Fatigue Behavior and Monotonic Properties For AISI 9310 Steel Four Point Bending Iteration 184 and 185

Wanhua Liang, T. H. Topper and F. A. Conle

Department of Civil and Environmental Engineering
University of Waterloo
Waterloo, Ontario, Canada, N2L 3G1

Prepared for:
The AISI Bar Steel Applications Group

November 12, 2017

Contents

List of Figures

List of Tables

Summary

The required strain-life fatigue data for AISI Iteration 184 and Iteration 185 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, carburized and then tested. 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 9310 Steel specimens (Iteration 184/185). The American Iron and Steel Institute provided the material. The objective of this investigation is to obtain the constant amplitude and the overload strain-life curves 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 4. 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 4. 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 and overload stroke amplititudes for Iteration 184 and 185 respectively.

After failure was indicated by the 50% load drop the specimens were often only partially cracked. In order to observe the fracture surface these specimens were held in a vice at one end and then struck with a hammer on the other end. Specimen fracture surfaces that indicated subsurface ”Fisheye” cracks were photographed and are shown in Figures 9 to 12. Note that the fast fracture darker regions are created by opening the crack. In order to conform with the AISI database structure Tables 2 and 3 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 Stress Amplitude divided by the Strain Amplitude.

Results

Chemical Composition

The chemical composition as provided by Chrysler corporation is shown in Table 1.

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 2. A constant strain- amplitude fatigue life curve for the steel is given in Figure 5.

Overload Fatigue Data

Overload fatigue tests were performed on bending specimens under stroke control. Stroke corresponding to the strain at fatigue life of 10,000 cycles were used for the overloads. The overload frequency ranges from 40 to 100 small cycles/overload. Damages caused by the overloads varies from 5% to 50%. Overload amplitude fatigue test data obtained in this investigation are shown in Table 3. The overload strain-amplitude fatigue life curve is presented in Figure 6 along with the constant amplitude curve.

