METASTABLE LIQUID TRANSIENT DISPERSING PHENOMENA INDUCED BY DYNAMIC LOADING

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Abstract In this paper, a brief survey is given to the research backgrounds of liquid dynamic dispersion for presenting some problems to study firstly. Second, some experimental results about the characters of liquid dispersion are demonstrated. Third, by the numerical analysis and other experimental results, the mechanisms of the metastable liquid transient phenomena induced by dynamic loading are proposed.

INTRODUCTION

Liquid transient dispersions induced by dynamic loading source are very complicated multi-scales and multiphase phenomena [1]. Many scientific works about the dynamic liquid dispersions have been made by worldwide researchers from much of industrial application fields. The dynamic loading source can induce shock wave with high strength penetrating the liquid, while produce a vast expanding gas compressing the liquid. A representative liquid dispersing device is composed of central dynamic loading generator or dynamic source, the liquid as a dispersing substance around the dynamic source and the external confined side shell (See Figure 1). Some theories supposed that the action of expanding gas produced by dynamic source is as a piston compressing and driving the liquid moving centrifugal outward, while the side shell impacted by shock wave will tends to breakup [1, 2]. When the side shell breaks, the liquid will continues moving centrifugal outward as a continuum. Therefore, a liquid annulus model was proposed that with the dynamic action of central expanding gas, the liquid annulus will expand thinner and thinner, while the perturbations on the inner interface (between gas and liquid) and outer interface (between liquid and air) will increase, and finally the liquid annulus will break to small drops. [2] At last, small drops will mix with the gas and air, continue to break or evaporate and form aerosol clouds [3]. A Samirant's experimental picture obtained by Flash X-Ray Radiograph was related evidence (See Figure 2) [4]. In order to calculating the clouds size and the distribution of liquid droplets, many scientists and engineers accepted the above theory for fear of the complex physical mechanism. But the deviation obliged to ask what the real dispersing state of liquid is, droplets or gas? How can we estimate the exact state of dispersing liquid? Other theories supposed that the liquid in the shell may be divided into two regions under the impact actions by shock wave and expanding gas, one is compressing region near the inner interface and other is uncompressing region near the side shell. Due to the potential energy accumulating from dynamic source, the liquid in the compressing region will disperse with inertial – called inertial dispersion. Due to the kinetic energy converted from dynamic source, the liquid in the uncompressing region will disperse with turbulent flow – called turbulent dispersion [1]. But what are the compositions in inertial dispersing and turbulent dispersing flow? What is the real state of liquid dispersing flow? In this paper, the real state of liquid during dispersion will be demonstrated and the mechanisms of dispersion will be exposed.

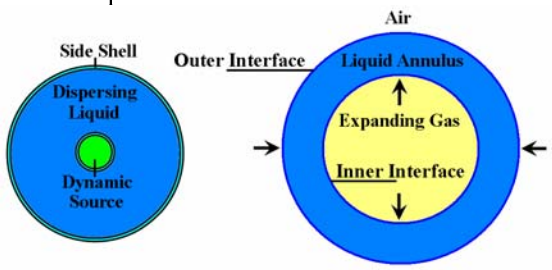

Figure 1. The experimental Model and Liquid Annulus Model.

Figure 2 A Liquid Annulus Picture by Samirant [4]

LIQUID TRANSIENT DISPERSING PHENOMENA

In every experiment, a series of pictures liquid dispersing flow can be photographed by a high-speed CMOS camera. When the dynamic source is small charge, the dispersing characters of liquid are like some pin, jet or sheet in an annulus region. This annulus liquid region is not a continuum, and is stretched to a sparse state by the rarefaction waves (See Figure 3). In Figure 3, from a to c, with the charge increases, the dispersing liquid becomes to vaporizing state with gas-liquid mixtures, so that we can not identify the difference between droplets and gas.

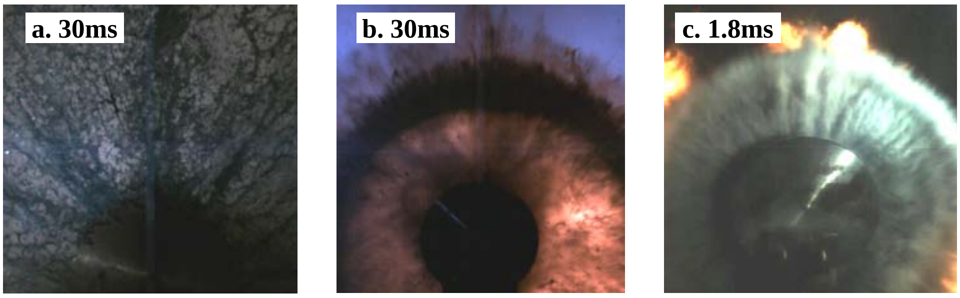

Figure 3 The pictures of liquid dispersing flow when the dynamic source is small charge [1]

When the dynamic source is large charge, the dispersing characters of liquid are jet with gas-liquid mixtures. Figure 4 are the pictures recorded by two high-speed CMOS cameras with 20000fr/s from different directions.

