Improvement of Atomization Characteristics of Spray by Multi Hole Nozzle for Pressure Atomized Type Injector

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Abstract

The purpose of this study is to invent high-efficiency atomization enhancement nozzle, which is obtained the spray with large spray angle, short liquid core length and small droplet diameter. In the previous study, the single hole atomization enhancement nozzle, which excellent spray characteristics are obtained at relatively low injection pressure, was developed [1], [2]. In this study, it was investigated about atomization of the spray of the multi hole atomization enhancement nozzle, and aimed to improve atomization characteristics and to obtain excellent spray characteristics. The effects of dimensions of the nozzle on atomization of the spray and atomization characteristics were investigated. As a result, it was clarified that in case of the multi hole atomization enhancement nozzle with hole number of N = 4, breakup length becomes short about 70 p.c. and spray angle becomes large about 60 p.c., spray droplets become considerably small compared with the single hole atomization enhancement nozzle. Atomization characteristics were improved considerably and uniform spray mass flux distributions are obtained by using the multi hole atomization enhancement nozzle with hole number of N = 4.

Experimental Apparatus and Method

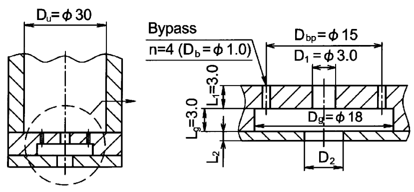
The experimental apparatus consists of a high-pressure pump, a spark light source for taking photographs of the spray. Water at room temperature pressurized by the high-pressure pump was continuously injected under atmospheric pressure condition. Disintegration behavior of the spray was photographed by transmitted light, using a stroboscope. Breakup length of the liquid core, which is defined as distance from the nozzle exit to the breakup point of the liquid core, was measured by electrical resistance method [1] in which a screen detector was used. Spray angle was defined as the spray boundary, and measured by images of photographed sprays.

Schematic of test nozzles are shown in Fig. 1. Test nozzles are the single hole atomization enhancement nozzle [Fig. 1 (a)], the multi hole one [Fig. 1 (b)]. Total sectional area of nozzle holes of the multi hole nozzle is constant of the single hole nozzle.

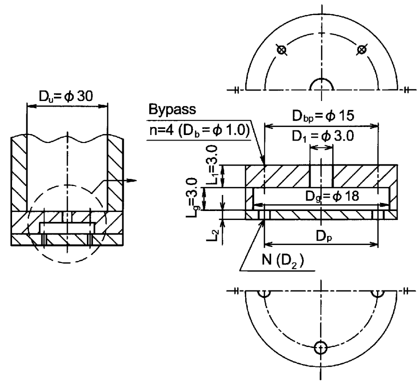
Effect of Hole Number of Atomization Enhancement Nozzle

The effect of hole number of atomization enhancement nozzle on atomization of spray is shown in Fig. 2. In case of the single hole nozzle, although ligaments exist in the spray, spread of the spray is small compared with the multi hole nozzle, and small droplets generates little. In case of the multi hole nozzle, spread of the spray of hole number of N = 4 is the largest, high-dispersion spray is obtained, and a great number of small droplets exist in the spray. When hole number becomes large of N = 8, spread of the spray becomes small. Moreover, in case of hole number of N = 5, although spread of the spray is relatively large, the spray, which was injected from the nozzle center, atomizes little. From these results, it can be seen that the multi hole nozzle with hole number of N = 4 is the most effective to atomize of the spray and to obtain high-dispersion spray.

The effect of spray mass flux distribution is shown in Fig.3. Spray mass flux except of hole number of N = 4 are the largest at nozzle center axis of x = 0 mm, and spray mass flux vicinity of nozzle center axis, for instance, x = 2.0 mm, it rapidly decreases and spray mass flux distribution becomes ununiformed. In case of hole number of N = 4, spray mass flux are obtained uniform distribution at wide ranges to radial direction of x = 15 mm.



(a) Single hole nozzle



(b) Multi hole nozzle

Figure 1. Schematics of test nozzles

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Effect of Bypass Number of Nozzle

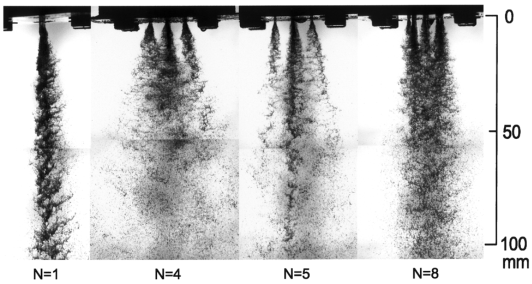
The effect of bypass number on atomization of the spray is shown in Fig. 4. When the bypass was installed, spread of the spray becomes large. To the contrary, in case of the multi hole nozzle, spread of the sprays becomes considerably large and small droplets are obtained compared with the single hole nozzle independent of existence of the bypass and bypass number.