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

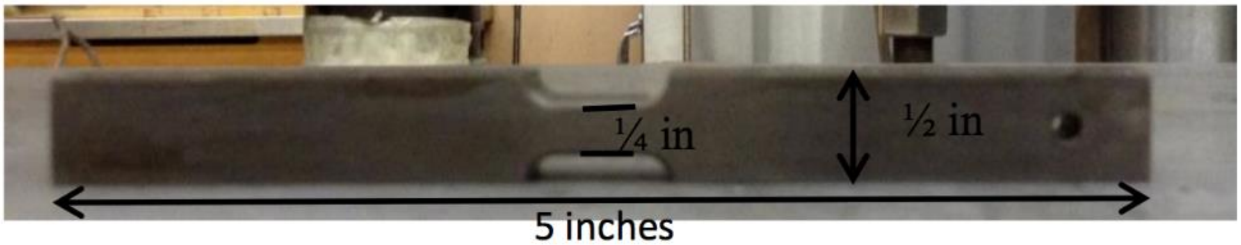

Figure 1: Bending specimen side view

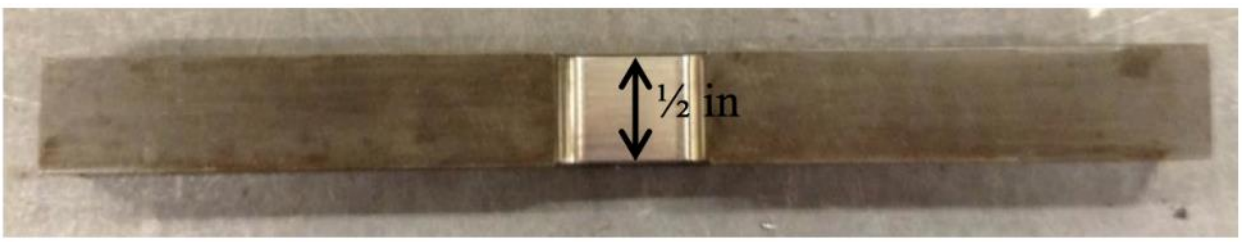

Figure 2: Bending specimen top view

