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METALLURGICAL EVALUATION OF TWO FRICTION WELDED GRADE 1045 STEEL BARS

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I. DESCRIPTION AND PURPOSE

Two friction welded steel bars were received for evaluation. The weld was between Grade 1045 hot rolled bars that had diameters of 2-3/8 inch and 5-1/4 inch. It was requested that two tensile specimens be extracted from one of the friction welded parts. In addition, the same part was to have the microstructure at the weld joint evaluated and a microhardness survey conducted through the fusion zone. Macro sections to show the grain flow at the weld locations were to be extracted from both samples.

II. TESTS AND RESULTS

The two friction welded samples are shown as-received in Figure 1. The samples were identified as A and B, for the purposes of this study. The detailed metallurgical evaluation was conducted on Sample A whereas only a macro section was cut from Sample B.

Two tensile specimens were extracted from Sample A at the location shown in Figure 1. The test results are presented in Table 1. Fracture occurred in the base metal of the small diameter bar for tensile Specimen A1, whereas it fractured in the base metal of the large diameter bar of Specimen A2. The tensile test results for the two specimens are similar.

Macro sections were prepared through both samples at the location shown in Figure 1. The etched surfaces of the cross sections are presented in Figures 2 and 3. Both samples show good fusion between the two bars. No evidence of lack of fusion was found.

A metallographic specimen was extracted from Sample A at the location shown in Figure 1. Examination of the base metals prior to etching revealed that both the small diameter and large diameter bars exhibited scattered manganese sulfide stringers, as shown in Figures 4 and 5, respectively. The manganese sulfide stringers are typical for a Grade 1045 steel. A cross section through the weld from the large bar base metal to the small bar base metal is shown progressively in Figures 6 to 9. The microstructures at the large bar base metal, heat affected zone for the large bar, weld region, heat affected zone for the small bar, and the small bar base metal are shown in Figures 10 through 14, respectively. The base metals of both bars consist of pearlite and ferrite, which is typical for a hot rolled medium carbon steel. The heat affected zones exhibit a finer structure of pearlite and ferrite. The fusion zone of the weld exhibits fine pearlite and Widmanstätten ferrite. It should be noted that the near surface region of the small diameter bar exhibited evidence of decarburization, which is shown in Figure 15.

A Knoop microhardness survey was conducted across the weld region of Sample A. The survey was conducted at a depth of 0.18 inches below the surface of the small bar. The survey spanned a width of 1 inch with impressions made every 0.04 inches, except within the fusion zone where the impressions were made at increments of 0.02 inches. The test results are presented in Table 2. Both base metals exhibited hardnesses in the 90 to 97 HRB range and the fusion zone exhibited hardnesses of 26 to 33 HRC.

If you have any questions concerning the contents of this report, please contact me. It should be noted that it is our policy to retain components and sample remnants for 30 days from March 29, 2007, after which time they will be discarded. If you would like to make alternate arrangements for disposition of the material, please let me know. This project shall be governed exclusively by the General Terms and Conditions of Sale and Performance of Testing Services by Stork Technimet, Inc. a Wisconsin business corporation d.d. March 22, 2004. In no event shall Stork Technimet, Inc. be liable for any consequential, special or indirect loss or any damages above the cost of the work.

Respectfully submitted,

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Table 1

Tensile Test Results

Property	**A1**	**A2**
Diameter, in.	0.501	0.505
Original area, in. ²	0.1971	0.2003
Dimension after fracture, in.	0.387	0.401
Area after fracture, in. ²	0.1176	0.1263
Yield load, 0.2% offset, lbs.	11,570	11,470
Tensile load, lbs.	20,740	21,010
Pretest gage length, in.	2.0	2.0
Post test gage length, in.	2.33	2.31
Yield strength, 0.2% offset, psi	58,500	57,500
Tensile strength, psi	105,000	105,000
Elongation, %	17	16
Reduction in area, %	40	37
Fracture location	Small diameter Base metal	Large diameter Base metal

