Distributed Fiber Optic Sensing: Measuring Strain Across Welds

Contents

Introduction

Welding residual stresses have consequences in the performance of components, including performance in corrosion, fatigue, and fracture. The microstructure changes across the weld, leading to potential non-uniform concentration of strengthening elements in the material. The heat affected areas may also have a change in alloy content since the welding rod is often made of a different alloy. Welding causes plastic deformations, elastic deformations, and intrinsic residual stresses, both tensile and compressive. The strain gradient across the weld seam is therefore often of interest to engineers. While strain gages adhered to welds result in an average strain measurement across the gage area, Luna's distributed fiber optic sensing allows the user to measure the strain profile across a weld with very high spatial resolution.

Test Setup

Low bend loss, polyimide-coated fiber was bonded along a motorcycle handle bar on the path outlined in red in Figure 1. A single, continuous 2.5 m fiber optic sensor was used to traverse this fiber path.

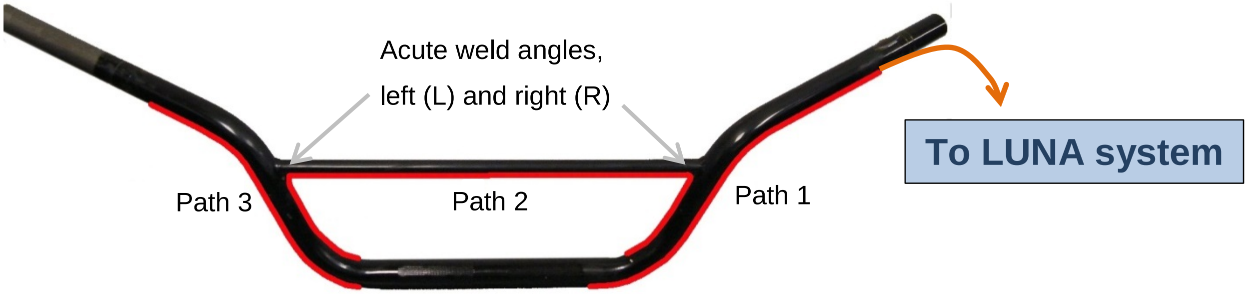

Figure 1. Red regions represent the bonded fiber paths of interest along the handle bars. The path numbers correspond to sensor paths as also labeled in Figure 4.

Particular attention was paid to the instrumentation of the acute weld angles pointed to in Figure 1 because of the challenging nature of these angles. A close-up image of an instrumented weld is shown in Figure 2, illustrating the ability of the fiber sensor to hug the profile of such a tight corner.

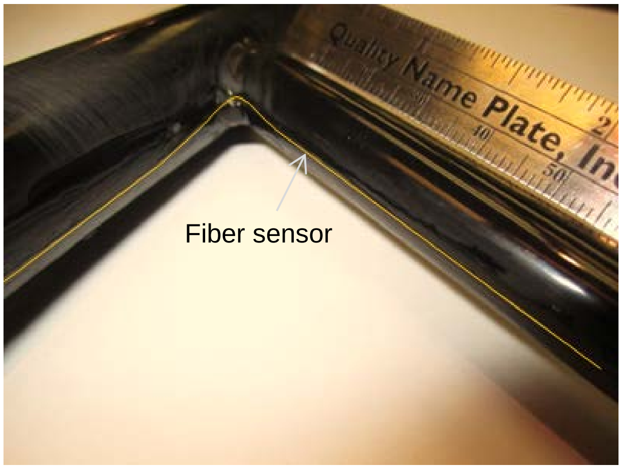

Figure 2. Close-up of acute angle weld instrumented with fiber optic sensor.

The base of the handle bar was clamped and 20 lb weights were suspended from each handle bar, as shown in Figure 3. While the loading was mostly uniform, it was a little asymmetrical due to the slight offset and angle in the clamping location.

Data was taken with an ODiSI B configured with a 1.25 mm gage length and 1.25 mm sensor spacing.