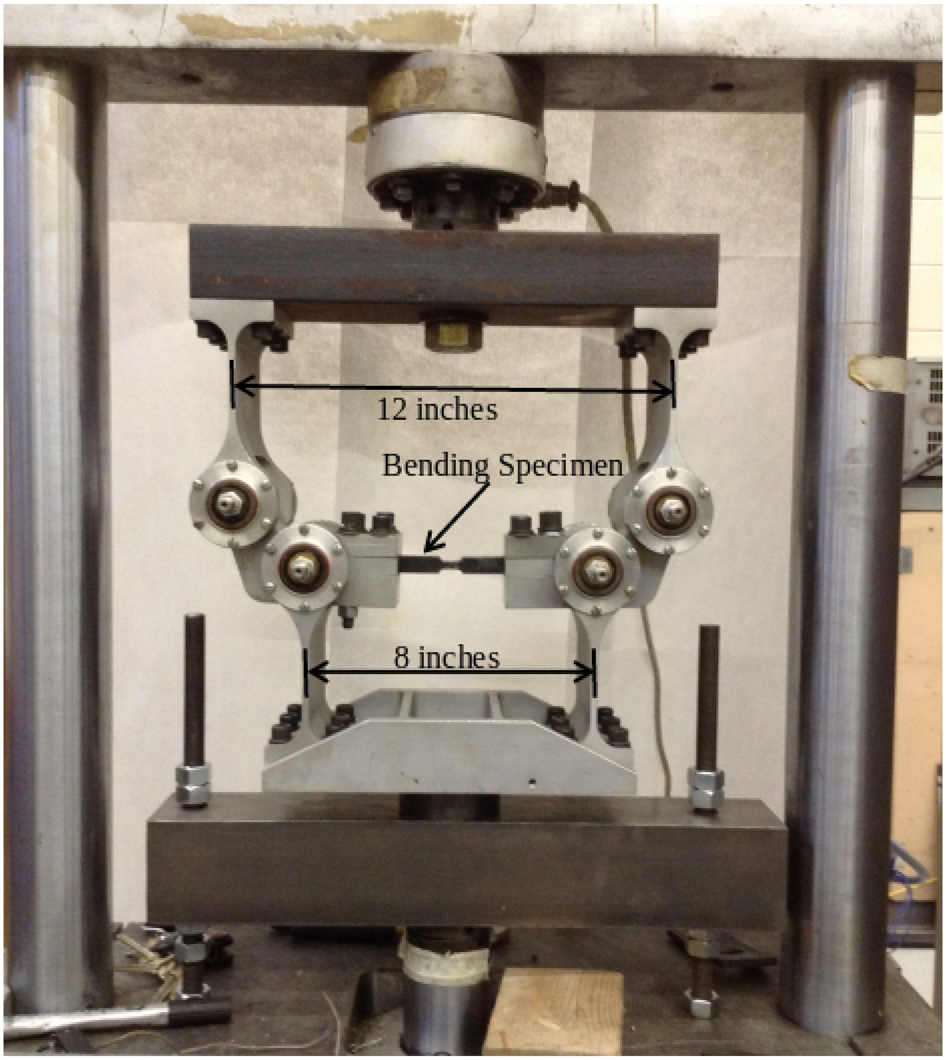

Figure 3: Bending Rig in the testing frame

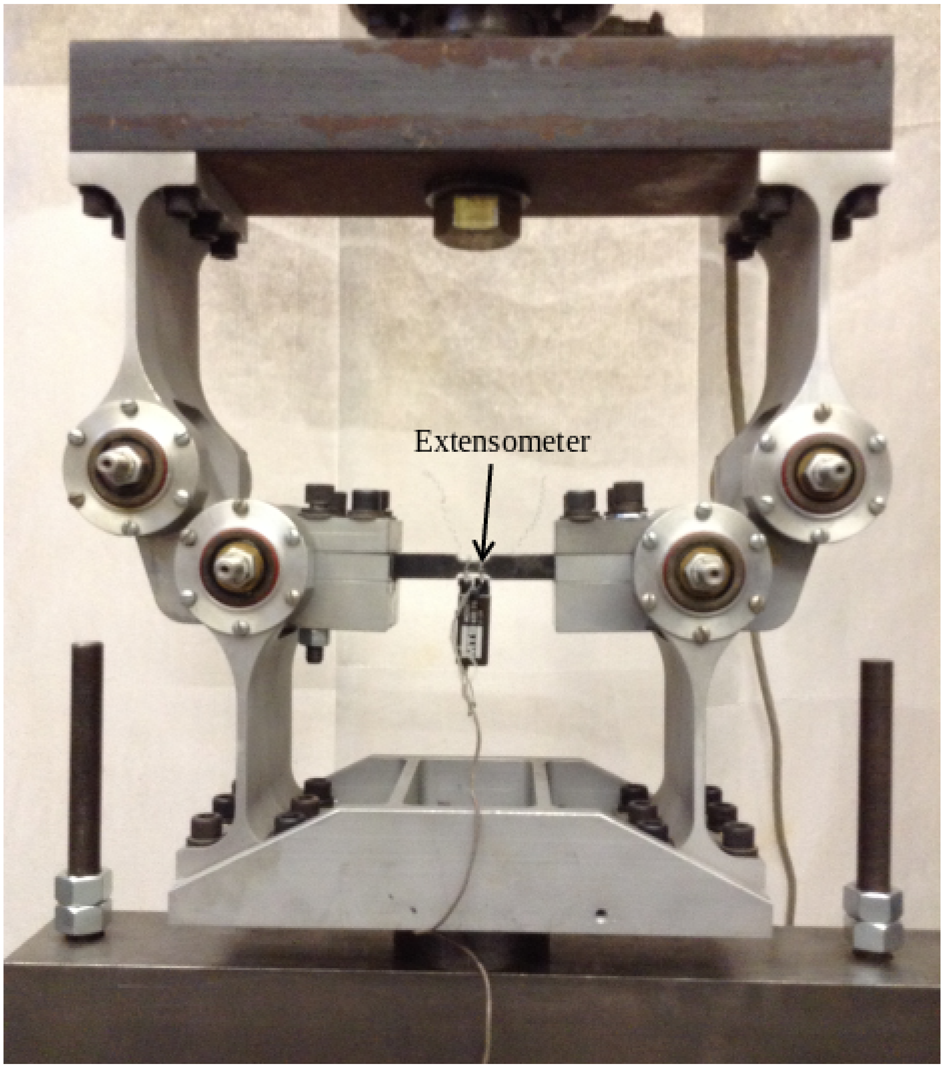

Figure 4: Extensometer installed on the bending specimen to measure the strain

