Fatigue Behavior
For AISI 16MnCr5 Steel
Case/Core Composite 1900F
Four Point Bending Test
Iteration 201A

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Summary

The required strain-life fatigue data for AISI Iteration 201A 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, polished and then tested. The Rockwell C hardness (RC) was determined as the average of nine measurements. Constant-amplitude 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 16MnCr5 case/core composite specimens heat treated at 1900F (Iteration 201A). The American Iron and Steel Institute provided the material. The objective of this investigation is to obtain a constant amplitude strain-life curve of the material under a four-point bending cyclic test.

Experimental Procedure

Specimen Preparation

Bending fatigue specimens, shown in 1 and 2, were machined from the metal bars and polished with a small 500 grit wheel that was spinning in the same direction as the beam length. The samples were then carburized and quenched in oil by the AISI group and returned for fatigue testing. Before testing, the specimens had a final polish in the loading direction in the gauge sections using 600 emery paper.

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 in Table 2. All fatigue tests were carried out in a laboratory environment at approximately 25°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 3. An extensometer was installed on the bending specimen to measure the strain as shown in Figure 3. Epoxy was applied to attach the extensometer onto the specimen to prevent slipping.

A process control computer, controlled by FLEX software [1] was used to output constant stroke amplitudes for Iteration 201A.

After failure was indicated by the 50% load drop specified by ASTM, the specimens were often only partially cracked. In order to observe the fracture surface, these specimens were placed at one end in a vice and then struck with a hammer on the other end after failure.

In order to conform with the AISI database structure Tables 1 also report a “bending stress” that assumes no plasticity in the beam. The stress is the bending moment, M, multiplied by the half height, c, of the beam section and divided by the moment of Inertia I as per Stress = M*c/I. Similarly the "Modulus" reported in the tables is simply the calculated Stress Amplitude divided by the Strain Amplitude.

Results

Chemical Composition

The chemical composition information is currently unavailable.

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 20 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.

No "Fisheye" or subsurface crack initiation site was observed at the fractured surface. Some typical fracture surfaces were photographed and shown in figures 5 to 7. Note that the fast fracture darker regions are created by opening the crack.

