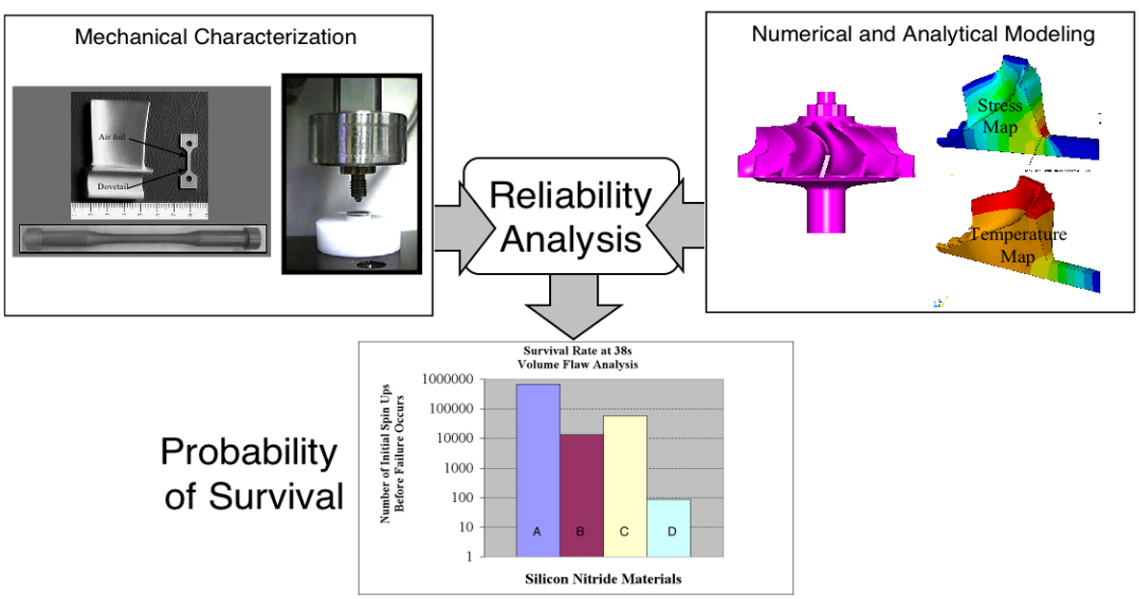
Software Evaluates Ceramic Materials for Turbine Efficiency

Integrated Reliability Assessment Software Selects Contemporary Ceramics for Structural Components and Predicts Properties Needed for Next-Generation Ceramic Materials

Background

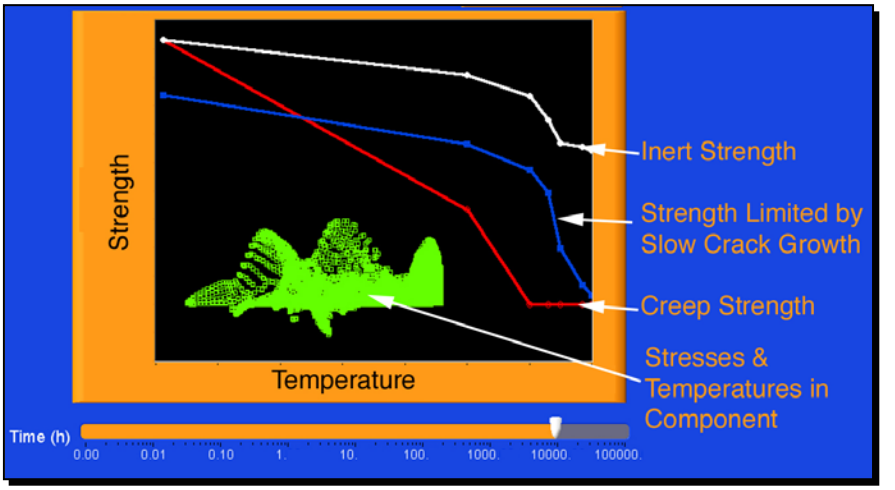
The successful application of structural ceramic components in gas turbines requires the use of well-established life prediction methodology to estimate the probability of survival at the desired operating life of the component. This assessment of component reliability results after three critical inputs are combined. First, mechanical properties including strength, slow crack growth, fatigue, and creep for the candidate ceramic must be collected. Next, numerical analyses are used to predict the temperature and stress distributions for the component in question. Finally, life prediction software is used to combine the experimental mechanical property data with the stress and temperature maps to estimate the probability of survival. If this value is too low, then either the component geometry must be modified to lower the maximum stress or a better (stronger, more fatigue resistance, etc.) material must be selected.

The implementation of the the reliability assessment process faces a number of challenges. The first involves the difficulty of collecting all of the required input data, which is generally scattered among a variety of sources (e.g., the materials suppliers, research laboratories, and universities). A second challenge is that most reliability software algorithms do not have a user-friendly process for varying properties so reliability can be maximized.



Software

The Integrated Reliability Assessment Software addresses the aforementioned challenges by first providing an integrated database for a number of commercial silicon carbides and silicon nitrides. As a result, the user is able to rapidly implement reliability estimates comparing a number of candidate materials. The results of each analysis are displayed graphically by generating strength/stress versus temperature plots to compare finite element results for a specific component with the strength-temperature data for a number of commercial ceramics from the database. The strength is adjusted to account for both slow crack growth and creep. At the same time, the effect of recession that would occur during turbine operation is simulated by increasing the finite element stresses as the material is lost. The program also allows the user to vary the key properties for a specific material so that component reliability can be maximized. The modified or target properties then become critical input to process optimization studies implemented by the materials suppliers in order meet the component lifetime requirements.



Fracture Map for Typical Silicon Nitride Ceramic

Benefits

Structural ceramic component end-users can readily screen the best ceramic material for their component. In those cases where the existing materials do not have properties sufficient to meet reliability requirements, the software can provide target properties of new or improved materials. The software also facilitates sensitivity analyses which illustrate how variation in key properties of the ceramic affect the component reliability.

Future Work

The program database currently includes strength distribution data for machining (surface) and bulk (volume) defects. It will be expanded to include available strength distribution data for as-processed surfaces.

Points of Contact:
Matt Ferber, 865-576-0818, ferbermk@ornl.gov
Andy Wereszczak 865-576-1196, wereszczakaa@ornl.gov