Tested in accordance with ASTM A 370-05

Table 2

Microhardness Test Results

Depth From Small Bar Side [1]	Material Condition	Knoop Microhardness, HK_{500}	Equivalent Rockwell Hardness, HRB/HRC
.040	Base Metal	213	92
.080	Base Metal	200	90
.120	Base Metal	212	92
.160	Base Metal	237	97
.200	Base Metal	212	92
.240	HAZ	224	95
.280	HAZ	235	97
.320	HAZ	243	98
.360	HAZ	262	22
.400	HAZ	275	24
.440	HAZ	271	24
.480	Weld	284	26
.520	Weld	291	27
.540	Weld	330	33
.560	Weld	324	32
.580	Weld	324	32
.600	Weld	312	30
.620	Weld	296	28
.640	Weld	305	29
.660	Weld	304	29
.680	Weld	312	30
.700	Weld	316	31
.720	Weld	297	28
.760	HAZ	279	25
.800	HAZ	272	24
.840	HAZ	249	20
.880	Base Metal	215	93
.920	Base Metal	204	91
.960	Base Metal	222	94
1.00	Base Metal	238	97

(1) Microhardness survey conducted for 1.00 inch across the weld at a depth of 0.18 inch below surface of small bar

(2) “Weld” defined as region where microstructure consisted of fine pearlite and Widmanstätten ferrite

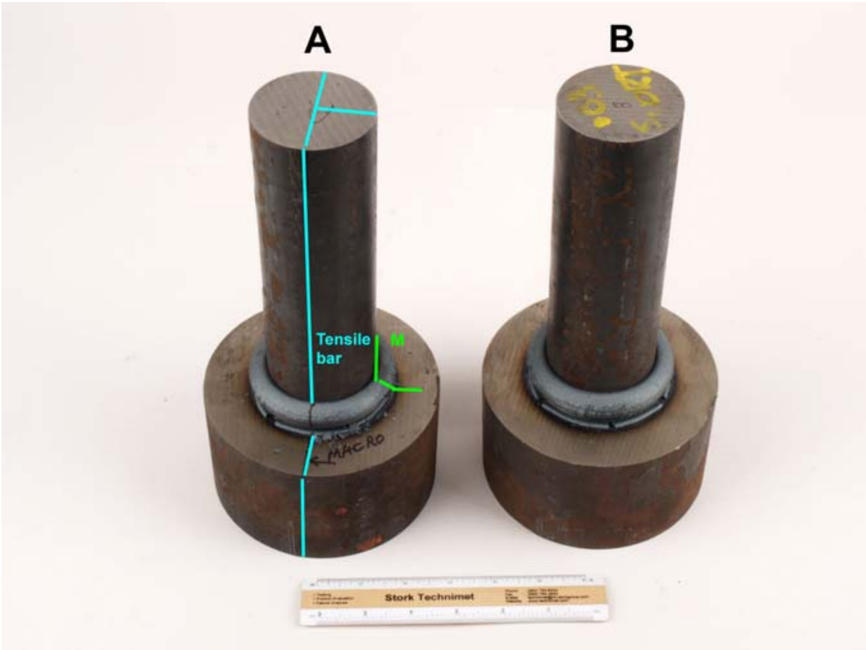

Fig. 1 - **The two friction welded bars, which were identified as Samples A and B, are shown. The black, green, and blue markings indicate the locations of the macro section, metallographic specimen, and tensile bar, respectively.**

