# Experimental report

20/02/2018

| | | | |
|---|---|---|---|
| **Proposal:** | **1-02-194** | **Council:** | 4/2016 |
| **Title:** | A study of the effect of thermal cycling on residual stress in the turbine housing component of the turbocharger. | | |
| **Research area:** | Materials | | |

**This proposal is a continuation of 1-02-141**

| | |
|---|---|
| **Main proposer:** | **Susan KILCOYNE** |
| **Experimental team:** | Susan KILCOYNE<br>Katy GANNON |
| **Local contacts:** | Thilo PIRLING |

**Samples:** Fe alloy (>95% Fe)

| Instrument | Requested days | Allocated days | From | To |
|---|---|---|---|---|
| SALSA | 3 | 6 | 13/09/2016<br>19/02/2017 | 16/09/2016<br>22/02/2017 |


## Abstract:

To meet European performance, durability and legislative conditions, a turbine housing must be capable of operating in harsh environments, in which they are subjected to thermal cycling up to 800°C. Many turbine housings are at the limits of operation with regard to strength and durability under these conditions, and failures have been recorded on accelerated durability tests. It is therefore of great importance to understand the fatigue performance of these components and the conditions that determine this fatigue. The proposed experiment is a continuation of preliminary work on SALSA in 2013 (proposal 1-02-141), which looked at the effect of heat treatment on residual stress relaxation. This experiment will now explore the effect of thermal cycling on residual stress stability, by obtaining measurements in fatigue crack initiation sites both before and after thermal cycling. It is hoped that this combined with additional work using high temperature strain gauges to measure surface strains induced during thermal cycling, will provide a complete picture of how residual and applied stresses change throughout the life of the housing, and allow the validation of simulation models.

# Introduction

Residual stress in engineering components has been shown in some cases to promote fracture and accelerate fatigue, causing unexpected failure during operation. It is important to understand residual stress magnitudes and distributions. In a turbine housing component of a turbocharger residual stresses can form due to the temperature differential that exits across the varying section thicknesses within the housing as the molten cast iron cools and solidifies in the mould.

During operation, turbine housings are subjected to a thermal cycle as a result of exhaust gas flowing through the housing, thermo-mechanical fatigue (TMF) is the primary mode of failure. This behaviour can be simulated using Finite Element Analysis (FEA) methodologies. However, current FEA methods do not consider the presence of residual stress as a 'pre stress' condition. It is unknown what effect this could have on the behaviour of the turbine housing during operation. In order to quantify the effect residual stresses have on the level of accumulated plasticity after thermal cycling it is necessary to obtain residual stress measurements before and after thermal cycling. Measurements prior to service will serve as a baseline of the initial condition of the housing and will be used to validate FEA models of residual stress. Measurements of residual stress in the part after thermal cycling will then be used to validate FEA simulations combining both the initial condition of residual stress and the applied load due to thermal cycling. By performing FEA simulations with/ without the presence of residual stress, and by confirming our simulations against measured values it is hoped we can determine the influence of residual stress on the plasticity accumulated after thermal cycling.

The complex shape of the turbine housing and the variable thickness of the internal sections, means that the residual stresses in the area of interest are difficult to measure by other means hence the need for neutron diffraction.

# Method

The residual stress measurements consisted of four line scans taken in various locations in the housing as shown in Figure 1a. These locations are referred to as positions 3, 6, 9 and 12 in relation to a clock face. The datum from which all dimensions were referenced against was set as the centre point of the housing (position zero).The positions were chosen to maximise the coverage of the turbine housing and all line scans were taken internally in the housing through the central divider wall which separates the two gas passages as shown in figure 1b.

The Measurements were obtained by scanning from the internal edge of the divider wall to the outer perimeter of the housing in 2mm steps. Depending on the line scan location and the required strain component the turbine housing was positioned so that the required strain component was in the direction of the scattering vector, Q. Tri-axial (hoop, axial and radial direction). The strain free d0 reference was obtained from EDM cut plates of the turbine housing material.

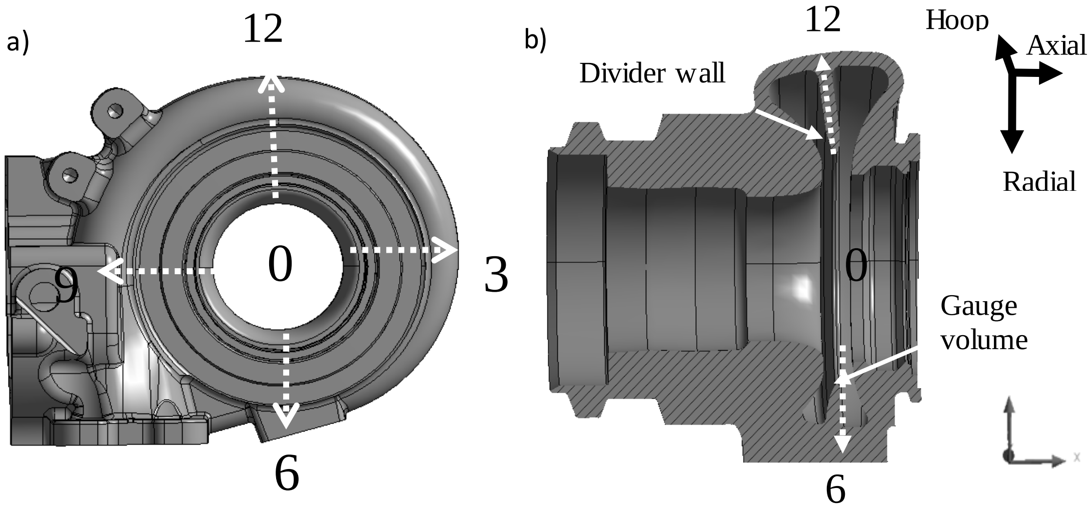


Fig 1 a) showing the locations of the 4 line scans and b) showing the interior cross sectional view of the housing and the lines scan through the divider wall.

