Experimental Measurements of Impinging Jet Atomization at the Vicinity of Liquid Fan

Ryota Sakisaka[1], Jun Hayashi[*1], Yu Daimon[2], Nobuhiro Yamanishi[2],
Fumiteru Akamatsu[1]
Affiliation, Osaka University, Japan[1], Japan Aerospace Exploration Agency, Japan[2]
sakisaka@combu.mech.eng.osaka-u.ac.jp, j.hayashi@mech.eng.osaka-u.ac.jp,
daimon.yu@jaxa.jp, yamanishi.nobuhiro@jaxa.jp, akamatsu@mech.eng.osaka-u.ac.jp

Abstract

Atomization by the impingement of two liquid jets of fuel and oxidizer is utilized as the primary process of combustion in the liquid thrust chamber of liquid propellant thrusters because of the compact size and the reliability of reigniting. Liquid propellant thruster has many merits, for example easily controlled thrust and high specific thrust. Breakup mechanisms of impinging jet atomizers consists of three main steps, i.e. formation of liquid fan, disintegrate to the liquid fragment and breakup into droplets. These processes of atomization are affected by the influence of aerodynamic, viscous, inertial and instability wave appeared on the liquid surface. Atomized droplets are ignited by its hypergolicity in thrust chamber. Computer fluid dynamics (CFD) has been applied to the analysis and development of the combustion chamber to reduce the costs of development. Since it is difficult to deal with the atomization process with combustion process at the same time in CFD, a simple model of atomization is used in the CFD. To make precise prediction of atomization and combustion phenomenon in the liquid propellant thruster, it needs to verify the impinging atomization model to the actual phenomena. In this study, in order to verify the reported numerical model, experimental measurements of impingement atomization process were conducted by using high-speed imaging and phase Doppler anemometry.

To simplify atomization phenomena, like-on-like impinging jet atomizer is used. The water is used as the test liquid, which is fed from N_2 pressurized tank to the test nozzle. Two flow channels are completely separated in order to stabilize flow rate. Droplet size distribution and vertical velocities of droplets are measured by phase Doppler anemometry (PDA). The light source is an Ar^+ laser. The region of liquid fan and ligament appearance is estimated by the results of high speed imaging. The measurements are conducted under two different Weber number with 336 measurement points in the x-y plane. Here, the x-y plane is the same plane of liquid fan. The average characteristic values of spray (e.g. Sauter Mean Diameter (SMD), droplet velocity) are obtained by using 20,000 samples at each point. This is enough number to obtain the average value.

The liquid fan and ligaments region were found from results of the high speed imaging. The region of liquid fan and ligaments were smaller than that of the theoretical analysis. This was because liquid jets and liquid fan had the larger instability in its flow than theoretical analysis. The SMD was small under high Weber number condition at all measurement points. And the SMD increased with increasing azimuthal angle from vertical axis. In addition, the SMD increased with increasing distance from the disintegration point. This is because there are many non-spherical droplets, which is ignored in the PDA measurement, at vicinity to the disintegration point. Non-spherical droplets became spherical with increasing distance from the disintegration point, and became possible to be measured by PDA. And From results of the PDA measurements in horizontal plane, mass flux is weighted in the center axis though SMD doesn't change in a direction perpendicular to the liquid fan. Spatial gradient of the mass flux became smoother with increasing distance from the disintegrated point. Currently, impinging atomization model doesn't consider mass flux distribution in a direction perpendicular to the liquid fan. The results indicated that the mass flux distribution should be taken into account to make a precise prediction of impinging atomization.