REDESIGN OF A CRACKED NOZZLE

Mentors—Solid Propulsion Systems Division

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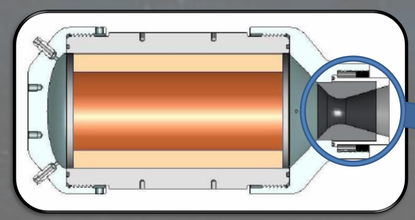
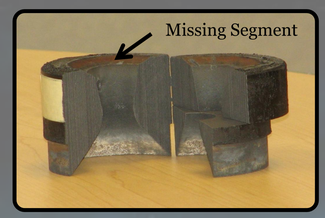
1. Abstract

This project involves the Army Ten Pound Charge (ATPC) motor being used to test the Ares I Ullage Settling Motor (USM) propellant. The exit section of the graphite nozzle insert used by the motor cracked approximately 1.2 seconds after ignition. The methodology applied in order to solve this problem involved using MATLAB to determine the flow conditions within the nozzle. These values were then entered into ANSYS to perform thermal and structural analyses of the nozzle.

Different alterations to the housing, nozzle geometry, and materials were analyzed to eliminate cracking. Altering the geometry of the nozzle by modifying the cracking extruded segment was found to be beneficial in reducing stress concentrations.



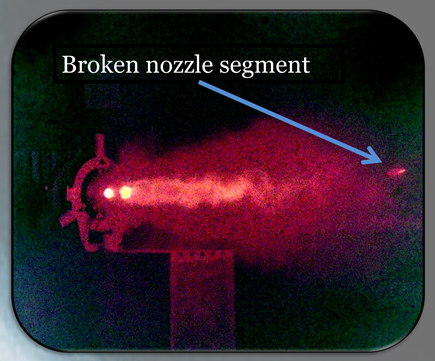
ATPC Motor Drawing



ATPC Graphite Nozzle Insert (Segmented)

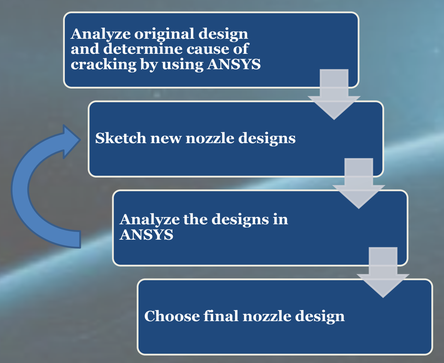
2. Background

Graphite has long been used for rocket nozzle inserts because of its low cost, low erosion rate, and favorable thermal properties. However, a drawback to this material is that it is brittle and tends to crack easily under rapidly increasing temperatures and pressures. This phenomenon has also occurred in Booster Separation Motors (BSM) as well as in the Heavy Wall test motors for the Ares program. Due to safety issues, it is crucial to all current and future programs that these anomalies be solved.

