PEREGRINE CONSULTING — TFLAMES

WHAT IS TFLAMES?

TFLAMES, or Turbine Field Life Analysis Multi-physics Engine Simulation, is a software program developed by Peregrine Consulting, Inc. for the US Air Force under the aegis of the Engine Rotor Life Enhancement Program (ERLE). It is a physics-based, non-linear tool employing a 3D finite element core that is specifically designed to calculate the stresses and lives of critical rotating parts in turbine engines, especially for as-flown mission conditions.

TFLAMES' unique implementation makes it possible to analyze the lives of components, taking into account their actual mission usage as well as their as-manufactured condition. In other words, the effect of manufacturing tolerances – and even discrepant (non-conforming) hardware conditions – is no longer a mystery but is analyzed explicitly for each engine serial number and each mission flown, eliminating a great deal of uncertainty with respect to the myriad variables affecting turbine component lives.

TFLAMES OVERVIEW

WHAT PROBLEMS DOES TFLAMES SOLVE?

"THE WORLD COMMERCIAL AVIATION MAINTENANCE, REPAIR AND OVERHAUL (MRO) MARKET FOR CRITICAL LIFE LIMITED ENGINE PARTS IS AROUND $6 BILLION A YEAR."

The world commercial aviation maintenance, repair and overhaul (MRO) market for critical life-limited engine parts is around $6 billion a year. In North America alone the commercial MRO market for life-limited engine parts is about $2.4 billion. Market studies show that the U.S. military MRO market for life-limiting engine parts is $1.2 billion.

These are maintenance costs caused by components reaching their service life limits on turbine rotors and do not include unscheduled engine maintenance caused by premature and unanticipated failure. Unexpected rotor disk failure events can cause significant turbine damage and typically command multiple millions of dollars in repair cost for each event, not to mention causing safety concerns to the flying public and military aircrews.

At a time when the DoD and the commercial airline industry are under tremendous pressure to cut costs, particularly in the maintenance of an aging fleet, it is advantageous to understand and quantify conservatism and even non-conservatism in traditional component lifing methodologies and to recapture the lost value that goes on the scrap heap when a rotor disk is taken off wing with more than half its useful life still remaining.

Increasingly accurate assessment of life consumed for expensive turbine components must be accomplished to recapture lost value attributable to outdated lifing methodologies.

F414-GE-400 TURBINE

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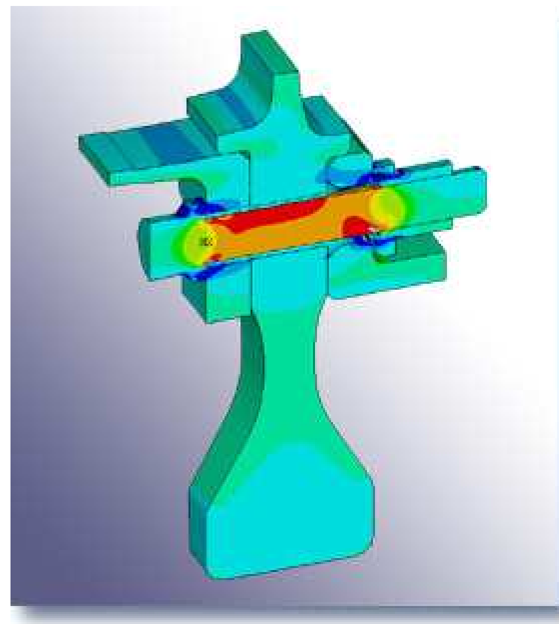
HOW IS TFLAMES BETTER THAN OTHER SOLUTIONS?

OEM's, third-party MRO operations, and even commercial air carriers are developing proprietary solutions to this problem. In most cases the solutions are either condition monitoring of engine data for early detection of performance loss or imminent component failure, or they track LCF life using traditional algorithms for scaling component thermal and mechanical stresses using as-flown engine data as input.



As for condition-monitoring tools, TFLAMES makes a fitting - if not necessary - compliment to this approach since condition-based monitoring cannot improve LCF life tracking. Reaching published life limits on rotating parts could drive an engine off wing long before condition monitoring would indicate a problem. This is a lost economic opportunity.

Traditional LCF life approaches are based on a well-known engineering principle called “superposition”, which means that the stresses from a known solution can be scaled to determine the solution for a variety of other conditions, i.e. different missions, using pre-determined relationships between engine cycle data and the resulting stresses. This principle holds up well for linear systems and, in fact, its use was a breakthrough back when computer power was so limited that it was only practical to analyze linear systems in the first place.

