Decoding fragmentation mechanisms in supersonic spray via MHz X-ray imaging

Topics: experimental; turbulent two-phase flows; supersonic flows; X-ray; data and image processing
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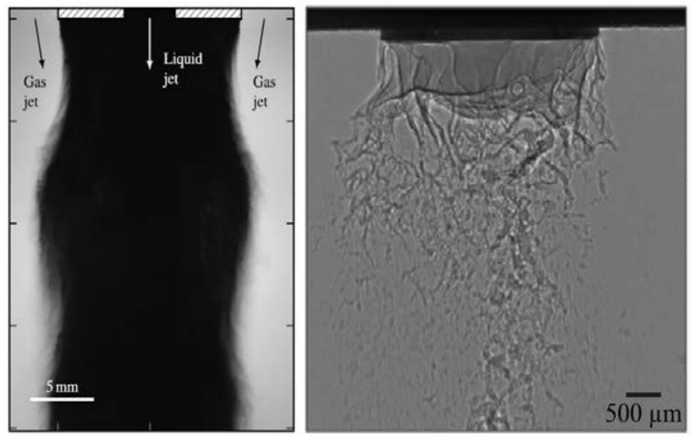

Context: In gas-assisted atomization, a liquid jet is broken into fine droplets by a high-speed gas jet. Supersonic spray technology enhances this by atomizing liquids at speeds exceeding Mach 1, improving multiphase fluid mixing and increasing surface area. This method is crucial in industries like manufacturing and space propulsion. However, current trial-and-error approaches fail to establish reliable correlations between spray and injection parameters due to the inability to visualize the process. Traditional visible light techniques are ineffective because of scattering and overlapping interfaces from fine droplets (see left image, from *Apell et al. 2024*). Existing models struggle to predict supersonic atomization, where gas velocity exceeds the speed of sound and shock waves are key to fragmentation. Supersonic atomization is vital in metal powder production for additive manufacturing, where balancing energy costs and powder quality is challenging (*Qaddah et al. 2024*). The variety of atomizer designs highlights the lack of fundamental knowledge. The proposed research aims to understand the underlying mechanisms and develop predictive models for supersonic atomization, using additive manufacturing as a key application.

Project: This doctoral project will study the complexities of spray atomization dynamics, focusing on primary and secondary fragmentation processes in supersonic sprays. The goal is to identify key control parameters by acquiring measurements not available in current literature due to the obscurity of fragmentation in supersonic sprays. This will be achieved using unique X-ray imaging techniques at the beamline ID19 (see right image), which can probe appropriate temporal and spatial scales near the nozzle exit where most atomization occurs.
The research aims to:

- Develop X-ray imaging techniques to quantify particle size during spray atomization, especially for very fine sprays where laser interferometry is ineffective.
- Quantify the leading mechanisms in primary and secondary spray fragmentation, focusing on the interplay between instability and shock dynamics, which are challenging to study with typical imaging techniques.
- Identify key components controlling supersonic turbulent two-phase flows to build scaling laws and models for practical applications.

X-ray visualizations of the atomization process (Mach 0.9): https://www.youtube.com/watch?v=JwELbDK4frY

References: Apell, N et al. Hussong, J. (2024). *Powder Technology*, *448*, 120199.
Qaddah, B et al. (2024). *Powder Technology*, *438*, 119665.

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