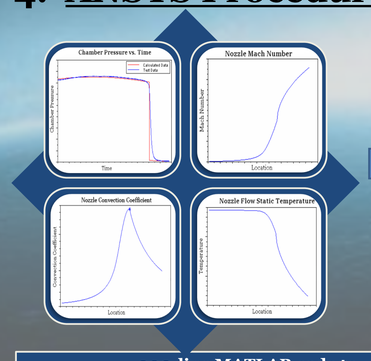


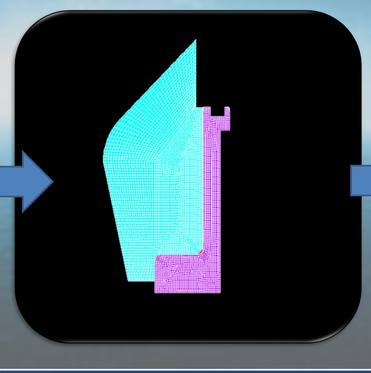
Test Firing of the ATPC Motor

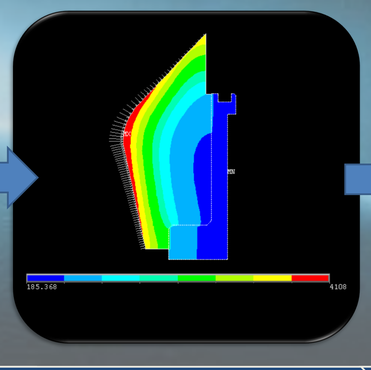
3. Project Methodology

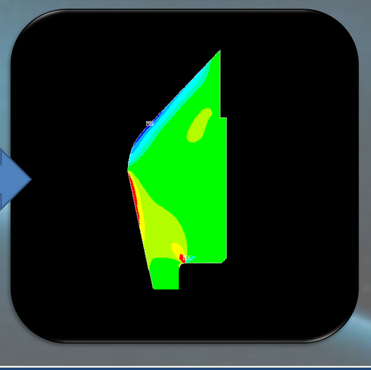


4. ANSYS Procedure





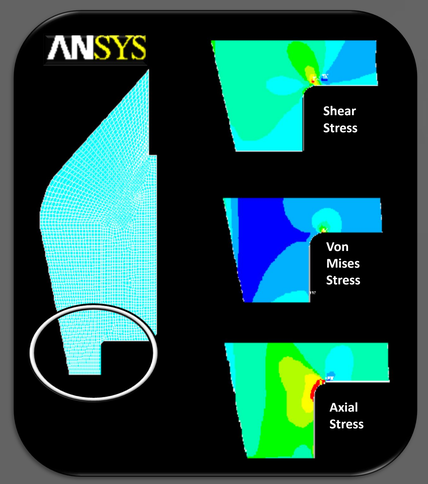




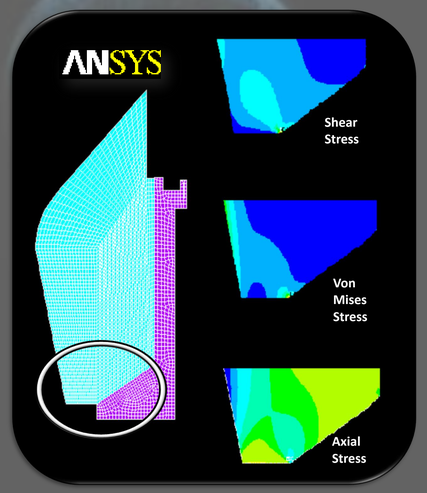
300-line MATLAB code to determine motor ballistics and nozzle flow conditions. → Model current nozzle geometry in ANSYS and load material properties → Load convection and flow temperature conditions from MATLAB. Perform thermal analysis → Load pressure conditions from MATLAB and import temperatures from thermal analysis. Perform structural analysis

Conclusions

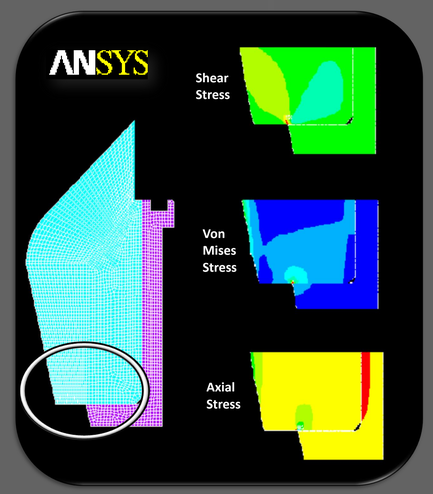
- The main causes for the cracking are:
  - Contact with the housing after deformation due to high thermal gradients ("banana effect")
  - High shear stresses created at housing corners
  - Sharp edges causing stress concentrations
- A redesign of the graphite nozzle geometry is able to eliminate the cracking
- Future analysis and work to be done:
  - Analyze the nozzles using Silica Cloth Phenolic and Pyrolitic Graphite materials.
  - Manufacture and test new design



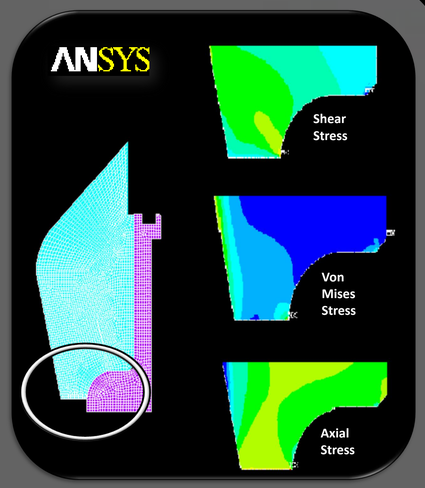
Original Design Stresses



Redesign #1 Stresses



Redesign #2 Stresses



Redesign #3 Stresses