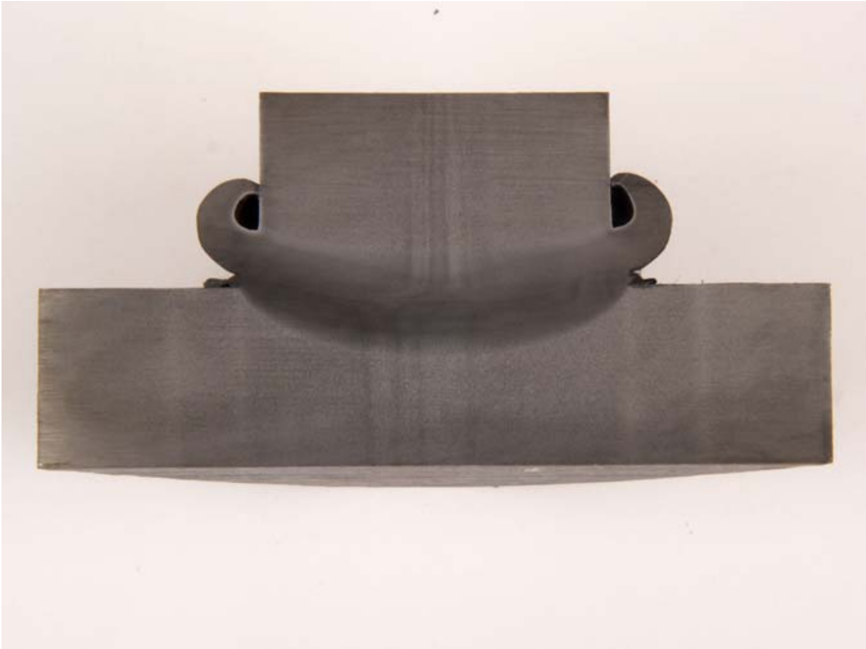

Fig. 2 - **Cross section through Sample A, showing the joint between the two bars.**

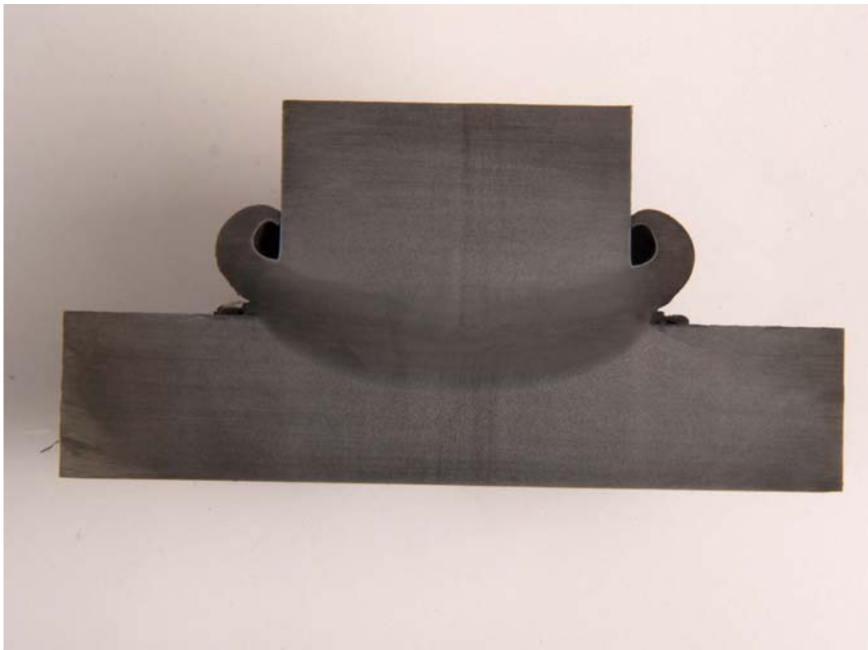

Fig. 3 - Macro section through Sample B, showing good fusion between the two bars.

Fig. 4 - Cross section through the small diameter bar, showing stringers of manganese sulfide inclusions. Unetched. (100X)

Fig. 5 - **Cross section through the large diameter bar, showing stringers of manganese sulfide inclusions. Unetched. (100X)**

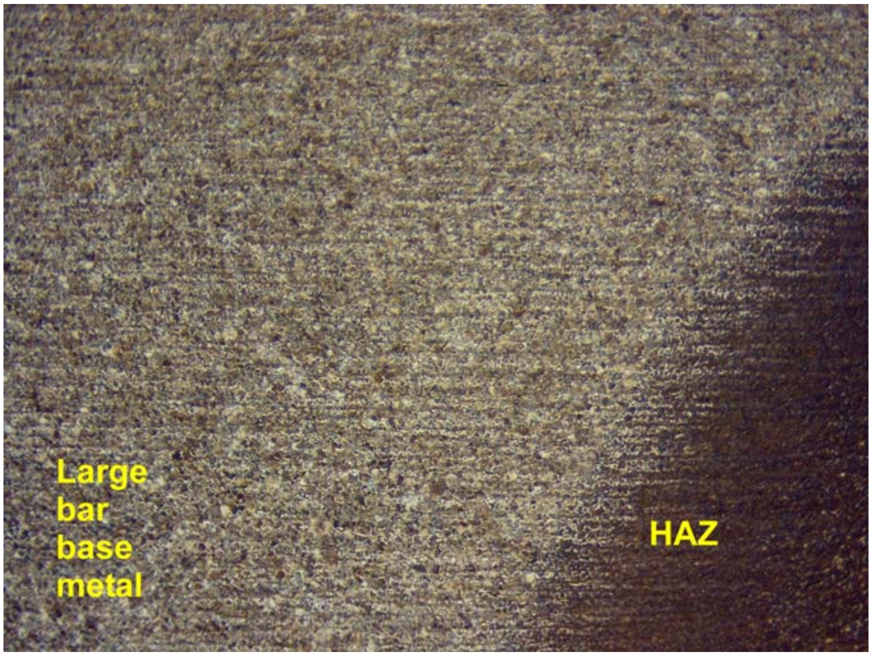

Fig. 6 - **Cross section through the interface between the base metal of the large diameter bar and the heat affected zone of the large bar. 2% Nital. (12X)**

