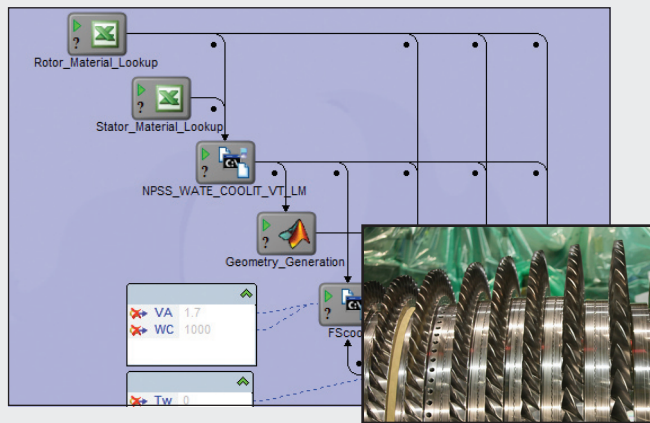


Improve Gas Turbine Design Success with Concept Stage Service Life Estimates

Challenge: Understand Service Life of Gas Turbines During Early Stage Design



Integrated Environment for Creep Life Analysis of Gas Turbines

Service life is a major constraint in the design of gas turbines since it places an upper bound on the firing temperature and, thus, affects the attainable efficiency of the machine. Factors that affect service life such as creep, geometry, and material properties are typically not known in the early design stages. Most gas turbine life calculations are embedded in design codes which are run during detailed design. Design spaces that are examined early in the process are frequently unrealistic due to service life constraints that are discovered later. Waiting for service life information until late in the design process results in more rejected designs and designs that are expensive to change.

Solution: A Physics-Based Prediction Method for Useful Information in Early Design

Based on study for a doctoral thesis at Georgia Tech, information could be identified and brought forward for quick, accurate estimates of creep life in the early stages of turbine design using PHX ModelCenter.¹ Chosen for its usability and availability of existing wrappers for the necessary tools integration environment, ModelCenter supported 0-D and 1-D analyses to obtain results quickly. The ModelCenter model consisted of material properties lookups in Excel; NASA Numerical Propulsion System Simulation (NPSS) for low-fidelity cycle analysis; a geometry generation tool in MATLAB; NASA's weight and sizing (WATE) code; a mean-line loss model based on Ainley and Mathieson; a blade cooling module (NASA's COOLIT program); a low fidelity stress and heat transfer method in MATLAB; and a rupture life lookup algorithm in Excel. A design of experiments (DOE) was run using a Latin Hypercube and Central Composite method. A response surface model (RSM) was built to study the design space using a Monte Carlo approach. Turbine entry temperature, material selection and operational parameters such as rotational speed were varied to obtain alternatives that met blade rupture life and engine weight requirements.

Benefit: A Better Chance for Early Design Success Downstream

Including creep life analysis in the conceptual design stage illustrated trends and choices that were unavailable had the design proceeded without the early design tools integration made possible by ModelCenter. Information on the effect of particular materials, for example, was known at the conceptual stage, which would not be possible with a traditional approach. By bringing turbine service life information to light at the conceptual level, early designs can proceed with a better chance of downstream success. ModelCenter also allows for easy changes and expandability should new or higher fidelity models become available.

¹ Smith, Marcus E.B., "A Parametric Physics Based Creep Life Prediction Approach to Gas Turbine Blade Conceptual Design", Doctoral Thesis, Georgia Institute of Technology.