Fuel Injection and Mixing
ADVANCED FUEL INJECTION

OVERVIEW

To optimize the combustor performance of present day aircraft engines, attention is directed to combustor dome geometry. Fuel and air mixing hardware have been studied extensively in an attempt to develop an understanding of the processes leading to effective liquid fuel and air mixing, as well as, satisfactory combustion and emissions performances. The geometric and operational features of gas turbine engine combustors are receiving increased scrutiny due to a growing concern regarding environmental impact, performance, durability, and manufacturability. To minimize the risk associated with new projects, optimization of designs which are similar to those in current operation is attractive. To achieve this goal, a methodology that is efficient and can reveal interactions between parameters that affect performance is necessary. An approach which addresses these requirements is statistically designed experiments (e.g., multivariate experiments or "design of experiments"), which offers efficiency as well as the ability to identify interactions between variables. This approach was adopted and demonstrated in the present study utilizing a set of hardware specifically developed to allow multivariate experiments to be conducted. A radial mixer geometry consisting of four parameters (primary and secondary swirl vane angles, the presence of a venturi, and the co-/counter-swirl sense) was examined. The responses selected for study are stability (i.e., reaction lean blow-out), fuel distribution, and emissions.

GOALS

- Apply a statistically based design of experiments to various mixer hardware configuration to identify main effects or interactions between geometric parameters influencing combustion performance.
- Identify mechanisms that affect combustion stability, efficiency and pollutant formation.
- Optimize hardware design to increase combustion performance

RESULTS

Analysis I

An Analysis of Variance (ANOVA) reveals that (1) the presence of the venturi and (2) the swirl sense play strong roles in determining the size of the spray area. Closer observation of the data reveals that in general (1) the spray area is smaller when the venturi is present or when the swirlers act in opposite directions (Counter-Swirl), and (2) the spray area is larger when the venturi is not present and the swirlers act in the same direction (Co-Swirl) Figure 2a illustrates the PLLIF image of the spray for Configuration 15, which employed a Co-Swirl arrangement without a venturi. The large spray generated is explained by (1) the increased swirl strength induced when the primary and secondary swirlers act in the same direction, and 2) the absence of the venturi which when present will physically block the fuel spray and reduced the area downstream.

RESULTS (continued)

Figure 2b is a PLLIF image for Configuration 20, which consisted of a Counter-Swirl (weaker resultant swirl) arrangement and a venturi (physical blockage of fuel), hence resulting in small spray area.

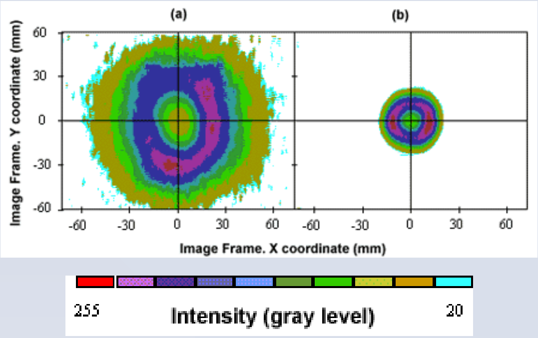

Figure 1. PLLIF Images of Spray Taken at One Flare Diameter Downstream:
(a) Configuration 15 (Co-Swirl, w/o Venturi),
(b) Configuration 20 (CC-Swirl, w/ Venturi)

Analysis II

Figure 3a shows the normal probability plot of the effects calculated for the Uniformity Index (U) which measures the uniformity of the liquid fuel spray. As seen in the figure the effect caused by the swirl sense deviates significantly from a normal distribution (hence, its effect is not random). The deviation signifies that swirl sense plays a strong role in determining spray uniformity (U) in the configurations tested. Figure 4b illustrates how the averaged values of configurations employing Co-Swirl (CO) and Counter-Swirl (CC) vary. In general, U decreases (spray fuel uniformity increases) when the swirlers act in opposite directions.

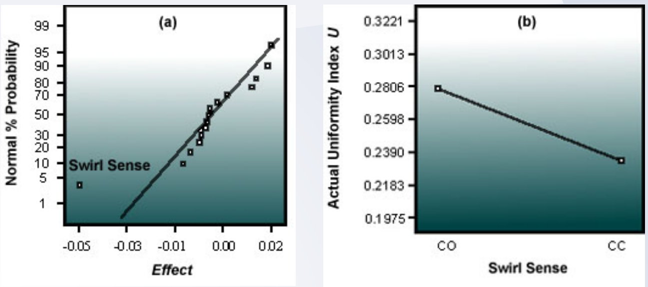

Figure 2.
(a) Probability Plot for Uniformity Index Response,
(b) Effect of Swirl Sense on Uniformity Index Response

RECENT PUBLICATIONS/PAPERS

LEAN BLOWOUT MODEL FOR A SPRAY FIRED SWIRL-STABILIZED COMBUSTOR (2000). Twenty-Eighth Symposium (International) on Combustion, The Combustion Institute, pp. 1281-1288. (A. Ateshkadi, V.G. McDonell, and G.S. Samuelsen).

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