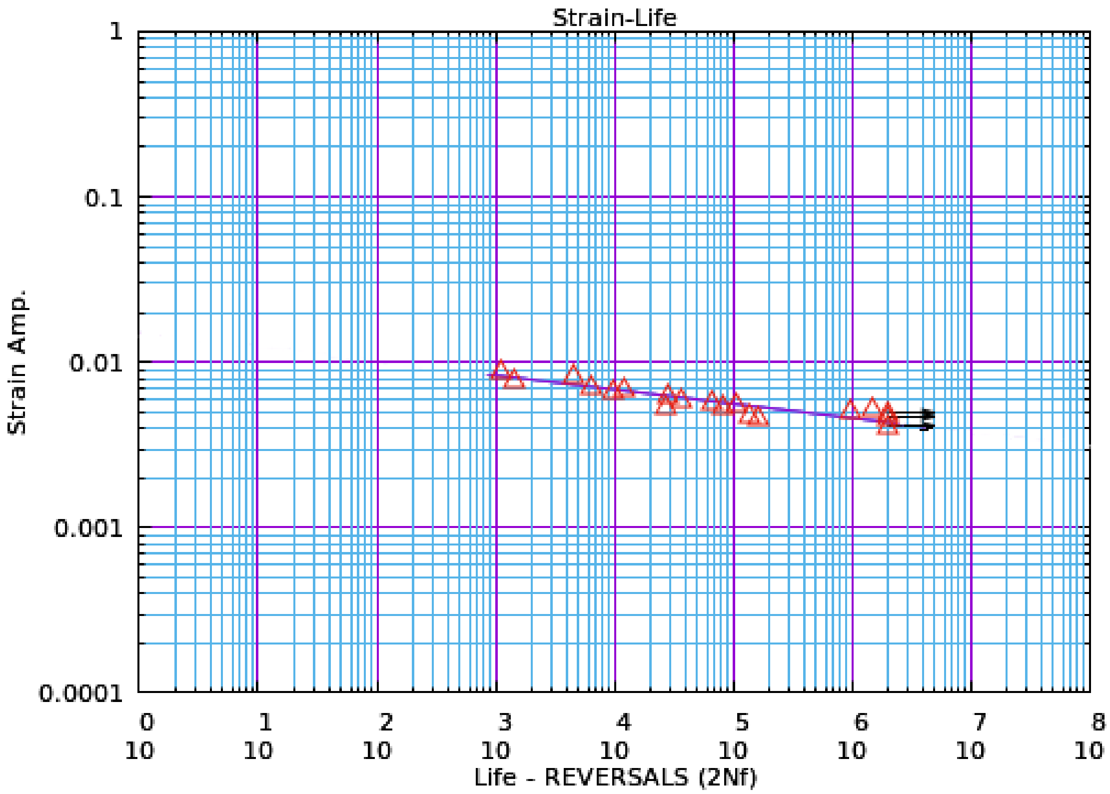

Figure 5: Strain-life fatigue curves for AISI 9310 (IT 184)

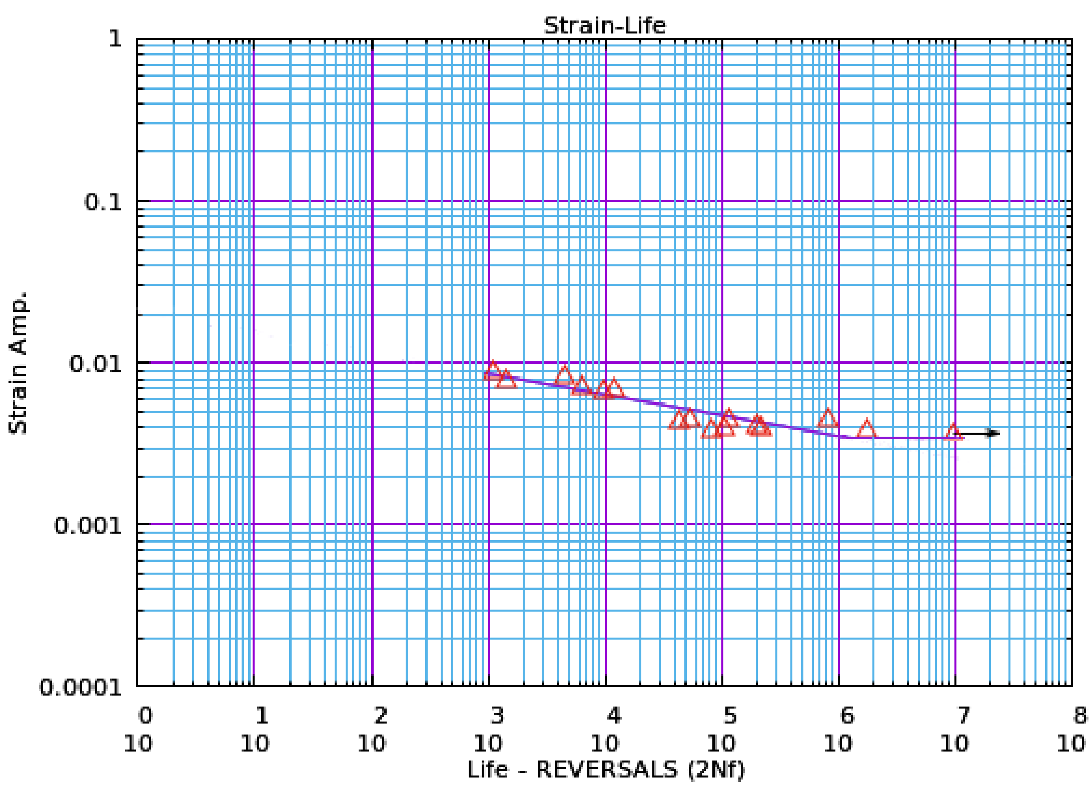

Figure 6: Strain-life fatigue curves for AISI 9310 (IT 185)

