FLOWNEX®

SIMULATION ENVIRONMENT

BOILER TUBE FAILURE THERMOHYDRAULIC ANALYSIS

The boiler hopper tubes at an Eskom Power Station suffer from continuous mechanical failures that lead to frequent unplanned maintenance. Using Flownex SE coupled to ANSYS, various hypotheses to the cause of these failures could be examined without affecting plant operations.

The project involved several first of its kind engineering practices, which included:

- The first full transient detailed thermal flow model done on a complete sub-cooled boiler section wall at near real-time modelling.
- The first large scale interactive communication between thermo-hydraulic systems CFD and structural analysis software.

Eskom

POWER GENERATION

CHALLENGE:

The challenge would be to investigate the effect of a delay in cooling water supply between two adjacent boiler tubes of different tube banks. The delayed effect is one of the hypotheses proposed as main thermal fatigue inducing contributors.

BENEFITS:

The benefits using Flownex for this system are:

- Detailed thermohydraulic results of the intricate system at near real-time solving speed.
- Performing multiple investigation studies without affecting plant operations.

SOLUTION:

The results from the model corresponded very well with the measured plant data. This enables further use of the model for various postulated plant conditions and operations sequences.

The results from the model indicated that the delay in water supply should not cause perturbing stresses as postulated.

"Performing multiple investigation studies without affecting plant operations."

INTRODUCTION

The boiler at Eskom's Power Station experiences continuous mechanical failures in its hopper section. Serious tube leaks result in unscheduled downtime and emergency repairs which in turn has large financial consequences.

Figure 1: An example of typical boiler tube failure locations

Various opinions on the cause of these failures exist, with most being attributed to consequences of the plant's enforced two-shifting operating regime.

SYSTEM DESCRIPTION

The tube failures investigated in this study occurred in the hopper section of the boiler. This section forms the bottom part of the boiler where the system's water arriving from the economizer is still in its sub-cooled phase.

Only one half of the four boiler hopper walls were modelled as this forms a representative region of the complete hopper section. This section was also instrumented with thermocouples and strain gauges to obtain measured plant data for validation of the model.

OBJECTIVE OF SIMULATION

The hypothesis for our investigation was that the water from the economiser will reach the closest tube bank first and cause significant fluid temperature difference between the first bank's outermost tube and the adjacent tube of the second bank.

"Serious tube leaks result in unscheduled downtime and emergency repairs which in turn has large financial consequences."

The objective of the simulation would be to determine the effect of the delay in cooling water supply between two adjacent boiler tubes of different tube banks. It was believed that this delay period contributed greatly to the mechanical failures experienced.

Flownex played an integral part in successfully completing this study.

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FLOWNEX MODEL

The Flownex model was set up by importing the geometry of a half symmetric section of the hopper's rear wall tubes based on the ANSYS[1] model iso-file. This way, nodes could be efficiently placed at all the required coordinates where temperature and other fluid property results were required for the stress analysis.
This unique Flownex model consists of a huge number of components, including 1219 pipes and 1858 vertices/nodes.

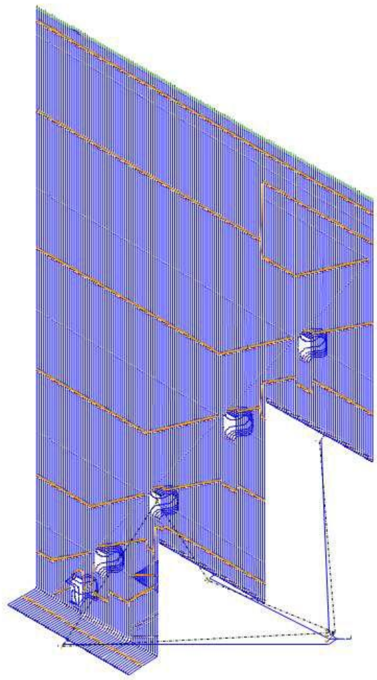

Figure 2: Flownex SE view of model

A full thermal transient model was also constructed to obtain valuable information for the evaluation phase of the project.

Custom compound heat transfer components were created to limit cluttering of the user interface and generate custom defined results.

[1]ANSYS-software offers simulation solution sets that are required in the process requirements for engineering simulation.

Figure 3 illustrates some of these custom compound components in the network that was modelled in Flownex SE.

