Endesa Develops Technical Basis for Extending Rotor Life of High-Cycle Gas Turbines

Endesa and EPRI jointly developed a condition-based rotor life management approach.

Endesa, the largest electric utility in Spain, organized and led a team, including EPRI and Spanish companies, to develop an independent, condition-based life management approach for the continued safe operation of Endesa's fleet of gas turbines beyond the original equipment manufacturer (OEM) nominal limit for turbine rotors of 5,000 starts.

Turbine manufacturers typically place design life limits on rotors based either on equivalent operating hours or start-stop cycles. While previous gas turbine (GT) rotor life extension efforts have focused on hours-based operation, this project with Endesa was the first to challenge the more difficult cycles limitation. Experience gained from this effort enabled Endesa to extend the useful life of its GTs and helped to further EPRI rotor developments in life analysis, nondestructive evaluation (NDE), and miniature material property testing.

Gas Turbine Rotor Life

GT rotor materials are subject to degradation from prolonged hours and multiple start/stop cycles of operation. Only limited inspection of exposed rotor rim areas can be performed during hot gas path and major maintenance intervals when casing covers are removed. For rotor life assessment, a more thorough inspection is often required by the equipment manufacturer, entailing complete disassembly in an off-site shop to qualify the rotor for extended service. This involves disassembly of the compressor and turbine sections of the rotor system and inspection of the components for signs of creep, embrittlement, corrosion, thermal fatigue, and high- and low-cycle fatigue. OEMs typically assist in these inspections and judge whether the rotor is suitable for continued service.

Inspection and retirement practices vary widely among the major equipment suppliers. Sections of the rotor may be deemed non-serviceable after anywhere from 100,000 to 250,000 hours of operation or between 2,500 to 5,000 starts. For high-starts machines, the recommendation often is to retire them without inspection.

Replacement of the rotor or key sections of the rotor can cost from $3 million to $6 million, plus associated production downtime if a spare rotor is unavailable. The engineering basis for rotor operational extension or retirement is unclear, with little field experiential data to establish a quantifiable risk. Owners of GTs, therefore, need objective, model-specific criteria for determining rotor life to guide their inspection and retirement decisions.

EPRI's Rotor Life Project

EPRI's Gas Turbine Rotor Life Project provides GT owners with procedures and technical information to objectively evaluate the condition of their GT rotors. The overall work scope is structured around two major tasks: Rotor Life Inspection and Evaluation Guidelines, and Model-Specific Component Evaluation. Life prediction procedures are developed for the specific rotor design and material, with particular emphasis on rim-blade interface, bolt holes, and center bores or alternatively welded rotors.

"The rotor life extension project has led us to implement a life-extension program among the entire Endesa MS6001B gas turbine rotor fleet, enabling us to extend the initial cycles limitation and perform the replacement based on actual rotor condition."

~ Tomas Alvarez, *Technology, Mechanical Maintenance and Systems Manager, Endesa Generation Technical Services*

Over the years, the project has assessed a broad range of GT rotors that use a variety of materials and construction, including bolted, welded, and shrunk-fitted systems. This assessment includes component stress analysis and material testing to address cracking in rim attachments and the general structural integrity of engines subjected to high hours and high starts.

The project's centerpiece is the Gas Turbine Rotor Life Assessment Guideline, which provides a technical foundation for objectively evaluating the current condition of GT rotors and formulating a basis for timely replacement or continued safe operation. It includes sections on rotor design alloys and properties; rotor damage mechanisms with compressor and turbine section examples; end-of-life criteria and analysis methodologies; in-service material degradation mechanisms; nondestructive testing (NDT); and material sampling, testing, and property correlations.

The Guideline, coupled with the EPRI degraded rotor material database, provides a sound technical foundation which is being further refined in studies on specific models, including the General Electric FA, E/EA, 6B and Frame 5; Siemens V-engines, 501F, and 501B; and Alstom GT24/26. Retired rotor components are being tested to refine degraded material property correlations and qualify small sampling and NDT techniques.

Endesa's Gas Turbine Fleet

Endesa operates a fleet of 18 GE 6B heavy-duty GTs serving isolated islands. The duty of these GTs is cyclic and spinning reserve, which results in several starts per day and few operating hours.

For this joint project, Endesa provided the project team with access to disassembled compressor and turbine rotors, which were then dimensionally scanned and used to develop stress analysis models. A root-cause analysis was performed of a turbine disc rabbet crack.

An NDT method was developed to detect the early crack development without rotor de-stacking. This technique was validated with field experience. Material testing was also performed to establish baseline properties and life thresholds.

Application of Life Evaluation Procedures

The findings of this project were very valuable to Endesa, and the life management approach has been implemented across the utility's 6B fleet. Once a rotor exceeds 5,000 starts, NDT is performed at each hot-gas-path inspection to ensure the disc rabbet integrity. As result of this evaluation, Endesa has implemented a rotor life extension program which has led to extensions of rotor life limits from 5,000 to 8,000 starts.

The replacement of the installed rotors are based on condition by means of an ultrasonic inspection performed in place without removing and de-stacking the rotor. This NDT is performed on those rotors which have exceeded the OEM limitation set at 5,000 starts. So far, four rotors have been replaced following this new approach, based on rotor condition and extending the rotor life to 8,000 starts.

Related EPRI Work

Gas Turbine Rotor Life Assessment Guideline. EPRI. Palo Alto, CA: December 2011. 1022088.

Gas Turbine Rotor Life. EPRI. Palo Alto, CA: August 2011. 1023634.

Gas Turbine Rotor Life: CrMoV Material Testing, 2013 Status Report. EPRI. Palo Alto, CA: December 2013. 3002001067.

Gas Turbine Rotor NDE and Material Properties: 2014 Status Report. EPRI. Palo Alto, CA: December 2014. 3002003416.

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