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

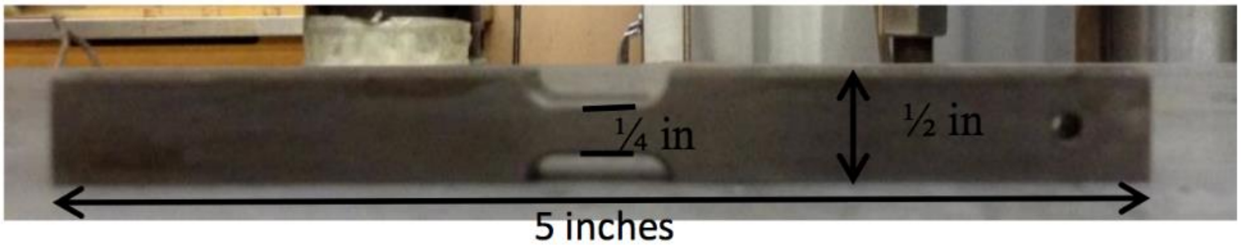

Figure 1: Bending specimen side view

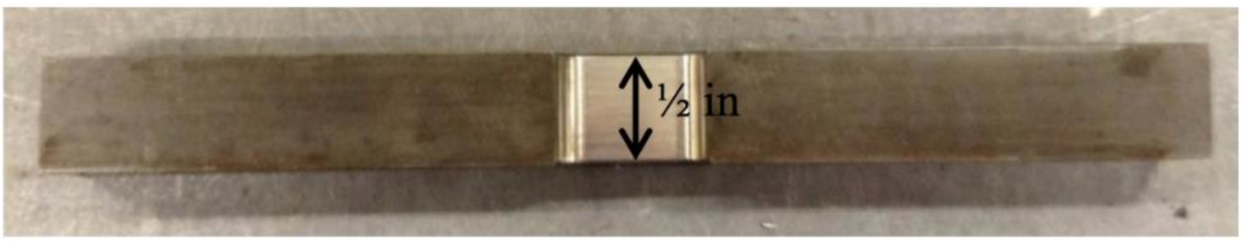

Figure 2: Bending specimen top view

