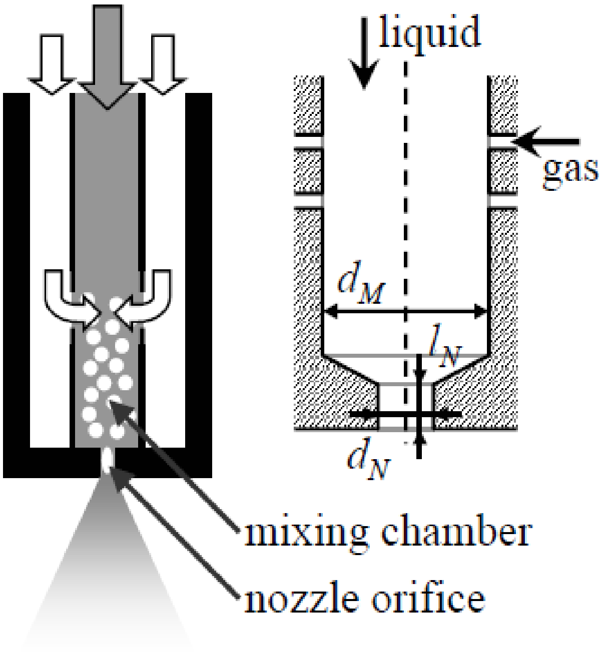


***Figure 1. Inner structure of the effervescent atomizer***

Compared with the conventional pressure, rotary and other twin-fluid atomizers, the main advantages exhibited by effervescent atomization are concluded below [7].

(1) At very low injection pressures and a low gas-to-liquid mass flow ratio small drop size (about several to decades micron) can be achieved, which means the cost of aerodynamic energy can be reduced.
(2) Large exit orifice size (several millimeters) is allowed and the atomization effect is relatively insensitive to the atomizer exit size. The problems of “plugging/clogging” can be significantly alleviated and the atomizer fabrication can be facilitated.
(3) Good atomization performance can be obtained for various liquid types and liquid physical properties,which means this atomizer can handle complex physical properties, such as viscous solutions, suspensions, non-Newtonian fluid and so on.
(4) The basic simplicity of the device lends itself to rugged applications, reliability, easy maintenance and low cost.

## III. SPRAY CHARACTERISTICS

Performance of an atomizer could be measured by their resultant spray produced by the atomizer. The performance parameters that are of most important to atomizer designers are mean spray droplet size (typically Sauter Mean Diameter), spray cone angle, and the discharge coefficient.

### 3.1. Spray cone angle

Better dispersion of fluid through atomizer is desirable in various applications such as spray combustion, spray painting and agriculture. The reason is mainly because the need of widespread of the fluid to the area involved. The opening of the spray as it flows through the exit orifice is often referred to spray cone angle. The definition of spray cone angle is the plane angle formed by the profile of a spray pattern. The spray angle determines the dispersion and coverage area of the resultant sprays.

### 3.2. Sauter Mean Diameter

The droplet size is the most fundamental index for evaluating the atomization performance. Smaller droplet not only improved the heat and mass transfer but also results in a faster chemical reaction of the fluid [10]. In spray combustion applications, smaller droplets size will improve the efficiency of combustion process as it provides larger surface area of the fluid expose to the combustion. The most common droplets size type studied by many previous researchers is Sauter Mean Diameter (SMD). SMD is defined as the diameter of a drop having the same volume/surface area ratio as the entire spray.

 

## IV. LITERATURE REVIEW

The influence of the geometrical parameters and operating condition towards the spray characteristics of any atomizer is very crucial since the change in the parameter will greatly affect the performance. The factors influencing effervescent atomization are classified into different categories such as liquid types, liquid physical properties, operating parameters (gas/liquid ratio, injection pressure), atomizer internal geometry and gas properties (bubble size, flow regimes) [8]. In this paper, we review the effect of change in atomizer internal geometry like: Mixing chamber diameter and its length, Aeration area, discharge orifice diameter, swirler.

