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Paper

CHARACTERISTICS OF AN AIR-COATED ABRASIVE SUSPENSION JET UNDER SUBMERGED CONDITION

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ABSTRACT

A sheathed nozzle with ventilation for producing air-coated abrasive suspension jets (ASJs) has been developed as a means of extending the effective standoff distance and improving the cutting capabilities of the ASJs under submerged conditions. In the present investigation, submerged cutting tests are conducted with aluminum specimens at a jetting pressure of 30 MPa in order to clarify the effect of the air flow rate on the cutting capability of ASJs. The nozzle diameter d used in the tests is 1 mm, and the length of the sheath L_{sheath} is 16 mm. In the small-standoff-distance region, the cutting capability of the ASJ issuing from the sheathed nozzle with ventilation is comparable to that of the ASJ in air. In order to investigate the flow structure of air-coated jets under submerged conditions, high-speed observations and measurements of the flow rate distribution of water jets are also carried out at a jetting pressure of 10 MPa.

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1. INTRODUCTION

A sheathed nozzle with ventilation for producing air-coated abrasive suspension jets (ASJs) has been developed[1, 2] as a means of extending the effective standoff distance and improving the cutting capabilities under submerged conditions. Previous cutting tests[2] revealed that a shorter sheath was preferable for submerged cutting by a sheathed ASJ nozzle with ventilation.

In the present study, submerged cutting tests by ASJs issuing from the sheathed nozzles with ventilation are conducted with aluminum specimens at a jetting pressure of 30 MPa. The nozzle diameter d used in the tests is 1.0 mm, and the length of the sheath L_{sheath} is 16 mm. In order to clarify the cutting capability of the air-coated ASJ under submerged conditions, high-speed observations and measurements of the water flow rate distribution of air-coated water jets are also carried out at a jetting pressure of 10 MPa.

2. EXPERIMENTAL APPARATUS AND METHOD

Experiments are conducted using an ASJ system based on the bypass principle [3]. The maximum working pressure of the system is 35 MPa, but submerged cutting tests are conducted at a jetting pressure p_i of 30 MPa. For details of the ASJ system, the reader may refer to References 1 and 2. The abrasive used in the experiments is garnet having a mesh designation of #100.

Figure 1 shows the water tank and robot used for the submerged cutting tests. The ASJ nozzle head is attached to the robot arm of a Motoman HP 20 six-axis robot. The jet discharges horizontally and the nozzle traverse speed V_T is 2 mm/s. The depth of water at the nozzle head is approximately 100 mm. During the cutting tests, the surface of the water is covered by a plate so as not to take in air through the surface of the water. Air is sucked into the sheath via a plastic tube having an inner diameter of 6 mm. The air flow rate is measured using a float type area flowmeter attached to the end of the plastic tube.

Figure 2 shows a sheathed ASJ nozzle. The diameter d_{sheath} and the length L_{sheath} of the sheath are 3 mm and 16 mm, respectively. An air supply port is equipped at the base of the sheath. A conical convergent nozzle followed by a straight passage, nozzle A10 [4], is used in the experiments. The diameter d and the length of the nozzle straight passage are 1.0 mm and 9.6 mm, respectively. The distances measured from the nozzle exit and from the sheath exit are denoted as X and X', respectively. The distances X and X' are related as follows:

