Modern gas turbine designs often include lean premixed combustion for its emissions benefits; however, this type of combustion process is susceptible to self-excited combustion instabilities that can lead to damaging heat loads and system vibrations. This study focuses on identifying a mechanism of combustion instability of a reacting jet in cross flow, a flow feature that is widely used in the design of gas turbine combustion systems. Experimental results from a related study are used to validate and complement three numerical tools that are applied in this study — self-excited Large Eddy Simulations, 3D thermoacoustic modeling, and 1D instability modeling. Based on the experimental and numerical results, a mechanism was identified that included a contribution from the jet in cross flow impedance as well as an overall jet flame time lag. The jet impedance is simply a function of the acoustic properties of the geometry while the flame time lag can be separated into jet velocity, equivalence ratio, and strain fluctuations, depending on the operating conditions and setup. For the specific application investigated in this study, it was found that the jet velocity and equivalence ratio fluctuations are important, however, the effect of the strain fluctuations on the heat release are minimal due to the high operating pressure. A mathematical heat release model was derived based on the proposed mechanism and implemented into a 3D thermoacoustic tool as well as a 1D instability tool. A three-point stability trend observed in the experimental data was correctly captured by the 3D thermoacoustic tool using the derived heat release model. Stability maps were generated with the 1D instability tool to demonstrate regions of stable operation that can be achieved as a function of the proposed mechanism parameters. The relative effect of the reacting jet in cross flow on the two dominant unstable modes was correctly captured in the stability maps. While additional mechanisms for a reacting jet in cross flow are possible at differing flow conditions, the mechanism proposed in this study was shown to correctly replicate the stability trends observed in the experimental tests and provides a fundamental understanding that can be applied for combustion system design.

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The public is welcome to attend.