Strain Gauging of Mining Machines

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Abstract

Strain gauging is an indispensable part of the engineering toolbox, serving as a means for understanding the structural performance of mining machines as well as the root causes of their failures. This article covers the principles, applications, and significance of strain gauging in engineering practice. From structural health monitoring to the optimisation of operational parameters, strain gauging allows engineers to ensure the safety, reliability and efficiency of critical infrastructure and machinery.

1. Introduction

The structural assessment of machines is based on strength of material calculations, where the quantity of interest is typically stress. Determination of structural stresses requires knowledge of the loads to which the structure is subjected, and this information is not always readily available. One practical method for the determination of stresses is based on the relationship between material stress and the accompanying deformation, called “strain.” This article will provide a brief introduction to strain measurement using foil strain gauges, including strain gauge selection and installation and application case studies.

2. What is a strain gauge?

Strain gauges function by virtue of the fact that the electrical resistance of metal changes proportionally to the amount of deformation that is caused in it by an external force. Strain gauges consist of a thin metal grid that is etched onto an electrical insulator backing. The strain gauge is bonded to a structure and deforms at the same rate as the structure surface. The measured resistance change in the strain gauge can be used to calculate the surface strain of the structure.

Figure 1 – Strain gauge installed on the long travel structure of a bucket wheel reclaimer.

3. The Wheatstone Bridge

The resistance change that a strain gauge undergoes during deformation is very small. In order to accurately measure it, an electrical circuit called a Wheatstone bridge converts the small resistance change into a voltage change which can more easily be measured. Strain gauge amplifiers can be set up for various Wheatstone bridge configurations, depending on the strain gauge arrangement and temperature compensating requirements for the structure.

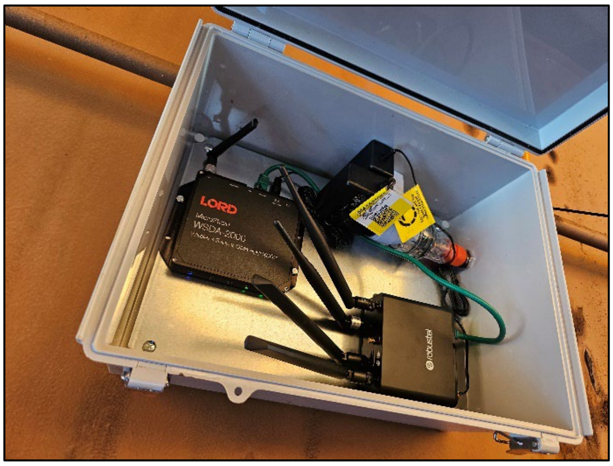

Figure 2 – ASPEC strain gauge installation using wireless telemetry allows logging of strain data to a cloud-based storage system.

4. Strain gauge arrangements

Strain gauges are almost always installed onto the surface of structures, and it is typically necessary to measure three strain directions at a single point to completely define the strain field. Measuring strains in three directions is done by installing a stacked strain gauge rosette. There do however exist situations where fewer gauges are required:

- Components with uniaxial, isotropic, and pure torsional stress states require a single strain gauge.

- Components with biaxial stress states only require two strain gauges, however they need to be aligned with the principal stress directions.

Strain gauges can also be installed and wired to either amplify or cancel out particular strain components, as shown below in Figure 3.

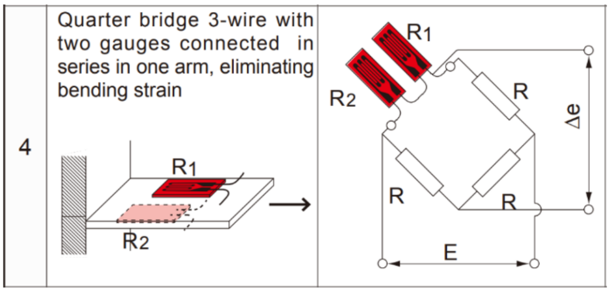

Figure 3 – Strain gauge arrangement eliminating bending strains (image source: TML strain gauges).

5. Case study 1 – Guide roller lateral load measurement

A screenhouse tripper had experienced premature failure of wheel and cam follower bearings due to higher-than-expected long travel skewing loads. ASPEC installed strain gauges to measure the lateral loads during tripper movements. A wireless telemetry strain gauging system was installed with a 5G network connection that allowed remote and live viewing, processing, and collection of strain data. The system had been calibrated prior to being put into service using a rotable spare bogie set and hydraulic jack for application of the calibration load.

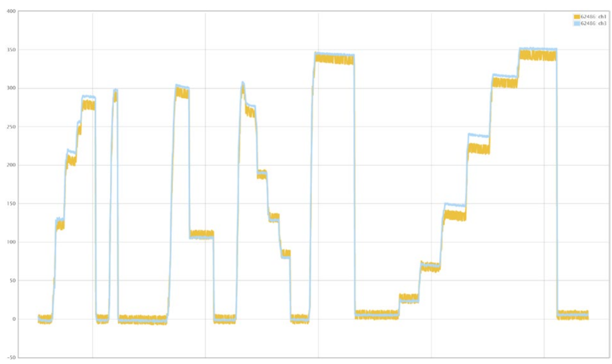

Figure 4 – The system was calibrated in the workshop by measuring strains in the bogie for known applied loads.

