Liquid CO2 Jets at Atmospheric Pressure for Cutting Applications

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Water jet cutting is a well-established industrial manufacturing technique for cutting various materials. For the jet cutting process, water is pressurized to some thousand bars before decompressing through a nozzle to atmospheric conditions to form a jet. Instead of water, other fluids can be used as a cutting medium. Using liquid carbon dioxide (CO_2) as a cutting medium enables residue-free and dry processing of water-sensitive materials, because CO_2 completely evaporates after cutting. The process is also promising for treating toxic or harmful materials, as no contaminated wastewater is produced.

In the cutting process, liquid CO_2 is taken from a CO_2 cylinder and compressed to up to 3000 bar. Afterward, it is cooled to the desired pre-expansion temperature and directed to the cutting nozzle. Through the nozzle flow, considered isentropic, the CO_2 is depressurized to atmospheric pressure. At thermodynamic equilibrium, the CO_2 should be solid-vapor at expansion conditions. However, a liquid CO_2 jet of some centimeters length can be observed, indicating metastability. This is especially the case for very small nozzles with diameters below 0.1 mm and low temperatures before the nozzle of about minus 20 °C. After a few centimeters of coherent liquid jet, phase transition into solid-gas phases occurs, and the jet breaks up into a spray.

In the last few years, CO_2 jet cutting has been subject to intensive research. Factors such as pre-expansion temperature and pressure significantly influence cutting properties such as stability or jet length. Post-expansion conditions, such as the density of the surrounding atmosphere, also affect the jet break-up. So far, by adjusting these parameters, it has been possible to generate liquid CO_2 jets suitable for cutting soft materials such as polymers, metal foils, or natural materials.

It is further observed that the same pre- and post-expansion conditions sometimes lead to a stable liquid jet and sometimes to an immediate jet breaking-up of the jet. This indicates that there is still a lack of comprehensive understanding of the formation of liquid CO_2 jets.

In our contribution, we aim to identify and narrow down the parameters that allow the formation of metastable liquid CO_2 jets in the solid-vapor region.