

A Simple Expression for Predicting Inlet Roundness of Hydroentangling Nozzles

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Hydroentangling nozzles have a diameter of about 80 to 140 micrometers and are required to have very precise geometries. Their small dimension makes the manufacturing process a major challenge. We have indicated before that inlet roundness (radius-of-curvature) is a critical parameter that needs to be precisely reproduced for all nozzles in a jet strip. It is however, fairly difficult and time consuming to measure the inlet radius-of-curvature of such tiny nozzles accurately, even with the use of powerful microscopes.

We have developed a method for predicting the inlet roundness of hydroentangling nozzles without relying on microscopic methods. This was made possible by obtaining a simple expression for predicting nozzle inlet roundness through measuring its discharge coefficient. Discharge coefficient is defined as the ratio of the actual flow rate to that obtained from Bernoulli equation. Discharge coefficient can be easily and reliably measured.

We have previously demonstrated that hydroentangling nozzles produce constricted waterjets. A constricted waterjet is a laminar stream that is resulted from a detached flow inside the nozzle. When flow detaches from the nozzle wall, it is enveloped by an air gap and so is protected from cavitation or wall-induced turbulence.

We have previously shown that the discharge coefficients predicted by our steady-state two-phase CFD simulations match perfectly results obtained for experimental nozzles. Therefore, we use the same steady-state two-phase CFD simulations on cone-capillary nozzles with inlet roundness values ranging from 0 to 0.1 to estimate the discharge coefficient.

As indicated in Figure 1, the discharge coefficients obtained for nozzles with inlet roundness values ranging from 0 to 0.1 are found to increase with increasing inlet roundness. A simple expression obtained by fitting a 2nd order polynomial to the

simulation data (presented in figure 1) is obtained as follows:

$$C_d = -7.65\left(\frac{r}{d}\right)^2 + 2.48\left(\frac{r}{d}\right) + 0.62$$

$$0 < \left(\frac{r}{d}\right) < 0.1$$

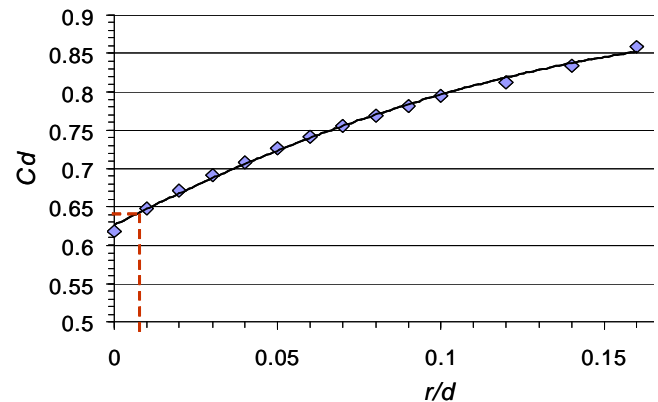


Figure 1: Discharge coefficient of a nozzle conducting a constricted flow increases with increasing the inlet radius-of-curvature. Red dashed line illustrates the discharge coefficient, and its corresponding inlet roundness, of an example of the hydroentangling nozzles made by Nippon Nozzle.

The discharge coefficient experimentally measured using a 128-micrometer diameter hydroentangling nozzle made by Nippon Nozzle is found to give a value of about 0.64 which corresponds to an inlet roundness of $r/d = 0.009$ according to the above equation (shown also by red dashed line in Figure1).

These results are very useful in that clearly, inlet roundness can be determined easily by experimentally determining the discharge coefficient.

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