Relaxation of Residual Stress in Welded Plates During Long Life Fatigue Loading

James Pineault[1], Casey Gales[2]*, and Albrecht Conle[3]

[1]Proto Manufacturing Ltd., [2]John Deere, Moline, Il, USA
[3]University of Waterloo, Ontario, Canada,
** Presenting Author email: galescaseye@johndeere.com*

Abstract

The presence of residual stresses affects the fatigue response of welded components. In the present study of a thick welded cantilever specimen, residual stresses were measured in an as-welded A36 steel sample and in a sample subjected to a long history of bending loads where minimal local plasticity is expected at the fatigue hot-spot weld toe. Extensive XRD measurements describe the residual stress state in a large region in front of the weld toe both in an untested as-welded sample and in a sample subjected to a long load history that generated an estimated 0.001 strain amplitude at the stress concentration zone at the weld toe. The results show that such a test will moderately alter the welding induced residual stresses. Fatigue life prediction methods need to be aware that such alterations are possible and incorporate the effects of such cyclic stress relaxation in life computations.

1. Introduction

Residual stresses occur in most manufactured parts due to plasticity caused by deformation, thermal application, vibrations, etc. These residual stresses can be measured or predicted analytically. When assessing fatigue life, the residual stress state must be incorporated to have confidence in the prediction. Usually, the residual stress state is applied to the loading spectrum as an offset, ether tensile or compressive. Advanced methods of life prediction will account for what happens to the residual stresses when loading is applied. The work performed in this paper helps understand what happens to the residual stress state of mild steel weldments cycled at a load that produces long life failures.

2. Results

Previous studies of significant strain amplitudes (0.01) with large peak plastic hysteresis loops have shown that residual stresses at welded joints will decay quickly. In only 20 cycles the as-welded residual stresses were decreased from near A36 material yield levels (250 MPa) to under 50 MPa at the weld toe. This paper will study the effects of residual stress relaxation due to much smaller strain amplitudes. Estimates of relaxation rate are made from summary plots of multi-material axial specimen cyclic mean stress relaxation tests. Figure 1 depicts this summary data in terms of plastic strain amplitude of axial specimen stress-strain hysteresis loops versus cycles to relax mean stress to 50% of the initial value. The local hot-spot stress-strain loop's plastic strain amplitude, computed for the welded T-Bar, is used with this figure to determine the expected rate of T-Bar residual stress relaxation. The results of the X-Ray diffraction measurements are expected to show a much smaller amount of residual stresses have relaxed at the same cycle count as the high amplitude strain loop. If a welded sample was cycled much longer, like 500,000 cycles, the measured residual stress would be expected to near zero.

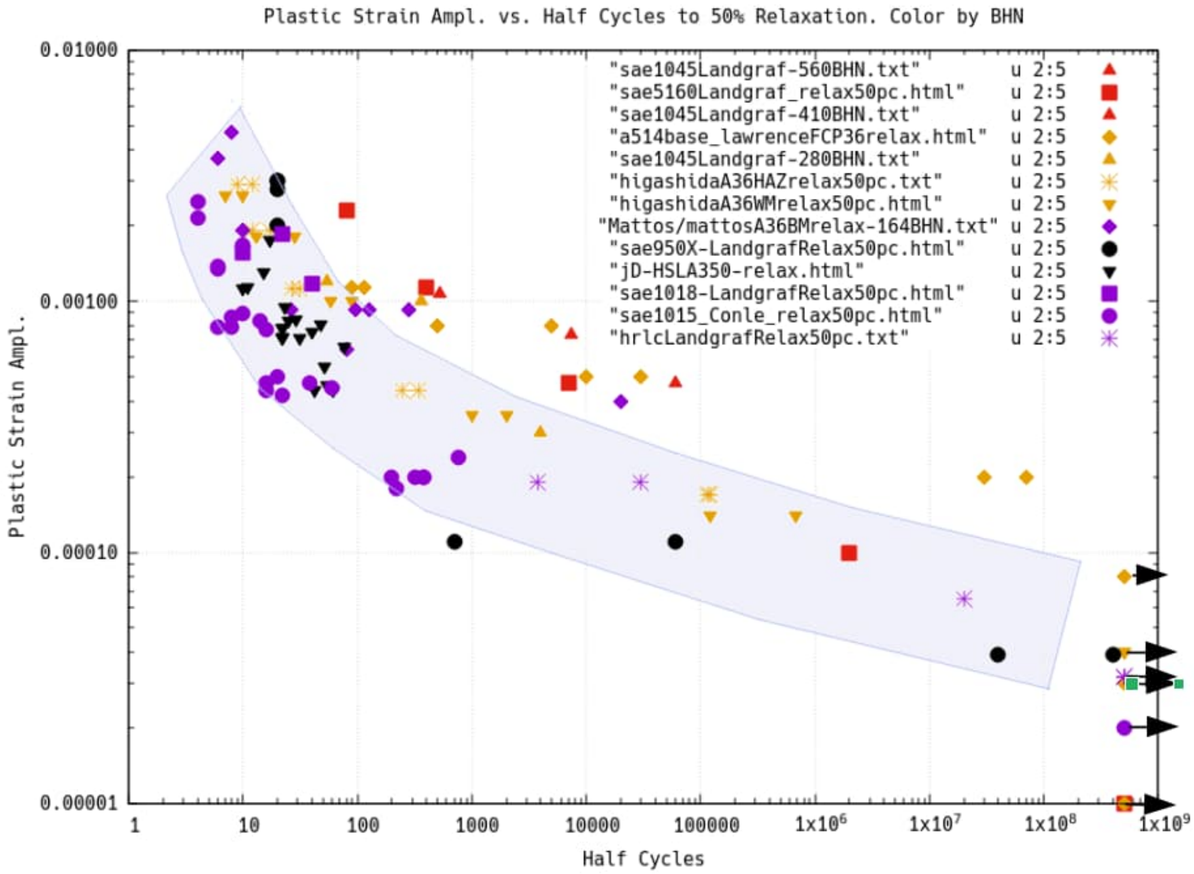

Fig.1 – Summary of the plastic strain amplitude of the hysteresis loops plotted versus a 50% drop in the mean stress of the loops

3. Conclusions

Residual stress decay is a real phenomenon that occurs when the embodied member is subjected to plastic deformation. The relationship between the amount of plastic strain and residual stress needs to be understood to determine how residual stresses relax. Residual stress relaxation effects can then be incorporated into fatigue crack growth calculations to improve prediction accuracy.

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