### 4.1. Effect of Mixing chamber diameter and its length:

Jan Jedelsky et al.[3] studied influence of size and number of aerator holes, their location and diameter of the mixing chamber parameters on spray performance at atomizing pressures 0.1, 0.3 and 0.5 MPa and gas-to-liquid-ratio (GLR) of 2, 5 and 10%. Higher influence of the mixing chamber diameter at lower pressure, where the smallest *ID32* was found for diameters between 8 and 11mm.Optimum results was acquired with mixing chamber diameter about 4-times exit orifice diameter.
Jan Jedelsky et al.[4] observed that Atomizer with short relative mixing chamber length, gave wider spray cone half-angle by 2.0° - 3.2° then atomizer with larger. Long mixing channel probably lead to bubble merging and finally to worse mixing.
Kushari [5] observed that droplet size decreased with increasing mixing chamber length.
Meng Liu et al.[14] also observed that a short mixing relative mixing chamber length provided slightly larger SMD and smaller droplet velocity for glycerol/water mixture.
Mona Hassanzadeh et al.[15] The length of the mixing zone was found to have an impact on the bubble size distribution inside the mixing zone; more uniform and smaller bubbles were generated in the shorter mixing zone. The mixing zone length, however, did not show a distinct impact on the droplet velocity and size. It was concluded that a conical base aerator tube and a shorter mixing zone could significantly improve the spray steadiness and the atomization process.
Meng Liu et al.[17] investigated that short mixing chamber produced good atomization, the high spray unsteadiness took place in the center region of spay.

### 4.2. Effect of Aeration area:

Jan Jedelsky et al.[3] found that increase of aeration area lead to improvement of the *ID32*. This effect was associated with a more homogeneous mixture in case of larger number of aeration holes. Larger number of aeration holes and their smaller diameter lead to decrease of droplet size.
Jan Jedelsky et al.[4] observed that Atomizer with large relative aeration cross-section area = 6.4, produced concentration half-angle wider by 1.3° - 2.2° compared to atomizer with aeration cross-section area = 1.3. Larger aeration area improved mixing of gas with liquid and lead to better exchange of the compressed gas energy to the liquid disintegration work. Size of aeration holes controlled the penetration of gas into liquid and final size of bubbles in the case of bubbly flow regime. Result showed that atomizer with aeration holes 0.6 mm produced by 0.1°-0.9° wider spray then atomizer with holes 1.5 mm in diameter.
Kushari [5] showed that for a particular ALR, a reduction in the air injection area reduced the SMD of the droplets produced in Figure 2. They also found that the droplet sizes decreased everywhere in the spray when the air injection area was reduced as shown in Fig. 4 at constant ALR 0.087. The behavior exhibited by the data plotted in Figure 2 and 3 could be attributed to the fact that the air enters the injector at a higher velocity and, thus, higher kinetic energy, through a smaller area because its mass flow rate was conserved.

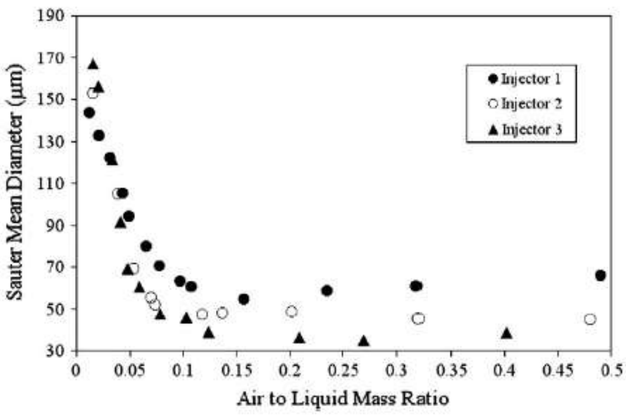


***Figure 2. Dependence of the droplets SMD on ALR for different air injection areas.***

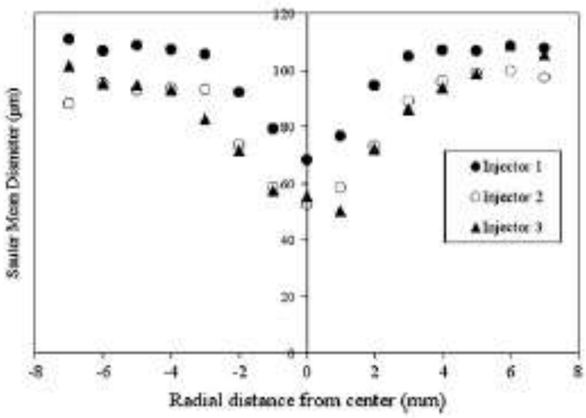


***Figure 3. Radial distribution of the droplets SMD for different injectors for an ALR of 0.087***

 