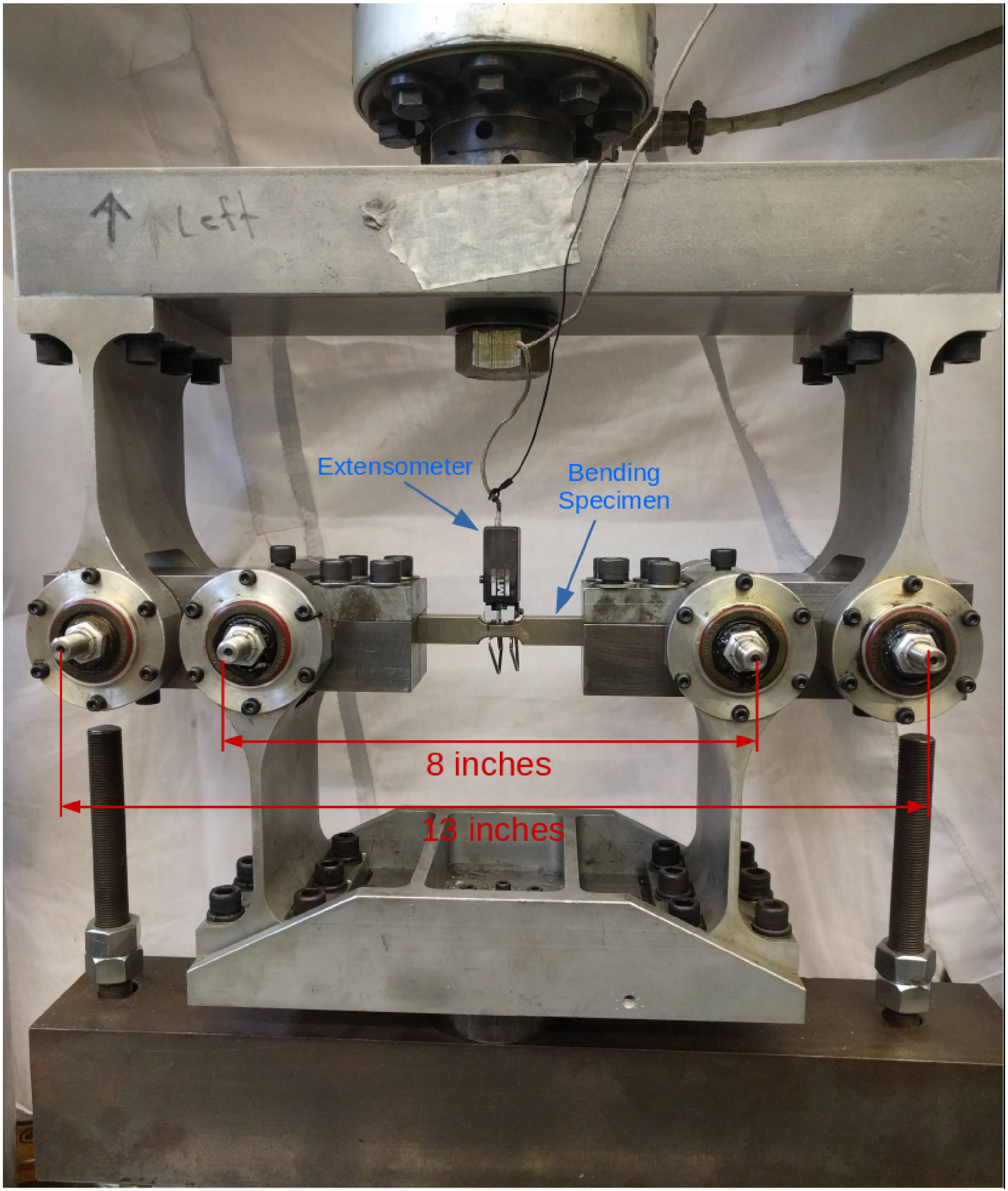

Figure 3: The Bending Rig and the Extensometer on the bending specimen

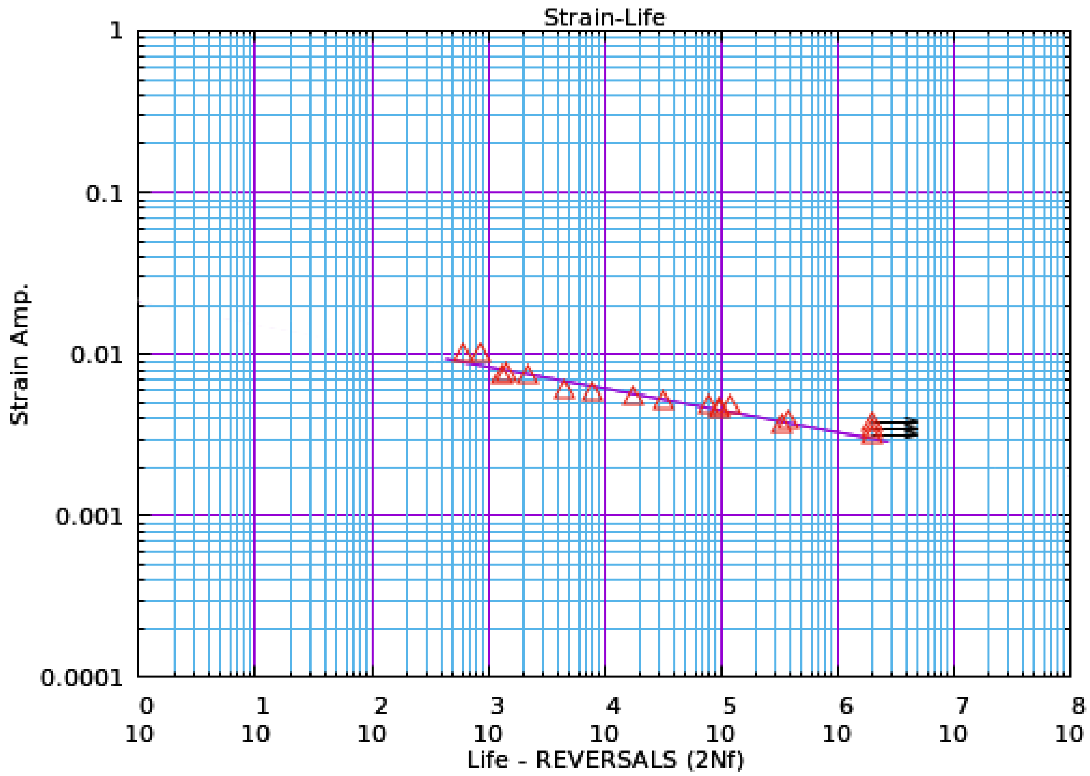

Figure 4: Strain-life fatigue curve for AISI 16MnCr5 case/core composite 1900F (IT 201A)

