Analyzing Catalyst Bed Degradation in Monopropellant Thrusters

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Introduction

Monopropellants are fuels used in thrusters that have the fuel and oxidizer mixed into one fluid. The leading monopropellant for space systems is currently hydrazine. However, hydrazine systems are highly toxic and highly reactive. AF-M315E is a new monopropellant that has been proposed to replace hydrazine as it is less toxic and requires less equipment to load and store, leading to lower costs [1]. AF-M315E has yet to be tested on an inflight system, but because it burns hotter than hydrazine, degradation of the internal components must be accounted for. To do this a family of micro-reactors has been created with 10 sec, 10 min, and 10 hr lifespans [2]. Current work is being done on the 10 min life span micro-reactors to develop diagnostic tools for the thrusters. One of the components being studied is the catalyst. Its size, shape and texture will be analyzed using a digital microscope and image processing software for Matlab. These programs will help to determine how the catalyst is breaking down and degrading over time.

Ellipse fit program

In order to analyze shape, this program took the isolated catalyst images from the microscope, isolated each grain and then fit and ellipse to the grains. Figure 8 shows an isolated grain with its perimeter which was used to fit the ellipse.

The program then returned the eccentricities for each catalyst grain as well as the semi-major and semi-minor axes for each. Figure 9 shows a histogram of the eccentricities for the grains in figure 7.

Conclusion

One of the main challenges with this project was not having the image processing software for Matlab to begin with. However, once it was acquired the programs became more efficient. Due to the complicated nature of ellipses it is difficult to validate the ellipse fit program. Some of the eccentricities were not going through the microscope program and program to validate. Since the version of Matlab was also from 2009 there were some updated functions that would be useful in these codes (e.g. circlefit). A lack in understanding of statistics also lead to difficulty in the texture analysis work. It was difficult to determine what values would work best for quantifying the texture.

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Catalyst imaging

The catalyst was imaged using the digital microscope (figure 5). An auto area function was then used to isolate out the crystals (figure 6), and then statistically insignificant crystals were eliminated (i.e. double catalyst crystals) (figure 7). This method also allowed the average size of each crystal.

Texture analysis

A texture analysis program is able to look at how the surface of the grains may be degrading. The program is still in progress but currently takes in a close up image of the catalyst (figure 10), then runs it through Matlab’s rangefilt function (figure 11).

The program then gave the median, IQR and mode of the grayscale values in the rangefilt image. Figure 12 is a histogram of the grayscale values.

Future Work

- Run fit ellipse program on catalyst before and after firing
- Further develop texture analysis program
- How best to quantify texture?
- What statistics are helpful?
- Look more in depth on texture analysis
- Cracks
- Look at degradation of other parts
- Catalyst bed
- Bedplate

References
