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The Numerical Study on Dynamics of Air Blasted Liquid Sheet

Takuya NAMEGAWA[1], Akiko MATSUO[1]

[1] Department of Mechanical Engineering, Graduate School of Science and Technology, Keio university, 3-14-1, Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, JAPAN
E-mail:takuya_keio_university@z2.keio.jp

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Atomization technology is applied to a wide range of industrial processes. On pre-filming air blast atomizer, which is one of the popular atomizers in gas turbine engine, atomization is caused by strong interactions with airflow and thin liquid film. In order to enable better mixing, it is well known that primary breakup is a dominant factor to characterize atomization property. In the past several decades, many experimental and theoretical studies were conducted on air-blasted/assisted liquid sheet. These approaches have given us useful knowledge on engineering application. However, dynamics of the breakup process has not been revealed yet in detail because of some experimental restrictions.

Meanwhile, it has been possible to simulate detailed atomization mechanism due to the development of numerical simulation methods and computer performance these days. For example, Shinjo and Umemura[1] performed simulation for primary breakup of liquid jet injected to static air using CIP-LSM(CIP-based Level Set & MARS)[2]. By using such numerical approach, we can easily obtain physical information regardless of complexity of the focused flow field. This point is a great benefit compared with experimental approach. In order to clarify the main factor of unique deformation in air-blasted liquid sheet atomization, a numerical investigation on dynamics of air blasted liquid sheet is carried out in this study.

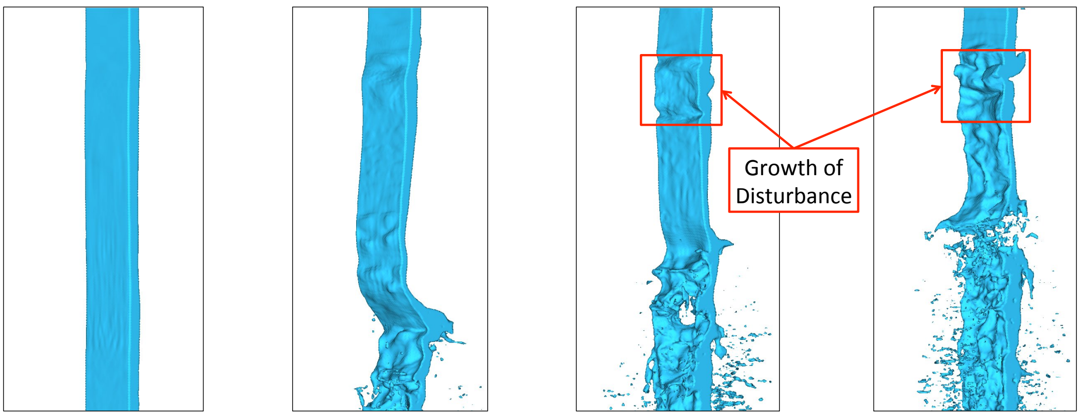
CIP-LSM is adopted for the analysis of atomization process. In this method, the governing equations for homogeneous two-phase flow are solved with TCUP[2], which is a fractional step method and the independent variables are $\vec{u}, T, p$. Density is calculated from EOS for each phase. HLSM (Hybrid Level Set & MARS)[2] employed as the surface tracking method. HLSM is a combined method of Level Set and MARS that is a kind of VOF approach.

As mentioned in the past several experiments, breakup of liquid sheet was observed in the vicinity of water and air nozzle exit. Therefore, the region should be chosen for the calculation target. Generally, it is said that Weber number is a predominant non-dimensional parameter for atomization process. In this calculation conditions, an air inflow velocity U_a changes from 10 m/s to 40 m/s with 10 degree incident angle and a water inflow velocity U_w is fixed. Therefore, Weber number changes from 0.70 to 12.79 along with U_a. In addition, Losano *et al.* [3] proposed the liquid sheet oscillation modes, which play an important role in spay characteristics, are classified by MFR (Momentum Flux Ratio). According to the classification, it is expected that transition to Mode 0, in which the liquid sheet is immediately broken up near the nozzle exit, is observed in U_a=30 m/s, 40 m/s conditions. Other physical properties, pressure, temperature, and surface tension were based on the values under the standard condition. Liquid sheet of thickness 0.5mm was prepared for the initial condition.

In our analysis, the dynamics agrees with their classification of oscillation mode qualitatively, though the airflow had no incident angle in Losano *et al*'s experiment. No oscillation is observed in 10 m/s condition. In U_a=20 m/s, the liquid sheet oscillation is periodic, while those of U_a=30 m/s, 40 m/s are not. Probably, the transition of oscillation mode occurs in these conditions. They mentioned that transition to Mode 0 seemed to be influenced by not MFR, which is dominant in other transitions, but another factor. In Fig.1, the liquid movement at the early stage in each air velocity is shown. This interface motion is caused by Kelvin-Helmholtz instability. We suggest that one of the factors for such transition should be growth of initial disturbance in recirculation region at near nozzle.

On the breakup patterns, Arai and Hashimoto[4] experimentally investigated the breakup of thin liquid sheet in a concurrent airflow. They suggested that the patterns of the disintegration should be divided mainly into two breakup patterns. These patterns are the primary breakup and the secondary breakup. Furthermore, they classified each breakup pattern into several types. According to their breakup classification, lump and ligament type are dominant in both the primary and the secondary breakup. In our simulation, the frequently observed patterns are ligament type in the primary breakup and lump type and ligament type in the second breakup. These trends are similar to Arai and Hashimoto's observation. Moreover, the pressure distribution in liquid ligament is analogous to that of formation of a liquid droplet by pinch-off phenomenon. From this result, it is also confirmed that ligament type breakup is driven by capillary wave.

Finally, investigations of droplet diameter distribution and spray angle, which are very important parameter in engineering, are conducted. Though these results are needed more considerations to validity, including more detailed grid refinement study, these parameters correspond to some experimental results qualitatively.



(a) 10 m/s (8.4 ms) (b) 20 m/s (7.2 ms) (c) 30 m/s (4.4 ms) (d) 40 m/s (3.5 ms)

Fig.1 The deformation of liquid sheet at early stage

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