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Thermal Fatigue Analysis of Weld Liner for the High Cyclic Operations

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Abstract— In the power plant industry, plant boilers have regulated steam temperature so that the boiler and turbine-generator can operate properly and efficiently. A replaceable liner is installed for protection against erosion and thermal shocking of the desuperheater pressure shell. The proposed methodology and concepts are new and unique, and demonstrate the applicability to general transient non-linear/linear thermal analysis situations. Characteristic features and pertinent details of the approach are described for non-linear/linear transient thermal problems, where in non-linearity's due temperature dependence of thermo physical properties and/or general non-linear boundary conditions to include radiation, effects due to phase change, etc., are considered.

Keywords: Thermal Expansion, Liner, Thermal Gradient, Stress

I. INTRODUCTION

The fundamental design principles and process for modern steam de super heating, in the power generation industry have been evolving since the early 1930s. Superheated steam is principally used in power generation plants as the driving force for turbines. Meeting the requirement for steam quality, quantity and temperature consistency is the foundation of traditional de super heater component design. Superheated steam is steam that is at a temperature higher than the saturation temperature for the steam pressure. A replaceable liner is installed for protection against erosion and thermal shocking of the desuperheaterpressure shell, which would otherwise occur as a result of intermittent desuperheater spray.

II. COMPUTATIONAL METHOLOGY

A. Geometry & Finite element model

Fig1 shows the sectional view of three piece weld liner before fabrication. As the geometry is of axis-symmetric in nature, a 2D model is considered for the analysis. Fig2 - gives the snap of geometry. Fig3 - gives the snap of finite element which is meshed with plane55.

Fig. 1: Sectional View of Liner

Fig. 2: 2D Model of Liner

A refined mesh is used to capture the stress & temperature transients. The geometry is divided into multiple zones and heat transfer coefficients are calculated based on pipe & free convection correlations.

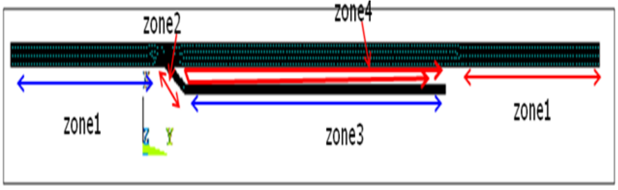
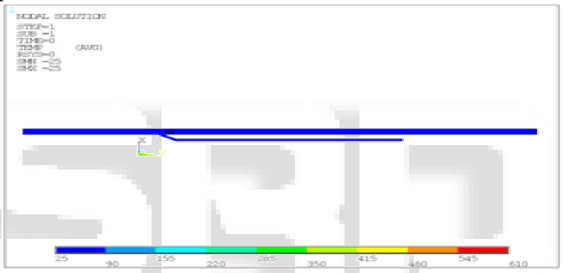
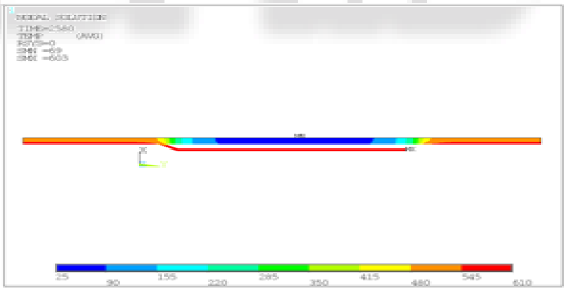


Fig. 3: Finite Element Model

B. Boundary conditions & thermal analysis

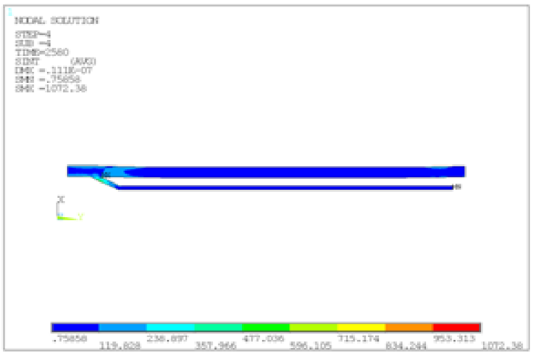
In the current study, cold start operating conditions are studied and analysed. A non-linear transient thermal analysis is performed and temperature scenario at 0.001sec & 2580sec is given in fig. Max thermal gradient is observed at 2580sec. At this point, it can be observed that min temperature is observed at the mid part of the pipe and max temperature is observed at liner.

