High Temperature Fuel Modulation for Improved Engine Performance

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Purpose

Project goal is to develop high temperature piezoelectric fuel injector technology that can be integrated in turbo- engine to achieve lean fuel combustion (LFC) operation to reduce fuel consumption and greenhouse emissions.

Background

Projected annual growth in global aviation over the next 20 years is 5%. Flight growth will increase the aviation environmental footprint above 4%. Current aviation fuel efficiency will not meet forthcoming environmental standards. Research has shown that improving engine efficiency and emissions reduction is dependent on fuel injection system. Lean fuel combustion (LFC) technology offers pathway for significant reduction in emissions and fuel consumption. LFC engines exhibit a special form of self-excited resonant behavior known as thermoacoustic instabilities. These oscillations can cause flame extinction, reduce engine life span, and/or cause catastrophic structural damage under extreme circumstances. Active combustion control that can control spatial and temporal variations in local fuel/air ratio is of considerable interest for suppressing combustion instabilities in lean gas turbine combustors thereby achieving lower NOx levels. In active control combustion, instabilities can be controlled by modulating the fuel out of phase with the thermo-acoustic vibration thus canceling out the vibration. High-bandwidth fuel modulation is currently one of the most promising methods for active combustion control. To attenuate the large pressure oscillations in the combustion chamber, the fuel is pulsed so that the heat release rate fluctuations damp the pressure oscillations in the combustor. A key component of the fuel control valve is the actuator that is capable of operating at high frequencies and operating temperatures of the fuel nozzle. Piezoelectric actuators offer advantages for fuel injection: fast response time (μsecond time constants), generate forces in excess of 2000 lbs, displacement occurs by solid-state phenomena and endurance tests conducted on commercial piezoelectric materials exceeds several billion cycles. Additionally, piezoelectric actuators are compact and low mass compared conventional actuators. However, there are currently no commercial piezoelectric materials that operate in temperature range of gas turbine engine; temperature limitation is ≤200ºC. This research is on the development of piezoelectric stack actuators that are operational at high temperatures of 400ºC.