Waterloo

Fatigue Behavior and Monotonic Properties

For

AISI 8615 CA Steel
Four Point Bending

Iterations 163 & 164

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Summary

The required strain-life fatigue data for AISI Iterations 163 & 164 have been obtained using bending tests. The American Iron and Steel Institute (AISI) provided the material in the form of metal bars. These bars were machined into bending fatigue specimens. The Rockwell C hardness (RC) was determined as the average of nine measurements. Constant-amplitude and overload tests under bending were conducted in the laboratory at room temperature to establish the strain-life curve.

Introduction

This report presents the results of fatigue tests performed on a group of 8615 CA Steel specimens (Iterations 163 & 164). The American Iron and Steel Institute provided the material. The objective of this investigation is to obtain the strain-life curve of the material under a four point bending cyclic test.

Experimental Procedure

Specimen Preparation

The material for this study was received in the form of bars. Bending fatigue specimens, shown in Figure 1, were machined from the metal bars. Before testing, the specimens had a final polish in the loading direction in the gauge sections using 240, 400, 500, and 600 emery paper and a thin band of M-coat D acrylic coating was applied along the central gauge section. The purpose of the M-coat D application was to prevent scratching of the smooth surface by the knife-edges of the strain extensometer, thus reducing the incidence of knife-edge failures.

Test Equipment and Procedure

Hardness tests were performed on the surface of three fatigue specimens using a "Rockwell C" scale. The hardness measurements were repeated three times for each specimen and the average value was recorded. All fatigue tests were carried out in a laboratory environment at approximately 25^{o}C using an MTS servo-controlled closed loop electro hydraulic testing machine. A bending rig was installed in the hydraulic testing machine as shown in Figure 2. An Extensometer was installed on the bending specimen to measure the strain as shown in Figure 3. A process control computer, controlled by FLEX software [1] was used to output constant stroke amplitudes.

Results

Constant Amplitude Fatigue Data

Constant strain amplitude, fully reversed (R=-1) stroke-controlled fatigue tests were performed on bending specimens. The tests were run under stroke control and the corresponding strain measurements were recorded. The load-strain limits for each specimen were recorded at logarithmic intervals throughout the test via a peak reading oscilloscope. Failure of a specimen was defined as a 50 percent drop in the tensile peak load from the peak load observed at one half the expected specimen life. The loading frequency varied from 0.5 Hz to 25 Hz. Constant amplitude fatigue test data obtained in this investigation are given in Table 1. A constant strain-amplitude fatigue life curve for the steel is given in Figure 4.

Overload Fatigue Test Data

Previous work at the University of Waterloo introduced an effective strain-life curve for use in fatigue damage calculations due to overloads [2]. This effective stain-life curve is derived from periodic overload tests consisting of two blocks of load cycles repeated. The first block consists of a single R=-1 overload (tensile and compressive overload peaks) cycle, and this is followed by a block of smaller load cycles that have the same tensile peak stress as the overload cycle. The minimum of the small cycles varies from test to test, and similarly the number of small cycles between the overload cycles is varied depending upon the expected life. These two blocks are then repeated until the specimen fails. The aim is to have the large cycle (overload cycle) occur frequently enough that the crack opening stress remains below the minimum stress of the smaller cycles and crack growth during the application of the small cycles is free of crack closure. The overload cycle amplitude used in this testing was set equal to the fully reversed constant-amplitude stress level that would give a fatigue life of 10,000 cycles. The reason for this choice was to achieve a large reduction in crack opening stress without allotting an undue fraction of the total damage to the large cycles. The number of small cycles in the second block was chosen so that they did 80 to 90% of the damage to the specimen and that they were free from closure. The damage due to the overloads was removed using Miner's rule [3] and the equivalent failure life of the small cycles in each test was calculated. The overload fatigue data are given in Table 4. The equivalent strain-life fatigue curve is shown together with constant amplitude fatigue life curve in Figure 4.

Microstructure

The microstructure was supplied by Chrysler lab as shown in Figures 5 to 8.

