Experimental report

14/06/2017

Proposal:	**1-02-191**	**Council:**	4/2016
Title:	Residual stress redistribution of laser cladded rail		
Research area:	Engineering		

This proposal is a new proposal

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Samples: Steel rail sample

Instrument	Requested days	Allocated days	From	To
SALSA	6	6	08/07/2016	14/07/2016
			14/07/2016	16/07/2016

Abstract:

To improve the railway networks, track components with greater durability are essential. To this end, we clad a layer of premium material on railhead to reduce wear and the likelihood of fatigue in an effective manner. The resulting residual stresses generated in both the clad and base metal and change in the microstructure of the substrate can be detrimental to their integrity. We propose to measure their residual stress to validate our finite element model for specimens of high and a low durability.

Introduction

Method

Sample Geometry

Two rail samples were considered. Each had been laser clad with a layer 2 mm thick and then ground back to 1.2 mm. The dimensions of each sample was approximately x=250 mm x y=75 mm x z=35 mm; an example of one is shown in Figure 1.

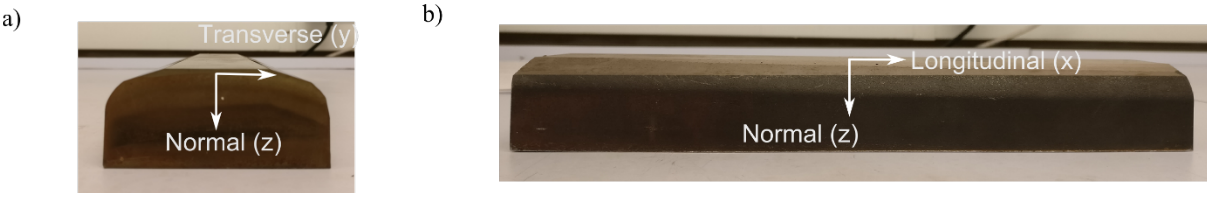

Figure 1: Image of clad rail sample in two different orientations

The samples differed in the clad materials used. One was clad with a martensitic stainless steel and the other with the cobalt alloy Stellite-6. The substrate material is R260, a ferritic steel alloy used primarily in rail track.

Measurement Locations

Measurements were made at the centre of each rail sample at several points through their depth (z direction). Measurements in the vicinity of the clad and heat affected zone (HAZ) were most important and therefore scans were made at increments of 0.2 mm from the clad surface to a depth of 2 mm and 0.4 mm from 2 mm to 4 mm. Below this, it was not expected that there would be significant residual stress effects as the clad is thin in comparison with the bulk of the material. Consequently, scans were made at increments of 2 mm through the remainder of the rail samples.

In the martensitic steel clad sample the diffraction peak chosen was the [2 1 1] iron (Fe) peak. With the Stellite-6 clad sample there are two materials of interest: cobalt and iron, with the possibility of mixing between at the clad-substrate interface. This meant that scans through the clad and near the interface were made using the cobalt peak and repeated for the aforementioned [2 1 1] Fe peak either side of the interface. As cobalt is a better neutron absorber than steel and therefore count time

Selected Gauge Volume

In the region of the clad and clad-substrate interface, the minimum collimator width possible (0.6 mm) was used as a high spatial resolution was desired. This configuration was used up to a depth of 4 mm in order to capture all of the HAZ as well. As mentioned previously, it was expected that the stresses are significantly lower in magnitude below 4 mm and likely to be more uniform in comparison to the clad. This meant that it was necessary to prioritise measurement speed over spatial resolution and hence the 2 mm collimators were used to provide a considerably faster count time.

The samples were oriented such that either the x or y axes of the rail were parallel to the height of the neutron beam. It was assumed that the stresses did not vary significantly in the x direction in the vicinity of the centre enabling the height of the neutron beam to be increased and hence a larger gauge volume to be used.

