An experimental investigation of discharge coefficient and cavitation length in the elliptical nozzles

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Abstract

This paper presents the results of an experimental study about breakup and flow characteristics on liquid jets discharging from elliptical nozzles into ambient air. Each elliptical nozzle cross-sectional area in this experiments was same but the aspect ratio was diversification. We introduce equivalent diameter ($\sqrt{ab}=D_{eq}$) to define one diameter because elliptical nozzle has different diameter between major axis(a) and minor axis(b). The ratio (L/D_{eq}) of all nozzles which are used in experiment is identical at 4. The results from experiment of an elliptical nozzle were compared with the characteristics of a circular nozzle having the same cross-sectional area. Liquid jet breakup and flow characteristics were analyzed using image captured by image grabber system. Flow rate of each nozzle was measured using flow sensors under same injection condition.

Introduction

Column breakup process injected from the nozzle has been the subject of theoretical experiments. Understanding about column breakup process becomes the foundation of an atomization control and drop formation processes. Column breakup classified dripping region, axial symmetric wave region, asymmetric wave region, atomization region and others according to the increase in flow. Variables affecting at the column breakup have flow condition at spray liquid, surface tension, viscosity, and ambient gas condition[(1)]. So far, the study of the circular nozzle about liquid jet breakup and flow characteristics was relatively active in progress. However, Study about non-circular liquid jet characteristics is not active. T.V Kasyap[(2)] was observed L/D_{eq} of 10 different elliptical orifice the breakup of the liquid jet, and were reported axis-switching in elliptical liquid jet caused by the liquid surface tension and inertia force. Iciek (1982) and Arai (1985) observed hysteresis to perform experiments using the small ratio(L/D_{eq}) and sharp edges nozzle when the fluid flow between the attachment and reattachment. So we used the elliptical nozzle that has the shape edge and a small ratio(L/D_{eq}), breakup and flow characteristics compared with the characteristics of the circular nozzle under same condition, and we investigate about hysteresis of the elliptical nozzle.

Materials and Methods

Fig.1 is an apparatus for this experiment. An apparatus largely consisted of the injection system, measurement devices and the image grabber system. Working fluid is normal temperature water. The Injection system consisted of high pressure chamber, air compressor, nozzles, flowmeter and air regulator. Measurement devices consisted of flow sensor, pressure transducer and A/D convert. Frozen images of discharging liquid jet from the injection system were captured by the image grabber system. We analyzed the image to investigate elliptical jet breakup and flow characteristics such as amplitude, wavelength of liquid jet. We utilized shadowgraph method without lens or mirror to obtain frozen images, measured injection pressure and flow rate by using measurement devices at the same time.

Results and Discussion

Iciek (1982) and Arai (1985) observed hysteresis to perform experiments using the small ratio(L/D_{eq}) and sharp edges nozzle when the fluid flow between the attach and reattach. So we used the elliptical nozzle that has the shape edge and a small ratio(L/D_{eq}=4), breakup and flow characteristics compared with the characteristics of the circular nozzle under same condition, and we investigate about hysteresis of the elliptical nozzle.

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Nomenclature

$R_e = \frac{\rho L v}{\mu}$ Reynolds number

$W_e = \frac{\rho v^2 L}{\sigma}$ Weber number

$D_{eq} = \sqrt{\frac{4 A_N}{\pi}} = \sqrt{a b}$ equivalent diameter [mm]

a major axis length [mm]

b minor axis length [mm]

A_N cross section area [m^2]

C_d coefficient of discharge

D nozzle diameter [mm]

L Hole length [mm]

L_b breakup length [mm]

P pressure [bar]

Q flow rate [m^3/s]

v liquid velocity [m^2/s]

μ liquid viscosity [kg·m/s]

σ surface tension [N/m]

ρ liquid density [kg·m^{-3}]

λ wave length [mm]

z distance from exit nozzle [mm]

References

[1] Arthur H. Lefebvre, *Atomization and Sprays, HEAMISPHERE PUBLISHING CORPORATION, 1989*

[2] T.V. Kasyap, D. Sivakumar, B.N. Raghunandan, "Flow and breakup characteristics of elliptical liquid jets", International journal of Multiphase Flow 35 (2009) 8- 19.

Table 1. Geometrical details for the nozzle used in this study

		A	B	C
Geometry		Circle	Ellipse	Ellipse
Hole	**d1(major)**	2.97	2.471	2.28
Diameter(mm)	**d2(minor)**	2.97	3.665	3.95
Hole area (mm^2)		6.93	7.11	7.07
Hole length (mm)		12	12	12
Aspect ratio		1	1.48	1.73
equivalent diameter		2.97	3.01	3.00

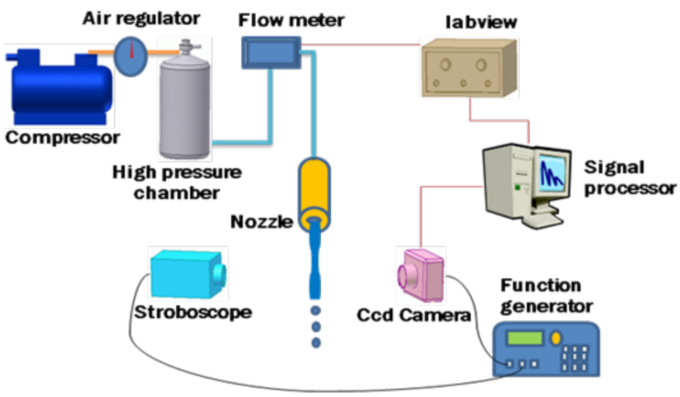

Figure 1. Experimental apparatus