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Stress imaging of welded steel by X-ray diffraction microscope

Mari MIZUSAWA and Kenji SAKURAI*
National Institute for Materials Science, Sengen, Tsukuba, Ibaraki 305-0047, Japan

Introduction

A projection-type X-ray microscope, which was initially developed for X-ray fluorescence, is a strong tool for 2D X-ray diffraction imaging of polycrystalline materials. Its recent extension to stress imaging [1] is significant because it can provide a good gauge of the reliability of the mechanical strength of materials. This report describes the preliminary results of an experiment to obtain the stress distribution of welded steel.

Experimental

The sample studied is a T-joint weldment of steel plates, as shown in Fig.1. The powder diffraction pattern (see Fig.2) indicates that the main structure consists of the α-Fe type. The (200) reflection has been chosen for stress analysis. Details of the instrumentation of the X-ray diffraction microscope are described elsewhere [1]. The experiment consists of repeated exposures during the wavelength scan of the incident X-ray photons for several 2θ angles, 78, 90, and 105 deg, in the present case. Typical exposure time was 1 sec.

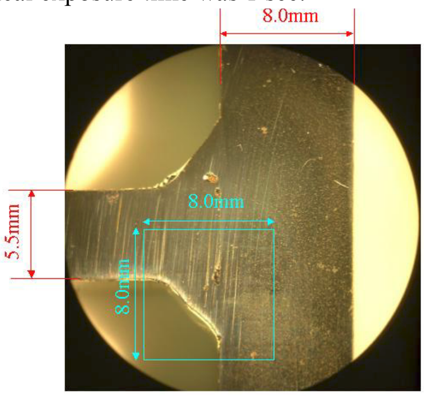

Figure 1 Top view of the sample. The size of the viewing area of the X-ray microscope is 8mm × 8mm. The stress distribution of the welded part was studied.

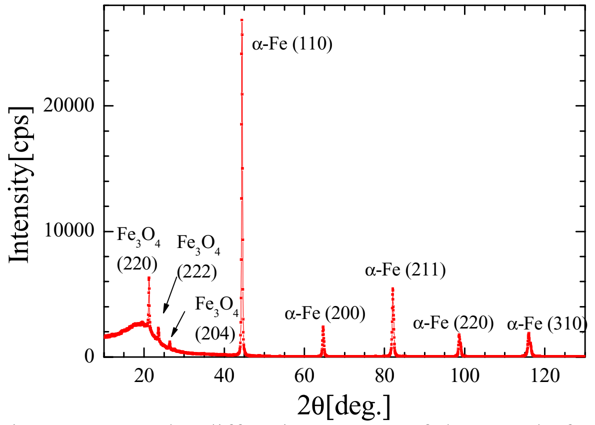

Figure 2 Powder diffraction pattern of the sample for CuKα radiation. In the present study, the (200) reflection peak found at around 65 deg was chosen for stress analysis.

Results and Discussion

In energy-dispersive X-ray diffraction experiments [2], the Bragg peaks are given as the X-ray wavelength. For the (200) reflection, when 2θ is 78, 90, and 105 deg., the wavelength is 1.798, 2.023 and 2.263 Å, respectively. The present technique can give a 2D map of the peak wavelength for each case. This corresponds to the strain map for different Ψ angles, i.e., the orientation of the sample, which almost equal half of the 2θ angles in the present case. Therefore, one can calculate the slope of the $\sin^2\Psi$-λ/λ_0 plot for each pixel from those three maps.

Figure 3 shows the stress image that was finally obtained. In the present study, the viewing area was preliminarily segmented as a 10 × 10 matrix, although the original X-ray image had 1000 × 1000 pixels. This is a compromise to improve reliability in the determination of the slope. As the figure shows, one can see some clear non-uniform distribution of the stress, in particular around the welded part. Good agreement has been confirmed by conventional X-ray stress analysis with a small X-ray beam, although the measurements were only for several points because such an experiment requires a very long measuring time. The advantage of the present microscope is that stress imaging can be performed much more quickly than with the conventional method. The authors would like to thank Drs. H. Sawa, Y. Wakabayashi, Y. Uchida, for their assistance and advice during the experiment.

References

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*sakurai@yuhgiri.nims.go.jp

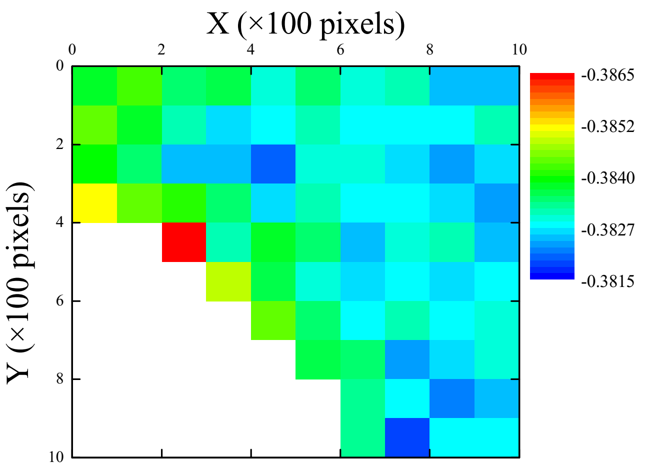

Figure 3 The results of stress imaging, which represents the map of the slope of the $\sin^2\Psi$-λ/λ_0 plot.