Correction for Partially Filled Gauge Volume

In both samples measurements are made near the boundary between two media: at the air-clad surface boundary and at the clad-substrate interface. This means that there will be measurement points where the gauge volume is spread over the two different materials meaning the peak positions are artificially shifted. To correct for this, a customised Mathcad script written by the instrument scientist Thilo Pirling was used to process the data and calculate the actual peak position.

Results

Martensitic Stainless Steel

Residual stresses measured in the sample with the martensitic steel clad are in Figure 2. The results for the near-clad region clearly show that the stresses within the clad are compressive and biaxial in nature closer to the surface. The normal component is near-zero until a depth of 0.6 mm after which it increases in magnitude. Towards the interface, starting at a depth of 1.0 mm, the stress state is triaxial. Beyond this, the stress tends closer to zero until 1.6 mm after which it reaches a relative plateau at 50-100 MPa. This flat trend continues beyond 4 mm depth as seen in Figure 2b and it is noted that any discrepancies in actual measured value between the two collimators in the substrate region are likely to be because the 2 mm collimator averages the stress over a greater volume of material.

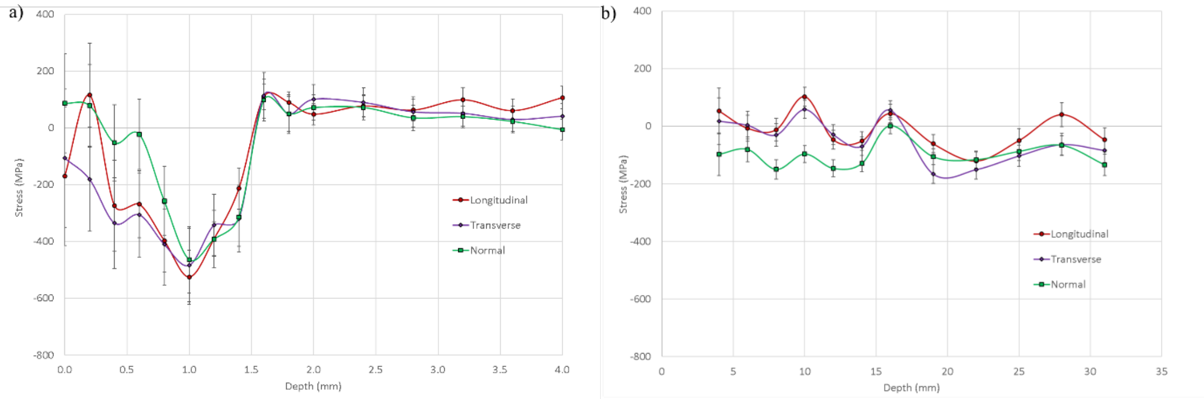

Figure 2: Stress measured in all three directions in martensitic steel clad sample using a) 0.6 mm collimator near clad and b) 2 mm collimator in the substrate (gauge volume corrections applied)

These results are plotted with corrections for gauge volume partial filling having already been made. The significance of the corrections are shown in Figure 3, where results before and after corrections were applied have been plotted together. Although there is some effect near the clad surface, the stress has only been altered by 70 MPa at most at the surface. There is negligible change at the clad-substrate interface, which may be because the two materials are iron-based and diffract at the same peak. However, it was noted that peak broadening did occur at the interface and it may be that this effect needs to be considered in future where a similar metal interface occurs.

