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Improving Performance and Efficiency of an Existing Energy Solution

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While there is a strong initiative to develop new (ideally renewable) energy sources for future applications, there is still a requirement for sustaining existing energy solutions, but with improved performance and efficiency. In the foreseeable future, there will continue to be a need for efficient steam based turbo-machinery for power generation, but with greater operating flexibility, to enable faster start-up times when required to supplement unavailable renewable resources such as wind or solar energy (e.g. the wind does not always blow and the sun does not always shine).

Turbine start-up times can be unnecessarily slow, simply because the constitutive model equations used to represent the cyclic response of materials used for high temperature rotors can be overly conservative. The objective of a recently completed Swiss CCMX-MERU funded project was to develop an elevated temperature evolutionary cyclic plasticity model with microstructural quantities providing the internal state variables to enable turbine start-up times to be determined in a less conservative way. Details of the gained experience of using neutron diffraction facilities in Europe and the United States for making ex-situ measurements to determine dislocation density and sub-grain size evolution during low cycle fatigue loading of a high temperature turbine rotor steel at elevated temperatures are presented, along with complementary microstructural evidence obtained by electron microscopy. The way in which this microstructural information was used to underpin a new microstructurally based evolutionary cyclic plasticity model is also reviewed.

Turbo-machinery efficiency is improved by increasing the temperature of the steam at the inlet stage of the high pressure module and/or by increasing the dimensions of the last stage blades at the exhaust of the low pressure module. As last stage blade size is increased, upper blade aerofoil speeds increase and enhanced water droplet erosion becomes a problem. One solution to limit this form of damage is to locally thermal harden blade leading edges. Unfortunately, limiting the risk of erosion damage in this way, increases local susceptibility to environmental cracking. Susceptibility to environmental cracking depends on material (hardness), environment and applied stress, and local applied stresses can be minimized by laser peening to generate compressive surface residual stresses to depths of ˜1-2mm. While the effectiveness of this solution can be demonstrated by a hole drilling technique on test plates, proof of concept on complex blade geometries requires residual stress measurement by neutron diffraction.

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