Observation of Primary And Secondary Breakup of Turbulent Liquid Jet in A Cross Flow

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Abstract:
Liquid jet in cross flow are widely used and play an important role in the propulsion system, such as ramjet combustion. In this paper, we will study about the primary and secondary breakup of turbulent liquid jet in a cross flow. In this, the Weber number controls the breakup of liquid column. The instability wave along liquid column leads to breakup of liquid jet. The primary and secondary breakup of the liquid jets still represent big challenge for the research community since both experimental and stimulation method are not yet been capable of capturing complete underlying physics. In this paper, we will study about Dispersed Phase Element (DPE) and its shedding which leads to the primary and secondary breakup. We will observe the characteristics of the primary and secondary breakup.

Keywords: Primary and secondary breakup of liquid column, instability waves, DPE.

I. INTRODUCTION

Liquid jet in gaseous cross flow are widely used in various propulsion system, such as gas turbine combustion, liquid jet rocket engine, diesel engine, ramjet engine and scramjet engine. The liquid jet atomization is achieved in two stages (primary breakup and secondary breakup). Atomization is the most important process which involve the mixing of the air and fuel for the efficient and the combustion process. Today it is accepted view that modern high pressure injector are used which produced a rapid atomization. Still the mechanism responsible for the jet breakup are not fully understood which makes it difficult to draw universal correlation liquid jet.

II. PRIMARY BREAKUP OF LIQUID COLUMN

Atomization of liquid fuel control combustion efficiency and pollutant emission of internal combustion engine and gas turbine. The liquid jet in the cross flow (LJCF) finds its application in lean premixed pre-vaporized (LPP) ducts, after burner for gas turbine, and combustor for ramjet and scramjet. This flow configuration which consist of turbulent liquid jet injected transversely into a gaseous laminar or turbulent flow which mainly focus on the liquid breakup.

Large liquid structure ligaments and drops that have just broken off the liquid column and classified to be part of the primary breakup regime are shown in dark grey. Ligaments and drops that constitute the secondary breakup regime are shown in light grey. A typical turbulent LJCF exhibits a Kelvin-Helmholtz type instability wave on the windward side of the liquid column. These waves travel along the liquid column and ultimately leads to the breakup around the time the liquid jet reaches the maximum penetration in the transverse direction. The liquid Weber number control the tendency of a liquid jet to breakup up, while the liquid Reynolds number control the range of length scale in a liquid jet turbulence. The most relevant parameter for the drop breakup criterion is the Weber number.

![Figure.1.Schematic Of Turbulent Liquid Jet In Cross Flow Illustration A Typical Breakup Scenario](http://ijesc.org/)
\[ \sigma \] = the surface tension of the fuel

Weber number is the ratio of disruptive aerodynamic force to capillary restoring force to capillary restoring force. The critical Weber above which a droplet disintegrates is \( WE = 10 \) (Hanson et al. 1963). When Weber number is high (\( WE > 200 \)) another mode of breakup called shear breakup become dominant. During shear breakup, aerodynamic force exerted by the flow on the surface of liquid jet or ligament strip off droplet by shear. Though both mode of breakup contribute to atomization of the liquid jet the domination of one mechanism over the other is dependent on Weber and on liquid jet momentum flux to air momentum flux ratio \( (q) \). [3]

For high Weber number and momentum flux ratio, a turbulent liquid jet with circular cross-section gradually changes to almost crescent shape [1]. These crescent shape small droplets are called the primary droplet. In which the ligament, drops and other structure are termed to be as dispersed phase element. These DPE’s shed along the edge of the crescent shape of the liquid column. The shedding of the DPE’s is prominent at the location of the travelling of waves and might be a primary source for DPE product in the LJCE. The primary breakup in the LJCE is referred to as the first stage of liquid breakup which involves the shedding of DPE and there involves the several step during the process. When DPE’s are shed from liquid column they are not in the circular shape. The shape depends upon of the speed and velocity of the shedding of DPE [1] The DPE may undergo further breakup which is called the secondary breakup. The second stage of breakup called the secondary breakup. Experiment says that distribution of the drop into primary and secondary droplets. A part from this other drops may form by joining the drops and ligaments and other drop source. Thus the primary breakup of LJCE must capture the size distribution or also it is called a volume distribution which is noted after shedding of DPE's [1]. The primary and the secondary breakup is show below [5].

### III. SECONDARY BREAKUP OF LIQUID COLUMN

The high speed liquid column which comes from the injector will increase its speed at the secondary breakup time. When the ambient air mixing with the secondary breakup and provide good combustion [3]. Due to the high droplet velocity the catastrophic or stripping breakup may occur. The parental droplet disintegrate into child droplet that further breakup to the small possible droplet size [3]. At the high Weber number the atomization in simulated by using the Kelvin -Helmholtz model with the Rayleigh Taylor accelerative instability. If the breakup length decreases with the increases of the gas Weber...
number, in addition to its increase with the increase of the momentum ratio. The droplet diameter decreases with the increase of both gas Weber number and momentum ratio although the gas Weber number will dominate the breakup process. The typical secondary breakup diagram is given below [6].

![Figure 4. Secondary breakup liquid column](image)

**IV. CONCLUSION**

The observation of the primary and secondary breakup is done. The primary breakup of the liquid column is almost crescent shape. Its velocity is less when compared to secondary breakup. We also observe that during the primary and secondary breakup there will be ligament and other drop source present. The secondary breakup of the fuel which is small tiny droplet with high speed reacts with hot and high pressure air in transverse direction, in which combustion process inside the engine takes place which produces the thrust for the plane.

**V. REFERENCE**


[6]. M. Broumand...M. Birouk: liquid jet in a subsonic gaseous cross flow: Recent progress and remaining challenge; volume 57, november 2016 ,page 1-29