References

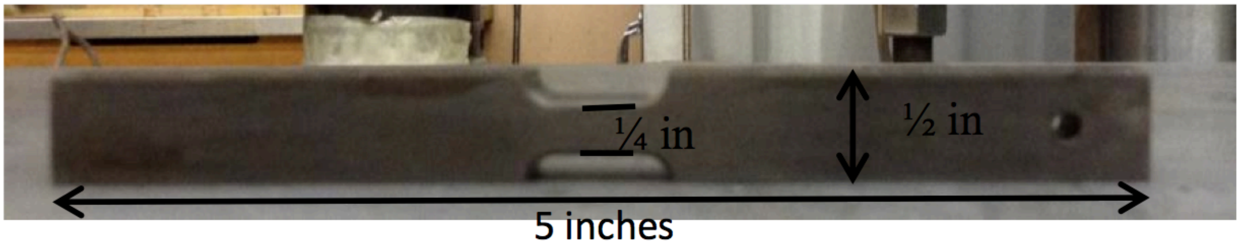
[1] M. Pompetzki, R. Saper, T. Topper, Software for rig frequency control of variable amplitude fatigue tests, Canadian Metallurgical Quarterly 25 (2) (1987) 181-194

[2] T. Topper, T. Lam, Effective strain-fatigue life data for variable amplitude loading, International Journal of Fatigue 19 (1) (1997) 137-143

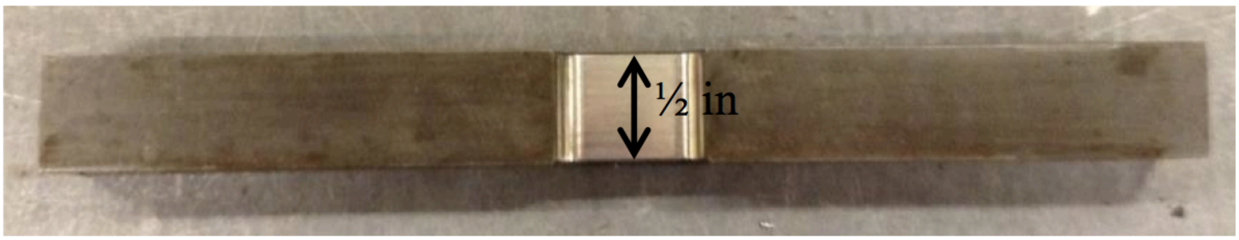
[3] I. Stephens, Metal Fatigue in Engineering, Second edition, John Wiley & Sons, 2001

Note:

Some specimen IDs, a digital number with a letter "B", such as 9B, it means this specimen (9) was tested at low strain amplitude without failure, then it was tested at high strain amplitude (9B).