$$X = X' + L_{sheath} \quad (1)$$

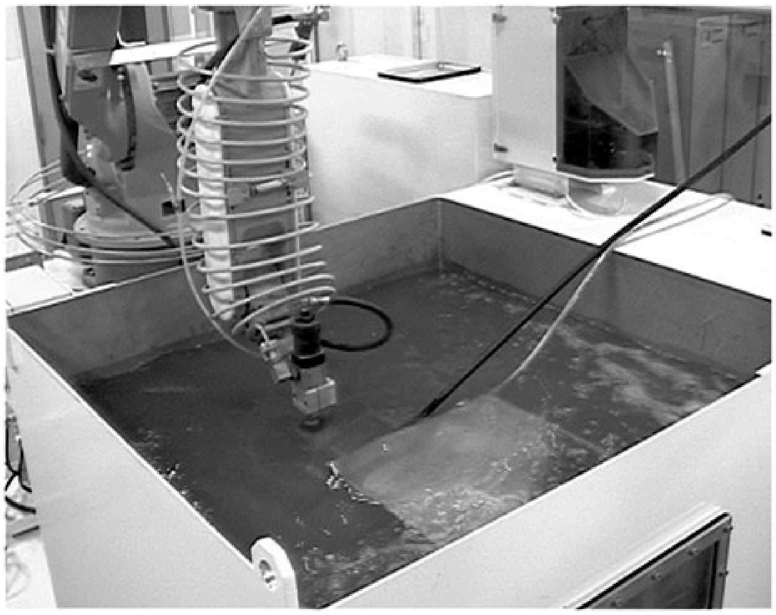

Figure 1 Water tank and robot arm for submerged cutting tests

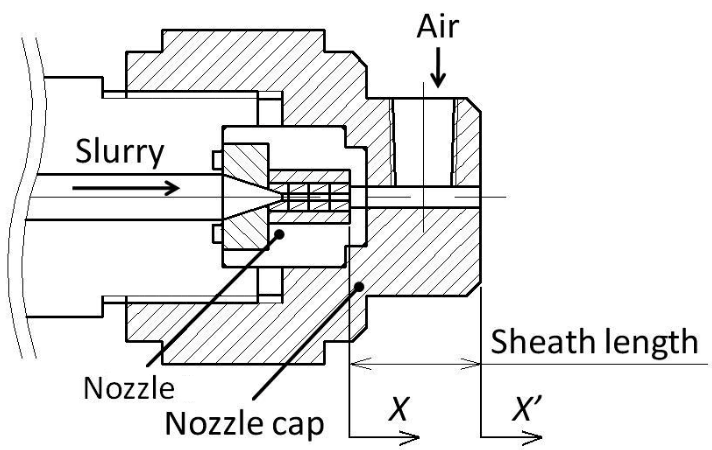

Figure 2 Sheathed ASJ nozzle (sheath length: 16 mm)

In order to clarify the flow aspects of an air-coated jet under submerged conditions, high-speed observations of the flow and measurements of the water flow rate distribution are carried out without the addition of an abrasive at a jetting pressure p_i of 10 MPa. For further details on the high-speed observations and the measurements of the water flow rate distribution, the reader should refer to Reference 5.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 3 shows the relationships between the non-dimensional depth of kerf *h/d* and the air supply rate Q_{air} with respect to non-dimensional distance X'/d = 5, 10, 20, and 40. The abrasive concentration is approximately 25 wt%. The depth of kerf increases linearly with Q_{air} up to some limit Q_{air} but is approximately constant irrespective of Q_{air} in the range greater than the limit Q_{air}. In the case of larger X'/d, a larger air supply is necessary in order to improve the cutting capability. However, an excessive air supply rate does not improve the cutting capability of the submerged ASJ.

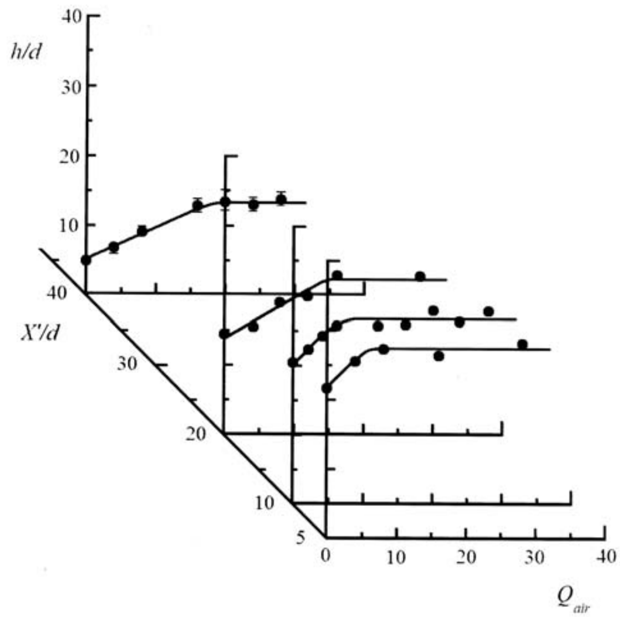

Figure 3 Variation of non-dimensional depth of kerf *h/d* with respect to air flow rate Q_{air} for X'/d = 5, 10, 20, and 40

The relationships between the non-dimensional depth of kerf *h/d* and the non-dimensional distance from the nozzle exit are shown in Fig. 4 for various air supply rates Q_{air}. The cutting results in air are also shown in the figure. The abrasive concentration under submerged conditions is approximately 25 wt%, whereas that in air is approximately 33 wt%. In every case, the depth of kerf decreases linearly with the increase of the distance from the nozzle exit. For the case in which Q_{air} = 28 L/min, the depth of kerf in the small-*X/d* region is comparable to that in air. The cutting capability of the air-coated jet is found to be remarkably improved in the small-standoff-distance region. However, the improvement of the cutting capability by the ventilation is limited in the large-standoff-distance region.

