Fluid Prefilming in Fuel Injectors

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Industrial Site: Mentor Facility, Gas Turbine Fuel Systems Div., Parker Hannifin Corp.

Objectives: To learn more about the prefilming process observed in fuel injectors.

Achievements:

- Completed prefilming experiments.

Comments on the UTSR Fellowship at Parker:

- The experience was very educational, both academically and professionally. The chance to apply critical thinking skills from the classroom really solidified my understanding of many concepts I learned from my coursework.
- The fast pace of the corporate environment served to strengthen my ability to think and act both effectively and efficiently.
- I feel that I have come to understand fairly well a critical component of the power generation process in gas turbine fuel systems.
- I enjoyed the freedom the UTSR program provided in terms of interacting directly with the industrial sponsor in a meaningful manner.
- I learned many useful skills relating to industrial mechanical engineering, such as operating lathes and mills as well as torch brazing.

Introduction

For my UTSR Fellowship, I had the privilege of working at Parker Hannifin Corporation's Gas Turbine Fuel Systems Division (GTFSD) headquarters in Mentor, Ohio. The GTFSD's main products are fuel injectors (nozzles) for gas turbine engines, used in both the aerospace and the power generation industries. Each series of nozzles may differ greatly in shape and size, as they are also subjected to greatly different operating conditions.

During my tenure in Mentor, I worked closely with my mentor Dr. Mansour as well as fellow engineers Dr. Erlendur Steinthorsson and Brian Hollon. Working together, we developed a series of experiments in order to determine how to optimize the prefilming process. My experiences have ranged from deep frustration to great satisfaction. Overall, my work was very rewarding, and I learned much about prefilming and fluid mechanics.

Background

Effective prefilming is an important part of reducing nitrogen oxides (NOx) emissions from gas turbine engines. The reduction of NOx is crucial to any aerospace company, due to environmental concerns and increasingly strict government regulations. Some methods of reducing emissions are to burn lean (using a low fuel-to-air ratio), to remove hot spots in the combustion chamber, and to improve uniformity of the spray. Uniformity of the spray can be improved with more effective prefilming with the goal of producing thinner and more uniform films and subsequent sprays. **Figure 1** on the following page illustrates an air-blast design utilizing a prefilmer.

