Design of a Hybrid Rocket Motor Injector Head for Combustion Studies using Fiber Optics

Jason Elsasser
Mentor: Andrew Wright, Ph.D.
Department of Applied Science
University of Arkansas at Little Rock

Abstract

An interest in the combustion chamber plume area has led to the redesign of the University of Arkansas at Little Rock (UALR) labscale hybrid rocket motor injector head. The goals of the project are to view and get data from the combustion chamber plume area and to obtain spectroscopic data using fiber optics. The project includes the redesign of a previous hybrid rocket motor injector head for fiber optic placement, viewing of the combustion chamber plume area using an imagining fiber optic, and distinguishing chemical elements inside the combustion chamber plume area using an ultraviolet fiber optic. A plug has been designed to hold the imagining fiber optic in place and to isolate the delicate optics from the high temperatures of the combustion chamber. The fiber optic plug allows for the imagining fiber optic to view through the center of the hybrid rocket motor combustion chamber plume area. This will allow for the study of how the fuel grains burn and the effects of chemical elements inside the combustion chamber plume area during the firing of the labscale hybrid rocket motor.

Introduction

The University of Arkansas at Little Rock has developed a labscale hybrid rocket motor testbed facility for observation of the rocket plume. This facility is constructed on the UALR campus and allows for plume instrumentation testing. All the work to date has focused on the development of plume spectroscopy instrumentation. The project included the design and construction of the labscale hybrid rocket motor, the supporting facility, the instrumentation and computer control of the motor, and the characterization of this particular motor.

The work described in this paper includes the redesign and construction of the hybrid rocket motor injector head, the viewing of the combustion chamber plume area inside the hybrid rocket motor using an imaging fiber optic, and distinguishing chemical elements in the combustion chamber plume area using an ultraviolet fiber optic.

Design and Materials

The focus of the project is to collect imaging and spectral information from inside the hybrid rocket motor while fuel grain burns are taking place. Several requirements need to be met with this new injector head design. It needed to have the same oxygen

flow area. This would allow the same combustion characteristics to be achieved as the previous design and allow comparison with prior results. The imaging fiber optic has to be mounted with the centerline of the combustion chamber plume area. Windows are used in the injector head to provide protection against high temperature and backpressure that may occur during the firing of the motor.

The injector head design consists of two main sections, the injector head shaft (see Figure 1), and the injector head fiber optic plug (see Figure 2). The oxygen inlet nozzle and the plug cross-sectional area have been designed to allow the same oxygen flow rate to occur as for the previous design. A 1.125-in diameter hole was bored in the front of the injector head shaft. The prior oxygen inlet nozzle had a 0.5-in diameter hole. The area of the previous oxygen inlet nozzle was 0.196-in^2. The new oxygen inlet nozzle design has an outside diameter that is 1.125-in and an inside diameter that is 1.00-in. Subtracting the inside diameter area from the outside diameter area, the new area of the oxygen inlet nozzle is 0.199-in^2. This will give the same flow rate through the motor as previously designed.

The fiber optic plug will fit into the 1.125-in diameter hole that was bored into the front of the injector head shaft. The plug is tapered so that, the plugs outside diameter is smaller than the shaft's inside diameter. Oxygen flows through the inlet nozzle into this annular region. The flow direction is turned 90° and forced into the combustion area. The distance between the oxygen inlet and the combustion area is such that fully developed flow results prior to the combustion zone.

The injector head fiber optic plug has a centerline channel for the insertion of the imaging and ultraviolet fiber optics. An o-ring for protection separates the front of the fiber optic from the wall of the injector head plug. The o-ring is used as a buffer to reduce contact with the injector head plug and to hold the fiber in front of the window. Mounted 0.25-in in front of the fiber optics is a 2-mm thick sapphire window. The window protects the fiber from soot and from the high temperatures of combustion. The window is held in place by a grooved retainer brace device on one side and against the wall on the other side. On the wall side, an o-ring seals the plug to prevent the combustion from blowing out through the rear of the motor.

Instrumentation

The plug allows different optics to be used to analyze the combustion region. Two options have been developed. A Hawkeye 3954 borescope can be inserted in the plug to view the combustion chamber (see Figure 3). A CCD camera is placed in-line with the borescope's eyepiece through a fixed lens adapter. The CCD camera image is converted to an NTSC video signal and passed to a video cassette recorder for storage. A television monitor allows the combustion chamber to be viewed.

A quartz fiber, which passes ultraviolet and visible light, can be installed in the fiber optic plug (see Figure 4). The quartz fiber optic will be collecting spectral data in the visual, ultraviolet, and near infrared range. The light collected by the quartz fiber optic will be passed to a spectrometer, which will send the data to a computer for storage and data evaluation.

Discussion

The images collected from the combustion chamber plume area can give information about the combustion process during firing. The image of the combustion zone will allow several basic questions about hybrid rocket combustion to be answered. Do combustion waves propagate down the bore of the motor? Does the flame front oscillate back and forth along the entire bore? Does the flame burn vaporized fuel at a distance from the fuel grain or does the fuel burn directly?

The spectral data collected with the quartz fiber optic will show bands and peaks where a chemical element is present. This will allow for distinguishing what chemical elements are present in combustion chamber plume area throughout the firing of the rocket motor.

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References

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