Effect of Hole Diameter Downstream from Gap

The effect of hole diameter downstream from the gap; simply called the outlet hole diameter on breakup length and spray angle are shown in Figs. 5 and 6, respectively. In case the outlet hole diameter is small of D_2=1.5 mm (correspond to the hole diameter of D_2=3.0 mm for the single hole nozzle), breakup length becomes short and spray angle becomes large at all injection pressure regions compared with the large outlet hole diameter of D_2=2.5 mm (correspond to D_2=5.0 mm for the single hole nozzle). These are considered as follows. In general, in case the injection pressure is the same, when volumetric flow rate is large, the spray hardly atomizes. Therefore, the spray of D_2=1.5 mm atomizes considerably compared with the nozzle of D_2=2.5 mm, which volumetric flow rate is large.

Conclusions

1. In case of the multi hole atomization enhancement nozzle, spread of the spray becomes large and breakup length becomes short compared with the single hole atomization enhancement nozzle. Moreover, uniform spray mass flux distributions are obtained.
2. In case of the multi hole nozzle, it is little affected to atomization of the spray, and the spray with large spread angle was obtained.
3. In case total sectional area of the upstream and downstream hole diameters from the gap are the same [D_1=3.0 mm, D_2=1.5 mm (N=4)], spread of the spray becomes considerably large, breakup length becomes short, spray angle becomes large and droplets of the spray become considerably small, compared with larger downstream hole diameter of D_2=2.5 mm.



n=4, D_1=3.0 mm, D_2=1.1 mm - 3.0 mm, D_p=15 mm, P_i=1.5 MPa, P_a=0.1 MPa

Figure 2. Effects of hole number on atomization of spray

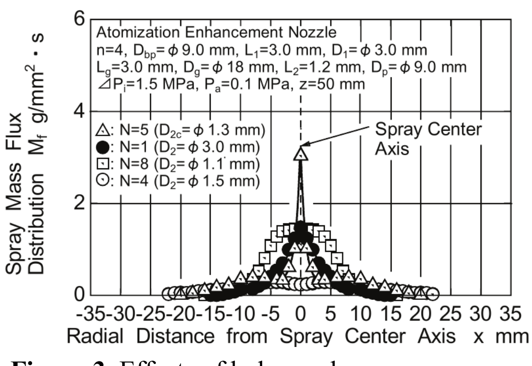
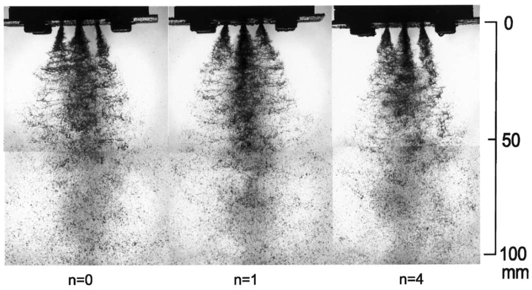


Figure 3. Effects of hole number on spray mass flux distribution



N=4, n=4, D_1=3.0 mm, D_2=1.5 mm - 3.0 mm, D_p=15 mm, P_i=1.5 MPa, P_a=0.1 MPa

Figure 4. Effects of bypass number on Atomization of Spray

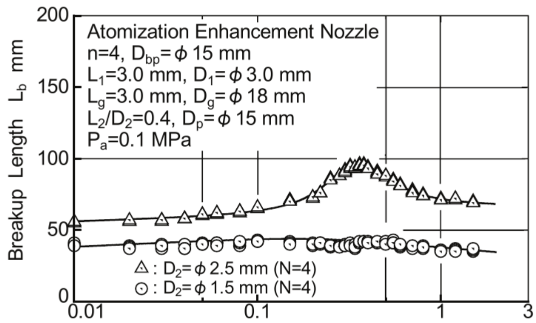


Figure 5. Effects of hole diameter downstream from gap on breakup length

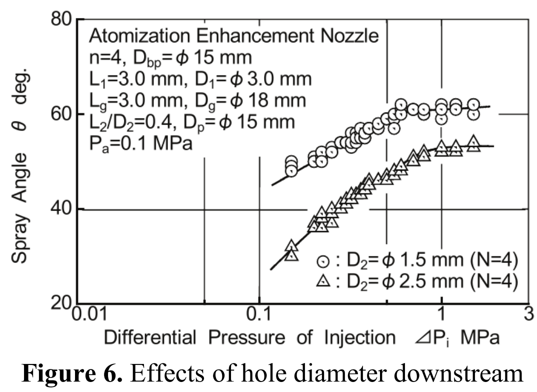


Figure 6. Effects of hole diameter downstream from gap on spray angle