Figure 5 – Strain gauges were installed on the bogie structure, above the cam follower. Wiring was coated to protect the installation from physical damage.

6. Case study 2 – Measurement of bucket wheel reclaimer long travel loads

A strain gauging system was installed onto the long travel arrangement of a bucket wheel reclaimer. There was concern that misalignment of the long travel rails was inducing high lateral loads in the equalisers, causing cracking of bogie pillow blocks. The aim of the strain gauging was to determine whether there was a correlation between measured strains and the position of the reclaimer along the rail length, to use the correlation to identify areas where the rails required improved alignment and to generate estimates of the lateral and skewing loads on the equalisers.

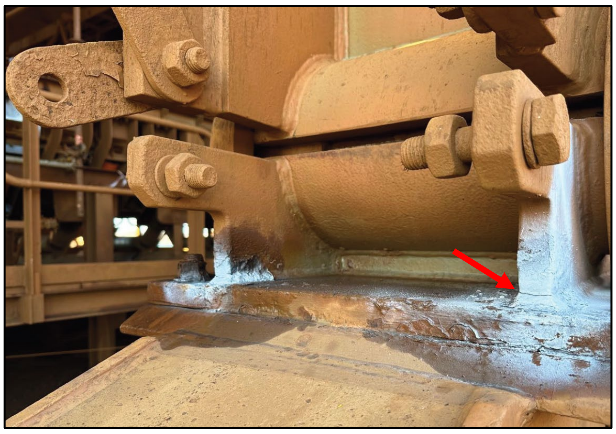

Figure 6 – Cracking of long travel bogie pillow block.

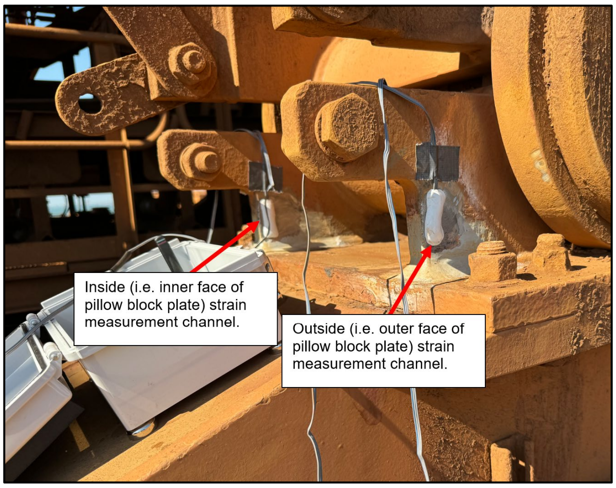

Figure 7 – Strain gauge installation on a long travel bogie pillow block.

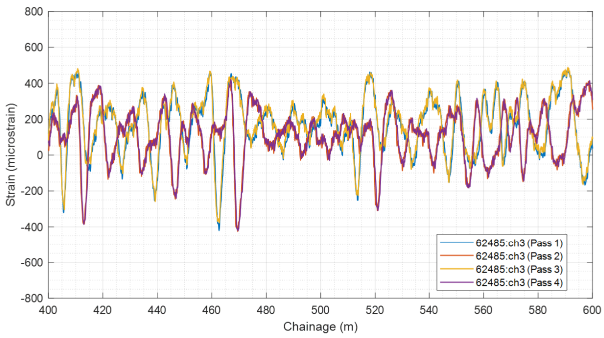

Figure 8 – Strain data for multiple passes of the long travel rails revealed a highly repeatable strain pattern.

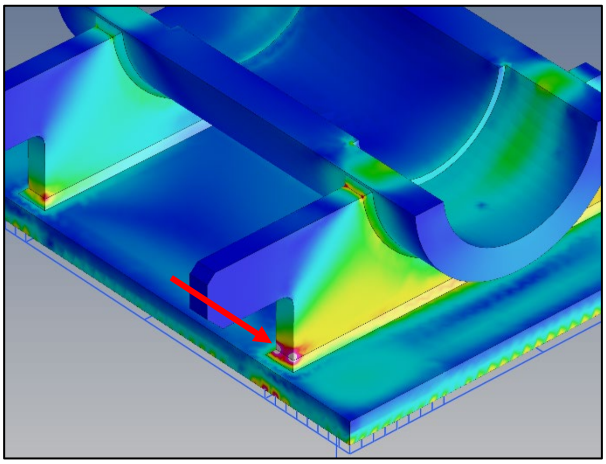

Figure 9 – FEA modelling, calibrated using the measured strains, generated stress results that correlated well with the observed crack locations.

7. Conclusions

Strain gauging is a measurement technique that gives deep insights into structural behaviour. Understanding this behaviour allows engineers to detect weaknesses and address vulnerabilities before they escalate into costly failures and extended downtime.

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