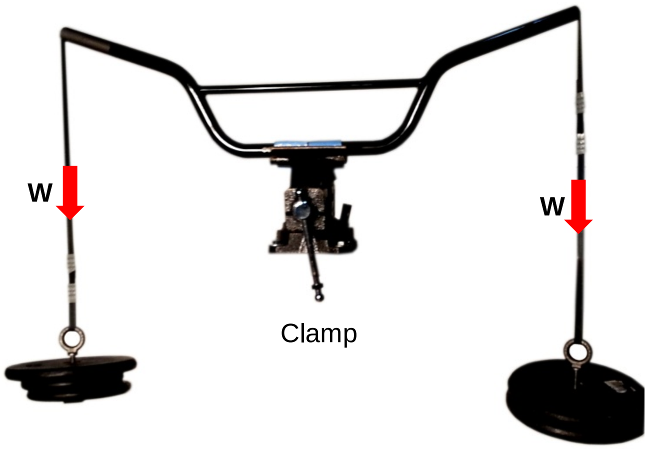

Figure 3. Experimental setup. The handle bar is held steady with a clamp, and weights are suspended from each handle bar.

Results

1 Strain Profile along Sensor

A plot of strain versus length along the fiber sensor when the handle bar is fully loaded is shown in Figure 4. The regions demarcated in Figure 4 identify the sections of data from the paths marked in Figure 1. The strain profile is mostly symmetrical, due to the symmetry of the sensor layout. By superimposing the strain profile on an image of the handle bar as shown in Figure 5, the strain distribution along the sensor path is more easily understood. The acute angle welds are areas of stress concentrations, while the straight bar connecting the two welds of interest sees a linear strain going from 0 to 40 με. The opposing faces of the same handle bar section display strain of similar magnitude but opposite sign.

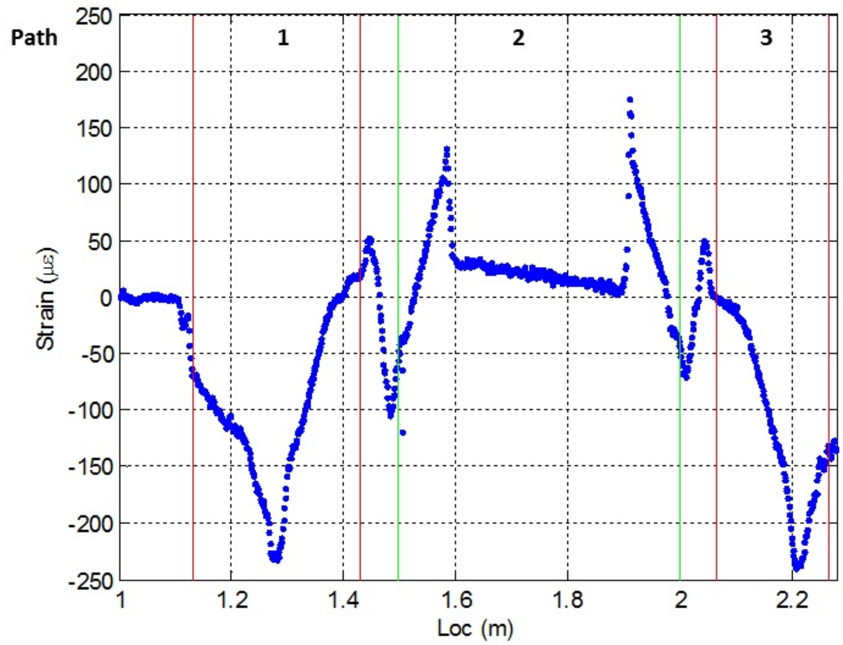

Figure 4. The strain along the sensor at maximum load. Each path of the handle bar is outlined on the graph by vertical lines.