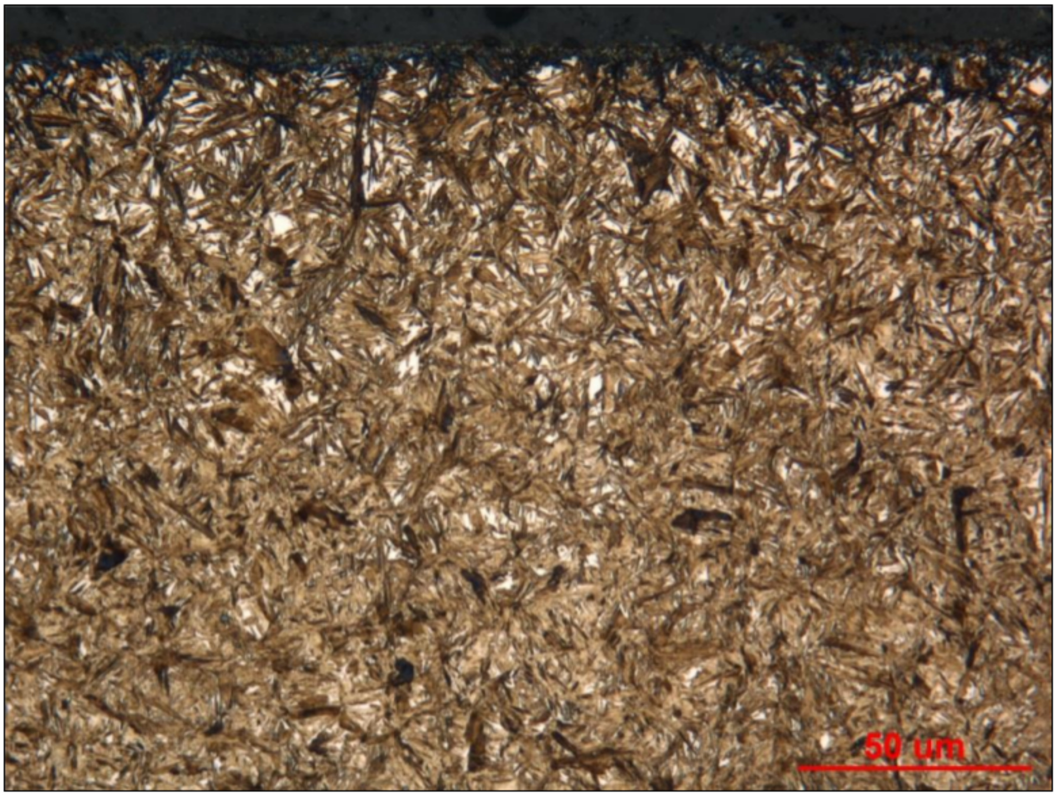

Figure 7: General microstructure at the surface of iteration 184/185 at 500X (Micrographs provided by FCA)