Meng Liu et al. [17] investigated the influence of diameter of incline aeration holes on the droplet velocity and SMD at ALR of 10% for atomizers A4 and A5 as shown in Figure 4. It was very obvious that the large diameter of incline aeration holes produced the high droplet velocity and small SMD. In other word, a good atomization can be obtained by increasing the diameter of incline aeration holes. The same result also was found by Meng Liu et al.[14].

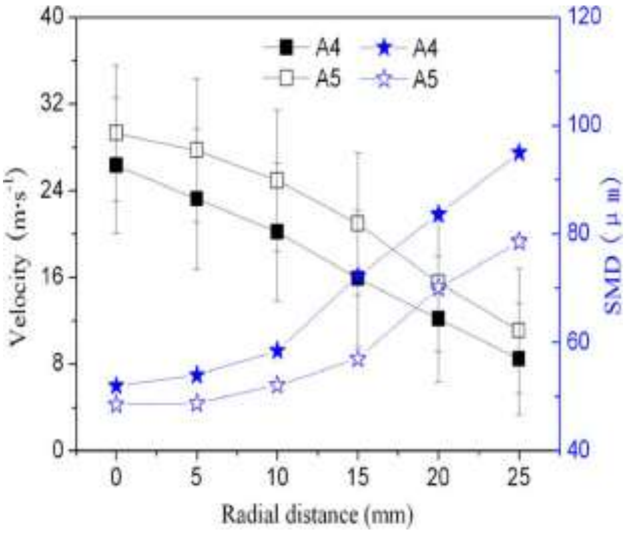


***Figure 4. Drop velocity and SMD versus radial distance at ALR 10%.***

**4.3. Effect of discharge orifice diameter:**

Zulkifli Abdul Ghaffar et al.[11] at observed that the spray angle showed a small increment with the increase of discharge orifice diameter. The increment rose slightly at larger discharge orifice diameter. The diameter of the discharge orifice had produced an increment of 4.93°to the spray angle to reach 24.6° as the discharge orifice enlarged from 1.5mm to 2.5mm.
Meng Liu et al.[14] confirmed that when the diameter of discharge orifice increased, good atomization was produced, the high spray unsteadiness took place in the center region of spay.
Broniarz et al. [16] stated that, the atomization quality reduced with the increase of discharge orifice diameter.

**4.4. Effect of swirl-generating vane:**

Zulkifli Abdul Ghaffar et al. [12] constructed a twin-fluid atomizer with attached swirl-generating vane. It was observed that, the spray angle showed an upward trend with the increase of the vane angle. This happened because increasing the swirl-generating vane angle had resulted in an increase of the swirl intensity of the liquid flowing in the atomizer. Despite of the dramatic increased of the spray angle during the changed of vane angle from 30° to 45°, only a slight increase of the spray angle was observed when the swirl-generating vane angle was changed from 45° to 60° as shown in Figure 5. This is unexpected and could be attributed to the existence of the gaseous bubbles in the liquid stream. The gaseous bubbles have reduced the influence of vane angle on the spray angle.

