Dynamic Characterization of Carbon Foils for Space Flight Applications

ABSTRACT

This project will evaluate the dynamic response of thin carbon foils under acoustic loading. Tests will be used to validate a numerical finite element model for assessing the survivability of foils in a space launch environment. Experimental modal analysis will be conducted with a laser vibrometer and compared to analytical and numerical methods.

PROJECT OUTLINE

For some mass spectrometers a carbon foil is used to generate a secondary electron from a particle as it passes through the foil. This secondary electron is attracted to a channel electron multiplier (CEM), which generates a signal. These carbon foils are made by floating carbon onto a very thin nickel grid (330 lines per inch). The density of the carbon foil ranges from 0.5 $\mu g/cm^2$ to 10 $\mu g/cm^2$, but in all cases the foil is very fragile. For space instruments that use a mass spectrometer with carbon foils, the foils must be able to survive the launch sequence that delivers the instrument and satellite into orbit. The launch sequence has high accelerations and acoustic loads over a large frequency range that vary depending on the launch vehicle. In extreme cases, the foils are not anticipated to survive the launch sequence, so a door is added to the instrument to reduce the acoustic loads to the foil. However, the door adds components, mass, and mechanical complexity and is avoided if possible.

The goal of this research project is to advance the understanding of the dynamic response of carbon foils and if possible to develop design guidelines for foils and foil holders. Numerical analysis will ultimately be used to develop new foil designs in the future. Thus, for this research the foils will be modeled numerically and compared to experimental tests.

The experimental setup/system will be characterized first to ensure that the experimental results are adequately understood. The experimental setup will consist of an acoustic source (speaker), the foil, the foil holder and other mechanical components, and the laser vibrometer, which is used to measure the velocity of the membrane. All of these different components are mechanically coupled somehow either through the air, the building, the table, or something else, and these components form a system. Thus to adequately separate the response of the foil from the system the other components and their interactions must be characterized.

In parallel with the testing, finite element analysis of the foil holder will be conducted for comparison to the experimental results. This model will be enhanced to include the foil and acoustic loads for comparison to the experimental tests on the foil. Initial tests on the foils will consist of sine sweeps of the acoustic source and the measurement of the dynamic response of the foil at various points over the foil. A comparison between the experiments and the analysis of the acoustic modes of the foil will be used to assess the accuracy of the numerical model. A refinement of the model may be necessary, so to validate the model, a different foil holder geometry will be considered.

Final experimental tests will consider higher acoustic loads, “damaged” foils, different density carbon foils and other yet-to-be-determined tests to better understand the dynamic behavior of carbon foils and enhance the numerical finite element model.

SCHEDULE

Weeks	Tasks
1	Orientation
2	Background research on membranes and acoustics. Experimental setup and characterization
3	Experimental setup and characterization
4	Vibration testing/modal analysis of the grid holders and finite element analysis of the grid holders
5 - 8	Modal testing of foils. Analytical and numerical analysis of foils.
9	Finish writing and presentation

BACKGROUND LITERATURE:

1. Wikipedia: Mass Spectrometry
2. Vibrations of continuous systems, specifically membranes (Should be discussed in any upper level vibrations book.)