University of Nottingham
UK | CHINA | MALAYSIA

CITRUS SOLUTIONS

A CFD-FEA Approach for TMF Life Assessment of a Steam Header with Validation through Experimental Fluid Dynamics

Kenanao Sithole
Supervisors: Chris Hyde, James Rouse, Richard Jefferson-Loveday

INTRODUCTION

Due to environmental pressures, power plant operators have adopted `two-shifting' operating strategies to remain profitable. They involve frequent start/stop and partial load operations of the plant, which pose new risks on the structural integrity of components. This research investigates the impact of these new strategies on steam headers through developing a novel constitutive model to describe thermo-mechanical fatigue (TMF), and FEA and CFD coupled models validated through experimentation, that describe the steam and header wall interactions.

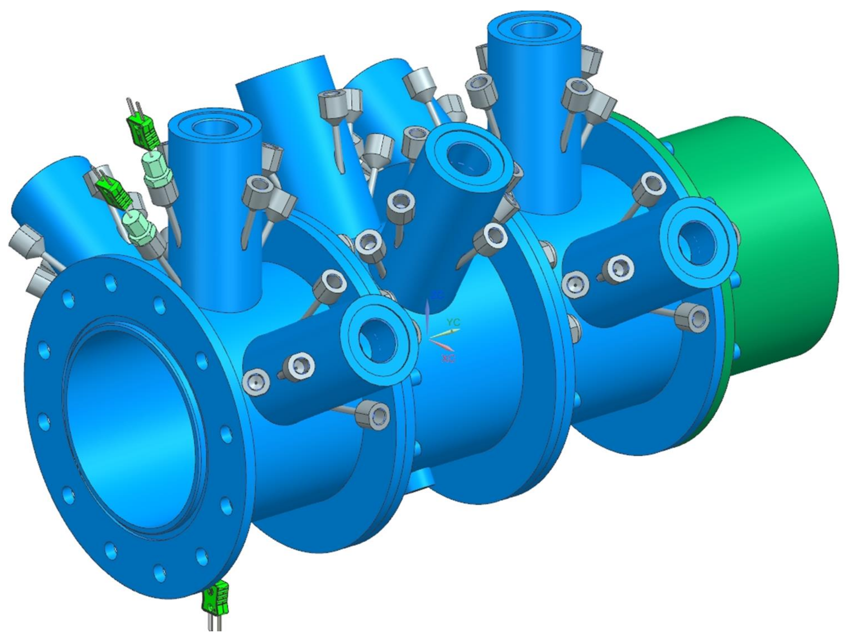

Figure 1: Steam header CAD model to be manufactured for test rig.

AIMS AND OBJECTIVES

Aim: Develop a CFD-FEA approach for thermo-mechanical analysis of steam headers to inform industrial life assessment procedures. **Objectives:** 1. Create accurate CFD models of steam header. 2. Conduct experiments to validate CFD models. 3. Develop a novel material model for 316 stainless steel (steam header material) in TMF applications. 4. Determine the mechanical behaviour of header through thermo-mechanical FEA analysis informed by CFD.

RESEARCH GAP

CITRUS is a novel software created within the G2TRC. It maximizes performance of components by providing live monitoring of stress and lifetime remaining. CITRUS uses neural networks and advanced algorithms to conduct complex transient stress simulations. The findings from this research will enhance its accuracy through CFD informed stress calculations.

METHOD & RESULTS

EXPERIMENTAL RIG
- Test rig designed to validate CFD method i.e. **mesh & turbulence modelling. (See figure 1)**
- **Representative fluid** used is **Eastman 2197 oil** because **steam pressure and velocity** are **unattainable** in university facilities.
- Measured values – **Wall temp.** & **fluid velocities.**

CFD TEST RIG MODEL
- **Validated CFD model (oil)** and **method** based on experimentation. **(See figure 2)**

CFD MODEL STEAM
- Validated CFD method extended to model steam in header. **(See figure 3)**

FEA MODEL OF HEADER
- Heat Transfer coefficients (HTCs) are obtained from steam CFD model and define heat transfer in thermo-mechanical FEA models of the header material. **(See figure 3)**
- Novel material model of 316 stainless steel is applied in FEA models. **(See figure 4)**

CITRUS
- HTCs from CFD model are used in training of CITRUS neural networks.

