Experimental Investigation on Spray Characteristics of Pressure-Swirl Atomizers for a Small-Sized Jet Engine

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Abstract

Within a design update of a small-sized jet engine combustor the original spill-return pressure-swirl atomizer is intended to be replaced with a newly designed low flow rate simplex atomizer. Objective of this study was to investigate the differences in spray morphology and atomization quality of both atomizers and the possible impact on the combustion process. Both atomizers were tested on a recently designed cold flow test rig including mobile fuel supply system with PC-based acquisition of flow rate, gauge pressure, liquid density and temperature readings in several regimes over the gauge pressure range from 150 kPa up to 1 MPa based on the typical operating conditions of the engine, from start and idle to maximum power regime.

Spray characteristics were studied by means of two established laser measurement techniques in fluid mechanics – Phase/Doppler Particle Analyzer (P/DPA) and Particle Image Velocimetry (PIV). These techniques complement each other; PIV gives instantaneous velocity distribution in the whole flow field and P/DPA gives both the droplet velocity and droplet size simultaneously in selected measurement points.

A 1-D P/DPA system was used for characterization of the atomizers in terms of their liquid distribution and droplet velocity. Data were acquired in two different planes normal to the atomizer axis in 25 mm and 50 mm distance downstream of the discharge orifice.

As for PIV, measurements were carried out in an axial section of the spray yielding 2-C and 3-C velocity vector fields. In case of the SPIV measurements, cameras were placed on the same side of the light sheet with 80° stereoscopic viewing angle between the lens axes.

Our measurements revealed that the new atomizer generates spray that differs from the original atomizer in terms of atomization quality and spray morphology. The new nozzle also showed different response to changes in gauge pressure, which may mean different demands on power regulation of the jet engine. Spray pulsations of the old atomizer have been observed in all operating regimes by fluctuating cone angle. The new atomizer was much more stable without any visible fluctuations in cone angle. The spray droplets generated by the new nozzle have lower Sauter mean diameter and lower droplet velocities at higher pressure regimes (Figure 2). This difference results from the different internal geometry of the new nozzle. Results of the SPIV measurements allowed determining the magnitude of the tangential velocity component.

Investigated differences will influence the behaviour of the nozzle in the combustion chamber, affecting mainly the evaporation, heat release and flue gas emissions. This study provides an extensive database for validation of numerical models of the tested nozzles.

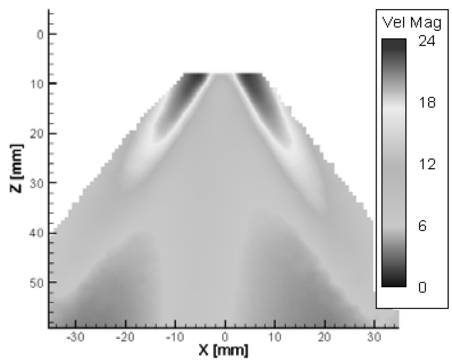

Figure 1 Velocity magnitude of droplets generated by the original spill-return nozzle at 690 kPa inlet pressure.

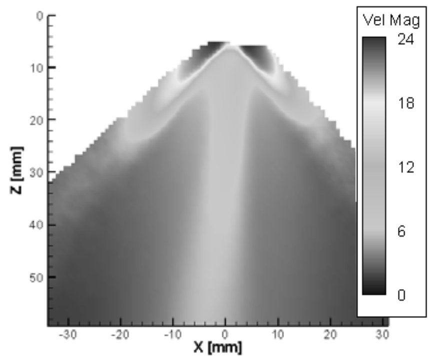

Figure 2 Velocity magnitude of droplets generated by the newly designed simplex nozzle at 690 kPa inlet pressure.

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