# Results/ Discussion

A selection of results of the experiment are presented in Figures 2 & 3. The effect of the thermal cycling on the magnitude of the hoop strain and the other strain components, appears to be minimal. Interestingly the strain measurements in position 9 and 12 and positions 3 and 6 appear to align together after the turbine housing was thermally cycled, this was also evident in the axial and radial measurements. This behaviour corresponds with the deformation of the turbine housing as it expands and contracts during operation.

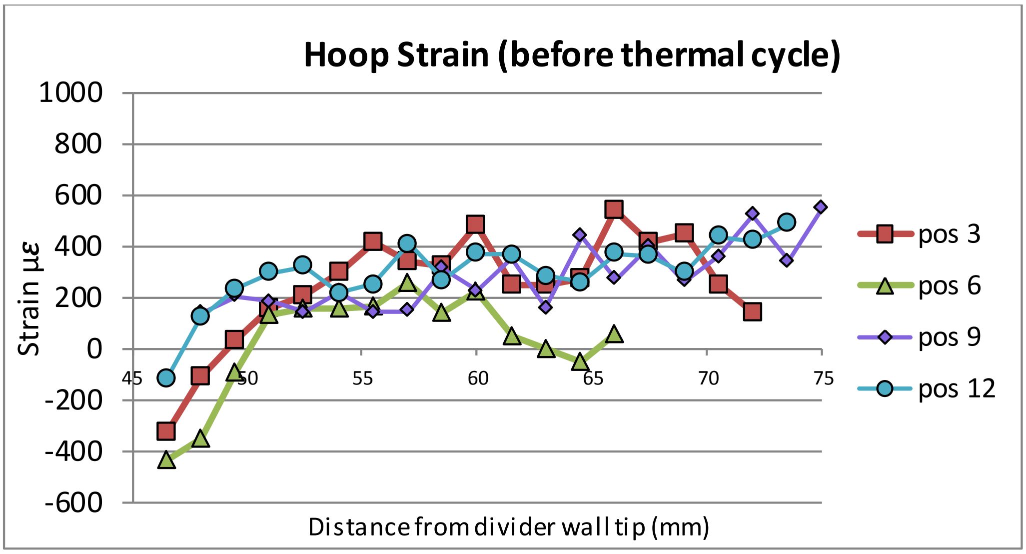


Fig 2 Hoop strain measurements in each of the measurement positions within the turbine housing prior to thermal cycling the error in the measurement is within the point marker.

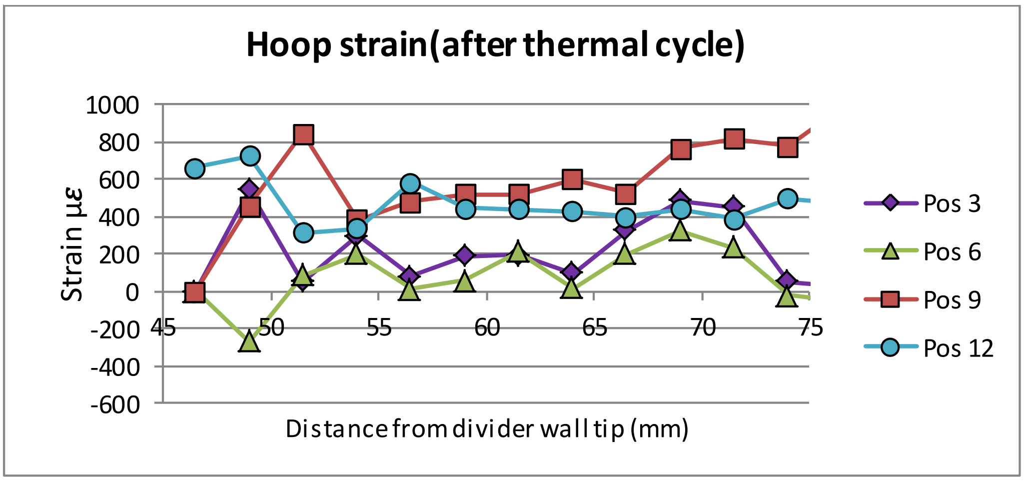


Fig 3) Hoop strain measurements in each of the measurement positions within the turbine housing after thermal cycling of the turbine housing. The error in the measurement is within the point marker.

## Further work

Further work is being undertaken to compare neutron residual stress measurements with contour measurements and simulation models to better understand the residual stress distribution throughout larger areas of the turbine housing. The results will then be used to simulate a pre-stress condition within the housing to understand the impact this has on the onset of plasticity in the turbine housing during operation.