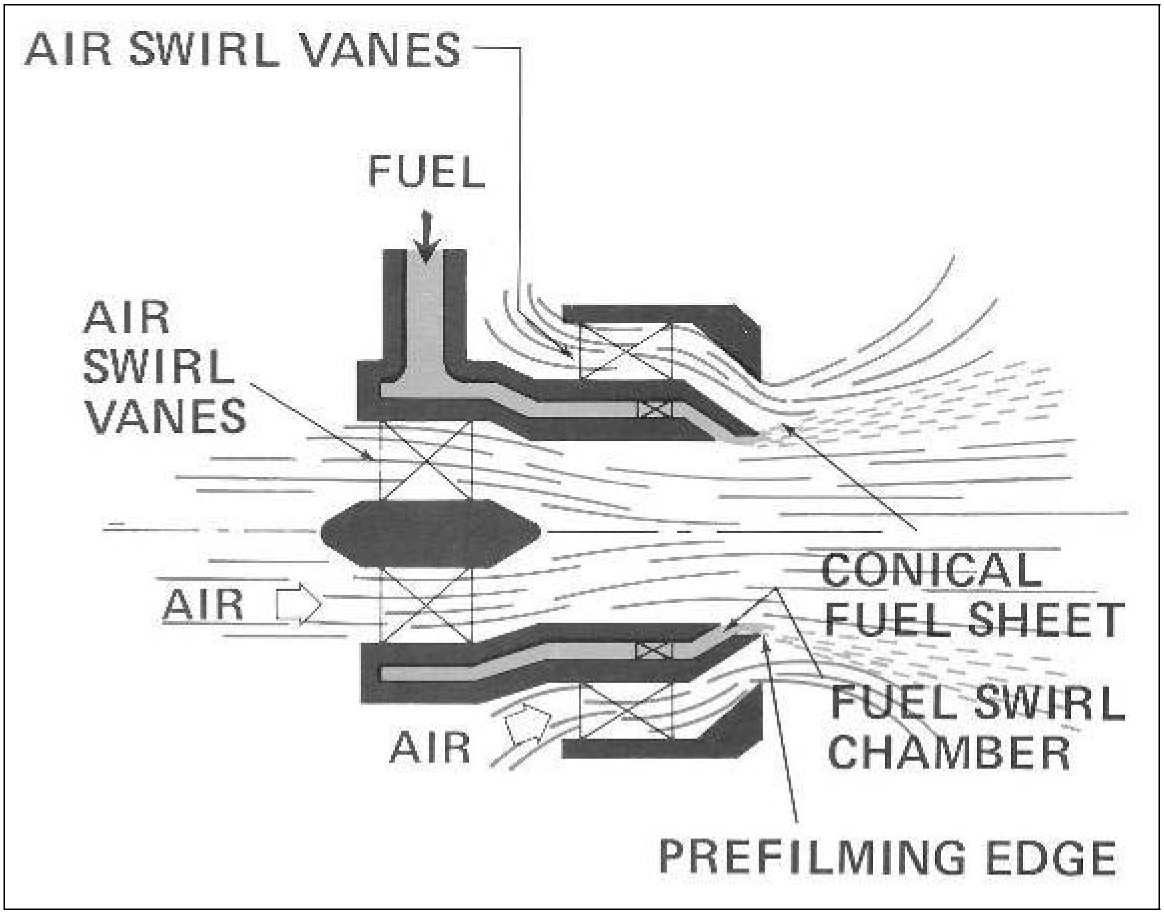

Figure 1* – Air-blast nozzle design with prefilmer

For this type of nozzle, the prefilmer plays a very significant role in determining the atomizing capability of the nozzle. The conical fuel sheet (film) is crucial to fuel atomization, since thinner film will yield smaller fluid droplets. Flowing, swirling air coming through the inner and outer air circuits breaks the sheet into droplets and disperses the droplets at a desired angle. The size of the droplets is again dependent upon the thickness of the film.

Fluid droplet size is but one measure of a nozzle's performance. Another equally important measure of a nozzle's performance is the uniformity or the patternation of its spray. A nozzle must spray evenly and uniformly to lower NOx emissions. The spray must be uniform 360° all around, with no streaks, voids, or other indications of unevenness. To accomplish this, the fluid film exiting the nozzle must be uniform 360° all around, and that was the kind of film sought in my experiments.

As shown in **Figure 1**, fuel is actually swirled in the fuel swirl chamber before it reaches the outermost lip to form a film. The fuel swirl chamber is typically comprised of two parts: the fuel swirler which imparts a tangential component to the velocity of the fuel, and the prefilmer which encloses the fuel swirler and facilitates the formation of film.

Experiments

The goal of the experiments was to find a fuel swirler and prefilmer combination which produced the best film, to be determined qualitatively by visual inspection. Four fuel swirlers and eight prefilmers were available, creating 32 possible combinations. Due to some issues and time constraints, not all 32 combinations were tested.

Testing involved connecting the fuel swirler inlet to a fluid line running Mil-PRF-7024E Type II calibration fluid. The fuel swirler and prefilmer assembly was then suspended in a spray chamber, and fluid was flowed through the assembly at 5, 10, 15, 20, 25, 30, 40, 50, 75, and 100 psig with photographs taken at every pressure drop. The photographs were then compared to determine the relative performance of each configuration. **Figures 2-3** on the next page show a few of the sprays seen during the experiments.

Figure 2 – Sample spray at 50 psig

Figure 3 – Sample spray at 100 psig

At the end of the experiments, some combinations which were not performing adequately have been removed from consideration for further testing. Plans are underway for the next phase of testing, which would involve new designs for the fuel swirler and prefilmers, with the same goal as these experiments.

* Courtesy of Parker Hannifin Corporation.