Impacting on Breakup Process of Free Round Jet by Man-made Pulsation

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Summary The breakup problem of free round jets has been investigated for more than one hundred years. Although much experimental and academic knowledge about the breakup is acquired, the phase interface evolvement and the kinetic mechanism are still unclear. Under the different man-made pulsations, the impacting on Taylor type breakup process of free round jet is numerically analyzed by using LES method. The interface between the free air and liquid is studied through VOF method in order to trace the temporal and spatial breakup topology around the surface of the jet. The power spectrums of the pressure fields are analyzed in different man-made pulsation which reveals that the introduced resonant frequency plays the main roles to accelerate the breakup process both in the breakup length and the breakup period.

INTRODUCTION

The breakup problem of free round jet is most important for many series of applications in different engineering projects, such as spray and combustion. Under the new technique and materials development especially in non-Newtonian fluid jets, the understanding about the mechanism of breakup process in free round jet always keeps dire needs. According to the recent development of the theory and practice, the breakup process can be remarkably impacted or even controlled through introducing some disturbances such as periodical man-made pulsations into the initial forming position. For example, the ink powders produced by laser jet printers largely need the manipulating technology to make all kinds of deeper or thinner shapes in text and graphics so as to improve the quality in printing.

As mentioned by Rayleigh, the perturbation increases on the surface of the jet and ultimately changes into breakup when the wavelength is longer than the diameter of free round jet. Rayleigh and Keller applied temporal and spatial instability of a disturbance to the breakup of jet respectively which testifies that the linear theory cannot accurately predict many behaviors of the jet flow in spite of several effective instances such as breakup length. Strayer and so on discovered that the certain type of actuators may regulate the process of the breakup.

In this paper, we investigate the phase interface evolution of free round jet using stability theory and numerical simulation for several governing equations. The intrinsic characteristics and rules of the primary flow can be quantized by some certain variables. The breakup length and breakup period are obviously identified in the temporal evolution process in Taylor breakup. By the power spectrums the main breakup frequency and the second one can be revealed in the distribution of the pressure fields which describes the most important parameters in breakup process. From then on a special manipulating strategy is introduced into the origination of the jet to control the advent of the breakup.

NUMERICAL SIMULATION

A high speed free round jet is simulated in LES method compared with published results. The governing equations include the continuity and momentum equations of multiphase flows which should be coupled with each others. The entire computational domain is shown in Fig.1 and a structured grid system is created in the commercial mesh generation package GAMBIT. Since this problem refers to the symmetrical computer region, only half of the domain shown as Fig.2 is simulated in a axis-symmetric space. Nearby the axial direction the computational meshes keep much denser than the external region and the axial or radial length of the domain is large enough to satisfy the pressure outlet boundary and the wall boundary conditions.

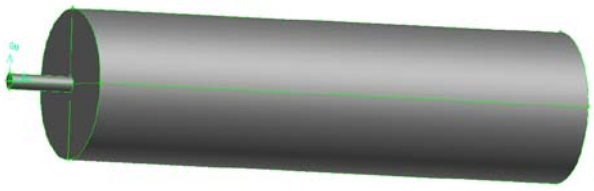

Fig.1 Diagram of computational domain

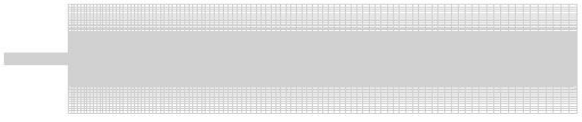

Fig.2 Computational mesh

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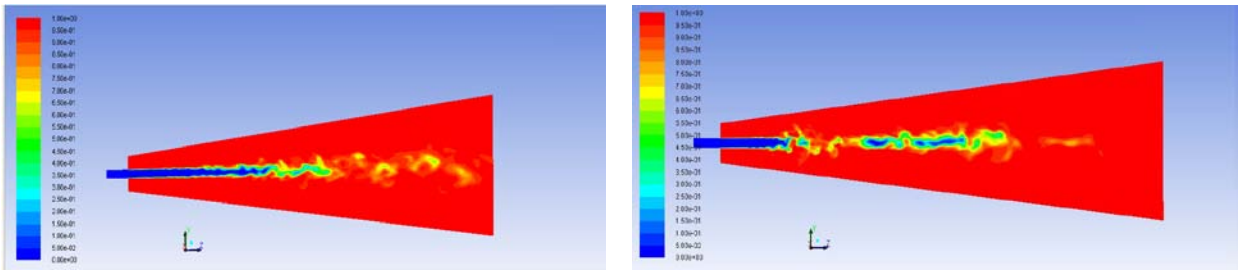
The inlet velocity of the nozzle is set to 50m/s and its exit velocity profile can be obtained by solving the nozzle flow on condition that the diameter of the nozzle equals to 1mm and exit velocity comes up to the fully developed turbulence considering the enough large Reynolds number. The subgrid model and the VOF are adopted to execute the computation of the multiphase flow and Pressure-velocity coupling is achieved by using the PISO algorithm. All the residuals tolerances are set to 10^{-7} and the time step size is 10^{-6} seconds. The jet parameters We is greater 384 which means the jet flow belongs to Taylor breakup. A periodic disturbance regarded as man-made pulsation will be introduced into the nozzle exit in order to impact on the characteristics of the breakup length and the breakup period.

RESULTS

It has been reported by some experiments that different frequencies for the additional disturbance can produce different patterns for the droplets sizes. This will be useful in applications requiring specific size. But what is the controlling mechanism of the breakup is still puzzled. Simultaneously the impacting of man-made disturbance on the other attributive aspects such as the breakup length and breakup period need to be further investigated. In this paper, a periodic disturbance is introduced into the primary round jet and then leads to the different breakup behaviours as shown in Fig.3 which indicates that the spatial distribution of the two phase, namely air and liquid at an instantaneous time. The breakup length of jet with man-made pulsation is obviously shorter than that of the original jet flow. Seen from the Fig.4, an obvious peak value equaling to the frequency introduced by man-made pulsation in the power spectrum of the pressure fields reveals that the external disturbance has the great effects on the breakup of the free round jet which leads to the shorter breakup length as shown in Fig.3.



(a) (b)

Fig.3 Contours of the volume fraction of jet
(a) Without man-made pulsation (b) With man-made pulsation

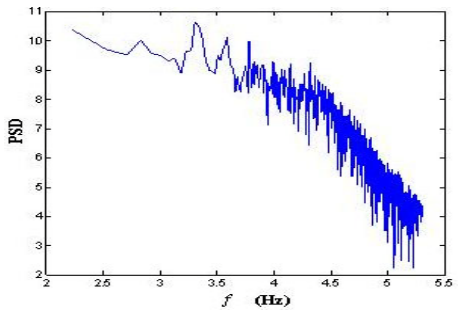


Fig.4 Power spectrum of pressure fields

CONCLUSIONS

Under the manipulating of the man-made pulsation on the free round jet, an remarkable reduction of the breakup length which indicates that an obvious resonance effects are produced when the disturbance frequency comes up to the system frequency of the jet flow.

Acknowledgements

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