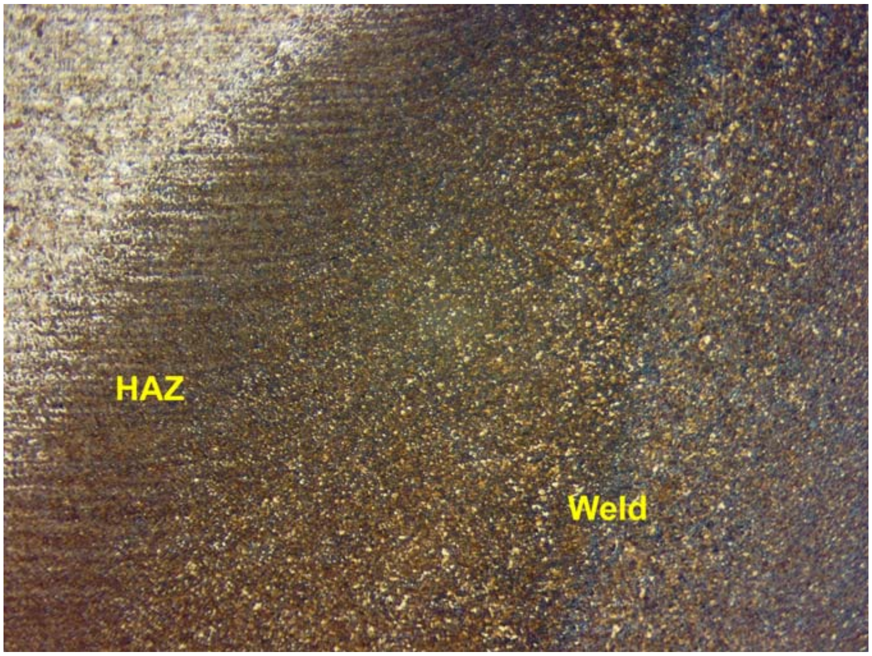

Fig. 7 - Cross section through the interface between the heat affected zone of the large bar and the weld fusion zone. 2% Nital. (12X)

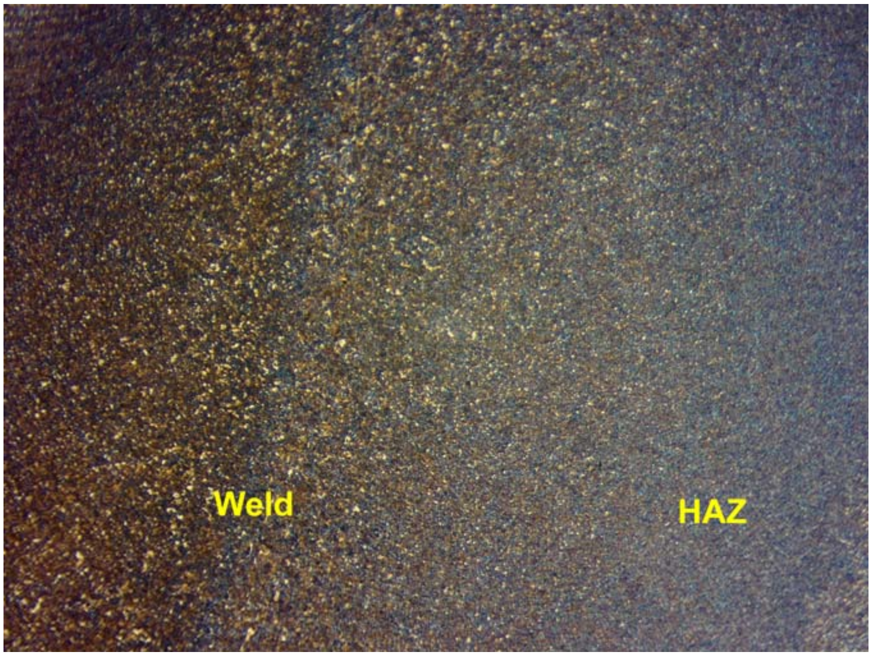

Fig. 8 - Cross section through the interface between the weld fusion zone and the heat affected zone of the small diameter bar. 2% Nital. (12X)