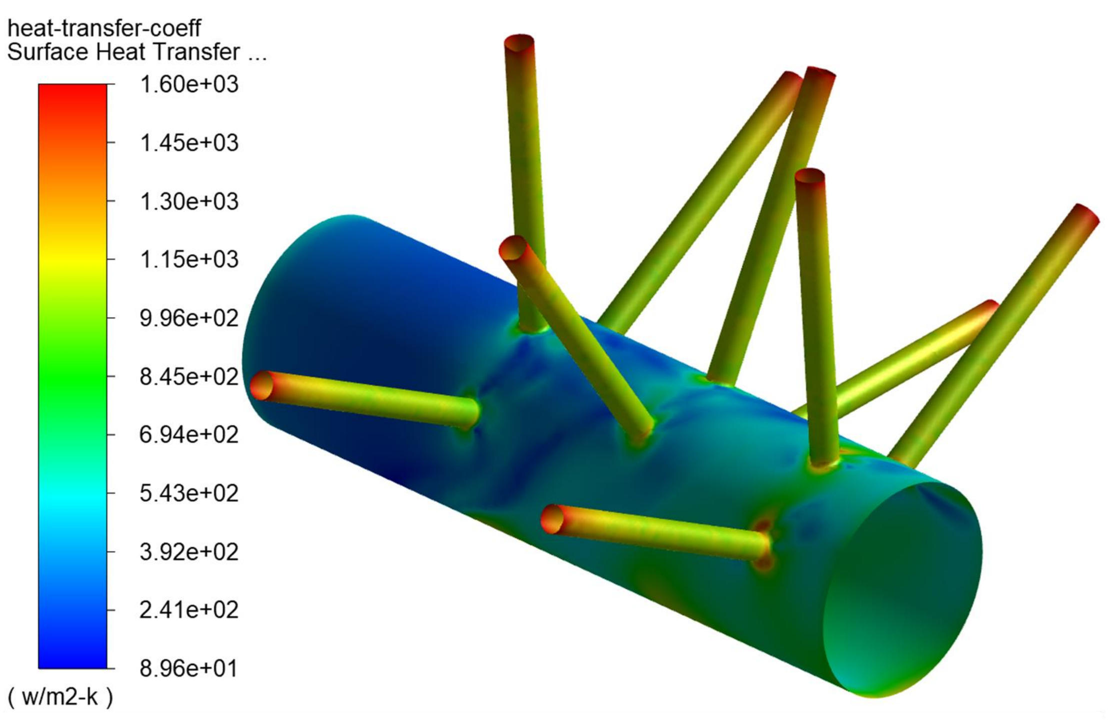

Figure 2: CFD model oil flow in test rig showing HTC field on inner wall.

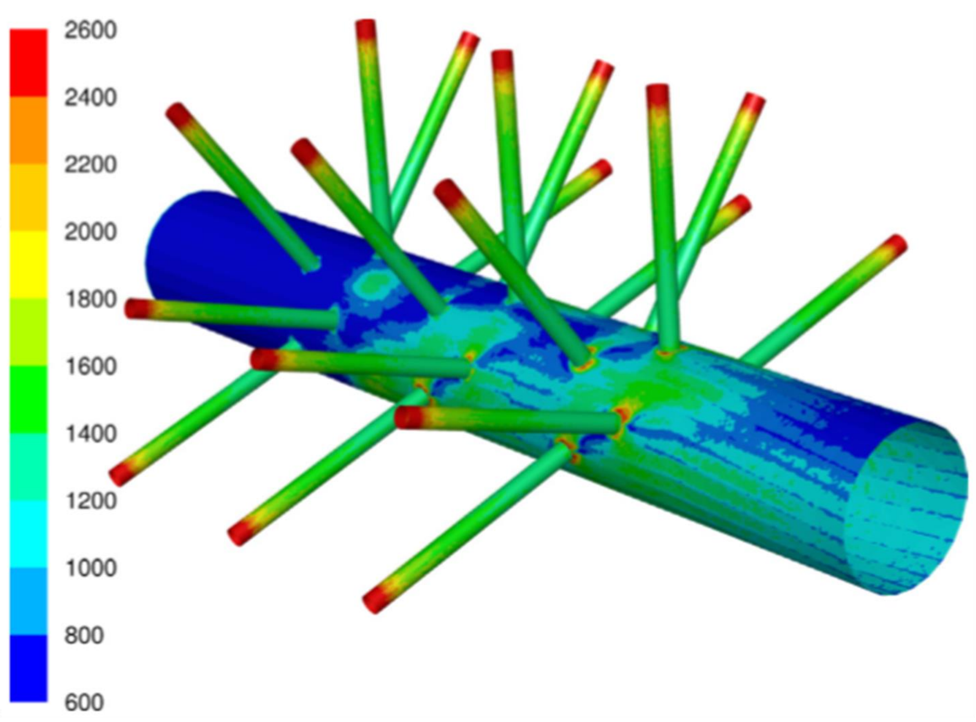

Figure 3: CFD model of steam flow showing HTC field on inner wall [1].