(1-a) Bending specimen side view



(1-b) Bending specimen top view

Figure 1: Bending Fatigue Specimen

Figure 2: Bending Rig in the testing frame

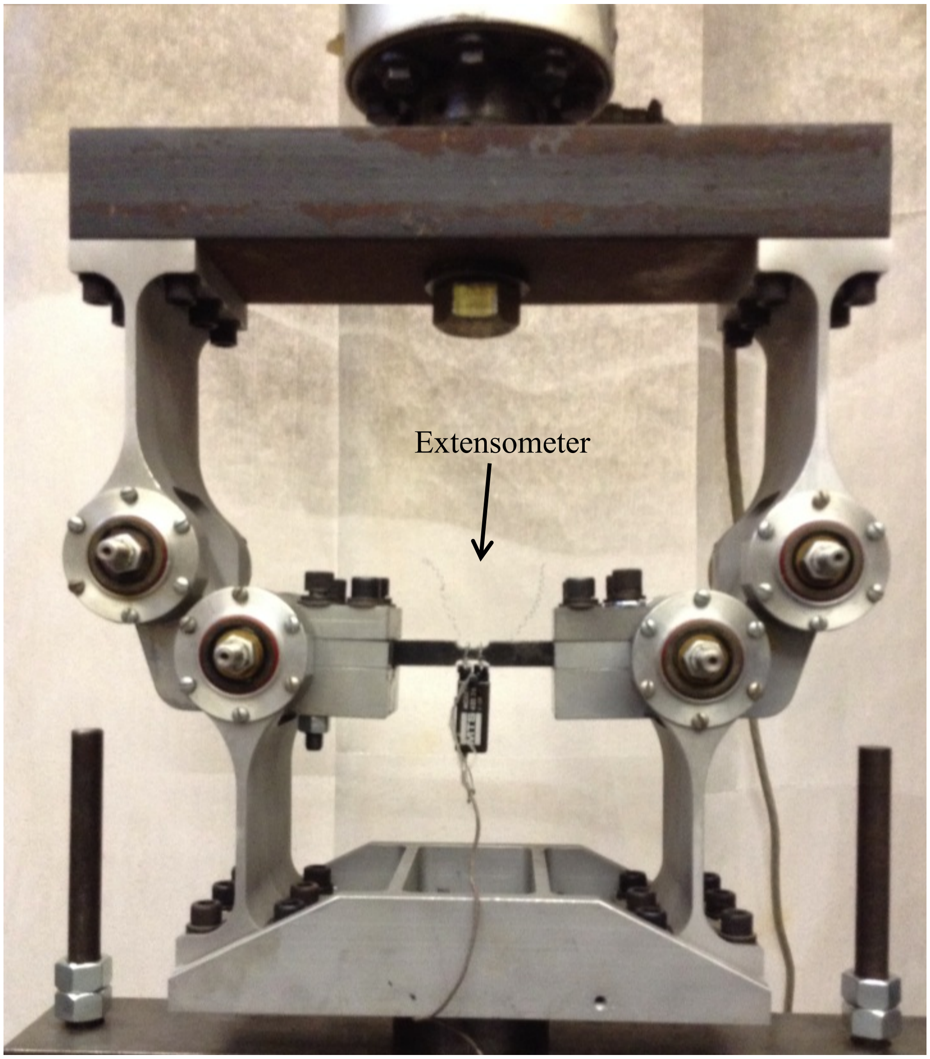


Figure 3: Extensometer installed on the bending specimen to measure the strain

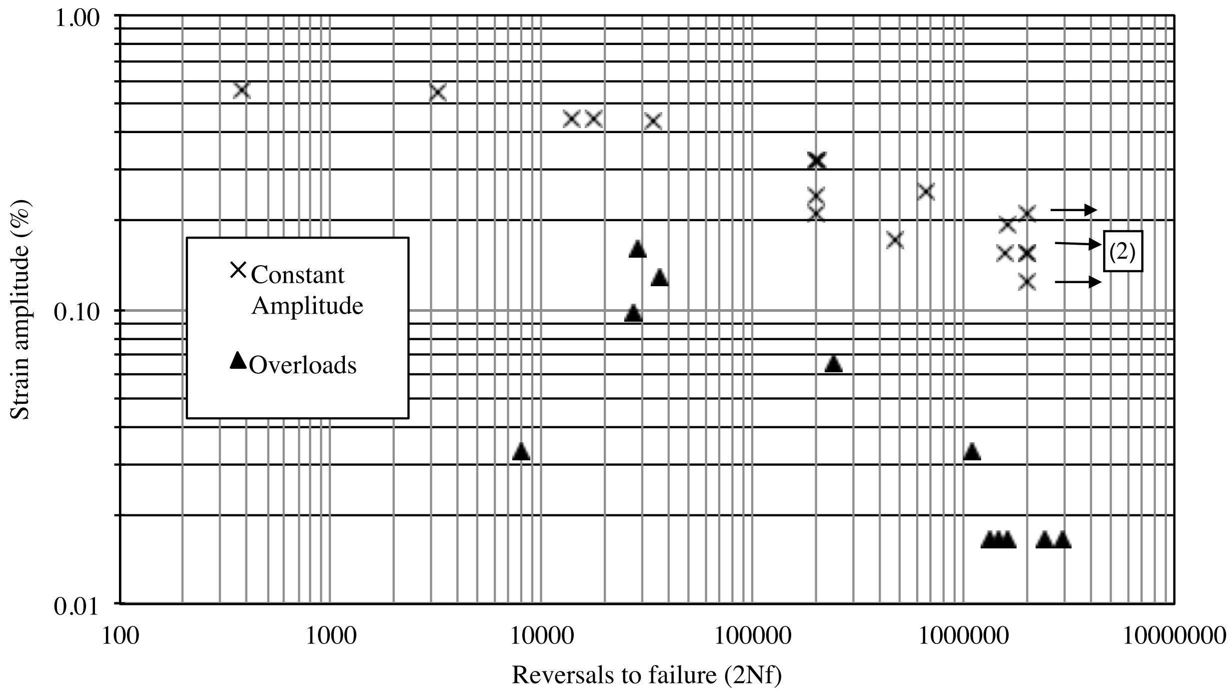


Figure 4: Strain-life fatigue curves for AISI 8615 CA (IT 163&164)