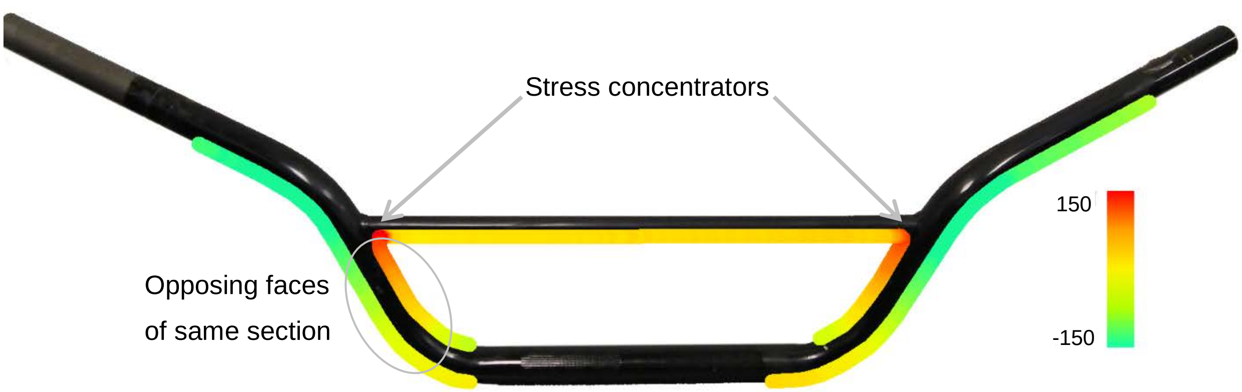

Figure 5. Strain along the fiber superimposed on handle bar image. Color bar = strain range in microstrain.

2 Strain at High Spatial Resolution

The ability to measure strain with high spatial resolution (1.25 mm) is demonstrated in Figure 6 where the strain profile across the weld is plotted at three instances during loading. As the sensor approaches the weld from the underside of the acute angle and traverses it to the horizontal connector bar, strain values transition from tension to slight compression along the horizontal connector bar.

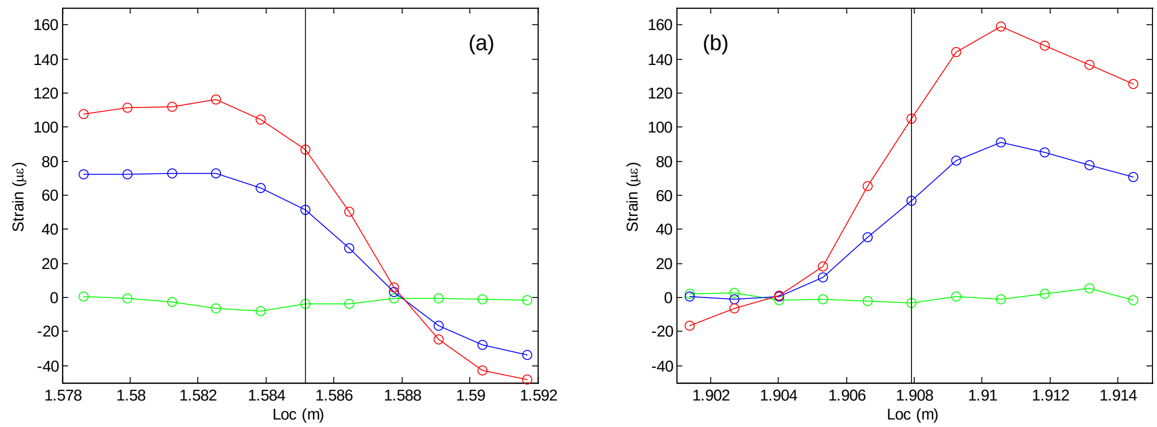

Figure 6. Strain across the weld shown at 1.25 mm spatial resolution for acute angle welds on the (a) Left and (b) Right welds, at three instances during the transition from zero loading to fully loaded. Green: zero load, blue: intermediate load, red: maximum load, black: weld location.