Fig. 9 - Cross section through the interface between the heat affected zone of the small bar and the small bar base metal. 2% Nital. (12X)

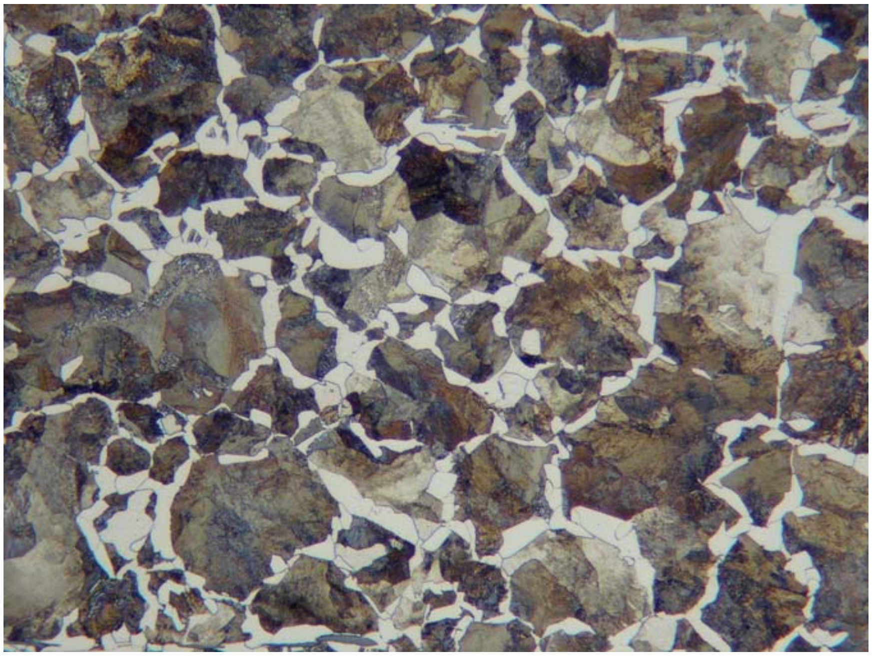

Fig. 10 - The microstructure of the large diameter bar base metal consists of pearlite and ferrite. 2% Nital. (200X)

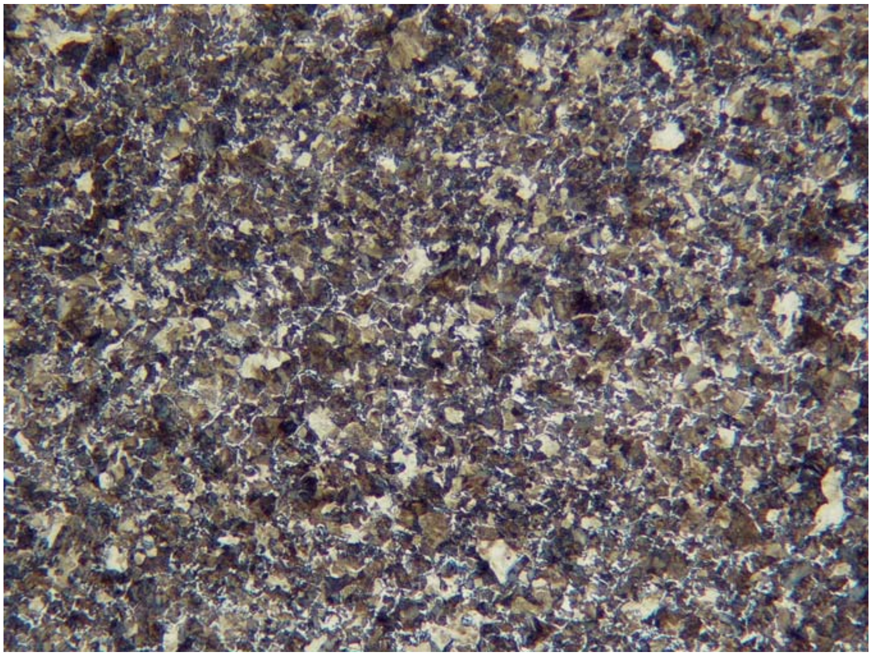

Fig. 11 - The heat affected zone of the large diameter bar consists of pearlite and ferrite. 2% Nital. (200X)