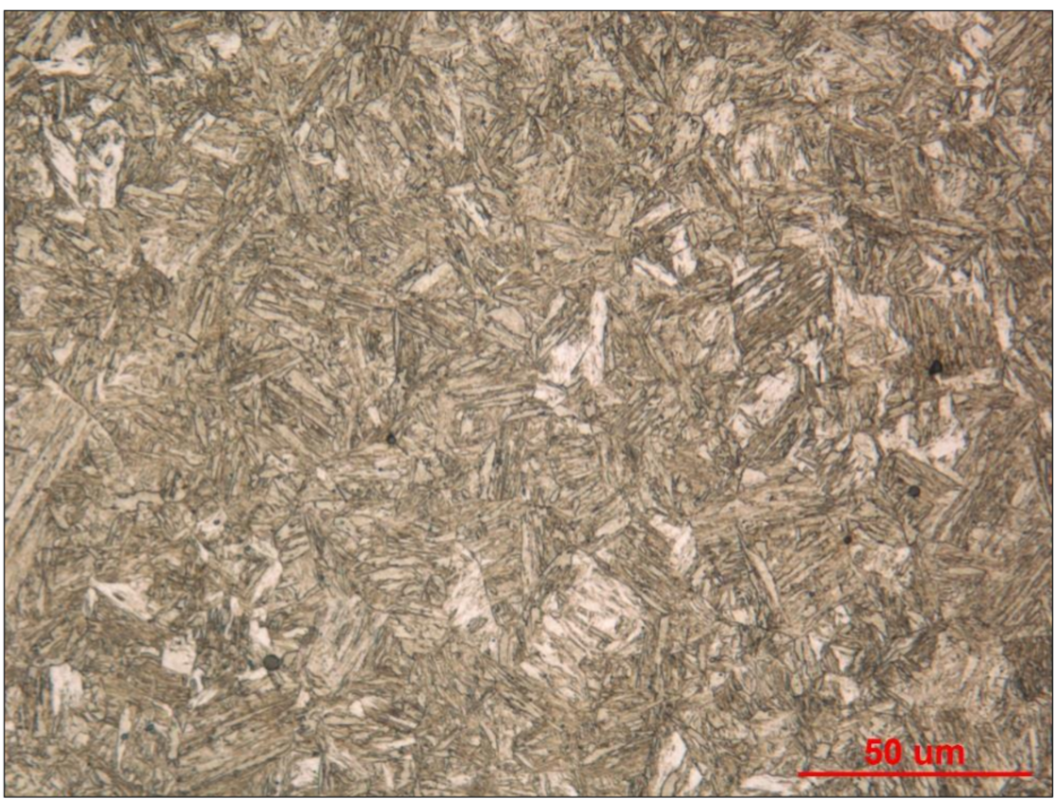

Figure 8: General microstructure in the core of iteration184/185 at 500X (Micrographs provided by FCA)

Figure 9: Fracture surface of specimen IT184-Calibration1

Figure 10: Fracture surface of specimen IT184-8

Figure 11: Fracture surface of specimen IT184-17

Figure 12: Fracture surface of specimen IT185-26

Table 1: Chemical Analysis (Bar Average) for AISI 9310 Steel (Iterations 184 and 185)

C	0.12
Mn	0.62
P	0.007
S	0.014
Si	0.19
Ni	3.12
Cr	1.11
Mo	0.09
Cu	0.16
Sn	0.008
Al	0.022
V	0.003
B	0.0002
Ca	0.0012
N	0.0066
As	0.004

Table 2: Constant Strain Amplitude Data for AISI 9310 Steel (IT184)

StrAmpl	2Nf	StressAmpl	Mean Stress	PlsStrAmp	Modulus	Comments		Spec ID
		ksi	ksi		ksi			
0.00890	1108	240	0	0	26993			1
0.00800	1426	217	0	0	27120			2
0.00695	12068	158	0	0	22757			3
0.00482	139768	132	0	0	27514			5
0.00576	67670	167	0	0	28958			6
0.00506	974476	135	0	0	26704			7
0.00565	105298	147	0	0	26039	#fisheye		8
0.00413	2000000	130	0	0	31549		#runout	9
0.00722	6234	196	0	0	27191			9B
0.00629	28790	183	0	0	29174			10
0.00470	2000000	140	0	0	29770		#runout	11
0.00836	4494	206	0	0	24632			11B
0.00495	2000000	134	0	0	27033		#runout	12
0.00544	81498	168	0	0	30867			13
0.00541	27414	158	0	0	29217			14
0.00470	162864	167	0	0	35540			15
0.00680	9910	218	0	0	32082			16
0.00526	1465486	171	0	0	32487	#fisheye		17
0.00593	37218	174	0	0	29423	#fisheye		26

* “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 3: Overload Test Data for AISI 9310 Steel (IT 185)

StrAmpl	2Nf	StressAmpl* ksi	Mean Stress* ksi	PlsStrAmp	Modulus** ksi	Comments	Spec ID***
0.0089	1108	240	0	0	26993	#CA	1
0.008	1426	217	0	0	27120	#CA	2
0.00695	12068	158	0	0	22757	#CA	3
0.00836	4494	206	0	0	24632	#CA	11B
0.00722	6234	196	0	0	27191	#CA	9B
0.0068	9910	218	0	0	32082	#CA	16
0.00434	44221	127	0	0	29253		18
0.00405	222286	124	0	0	30616		19
0.00392	81943	120	0	0	30490		20
0.00387	1807304	121	0	0	31194		21
0.00416	204233	125	0	0	30094		22
0.00401	106586	126	0	0	31479		23
0.00456	827357	123	0	0	27030		24
0.00368	9639920	122	0	0	33306	#runout	25
0.00456	54786	134	0	0	29421		27
0.00457	116071	127	0	0	27864		28

Table 4: Rockwell C Hardness Test Data for AISI 9310 Steel

Specimen ID	Test 2	Test 2	Test 3	Average
17	52	56	55	54.33
23	52	53	51	52.00
24	53	54	51	52.67

* Specimens of which ID containing "HRC" were not tested in fatigue.