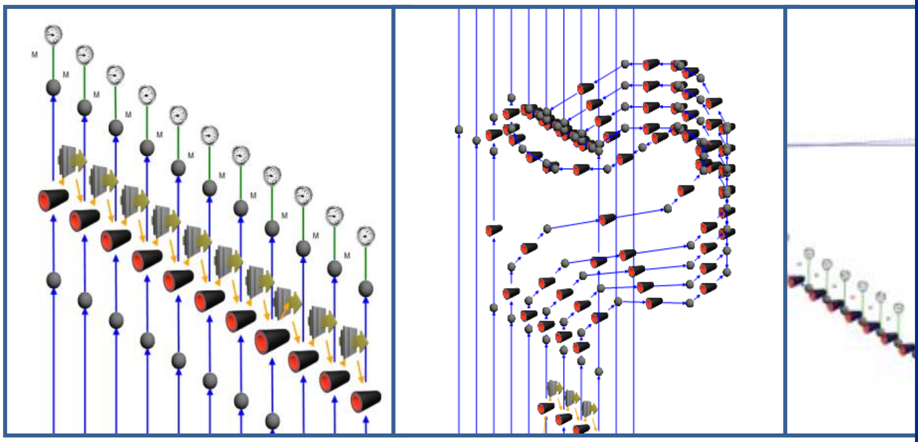

Figure 3: Zoomed view of the Flownex Model illustrating some of the custo

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DESCRIPTION OF SIMULATION

Flownex was deemed the ideal thermohydraulic software to model the fluid and tube wall temperature distribution. This decision was based on Flownex's capability to fundamentally calculate flow and heat transfer behaviour of both fluid and tube wall material during steady state and dynamic conditions.

Using the same economizer outlet temperature profile as obtained during the plant measurement sequence together with adjusted gas side heat transfer properties, a dynamic start-up scenario was modelled to validate the results from the model against that of the measured plant data. A number of other scenarios were also successfully undertaken.

The temperature distribution results from Flownex were then imported into ANSYS where the structural stress analysis was performed.

Figure 4: Process followed in completing the simulation

This model was used to investigate both steady state and transient conditions.

RESULTS

Our first aim was to achieve the same temperature distribution results in Flownex SE as measured on the boiler hopper section itself. The comparison of the temperatures at the inlet to each tube bank is shown in Figure 5, with that of the staith intersection shown in Figure 6.

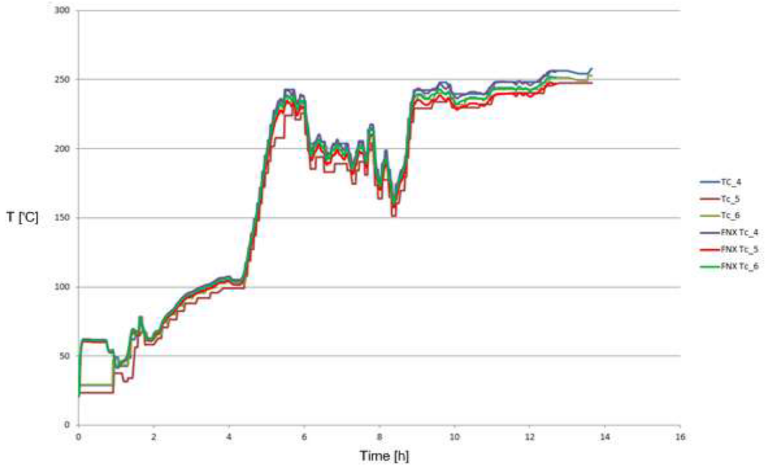

Figure 5: Tube bank inlet temperature comparison

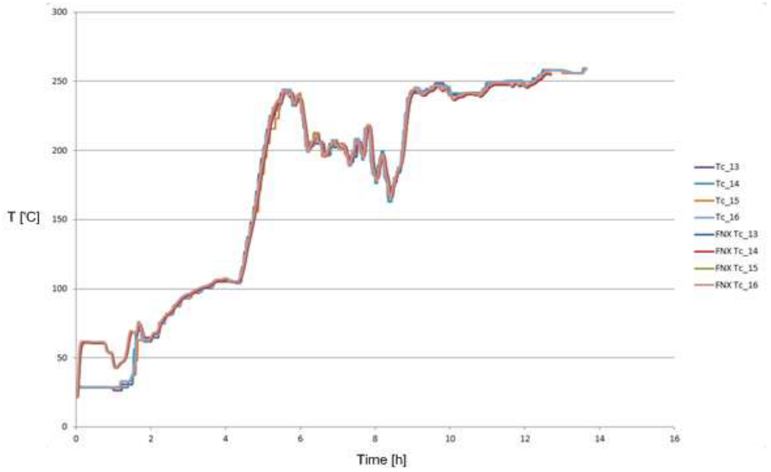

Figure 6: Staith intersection temperature comparison

Due to the Flownex results corresponding very closely with the measured data, several other scenarios could be investigated with confidence.

From the output data we discovered that the delay in water supply should not cause perturbing stresses as postulated. This proved to be due to the conduction and thermal inertia of the tube walls and webbing that causes a smooth transition in adjacent tube wall temperatures.

CONCLUSION

Possible causes of boiler hopper tube failures were investigated using Flownex SE and ANSYS FEA. The importing and exporting capability of Flownex SE to and from 3rd party software made it possible to generate fluid and tube wall temperature profiles of the exact ANSYS geometry, from which the required structural effects could be scrutinized again in ANSYS.

By using determined gas side heat transfer properties, a good thermodynamic similarity was obtained with that of the measured data. This similarity provided assurance that the model's results will be valid for all other scenarios to be investigated as well.

The results from the model indicated that the delay in water supply should not cause perturbing stresses as postulated.