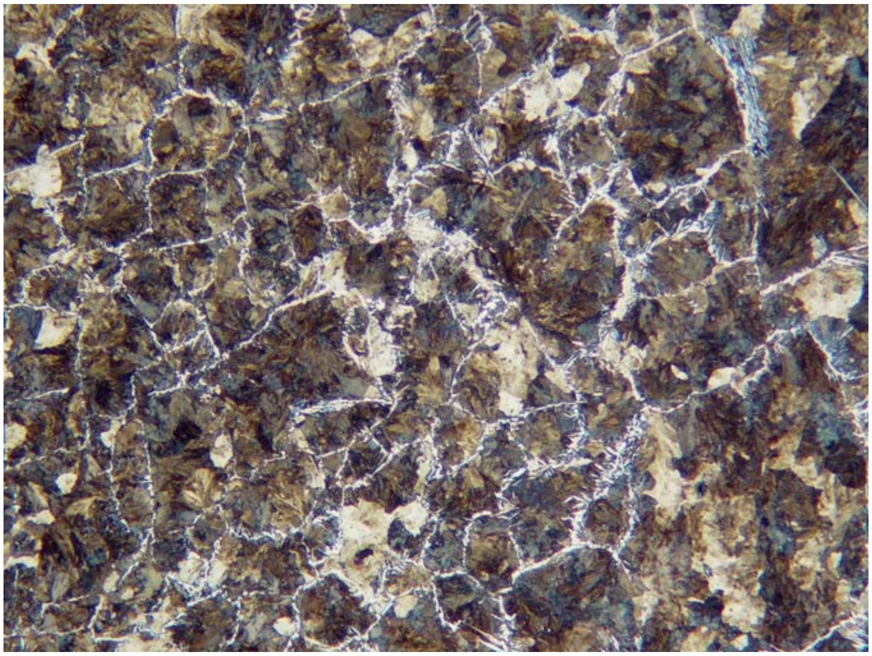

Fig. 12 - The fusion zone exhibits a microstructure of fine pearlite and Widmanstätten ferrite. 2% Nital. (200X)

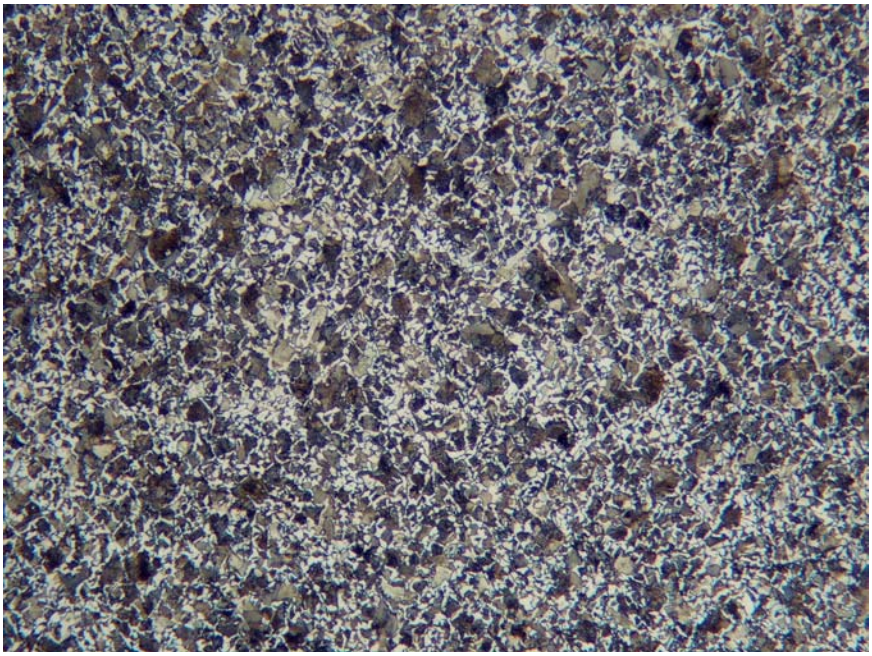

Fig. 13 - The heat affected zone of the small diameter bar exhibits a microstructure of pearlite and ferrite. 2% Nital. (200X)