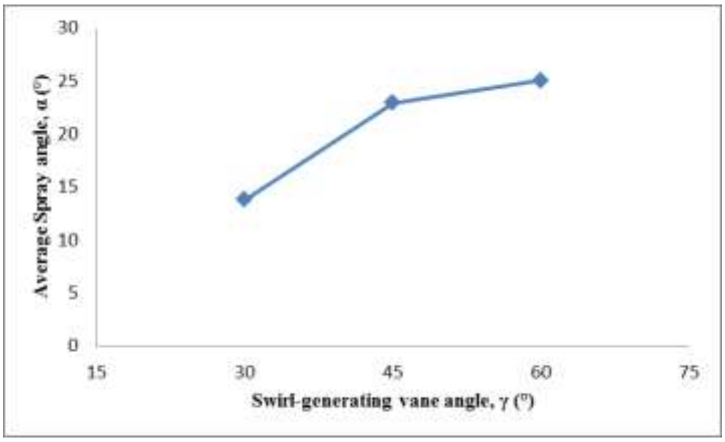


***Figure 5. Effect of swirl-generating vane angle on spray angle***
***(a) in all 15 experiments and (b) with average spray angle***

 

Zulkifli Abdul Ghaffar et al. [11] found that the spray angle increased up to 11.23° with 60° swirl-generating vane angle to achieve a 25.01° angle. This was probably occurring because swirl generating vane angle associated with the swirl intensity of a liquid/liquid-gas mixture flowing in the atomizer.

J. Jedelsky [6] studied a single-hole effervescent atomizer spraying light heating oil with air as an atomizing medium in the "outside-in" gas injection configuration. They focused on modification of geometry of the atomizer exit section .They studied that Atomizers with moderate (I) and intense (II) swirler the exit orifice gave by 5 % lower over-all Sauter mean diameter.

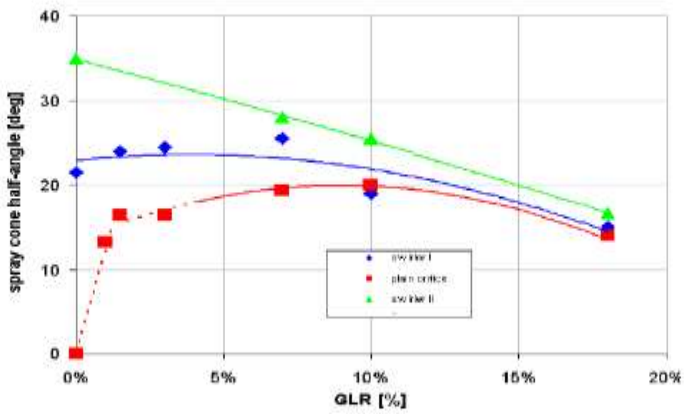


***Figure 6. Influence of the mixture swirl on the spray cone half-angle.***

Soon Hyun Yoon et al. [13] is designed the twin-fluid water mist nozzles with swirler having two types of swirl angles such as 0°, 90° and three different size nozzle hole diameters such as 0.5mm, 1mm, 1.5mm. It was confirmed that SMD was varied with the location of swirler as well, as a result, the smallest SMD was the nozzle for Type 2 in circumstance that swirl angle was 90° and diameter of swirler was 1mm.

## V. CONCLUSION

The results presented in this paper suggest that the performance of effervescent atomizer depends on the effervescent atomizer's geometry.

In this study, The conclusions from the results of this review can be summarized as follows:

1. Optimum results are acquired with mixing chamber diameter about 4-times exit orifice diameter of effervescent atomizer.
2. It is concluded that a short mixing chamber length provides slightly larger SMD and gives wider spray cone half-angle.
3. It finds that the droplet sizes decrease everywhere in the spray when the air injection area is reduced. Large relative aeration cross-section area produces concentration half-angle wider. Moreover, Larger number of aeration holes and their smaller diameter leads to decrease of droplet size. Good atomization is obtained by increasing the diameter of incline aeration holes.

4. The spray angle shows a small increment with the increase of discharge orifice diameter. When the diameter of discharge orifice increases, good atomization is produced, the high spray unsteadiness will take place in the center region of spay. But, in some cases, the atomization quality reduced with the increase of discharge orifice diameter.

5. The spray angle visualizes an upward trend with the increase of the swirl generating vane angle.A larger spray angle is often required in providing a better spray dispersion.

