MECHANICAL & INDUSTRIAL ENGINEERING COLLOQUIUM: ME 794 002

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221 MEC
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Biography

Dr. Wookyung Kim is a Staff Research Scientist/Engineer in the Combustion Group at United Technologies Research Center (UTRC). As an experimentalist, his research interests span the various aspects of flame and flow stability, which includes plasma assisted flame stabilization, plasma aided flow control, and flame stability improvement in augmentor geometries, and spray physics. He is currently serving as a PI of NASA LEARN sponsored plasma assisted combustor dynamics control program.

Dr. Kim received a B.S. in mechanical engineering from Seoul National University, Seoul, Republic of Korea, and an M.S. and Ph.D. in mechanical engineering from Stanford University, Stanford, CA. He worked as a post doctoral fellow/research associate at Stanford for three and half years before joining UTRC as a senior research scientist in 2010. He has published more than 15 articles in peer reviewed journals and has served as a reviewer for various internationally recognized plasma, combustion, and fluid mechanics journals.

Abstract

The implementation of nanosecond pulsed discharge (NSPD) to combustion applications is receiving growing attention because of its capability to increase flame stability. Under this context, the current presentation consists of two parts: the fundamental aspects of the NSPD assisted combustion, and its application to combustor dynamics control. In the first part, our efforts to answer fundamental questions such as how much and why the NSPD can improve the flame stability, are summarized. The flow configurations of interest are: methane-air jet diffusion flames in coflow and crossflow, and methane-air laminar premixed flames. For the methane jet in coflow, it is shown that the flame stability is improved by ten-fold (in terms of coflow speed) with the aid of the NSPD. For the methane jet in cross flow, it is found that there exists a significant distance through which radicals formed by the NSPD cannot survive between the NSPD and flamebase. Based on the observation of jet in cross flow experiments, a simple model (preflame model) of a plasma-assisted methane flame is proposed, which suggests that the central role of the plasma discharge in this case is as an in-situ reformer, not a direct radical source. The verification is carried out by 0-D/1-D discharge/flame simulations along with subsequent experimental validations including GC sampling and hydrogen/air flame analyses.

As an example of its applications, the second part shows the effectiveness of the NSPD to improve combustor dynamics. The NSPD was applied to a laboratory scale premixed methane/air dump combustor. Up to ~ 25 dB noise reduction was observed in the presence of the NSPD. The NSPD relocated the flame stabilization point from the outer recirculation zone to the center zone based on high speed imaging. Due to the highly non-equilibrium temperature characteristic of the NSPD, the incremental increase of emissions in the presence of the discharge was minimal, while the increase of combustion efficiency was significant (on the order of ~ 20%). A control algorithm was developed that measured pressure oscillation amplitude and adjusted the plasma power for control of the oscillations. This algorithm does not require knowledge/measurement of the pressure oscillation phase. Therefore, challenges associated with convective and actuator phase delays are avoided. The impact of NSPD on swirl-stabilized flames was also investigated for swirl numbers from 0 – 0.33. The relative effect of NSPD on dynamics reduction decreased with increasing swirl due to the inherent decrease in the non-controlled flame dynamics. This current work indicates that the flame shape plays a central role in determining the degree of plasma effectiveness and that dynamics associated with outer recirculation zone stabilized flames can be significantly reduced by implementation of NSPD.

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