Figure 5: Microstructure of Iteration 163 & 164, case high magnification

Figure 6: Microstructure of Iteration 163 & 164, case low magnification

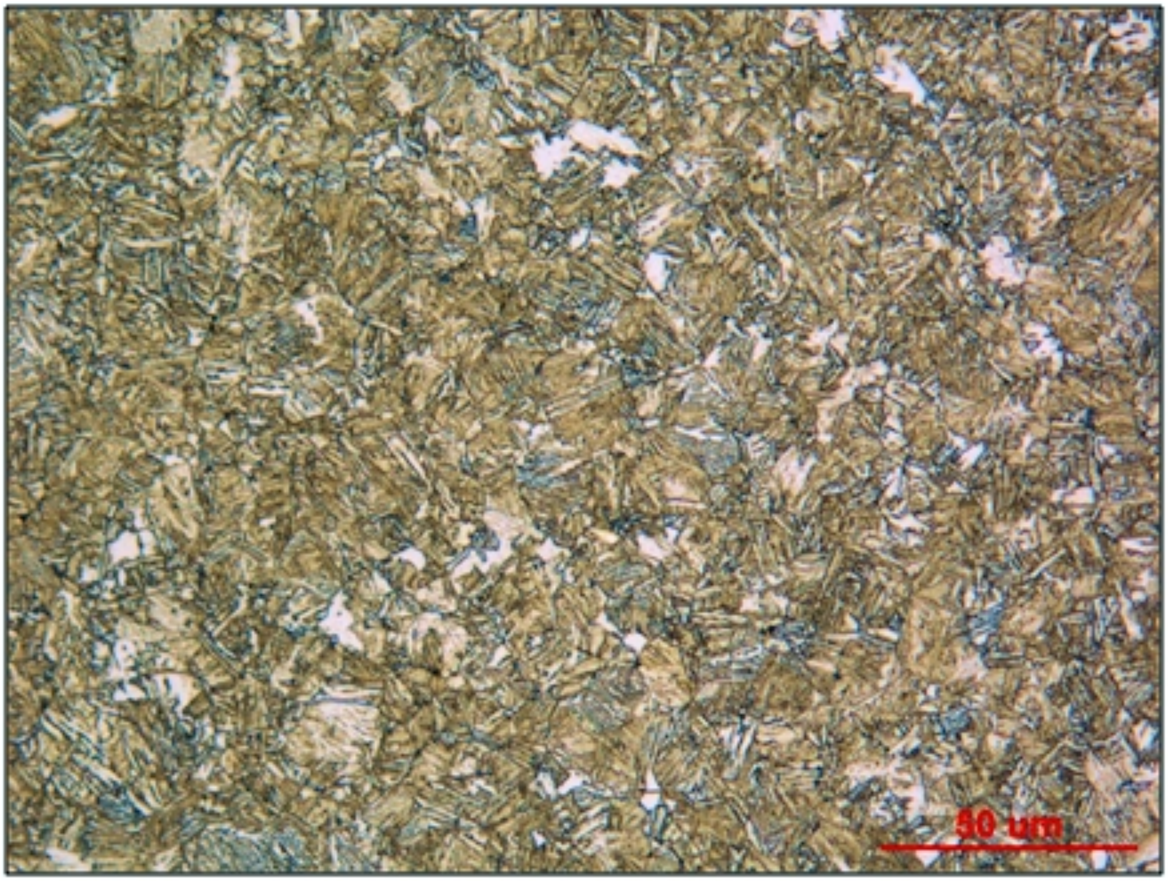


Figure 7: Microstructure of Iteration 163 & 164, core high magnification

Figure 8: Microstructure of Iteration 163 & 164, core low magnification

Table 1: Constant Strain Amplitude Data for AISI 8615 CA Steel (IT 163&164)

Specimen ID	Strain amplitude (%)	Reversals (2N)	Hardness (HRC)
1	0.44	33920	
2	0.24	200018	
3	0.21	200010	
4	0.12	2000000	
5	0.55	380	
6	0.55	3200	
7	0.45	17690	
8	0.45	13890	
9	0.21	2000000	
10	0.19	1600008	
11	0.17	473078	
12	0.16	2000000	
13	0.16	2000000	
14	0.16	1579700	
15	0.32	203020	
16	0.32	201100	60.17
17	0.25	659140	59.67
18	0.32	201900	60.00

**Hardness obtained as the average of three readings*

Table 2: Overload Strain Amplitude Data for AISI 8615 CA Steel (IT 163&164)

Specimen ID	Regular cycle	Overload cycle	Number of regular cycles	Total reversals (2N)	Equivalent regular cycle reversals
	Strain amplitude (%)	Strain amplitude (%)			
OL1	0.16	0.43	50	28000	28231
OL2	0.13	0.43	50	35550	36126
OL3	0.10	0.43	50	27000	27195
OL4	0.07	0.43	50	197120	240628
OL5*	0.03	0.43	100	8000	7951
OL6	0.02	0.43	100	900000	1620291
OL7	0.02	0.43	200	1000000	1326841
OL8	0.02	0.43	300	1709558	2439530
OL9	0.02	0.43	400	2160000	2951908
OL10	0.02	0.43	600	1300000	1455621
OL11	0.03	0.43	100	710000	1089933

**Outlier, likely overloaded due to an overnight power surge. Test repeated as OL11*