UTSR Gas Turbine Fellowship Program

Project Summary

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Introduction

For my UTSR Gas Turbine Fellowship I was assigned to work at Parker Hannifin in Mentor, OH. During the 12 weeks of the internship I worked in the Gas Turbine Fuel Systems Division (GTFSD), a division of Parker's Aerospace Group. The GTFSD makes nozzles for fuel injection and inlet air cooling used in aircraft engines and power generation. At the GTFSD I mainly dealt with aircraft fuel nozzles and cooling nozzles, however I found that most of the basic turbine features are similar to those used in power generation. My industrial advisor, Dr. Adel Mansour, was very helpful in making sure I adjusted to the work environment and in offering me guidance throughout my internship. During the internship most of my time was spent working with test engineers in the R&D lab running and assisting with vibration, spray quality, and contamination tests. However I was also given the opportunity to shadow design engineers and actively participate in meetings with my co-workers and our customers. This experience gave me a well rounded understanding of the gas turbine industry.

Background

One of the major limiting factors in increasing gas turbine system performance is the efficiency of the combustion process. More efficient combustors produce lower NOx emissions which are becoming increasingly important with more stringent government regulations. The quality of spray produced by the fuel nozzle component is a key factor in achieving these higher combustion efficiencies. Fuel nozzles discharge a conical spray of liquid fuel in efforts to create the optimal air/fuel ratio to facilitate complete combustion. The spray is created through the process of atomization in which a stream of fuel is broken into small droplets. Atomization is onset when the fine sheet or jet spray of liquid at a high velocity is disturbed by an air stream traveling at a low velocity, or vice versa, causing the spray to become unstable and breaks the sheet into drops. The quality of the spray is characterized by the droplet size, distribution, patternation, and cone angle. These characteristics are all dependent on nozzle design as well as the physical properties of the air and fuel. A well atomized spray is characterized by having a small and uniform drop size, and an even spray distribution over the sprays cross-section. For the most part these characteristics may be modified through fuel nozzle design.

Drop Size Testing

The most common method of determining the droplet sizes the spray produces is by measuring the Sauter Mean Diameter (SMD). The SMD is defined as the diameter of a drop having the same volume/surface ratio as the whole spray. The acceptable SMD values vary depending on the combustor and conditions. However for most of the Parker nozzles I tested we looked for SMD's to be below 50 µm. The SMD test is conducted by a Sympatec HELOS™ laser diffraction system that Parker owns. HELOS™ works by measuring the amount of diffraction by the laser beam when passed through the spray. The system consists of a spray chamber in the center, a laser generator on one side, and a detector on the opposing side. The laser is operated by an external computer using the Sympatec WINDOX™ software.

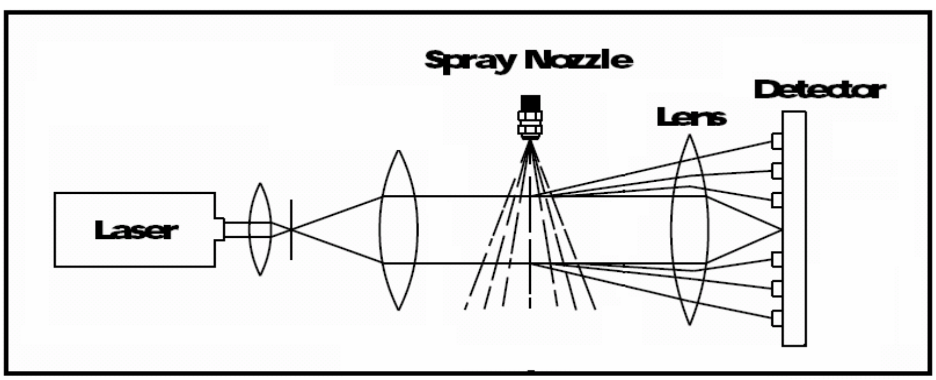

Figure 1: Laser Diffraction Using the HELOS System

For each of the tests I had to set up some fixture configuration to get the nozzle so that the laser beam is aligned to go through the center line of the spray two inches below the nozzle tip. For each set of tests I chose an appropriate lens for the laser that would capture all of the drops with greatest precision.

