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Aerospace applications of pulsed plasmas

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The use of a thermal equilibrium plasma for combustion control dates back more than a hundred years to the advent of internal combustion (IC) engines and spark ignition systems. The same principles are still applied today to achieve high efficiency in various applications. Recently, the potential use of nonequilibrium plasma for ignition and combustion control has garnered increasing interest due to the possibility of plasma-assisted approaches for ignition and flame stabilization. During the past decade, significant progress has been made toward understanding the mechanisms of plasma chemistry interactions, energy redistribution and the nonequilibrium initiation of combustion. In addition, a wide variety of fuels have been examined using various types of discharge plasmas. Plasma application has been shown to provide additional combustion control, which is necessary for ultra-lean flames, high-speed flows, cold low-pressure conditions of high-altitude gas turbine engine (GTE) relight, detonation initiation in pulsed detonation engines (PDE) and distributed ignition control in homogeneous charge-compression ignition (HCCI) engines, among others. The present paper describes the current understanding of the nonequilibrium excitation of combustible mixtures by electrical discharges and plasma-assisted ignition and combustion. Nonequilibrium plasma demonstrates an ability to control ultra-lean, ultra-fast, low-temperature flames and appears to be an extremely promising technology for a wide range of applications, including aviation GTEs, piston engines, ramjets, scramjets and detonation initiation for pulsed detonation engines. To use nonequilibrium plasma for ignition and combustion in real energetic systems, one must understand the mechanisms of plasma-assisted ignition and combustion and be able to numerically simulate the discharge and combustion processes under various conditions.