## REFERENCES

[1] Beyvel L & Orzechowski Z (1993), Liquid Atomization, Taylor and Francis,Philadelphia.
[2] Lefevbre A H (1989), Atomization and Spray, Hemisphere Publishing Corporation, New York
[3] J. Jedelsky, J. Otahal and M. Jicha, "Effervescent atomizer: influence of the internal geometry on atomization performance". Proceedings of the 21$^{th}$ ILASS - Europe Meeting 2007.
[4] Jan Jedelsky, Michael Landsmann, Miroslav Jicha, Ivo Kuritka, "Effervescent atomizer: influence of the operation conditions and internal geometry on spray structure; study using PIV-PLIF", Paper ID ILASS08-A036, ILASS 2008
[5] A. Kushari, "Effect of injector geometry on the performance of an internally mixed liquid atomizer", Fuel Processing Technology 91 (2010) 1650–1654

[6] J. Jedelsky and M. Jicha, "Novel Modifications of Twin-fluid Atomizers: Performance, Advantages and Drawbacks", ILASS – Europe 2010, 23rd Annual Conference on Liquid Atomization and Spray Systems, Brno, Czech Republic, September 2010

[7] QIAN LiJuan & LIN JianZhong, "Modeling on effervescent atomization: A review" ,December 2011 Vol.54 No.12: 2109–2129

[8] Mohammad Azizur Rahman. "Scaling of Effervescent Atomization and Industrial Two-Phase Flow." Ph. D. thesis, University of Alberta, 2011.

[9] Pipatpong Watanawanyoo, Hirofumi Mochida, Teruyuki Furukawa, Masanori Nakamura, Hiroyuki Hirahara , "Experimental Study on the Spray Characteristics of an Air Assisted Atomizer with Internal Mixing Chamber", ISSN 1450-216X Vol.84 No.4 (2012), pp.507-521

[10] Chia-Chien Chu ,Shyan-Fu Chou, Heng-I Lin,Yi-Hai Liann. "An experimental investigation of swirl atomizer sprays", Heat and Mass Transfer, Vol. 45, pp. 11-22, 2008.

[11] Zulkifli Abdul Ghaffar, Salmiah Kasolang, Ahmad Hussein,Abdul Hamid, Ow Chee Sheng, Mimi Azlina Abu Bakar,"Effect of geometrical parameters interaction on swirl effervescent atomizer spray angle" , 31 may 2015

[12] Zulkifli Abdul Ghaffar1,Salmiah Kasolang, and Ahmad Hussein Abdul Hamid, "Characteristics of swirl effervescent atomizer spray angle", Trans Tech Publications, Switzerland, ISSN: 1662-7482, Vol. 607, pp 108-111,2014.

[13] Soon Hyun Yoon, Do Yeon Kim, Dong Keon Kim and Bong Hwan Kim, "Effect of nozzle geometry for swirl type twin-fluid water mist nozzle on the spray characteristic" , Journal of Mechanical Science and Technology 25 (7) (2011) 1761~1766

[14] **Meng Liu,** Yufeng Duan, Tienan Zhang, Yiqian Xu, "Evaluation of unsteadiness in effervescent sprays by analysis of droplet arrival statistics – The influence of fluids properties and atomizer internal design",School of Energy and Environment, Southeast University, PR China Experimental Thermal and Fluid Science 35 (2011) 190–198

[15] **Mona Hassanzadeh** Jobehdar, Kamran Siddiqui , Aly H. Gadallah ,Wajid A. Chishty , "Effect of atomizer internal geometry on the internal and external two-phase flow in effervescent atomization", Canada

[16] **L.Broniarz-Press**, M. Ochowiak, S. Woziwodzki, "Atomization of PEO aqueous solutions in effervescent atomizers", International Journal of Heat and Fluid Flow. 31 (2010) 651-658.

[17] Meng Liu, YuFeng Duan, TieNan Zhang, "Evaluation of effervescent atomizer internal design on the spray unsteadinessusing a phase/Doppler particle analyzer", School of Energy & Environment, Southeast University, PR China, Experimental Thermal and Fluid Science 34 (2010) 657–665

[18] J. Jedelsky, M. Jicha, J. Slama, J. Otahal, Development of an effervescentatomizer for industrial burners, Energy Fuel 23 (2009) 6121–6130.