Augmentor Combustion Instability with the COMSOL Multiphysics® Software

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Abstract

Combustion instability has been a serious issue through the developmental history of gas turbine augmentors. When heat release rate oscillations occur in phase with resonant chamber acoustic modes, a feedback cycle is formed in which the strength of local heat release rate and chamber pressure oscillations can cause severe damage to engine structures and components.
Classification of combustion instability in augmentors is typically done on a frequency basis, where low and high frequency instabilities are referred to as rumble and screech, respectively. Given that augmentors are much longer than they are wide, rumble typically corresponds to the first few longitudinal modes while screech corresponds to transverse modes.
While longitudinal instabilities are readily avoided in final engine designs through modification of the augmentor geometry and fuel injection scheme, avoiding transverse screech instability remains a significant technical challenge for engine designers. In the past, perforated liners were used to provide sufficient damping to high frequency instabilities. However, next generation augmentor feature shorter lengths and wider duct diameters that drop the frequency of transverse modes below the effective range of traditional liners. Therefore, new technologies must be developed for the mitigation and suppression of transverse instability in gas turbine augmentors.
Small-scale test facilities are a relatively low cost means for building a better understanding of the physics behind combustion instability. They also provide a means for testing the initial effectiveness of instability control strategies. The Combustion Wind Tunnel Facility at the University of Cincinnati is capable of generating both high and low frequency combustion instability at augmentor relevant conditions. While longitudinal rumble instabilities are readily obtained at a wide array of operating conditions, screech instabilities are difficult to obtain and only occur at high fueling levels that can cause severe damage to wind tunnel components, much like in an actual augmentor.
The COMSOL Multiphysics® software is used to provide insight into the relevant geometric and fluid dynamic factors that result in screech instability in augmentor environments. The CFD and Acoustics Modules are used to simulate the influence of flow, geometry, boundary conditions, and temperature gradients acoustic modes. Results are used to give a greater understanding of the coupling pathways between flow and chamber acoustics such that screech conditions can be replicated accurately at laboratory scales.