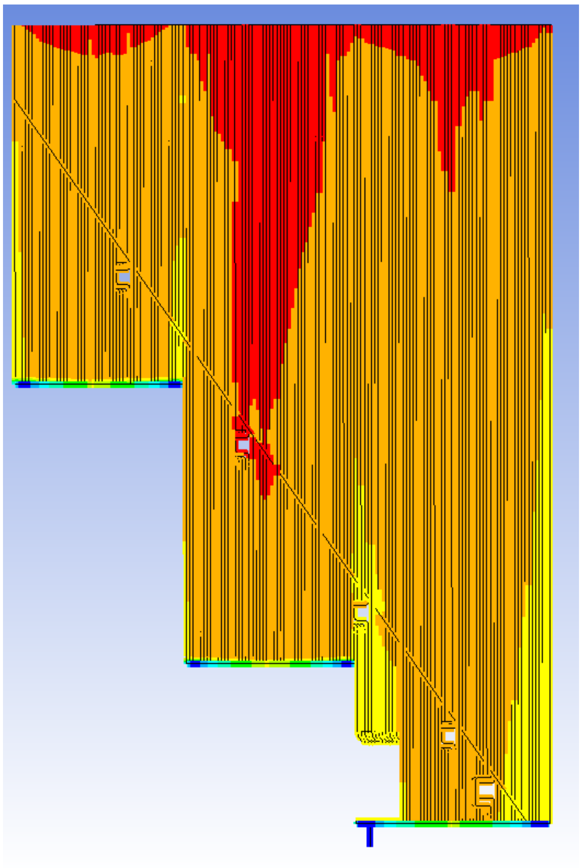

Figure 7: Solved thermal field in Flownex (Front Wall)

Similar problems have been reported at various Eskom power stations. Identifying the main contributing factor to these stresses may lead to the mitigation of numerous outages due to tube failure repairs, which in turn will result in a vast financial benefit to Eskom.

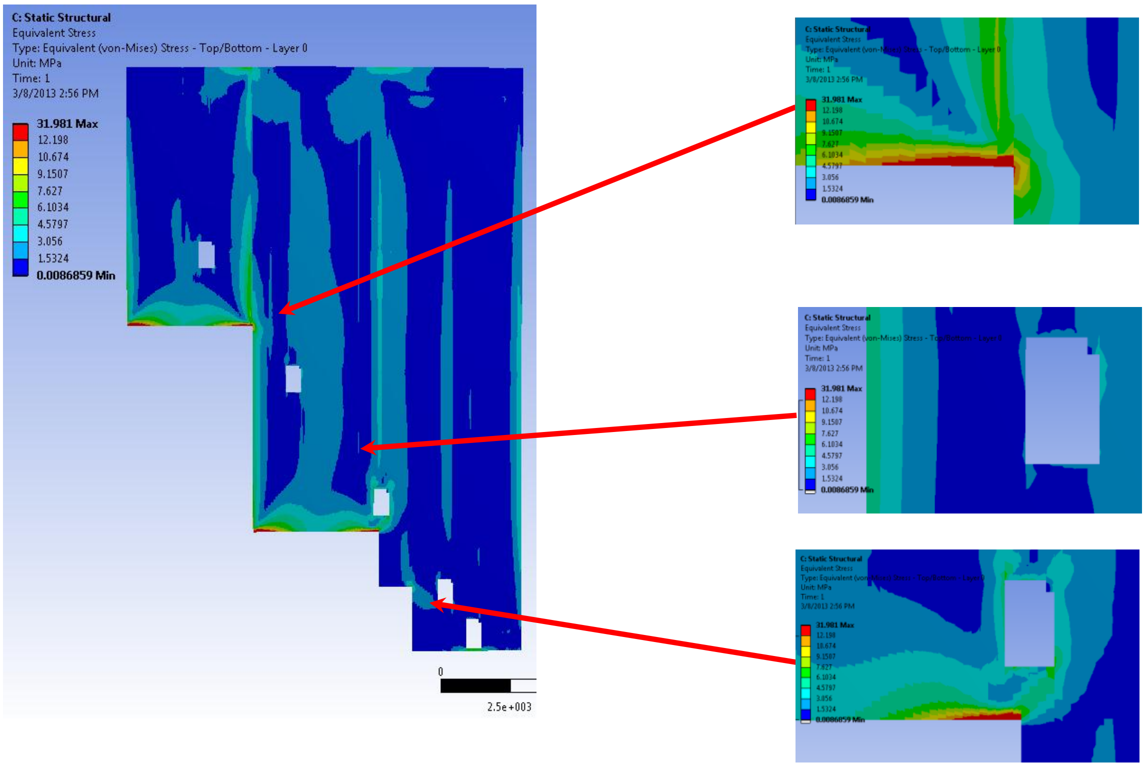

Figure 8: Thermal Stress Results (Tube wall only)

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- The first large scale interactive communication between thermohydraulic systems CFD and structural analysis software.

TESTIMONIAL

Testimonial provided by Roelf Laurens, Flownex SE Simulation Design Engineer, M-Tech Industrial:

"The capabilities and speed of result generation impressed several involved parties, but more importantly, the investigations gave a much better understanding of the plant's behaviour that would only have been previously obtainable through years of documented plant measurements. "

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