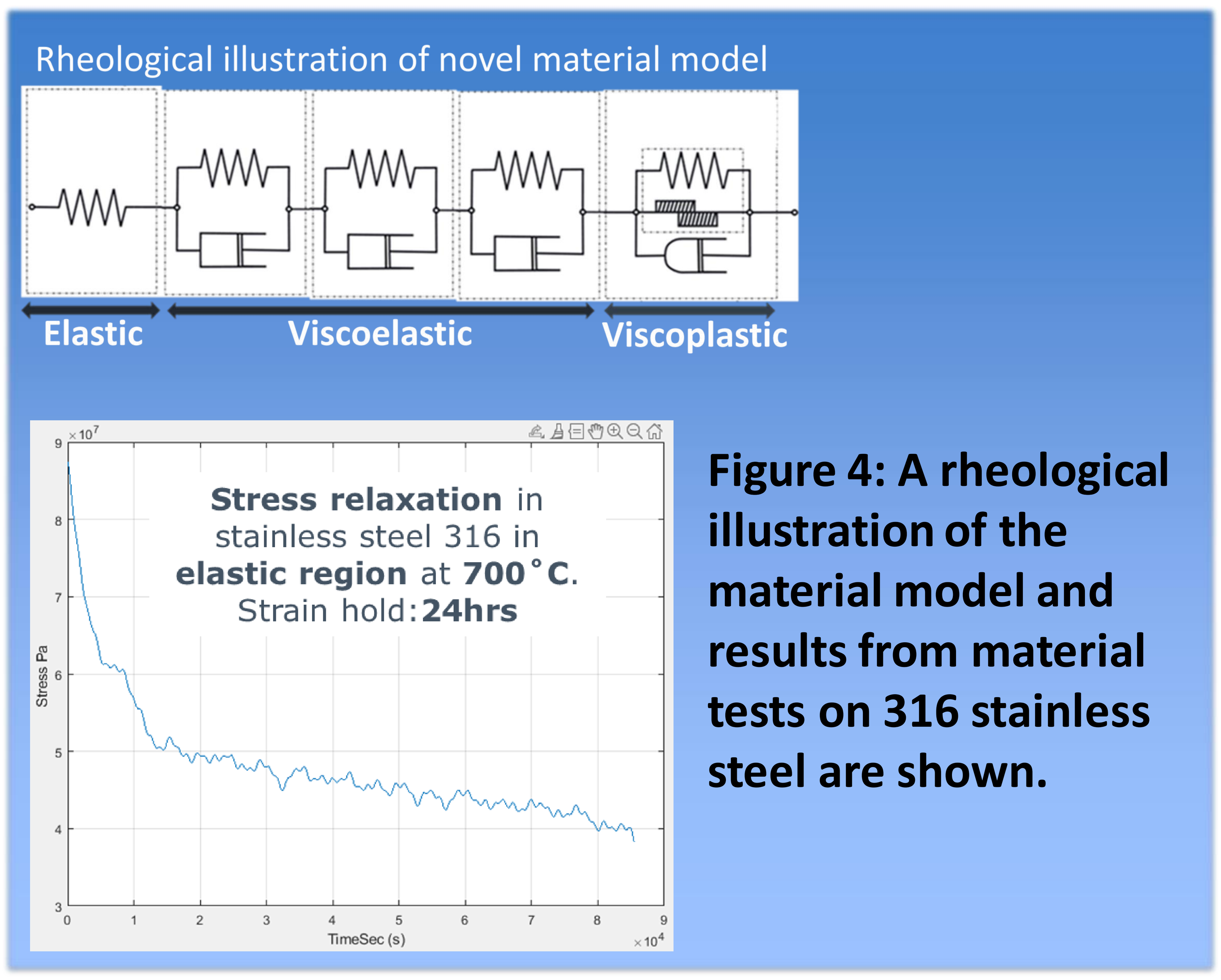

Figure 4: A rheological illustration of the material model and results from material tests on 316 stainless steel are shown.

CONCLUSIONS & FUTURE WORK

The preliminary results of this research show that due to the HTC gradients, heat transfer on the wall of the header is not uniform. The HTC field is heavily impacted by the behaviour of the fluid flow. Future work aims to validate these results through the test rig experiment.

REFERENCES

[1] Rouse, J.P., et al., A case study investigation into the effects of spatially dependent convection coefficients on the fatigue response of a power plant header component. Int J Fatigue

Gas Turbine and Transmission Research Centre (G2TRC)