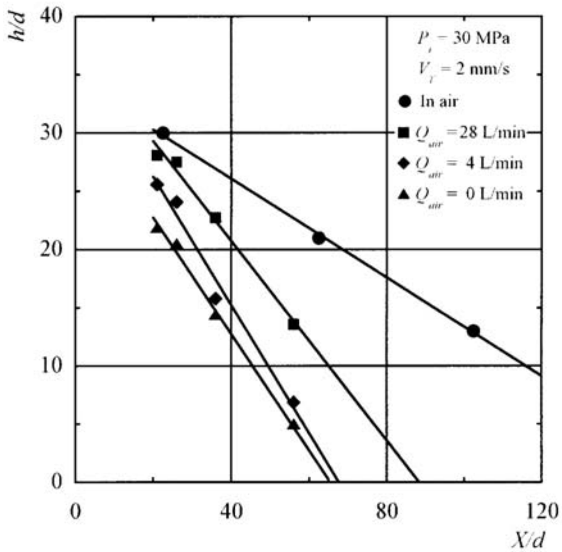

Figure 4 Variation of non-dimensional depth of kerf *h/d* with respect to non-dimensional distance measure from the nozzle exit *X/d* for various Q_{air}

High-speed observations of the air-coated water jet are conducted at a jetting pressure of 10 MPa and an air supply rate Q_{air} of 20 L/min. The non-dimensional sheath length L_{sheath}/d is 16. Figure 5 shows a series of successive images of the air-coated jet at 0.3125 ms time intervals. It is observed that the water jet penetrates through an air-filled cavity in the region just downstream of the sheath exit. The air-filled cavity around *X'* = 5 mm is contracted and the boundary of the air-filled cavity contacts the water jet at *T* = 0.625 ms. After that, the air-filled cavity upstream of the contract point grows until *T* = 3.4375 ms. At *T* = 3.750 ms, the boundary of the air-filled cavity contacts the water jet, and the air-filled cavity upstream of the contact point begins to grow again. The air-filled cavity is very unsteady and tends to pulsate periodically with the increase of the air supply rate Q_{air}. Since, for the large air supply rate, the ventilation does not form a steady air-filled cavity, the cutting capability of the air-coated ASJ in the large-standoff-distance region is much smaller than that of the ASJ in air, as shown in Fig. 4.

