AEGIS

Loss Control

Steam Turbine Equivalent Operating Hours (EOH)

White Paper

Calculation and Maintenance Interval Considerations

An Insurer's Loss Control Perspective

Introduction

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Steam Turbine Equivalent Operating Hours (EOH), different from Actual Operating Hours (AOH), take into consideration the exposure to various stresses and operating conditions of the turbine. Such exposures are most commonly associated with high-temperature creep, high cycle fatigue (HCF) and low cycle fatigue (LCF), erosion, and corrosion. EOH is the preferred trigger for aligning maintenance intervals and determining component life.

With a significant amount of design, operating and service experience, the Original Equipment Manufacturers (OEMs) and industry groups have associated the additional stresses as only a relationship to unit starts. The caveat is that the EOH determination assumes the unit is operated and maintained within the OEM design criteria. A unit's operation and maintenance manual identifies those limitations.

With the advent and growth of renewable energy, base-loaded operating profiles no longer align with the original design criteria of conventional steam turbines. Load profile changes, faster starts and more frequent cycling are now commonplace. Factors such as modified startup profiles, over temperature, sliding pressure, increased duty cycles, low-load operation, full or partial load trips, inadequate or unstable water chemistry, and other variables can impact and shorten the remaining useful life.

The effect of these factors and the resultant mechanisms become variables for consideration when evaluating EOH.

EOH Formula

Several OEMs and industry organizations have long-standing equations for determining equivalent hours. A very common equation is:

$$EOH = AOH + 25(S)$$

Where:

EOH = Equivalent Operating Hours
AOH = Actual Operating Hours
S = Number of Starts

The factor of 25 highlights the additional stresses incurred during a startup. Some OEMs differentiate between hot and cold starts while others group all starts into one bucket.

EOH Variables

Where operation is no longer as originally designed, unexpected maintenance findings and forced outages occur more frequently. A more conservative approach is needed, and AEGIS Loss Control offers an expanded EOH formula to identify additional variables.

$$EOH = AOH + 25(S) + Variables$$

Variables for Consideration:

Low-Load Operation: Low-load operation may result in low-pressure turbine component damage. The Wilson Line (steam phase transition zone) may move upstream and result in increased component erosion from condensation. Additionally, low-load operation can potentially excite blade resonances, leading to HCF.

$H_{<15\%}$ Hours at <15% of nameplate rating
$H_{15\text{-}30\%}$ Hours at 15-30% of nameplate rating

Starts: Thermal cycling drives LCF and reduces remaining component life. Thermal stress is proportional to ramp rates and starting temperatures.

S Number of Starts
S_{HOT} Number of Hot Starts
S_{COLD} Number of Cold Starts

The impact of cold starts may be mitigated by the appropriate application of turbine casing heating blankets and/or the use of gland seal steam (casing pre-heat) at startup.

Overspeed Events: Overspeed events have a profound impact on rotor integrity. Events where actual rotor speed increases beyond synchronous speed can be caused by testing, misoperation, component degradation, or equipment failure. Some rotor configurations or designs may have a greater sensitivity to those resultant stresses.

$OS_{\geq 110\%}$	Number of Overspeed tests ≥110% rated speed
$OS_{\geq 110\%\text{ with shrunk-on discs}}$	Number of Overspeed tests ≥110% rated speed with shrunk-on discs

Idle and Layup: While off-line in an extended idle condition, turbine components are more susceptible to pitting corrosion in the absence of an adequate layup. Corrosion pits have been identified as the initiating events leading to component failures.

$H_{L/U}$	Hours Idle with layup
H_{I}	Hours Idle without layup

Weighted Equation:

$$EOH = AOH + (H_{1\text{-}15\%} \times 20) + (H_{15\text{-}30\%} \times 5) + (S_{hot} \times 5) + (S_{cold} \times 25) + (OS_{\geq 110\%} \times 50) + (OS_{\geq 110\%\text{ with shrunk-on discs}} \times 500) + (H_{L/U} \div 5) + (H_{I} \div 2)$$

Note: Each actual overspeed event and/or full load reject event should be evaluated individually for impact.

Additional factors for consideration:

- Hours of operation with vibration over International Standards Organization (ISO) advised alarm levels
- Hours of operation with vibration over ISO advised trip levels
- Hours of operation with steam temperature ≥25°F over design temp
- Number of accelerated startups
- Water induction events
- Loss of vacuum trips or poor vacuum conditions
- Rotors with shrunk-on disks and/or bored rotors
- Pre-existing conditions (cracks, stress corrosion, pitting, erosion, creep, etc.)

EOH Maintenance Intervals and Remaining Life

AEGIS Loss Control suggests a major inspection interval: 50,000 to 80,000 EOH

- Based on unit design, duty cycle, pre-existing damage, and approaching end of life, the interval may change.
- Monitoring operational conditions with advanced analytics and predictive models may justify modifying intervals.
- Calendar time with low operational hours and high idle time should be considered for shortened EOH intervals due to the potential of corrosion and pitting.

Suggested remaining life evaluation: 200,000 – 250,000 EOH

- The remaining life evaluation can be applied to components subject to creep, such as valve bodies, inlet steam piping, turbine cylinders and casings and rotors.
- Most rotors are designed for a 30-year life, assuming OEM-provided operating guidelines are followed. Contingency planning should commence well before reaching the original OEM design life, based on EOH.
- Evaluations include metallographic inspections, microstructure replication, (scoop/boat) sampling, rotor bore examination, and various Non-Destructive Examinations (NDE).
- Remaining life in hours and subsequent inspection timing should be provided and documented by the evaluators.

Conclusion

Lessons learned within the power generation industry have been a factor leading to significant advancements in equipment, system design and monitoring capabilities. Lifetime events can accelerate wear and component life consumption, which may change how maintenance is planned and performed. AEGIS Loss Control suggests incorporating applicable essential variables into steam turbine EOH calculations to refine maintenance intervals.

References

OEM guidelines and industry experiences were used in the compilation of this document. The principles are sound and can be applied to most types of steam turbines, if not all. For questions regarding applicability, contact the OEM for unit-specific guidance.

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