3 *Strain Map over Time*

By taking multiple scans during the loading and unloading process, it is possible to plot the strain along the sensor in the form of a heat map as demonstrated in Figure 7(a). The completion of loading and the initiation of unloading can be seen from the discontinuities in strain at time step 11 and 27 respectively. This is confirmed by looking at a plot of strain at location 1.63 m along the fiber, over time (Figure 7(b)). When the handle bars are initially loaded, the strain reaches a maximum before settling at a lower strain plateau. When the handle bars are unloaded, the strain decreases, and again overshoots before settling at zero strain.

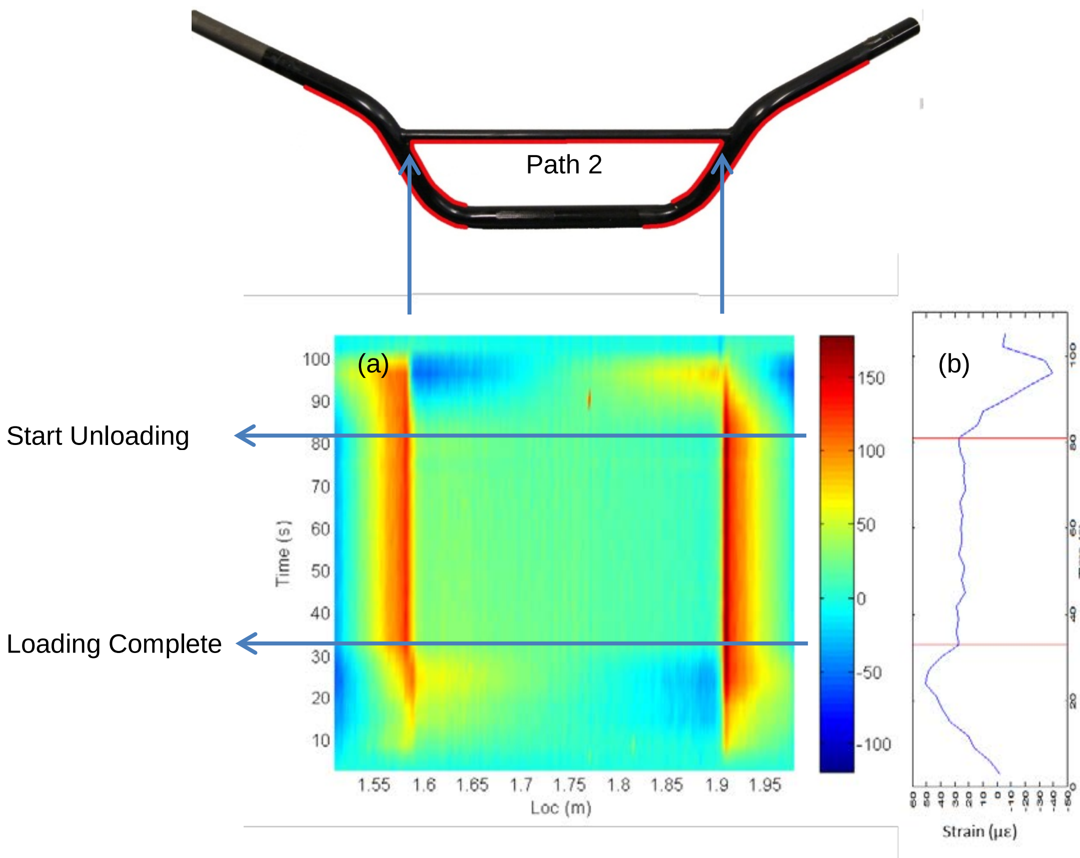

Figure 7. (a) The strain of path 2 shown over time. (b) Strain at 1.63 m along the sensor over time.

Summary

This Engineering Note demonstrates the ability to measure strain across the welds of a handle bar instrumented with a fiber optic sensor with great spatial fidelity. With data taken at a spatial resolution of 1.25 mm, it is possible to resolve the high strain gradients across the weld seam as the handle bar is statically loaded.

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