Note

Note on a vertical water-jet emanating downwards from a slit in the air

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Summary. In this study the critical dimensionless parameters, controlling the alternate 90° turn and oscillation along the axis of a vertical water-jet emanating downwards from a slit in the air are determined.

1 Introduction

When water discharges under some pressure from a circular orifice in a thin plate, a jet is formed, and its section, though diminished in area, retains the circular form. But if the orifice is not circular, the section of the jet undergoes remarkable transformations: A water-jet emanating from an orifice in the form of a regular polygon, of any number of sides, resolves itself into an equal number of thin sheets, whose planes are perpendicular to sides of the polygon [1]. For example, when the orifice is a slit, the section of the water-jet shows a gradual narrowing of the sheet with increasing distance from the slit, until a compact form is attained. Beyond this point, if the jet retains its coherence, the sheet is gradually thrown out again, but in the direction perpendicular to the former sheet and bisecting it vertically. This sheet may, in its turn, reach a limit of development, again contract, and so on.

Geer and Strikwerda [2] have studied the shape of a vertical slender jet of fluid falling steadily under gravity, neglecting the surface tension. Their computational results have shown that in the absence of surface tension the transformation from one section which is flattened in a plane to another section which is flattened in the perpendicular plane can occur only once. Geer and Strikwerda [3] have extended their previous work [2] to include the surface tension. They have demonstrated numerically how the surface tension effects the shape of the jet and the periodic variation of the section.

The main purpose of this study is to find the critical dimensionless parameters, controlling the alternate 90° turn and oscillation along the axis of a vertical water-jet emanating downwards from a slit in the air.

2 Dimensional analysis

In this Section, the important dimensionless parameters associated with the vertical water-jet emanating downwards from a slit in the air will be derived.
First of all, it is postulated that the wave length $\lambda$ of the water-jet which is defined in Fig. 1, depends on the following variables:

$$\lambda = \lambda(A, Q, g, \rho, \sigma, \mu),$$

where $A$ is the slit area, $Q$ the water discharge, $g$ the gravitational acceleration, $\rho$ the water density, $\sigma$ the surface tension of the water, and $\mu$ the dynamic viscosity of the water.

Thus, according to the Buckingham $\pi$-theorem of dimensional analysis [4], (1) can be rewritten in terms of four non-dimensional groups,

$$\frac{\lambda}{A^{1/2}} = f\left(\frac{Q}{g^{1/2}A^{5/4}}, \frac{Qg^{1/2}}{A^{3/4}g^{1/2}}\right),$$

where $v = \mu/g$ is the kinematic viscosity of the water.

Now, all of the $\pi$-ratios will be converted into conventional practice as follows. The first $\pi$-ratio is replaced by $\bar{\lambda} = \lambda/A^{1/2}$, which is the dimensionless wave length. The second $\pi$-ratio is replaced by $Fr = Q/(g^{1/2}A^{5/4})$, which is the Froude number. The third $\pi$-ratio is replaced by $We = Qg^{1/2}/(A^{3/4}g^{1/2})$, which is the Weber number. Finally, the fourth $\pi$-ratio is replaced by