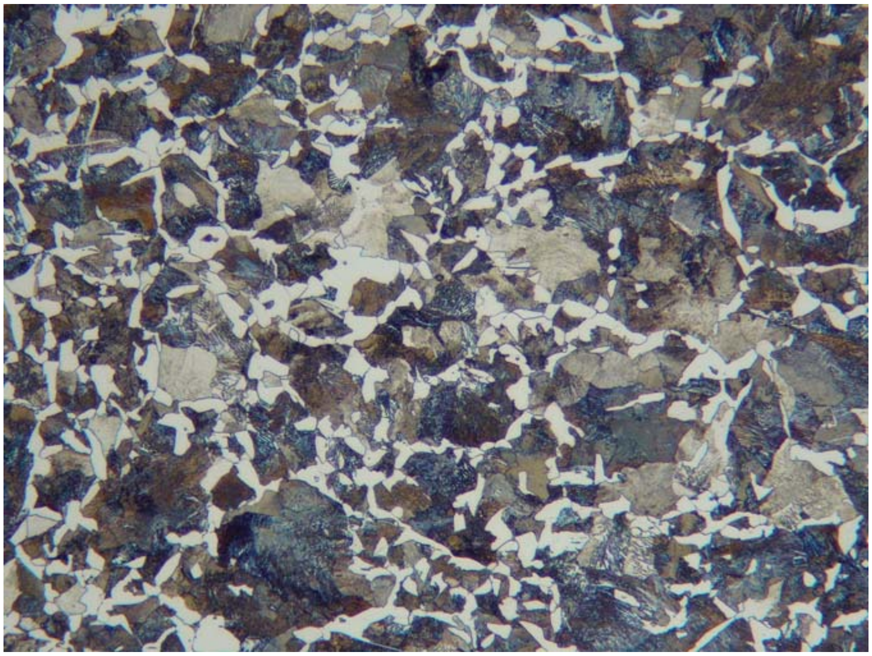

Fig. 14 - The microstructure of the base metal of the small diameter bar consists of pearlite and ferrite. 2% Nital. (200X)

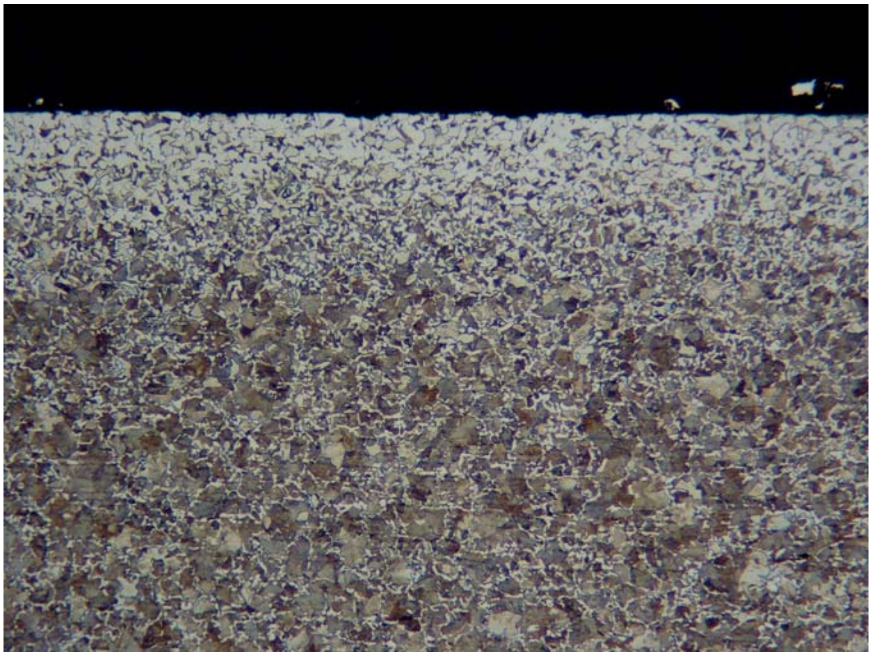

Fig. 15 - Cross section through the near surface region of the small diameter bar showing a zone of decarburization at the surface. 2% Nital. (50X)