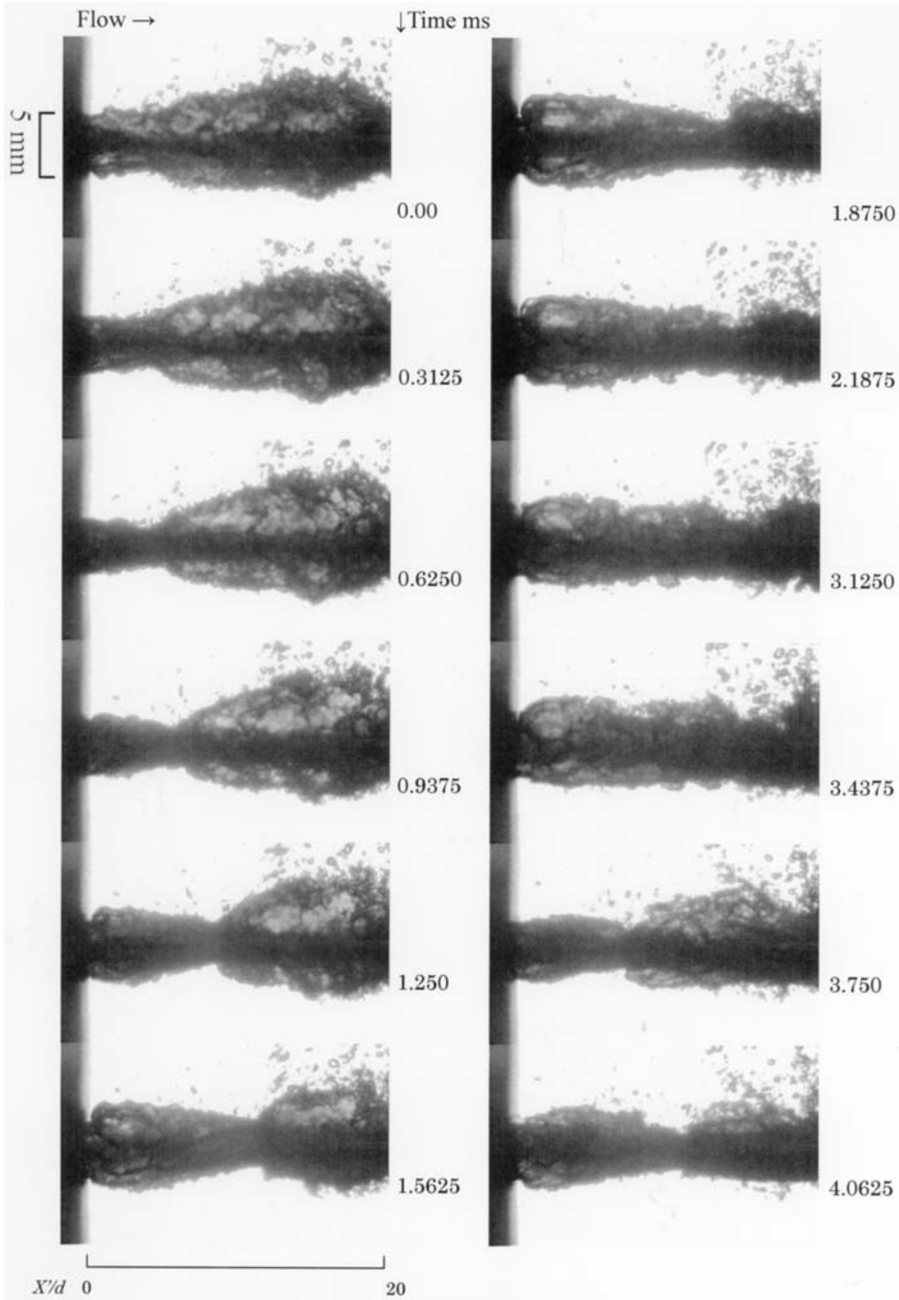

Figure 5 High-speed video images of an air-coated water jet issuing from a sheathed nozzle (L_{sheath}/d = 16, Q_{air} = 20 L/min, p_i = 10 MPa)

In order to investigate the effect of the ventilation on the deceleration of the submerged water jet, measurements of the water flow rate on the jet center line are conducted using a sampling probe with an inner diameter of 0.5 mm. The jetting pressure is 10 MPa. The water flow rate on the jet center line q_c is normalized by the maximum water flow rate of the jet in air just down-stream of the nozzle exit q_{cmax} and is shown in Fig. 6. For the case of the water jet in air, the axial velocity of water lumps is approximately constant, irrespective of *X/d*, in the region of *X/d* < 300[6]. The decreasing tendency of q_c/q_{cmax} for the jet in air is caused by the disintegration of the jet. In the case of the submerged water jet without ventilation, because of the momentum exchange with the surrounding water, the jet velocity decreases rapidly with the increase of the distance from the nozzle exit. When the water jet is ventilated, the deceleration of the jet is suppressed by the formation of the air-coated jet. However, q_c/q_{cmax} for the air-coated jet is smaller than that for the jet in air. The interaction between the air-filled cavity and the water jet shown in Fig. 5 causes deceleration and disintegration of the water jet.

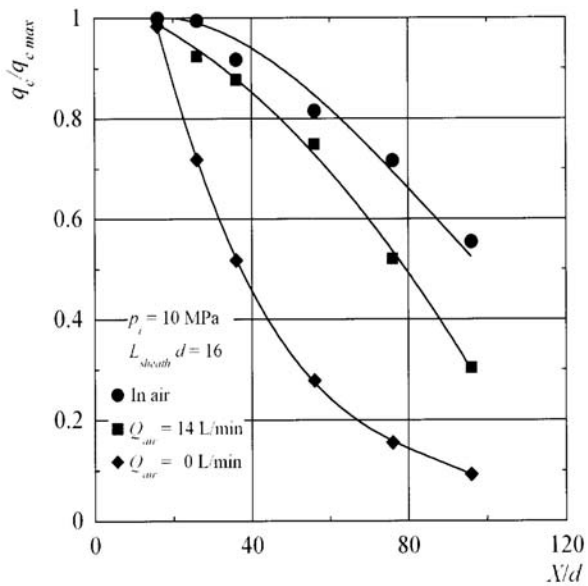

Figure 6 Variation of non-dimensional water flow rate on the jet center line q_c/q_{cmax} with respect to *X/d*

4. CONCLUSIONS

Submerged cutting tests of aluminum specimens by the ASJs issuing from sheathed nozzles with ventilation are conducted at a jetting pressure of 30 MPa. The effects of the air supply rate on the cutting capability of the ASJs are investigated experimentally. High-speed observations of water jets issuing from the sheathed nozzle with ventilation and measurement of the water flow rate on the jet centerline are also carried out in order to clarify the flow aspects of the air-coated water jets under submerged conditions.

In the small-standoff-distance region, the cutting capability of the ASJ issuing from the sheathed nozzle with ventilation is comparable to that of the ASJ in air. The sheathed nozzle with ventilation of sufficient air flow rate forms an air-coated jet in the region just downstream of the sheath exit. The air-coated region is unstable and tends to pulsate with the increase of the air supply rate.

5. REFERENCES

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