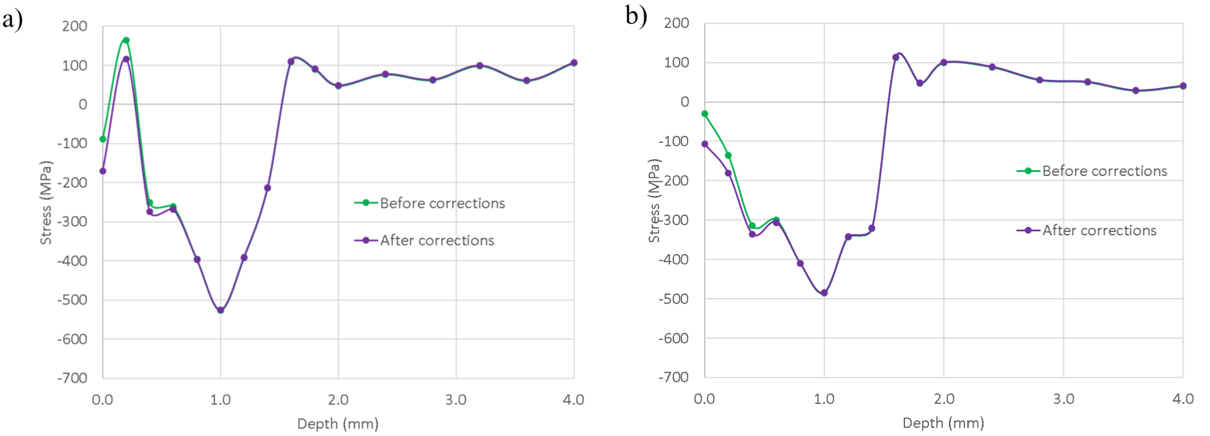

Figure 3: Martensitic steel clad rail results before and after corrections shown for a) longitudinal and b) transverse directions

Stellite-6

As predicted, the cobalt clad had a deleterious effect on counting times and the peaks obtained were generally unsuitable for fitting when measured at the cobalt diffraction angle. Attempts were made to measure peaks at other diffracting planes although these were unsuccessful. Results are plotted for the Fe peak showing results below the clad-substrate interface. Results with the 0.6 mm collimator show that the residual stresses are compressive and triaxial below the interface and reach zero at 2.8 mm depth. This is supported by results made with the 2 mm collimator (Figure 4b). As explained previously, the larger gauge volume causes some discrepancy between measured values using the two collimators.

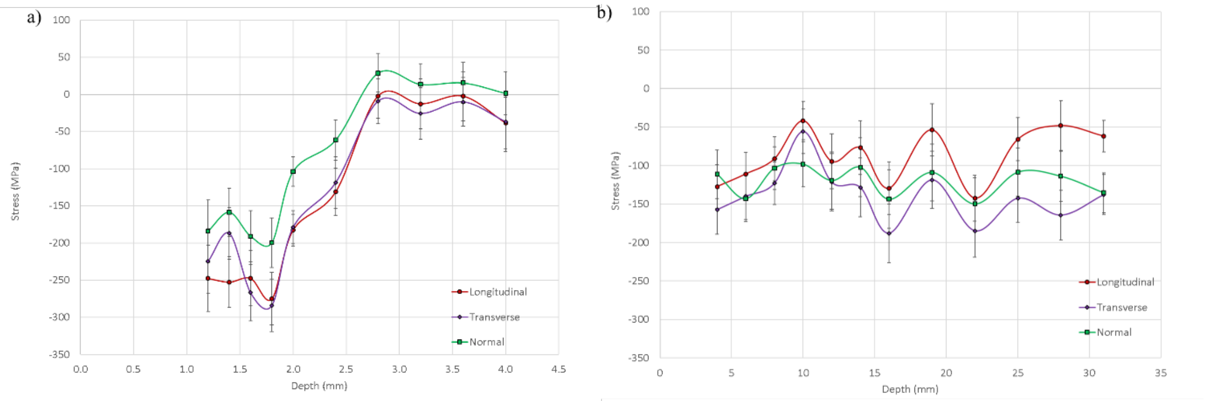

Figure 4: Stress measured in all three directions in Stellite-6 clad sample using a) 0.6 mm collimator near clad and b) 2 mm collimator in the substrate (gauge volume corrections applied)

Conclusions

The residual stress field in two laser clad rail specimens were measured successfully. The study was a preliminary investigation to identify the level and distribution of the residual stress field which will be used to design an in-situ loading experiment that will study the effects of the field on the fatigue performance of clad rails. The results are being prepared to be published along with other studies such as deep hole drilling and incremental centre hole drilling in the journal Fatigue.