Introduction

The growing importance of variable renewable power sources results in coal-fired boilers being operated with more thermal cycles than envisioned when they were designed. This may lead to increased oxide spallation inside boiler tubing, which may result in downstream hot short failures or turbine erosion. The overall aim of this research project is to develop an oxide spallation model using a physics-based approach, that incorporates oxide morphologies and structures, to improve power plant performance. The research presented here is a parallel experimental approach to examine the cyclic oxidation performance and spallation of T91 boiler tubes pre-oxidized with a thick scale.

Variable Energy Resources

- Solar and Wind
- Often Deployed Ahead of Coal
- Increased Thermal Cycles in Coal Power Plants

Magnetite Coefficient of Thermal Expansion—CTE

- Reinterpretation of Arritt report of magnetite (Fe₃O₄ CT) (2.4×10⁻⁶ °C⁻¹ at 550°C)
- Overstated magnetite CTE
- NETL revisited original Russian data (Arkharov) it was based on (and also Levy, Okudera, Sharma, Takeda, Gorton and Fry)
- Different implications in thermal strains (and oxide spallation) from alloy type and oxide composition
- Oxygen activity effects on CTE will be addressed in phase field models

Experimental Procedures

Advanced Ultra-supercritical (A-USC) Steam Autoclave

- Flow controlled with a high pressure pump
- Pressure controlled with a back pressure regulator
- ASME dual rated to 704°C/346 bar and 760°C/228 bar
- Autoclave body made of 230

Cyclic Plans for Spallation

Summary

Cyclic oxidation tests in high pressure steam on T91 boiler tube sections to support verification of boiler oxide spallation models

Progress:
- Critical review of the available CTE data of Fe₃O₄
- Pre-oxidation at 710°C/200 bar steam of T91 boiler tube sections to establish thick initial oxide scales prone to spallation
- 210 µm after 486 h
- 375 µm after 1984 h
- Morphology similar to that found from long-term boiler exposures
- Cyclic test plan to simulate 12 cycles in 29 days—600°C/200 bar to 400°C/10 bar
- Other cycles planned for 600°C/200 bar to 200°C/10 bar

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