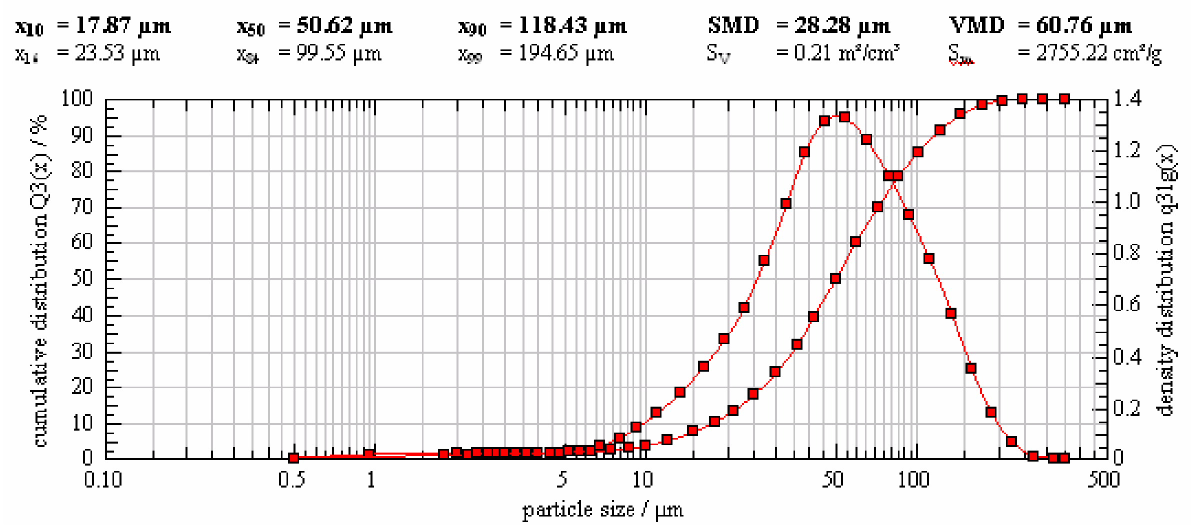

Figure 2: Example of WINDOX software output for SMD test.

A portion of the program’s output is shown in the figure above. In this particular nozzle test we used a common in lab jet fuel substitute, MIL PRF 7024 Type IIE, set to 100 psi as the test fuel. The output shows the SMD of this particular spray was 28.28 µm. The graph shows the distribution the different drop sizes in the spray. A majority of the drops fall in between 10 µm and 200 µm with a mean particle size of about 50 µm. This graph indicates that the nozzle produces a satisfactory spray.

Vibration Testing

Another project I worked on during my time at Parker was assisting with vibration tests of several new Parker fuel nozzles. The vibration test is used to find the frequency response of the nozzle as well as the maximum stress and strains at resonance. In these tests the nozzles were secured to fixture on the vibration table that simulates engine installation as closely as possible. The nozzles as well as the fixture are then fitted with accelerometers and strain gauges which output through a computer. A test is set in such a way that it scans through the frequencies of interest at a specified acceleration. The resonance frequency is indicated by sharp spikes on the output graph of amplitude greater than the input. Because of the complex geometries of the nozzle it is common that the different components have different frequency responses therefore often times additional accelerometers must be placed on to plot its response. At resonance portions of the nozzle experience larger displacements producing large localized stresses in the strained regions. At these times the nozzle almost seems to bend back and forth in a wave motion. Strain gauges are fitted at these points of maximum deflection to detect the strains that these areas experience. This information in important in helping determine the characteristics of the nozzle while in operation.

<u>O-ring Testing</u>

Throughout most of my 12 weeks at Parker I ran series of fuel nozzle o-ring tests on a weekly basis. The purpose of these tests were to determine if the o-rings in a sample of Parker nozzles deteriorate and cause leakage when they are exposed to high temperatures at an extended period of time. O-rings which leak through out their lifetime may lead to carbon build up causing damage to the nozzle through carbon jacking and subsequent operation of the turbine turbine. Several nozzles utilize o-rings to create this tight seal. The particular nozzles tested contained o-rings labeled specimen A and B. Ten of each type of nozzle were placed in a 500°F oven. Each week one of each specimen was removed and tested by running fuel at 50 psi to check for leakage.

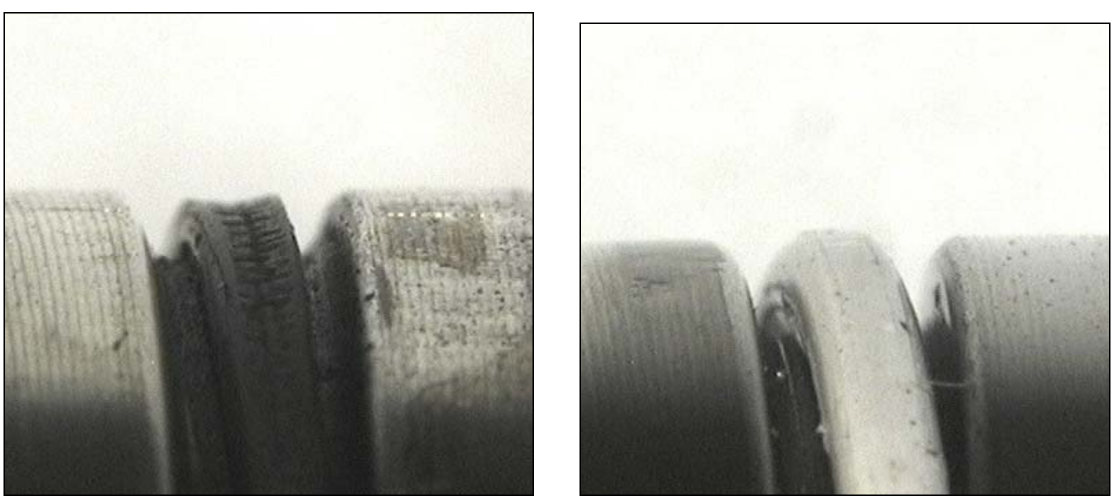

Figure 3: O-ring specimen A (left) and B (right) after 7 week of heat exposure

The o-rings were then examined under magnification as shown in Figure 3. After being under heat exposure for 3 weeks specimen A began to leak when tested at 50 psi, while specimen B continued not to leak throughout the 10 weeks. Figure 3 shows that specimen A developed cracks after 7 weeks in the oven while specimen A's appearance remained unchanged.

Conclusion

The UTSR fellowship was an invaluable learning experience. My co-workers at Parker Hannifin presented me with challenging tasks and at the same time were more than willing to assist me and to answer any questions I had. As a result I feel the internship gave me a hands on approach to learning about gas turbines and the industry.