Over time, engine manufacturers found that certain non-linearities have a profound - and in many cases deleterious - effect on stresses and lives of critical components. For example, early finite-element tools introduced the ability to model non-linear contact between components. Other non-linear effects like stress-stiffening and large deflections were later included and shown to have an effect on component lives as well.

Finally, with the advent of still faster computers, stress analysts found that they could no longer ignore the effects of friction at each component interface. Modeling friction at component interfaces such as rabbets and flange faces has significantly increased the amount of compute resources required for life calculation for even a single generic mission, but the effect of friction on component life was found to be significant.

Accuracy in calculating lives for critical rotating components requires the inclusion of these non-linear effects. But what about the principle of superposition? Including these non-linear effects causes that principle to break down, making scaling algorithms for LCF life tracking problematic at best and, when taken at face value, potentially dangerous at worst. That's where TFLAMES steps in.

In TFLAMES, scaling of stresses - whether by stress concentration factor, mechanical speed, or thermal conditions – does not take place. All calculated stresses are found explicitly for engine-condition inputs, and for that specific engine serial number. This results in an unprecedented level of accuracy and an unparalleled opportunity for completely understanding the turbine's sensitivity to manufacturing variation and mission variety.

WHAT IS THE STATUS OF TFLAMES DEVELOPMENT?

In 2003, Peregrine Consulting launched the program to develop the twelve key technologies as well as the overall implementation of TFLAMES for a specific engine line, namely, the F414 which powers the Navy’s F-18 Superhornet.

Having demonstrated the feasibility of core technology in Phase I, Peregrine is now engaged in Phase II prototype development and will have the ability to demonstrate the technology with a working prototype by the end of 2006.

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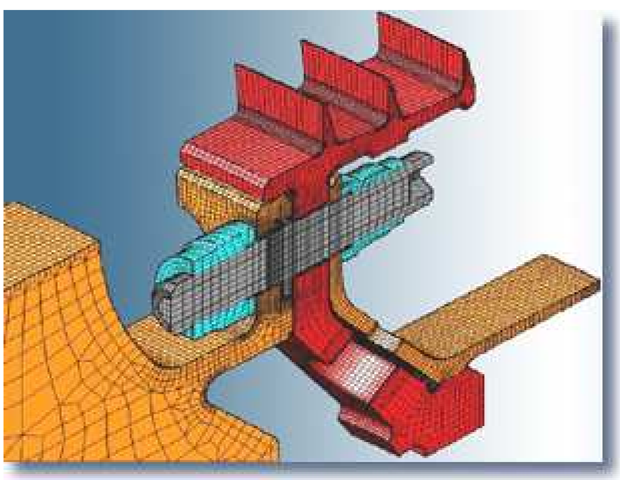
WHAT ARE THE CREDENTIALS OF THE DEVELOPERS?

The principal investigator on the TFLAMES research and development effort is David Stapp, a 20 year veteran of turbomachinery design and life analysis. David began his career as an engineer at GE Aircraft Engines where he designed rotor components and assemblies for both cold and hot sections of several new centerline engines including the GE36, F412, GE90 and the T407/CFE738. After a tour of duty conducting certification stress and life analyses for several engine modules, David founded Peregrine Consulting, Inc. in 1996. Since then Peregrine has distinguished itself as an important resource to GE for outsourcing stress and life work for multiple engines including the CF34, CT7, and the F414.

Matt Medford is a key member in the research and development team as well. Also a former GE employee, Matt was the 3D stress analysis process owner while working for the Small Engine Stress Analysis (SESA) group in Lynn , MA . Matt's experience in stress analysis is extensive, having worked on over a dozen engines for both GE and Pratt & Whitney.

Also part of the TFLAMES team, Mark Stephenson joined Peregrine Consulting as the Director of Software Development. He is a Subject Matter Expert (SME) for and certified to instruct the Rational Unified Process (RUP), Object Oriented Analysis and Design (OOAD), and the Unified Modeling Language (UML) Modeling Using Rational Rose. Mark brings a depth and breadth of experience beginning in mechanical design in high-end, 3-dimensional CAD systems through large-scale database and distributed-enterprise software applications for defense contractors, government, and financial institutions. Mark leads our team of expert software engineers in developing TFLAMES.



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