Figure 5: Fracture surface of specimen IT201A-3, 2Nf=848

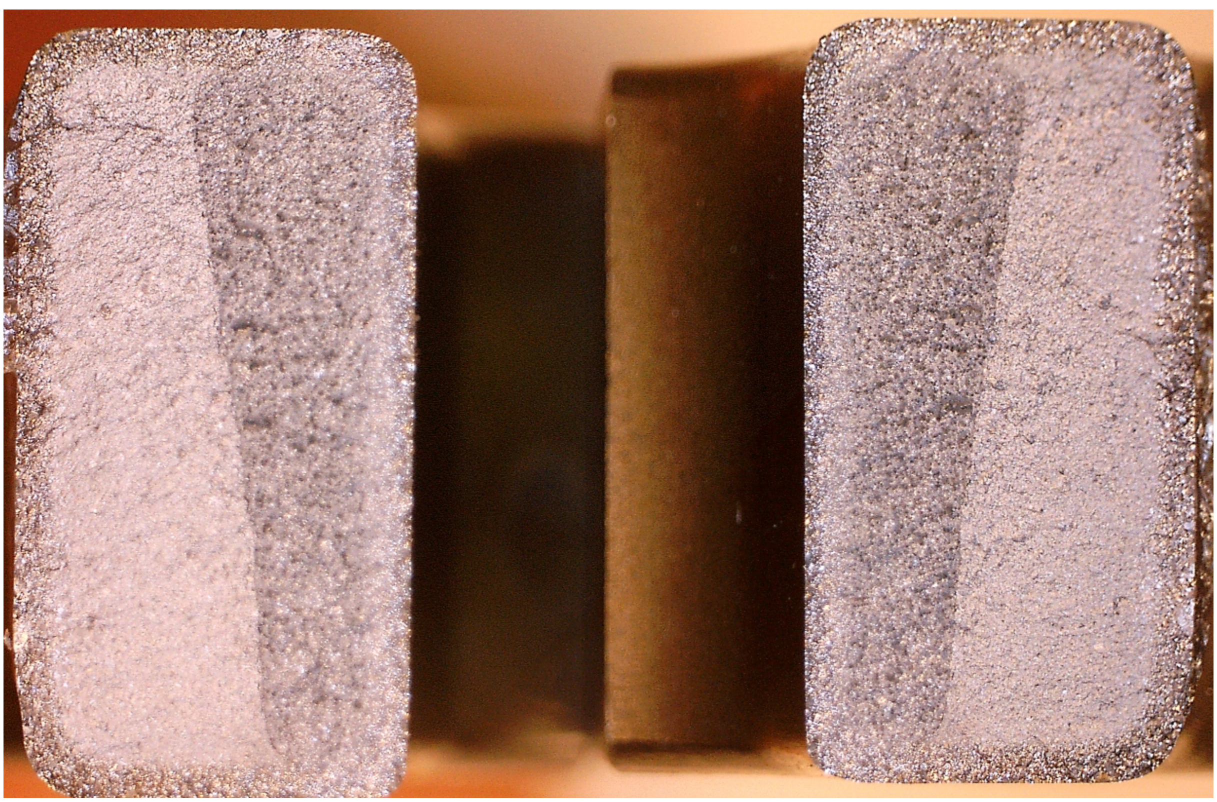

Figure 6: Fracture surface of specimen IT201A-16, 2Nf=98,904

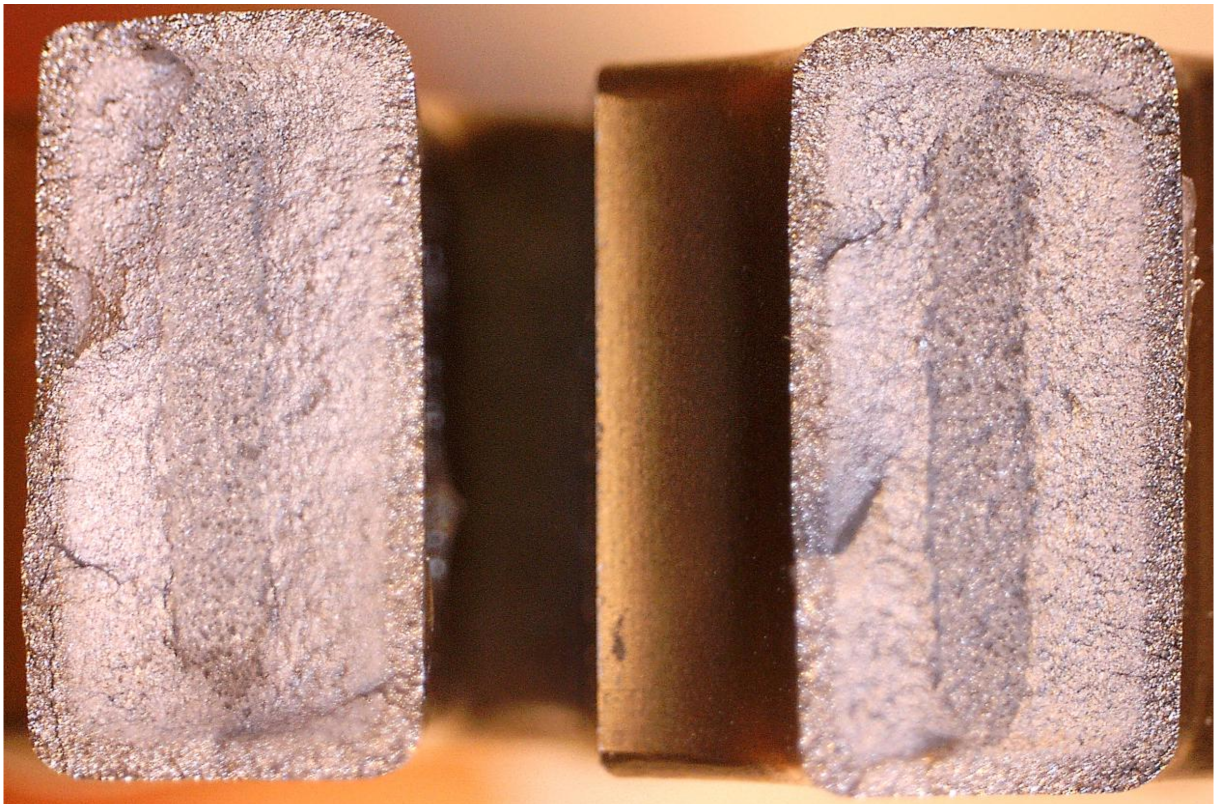

Figure 7: Fracture surface of specimen IT201A-9B, 2Nf=1,320

Table 1: Constant Strain Amplitude Data for AISI 16MnCr5 case/core composite 1900F Steel (IT201A)

StrAmpl	2Nf	StressAmpl* Mpa	Mean Stress* Mpa	PlsStrAmp	Modulus** Mpa	Comments	Spec ID***
0.009950	600	1431	0.00	0	143854		10B
0.010050	848	1363	0.00	0	135631		3
0.007470	1320	1380	0.00	0	184691		9B
0.007645	1452	1311	0.00	0	171535		8B
0.007400	2218	1222	0.00	0	165195		11
0.005925	4498	1119	0.00	0	188864		12
0.005870	7882	1069	0.00	0	182177		13
0.005450	17344	1034	0.00	0	189764		1
0.005050	31876	931	0.00	0	184315		14
0.004765	78540	885	0.00	0	185790		2
0.004515	98904	798	0.00	0	176836		16
0.004690	99440	840	0.00	0	179058		4
0.004790	122850	815	0.00	0	170138		5
0.003710	330300	755	0.00	0	203498		6
0.003855	380460	705	0.00	0	182966		7
0.003825	2000000	643	0.00	0	168178	#runout	9
0.003450	2000000	633	0.00	0	183461	#runout	10
0.003180	2000000	645	0.00	0	202940	#runout	8

* "Stress" implies Stress = M*c /I where M is bending moment, c is half height of beam, and I is moment of inertia

** Modulus = (StressAmpl. / StrainAmpl.)

*** Some specimen IDs, have a digital number with a letter B, such as 9B, it means that specimen no.9 was tested at a low strain amplitude without failure, and then tested again at a higher strain amplitude and given the label "9B"

Table 2: Rockwell C Hardness Test Data for AISI 16MnCr5 case/core composite 1900F Steel

Specimen ID	Test 1	Test 2	Test 3	Average
5	60	61	59	60.00
6	55	59	61	58.33
16	56	58	59	57.67
Overall				58.67