INDUCTION HEATING MODEL OF CERMET FUEL ELEMENT ENVIRONMENTAL TEST (CFEET)

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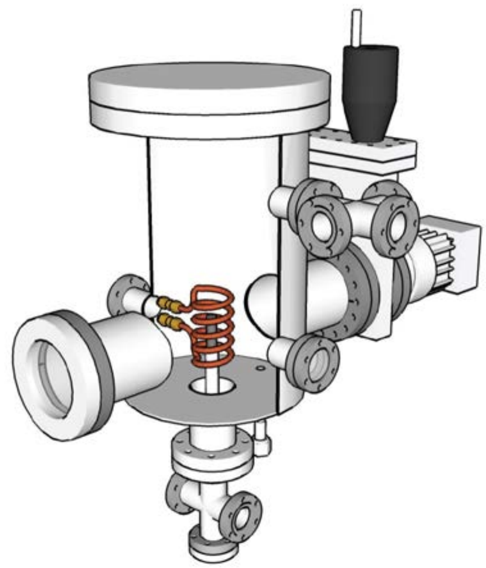
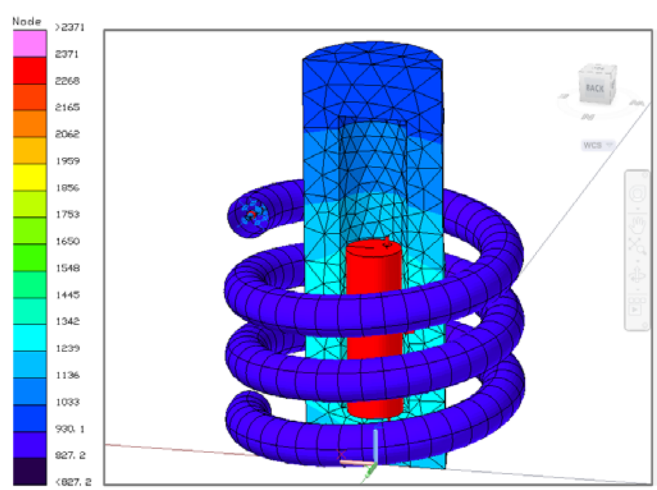
Introduction: Deep space missions with large payloads require high specific impulse and relatively high thrust to achieve mission goals in reasonable time frames. Nuclear Thermal Rockets (NTR) are capable of producing a high specific impulse by employing heat produced by a fission reactor to heat and therefore accelerate hydrogen through a rocket nozzle providing thrust. Fuel element temperatures are very high (up to 3000 K) and hydrogen is highly reactive with most materials at high temperatures. Data covering the effects of high-temperature hydrogen exposure on fuel elements are limited. The primary concern is the mechanical failure of fuel elements due to large thermal gradients; therefore, high-melting-point ceramics-metallic matrix composites (cermets) are one of the fuels under consideration as part of the Nuclear Cryogenic Propulsion Stage (NCPS) Advance Exploration System (AES) technology project at the Marshall Space Flight Center. The purpose of testing and analytical modeling is to determine their ability to survive and maintain thermal performance in a prototypical NTR reactor environment of exposure to hydrogen at very high temperatures and obtain data to assess the properties of the non-nuclear support materials. The fission process and the resulting heating performance are well known and do not require that active fissile material to be integrated in this testing. A small-scale test bed; Compact Fuel Element Environmental Tester (CFEET), designed to heat fuel element samples via induction heating and expose samples to hydrogen is being developed at MSFC to assist in optimal material and manufacturing process selection without utilizing fissile material. This paper details the analytical approach to help design and optimize the test bed using COMSOL Multiphysics for predicting thermal gradients induced by electromagnetic heating (Induction heating) and Thermal Desktop for radiation calculations. heating) and Thermal Desktop for radiation calculations.

The objective for the Cermet Fuel Element Environmental Test (CFEET) simulation effort is to develop and correlate a mathematical model for induction heating of cermet samples. The primary interest is for samples to reach temperatures of 3000 K and determine their ability to survive and maintain thermal performance in an Induction heating environment. Initial test show that reaching high temperatures by induction heating has proved difficult due to large amounts of thermal energy being lost by radiation and the low energy efficiency of the inductor coil. Power and energy can be computed using text book equations for induction heating and processing, but these values are only estimations which don't take into account accurate energy losses such as radiation and electromagnetic losses. Thermal Desktop is being used to model and improve the energy transferred to the sample in order to reach high temperatures. In addition, an Induction heating model created in Common Solution Multi Physics (COMSOL) will be used to predict the energy induced by the electromagnetic field. The analytical approach using both simulations will help design a better and more efficient test bed.



CFEET Vacuum Chamber Configuration



Thermal Desktop Steady-State Temperature Profile