UNIVERSITI TEKNOLOGI MARA

CHARACTERIZATION OF SWIRL EFFERVESCENT SPRAY AT LOW REYNOLDS NUMBER USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

The disintegration of bulk liquid into sprays is known as liquid atomization and could be characterized using a map called the liquid disintegration regime map. Mapping a liquid disintegration regime of any atomizer help in sizing the atomizer for a given desired resulting spray characteristics. However, the map for a type of atomization, namely swirl effervescent atomization, is hardly available. Swirl effervescent atomization has broad advantages within the hybrid category, and it is crucial to map the liquid disintegration regime for this type of liquid atomization. Water acts as the working fluid and air is used as the atomizing gas. Dimensional analysis was applied to determine the dimensionless numbers affecting the spray characteristics (spray angle, breakup length, and droplet diameter). Liquid Reynolds number (Re_L), gas Reynolds number (Re_G), and swirl chamber length to discharge orifice diameter ratio (l_s/d_o) were the dimensionless numbers acquired. The liquid disintegration regimes for swirl effervescent atomization are tested across $847 < Re_L < 2540$, $0 < Re_G < 1514$, and $0 < l_s/d_o < 9$. The shadowgraph and image processing technique were utilized for the acquisition and quantification of the spray images. Response surface methodology (RSM) was employed to plan the experimental order, analyses the resultant spray characteristics, and formulate the empirical model. The spray characterization test demonstrated the spray angle to increase linearly with Re_L from 0.25° to 15.53° and increase linearly with Re_G from 5.40° to 22.41°. The l_s/d_o portrayed an inverse relation with spray angle with decrement from 20.25° to 4.73°. The breakup length shortened with Re_G from 25.77mm to 12.90mm, unchanged with Re_L at ~22.00mm, and lengthened with l_s/d_o from 11.50mm to 27.61mm. The Sauter mean diameter shrink with Re_L from 3041.52μm to 2362.31μm and Re_G from 3232.25μm to 2140.85μm but almost unaffected by l_s/d_o with an almost constant value at ~2800μm. The formulation of the empirical model for all the resultant spray characteristics which are the spray angle, breakup length, and droplet mean diameter portrays a minimum error. A liquid disintegration regimes map was constructed and showed that both the liquid and gas Reynolds number play important role in characterizing the disintegration regimes. The disintegration regimes also illustrated the capability of this type of atomization to break a bulk liquid with a low liquid consumption. The results of this research may offer a good assistance to sprays community in understanding the swirl effervescent atomization.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Liquid atomization is a process of disintegrating bulk liquid into accumulated droplets. The disintegration process is initiated with the introduction of disturbances. The disturbances are in the form of either turbulence, inertial effects, or changes in velocity profile (flow relaxation or bursting effects) [1] which induce the formation of waves on the surface of liquid jets and sheets. If the conditions permit, the amplitudes of these waves may grow rapidly, resulting in instability and further breakup of the liquid jets and sheets.

One example of atomization mechanism is named swirl effervescent atomization. This atomizer is a combination of swirl and effervescent atomization in one embodiment. This type of atomization has advantages such as a wider spray angle (compared to effervescent atomization) and lesser liquid flow rates (compared to the swirl atomization). The approach of combining liquid atomization in a single atomizer was reported to be advantageous for each atomization. Pandey and Kushari [2] stated that by combining two or more atomization mechanisms into a single atomizer could overcome the drawbacks of the co-atomization.

The liquid atomization or breakup of bulk liquid into sprays can be characterized using a liquid disintegration regime map. A liquid disintegration regime map illustrates stages of liquid disintegration that are subject to forces from the changes of certain parameters. The liquid disintegration regimes for the simplest form of liquid atomization mechanism (i.e. pressure atomization) was explained by Ohnesorge [3]. The liquid disintegration regimes were divided into three sections which are (i) the Rayleigh mechanism, (ii) the sinus wave breakup, and (iii) the secondary atomization as shown in Figure 1.1. The regimes depend on the liquid Reynolds number and a dimensionless number that contains only liquid properties known as Ohnesorge number, Oh. Ohnesorge number gives a measure of the viscous resistance offered by the drop to the external deformation. The higher the value of Ohnesorge number, the