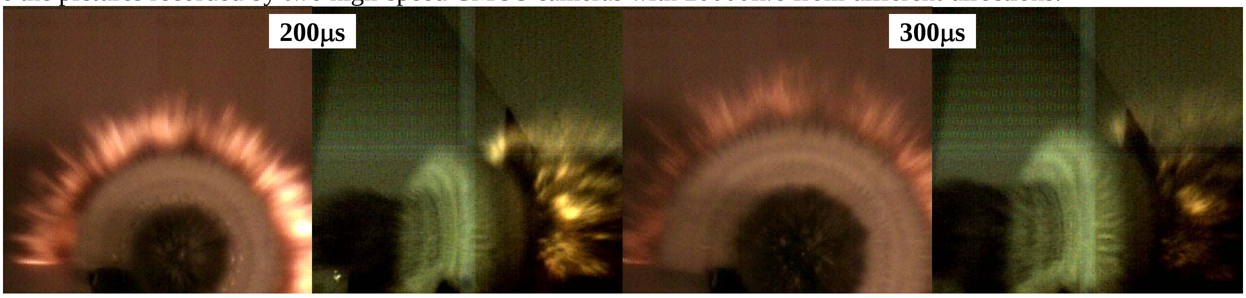

Figure 4. The pictures of liquid dispersing flow when the dynamic source is large charge.

THE MECHANISM OF LIQUID DISPERSION BY DYNAMIC LOADING

With numerical analysis, we can see the negative pressure region appearing near side wall, the inner interface and bottom end wall (See Figure 5 a). It means that where the liquid pressure is lower than its saturated pressure, the cavitations will come into being. The experiment of unconfined liquid dispersion can give evidence [ ]. Apply the equation of state of water [ ], we also obtain the temperature at 12 tracking points (See Figure 5 b).

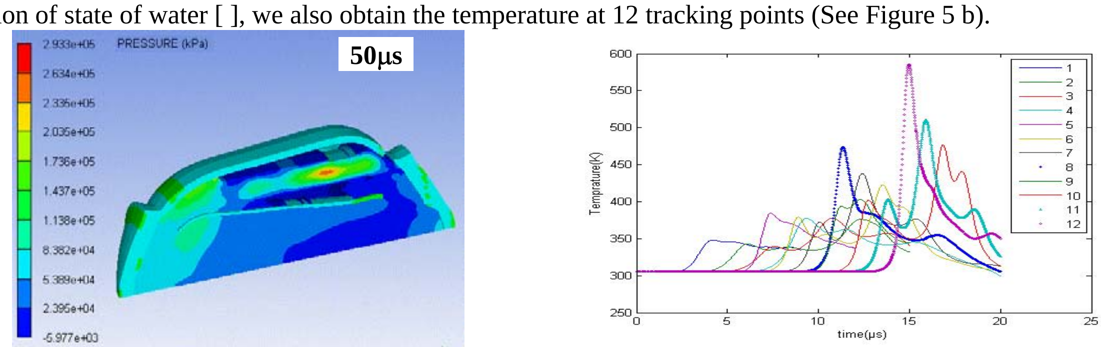

Figure 5 Pressure field in the container and the temperature at 12 tracking points

From the Figure 5 b, the highest is about 580K (lower than the critical point 650K) and there is a temperature platform at about 400K after 10s (higher than the boiling point 373K). That means that before the confined side shell break, the thermodynamic state of liquid has been changed by the impact action of dynamic shock waves and stretching action of strong rarefaction waves. The liquid state means a metastable liquid state or a superheated liquid with cavitations and nucleation induced by dynamic loading. Therefore, when the confined side shell break, the metastable liquid will evaporate into gas – liquid mixture rapidly while dispersing centrifugal outward. The mechanisms of liquid dispersion by dynamic loading presented here is a breakthrough to the liquid annulus model by Gardner, and render a new regime to the process of liquid dynamic dispersion. A one-dimensional model has been proposed to calculating the vaporizing rate. However, more works should be made to establish two-dimensional and three-dimensional model in the future.

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