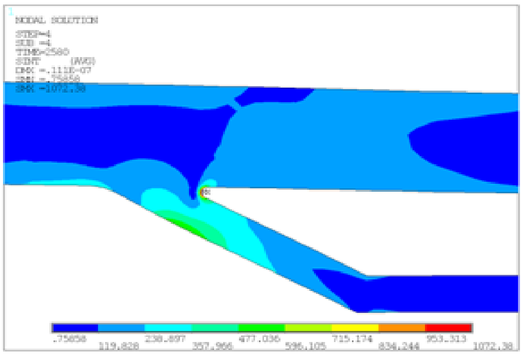




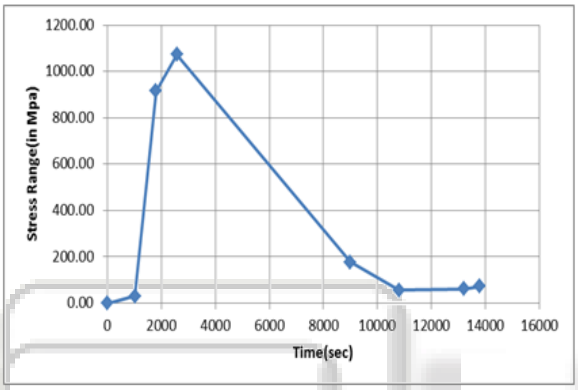
C. Structural analysis

Boundary conditions for structural analysis are the internal pressure of steam & the temperatures from thermal analysis. To estimate the max thermal stress, structural analyses at discrete points are calculated.





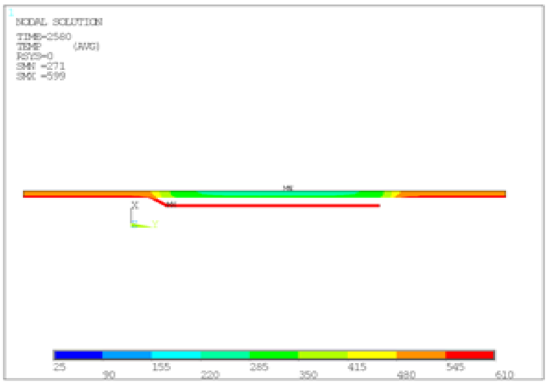
Due to the max thermal gradient at 2580sec, max thermal stress is observed. Fig gives the trend of this thermal stress. Till 2580sec, thermal gradient increases and in turn increases the thermal stress. Later, component tries to achieve steady state & in turn reduces the thermal stress too.



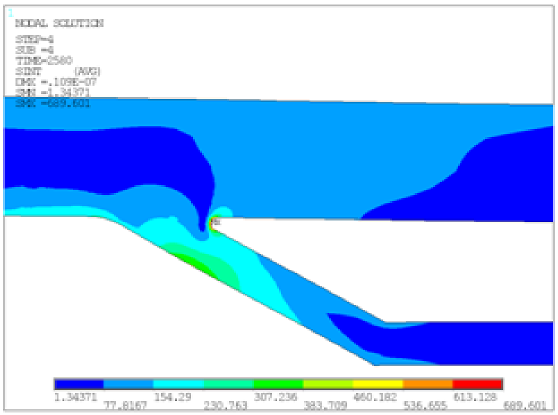
Using the max thermal stress of 1072Mpa, fatigue life is calculated using EN 12952-3. From this calculation, estimated no of life cycles are 332 & damage index due to cold start is 1.51(>0.4). Based on the assessment criterion of section-13 of EN 12952-3, as this is greater than 0.4, component is disqualified for the use of current operating conditions.

D. Optimization & improvement of fatigue life

As part of the improvement of fatigue life of the component, design of the component & operating philosophy of the component are changed significantly. To reduce the thermal gradient, pre-heating of the component to 80C is suggested & necessary arrangements are done. Also, due to the high temperature difference, radiation heat transfer is modelled. Fig- gives the design changes performed in the component. Holes/slots are created in liner to increase the steam flow rate in back side cavity b/w liner & pipe. This helps in creating forced convection & decreases the thermal gradient in the pipe.



In the current axisymmetric analysis, modelling of these holes are neglected. By performing nonlinear transient thermal analysis, temperature at different time points can be seen. Fig gives the thermal scenario of component at 2580sec. Fig- gives the stress contour at 2580sec.



Fatigue life is calculated based on 689MPa & is found to be 1698 cycles. Damage index is estimated as 0.29(<0.4). So, current design is qualified for the given operating conditions.

III. CONCLUSION

As per the current study, weld liner is modelled and analysed using axisymmetric FE methods. Heat transfer coefficients over time are calculated and non-linear transient thermal analysis is performed to get thermal scenario at different time points. Thermal stress is estimated by performing structural analysis. Initially, high thermal stress of 1072Mpa is observed. Fatigue life & damage index are estimated using EN 12952-3 and damage index is found to be 1.51. Component is redesigned and thermal stress is reduced to 689MPa and damage index is reduced to 0.29 which qualifies for the current operating conditions. Traditional weld liner can be used for faster ramp up operating cycles by doing proposed modifications in the design.

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