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LABORATORY

INDEXED

640/98

AD-A953 306



WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 640/98

WELDING OF ARMOR

Metallurgical Examination of Samples from
Ballistically Tested Unionmelt Welded "H" Plate,
New York Air Brake Company, No. 47

BY

DECLASSIFIED
DOD DIR 5200.9

S. A. Herres
1st Lt., Ord. Dept.

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 640/98

Problem Number D-2.2

15 February 1944

WELDING OF ARMOR

Metallurgical Examination of Samples from Ballistically Tested
Unionmelt Welded "H" Plate, New York Air Brake Company, No. 47

OBJECT

To examine samples from leg welds of subject plate and determine whether reported inconsistency in ballistic performance was due to differences in metallurgical structure.

SUMMARY OF RESULTS

1. No significant difference in hardness, macrostructure, or microstructure of the two leg welds was observed.
2. Ballistic cracking occurred principally in the heat-affected zone near the fusion line. Similar coarse-grained microstructures consisting of high temperature transformation products and considerable free ferrite were observed in both leg welds in this region, and a nick-break fracture test showed a coarse crystalline fracture through this area in the ballistically undamaged leg weld.
3. Part of the ballistic fracture was associated with a lamination in the armor plate, but it was not possible to determine whether this condition affected the extent of ballistic fracture.

S. A. Herres
S. A. Herres
1st Lt., Ord. Dept.

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INTRODUCTION

Two samples from New York Air Brake welded H plate No. 47 were received from Aberdeen Proving Ground. As explained in the basic correspondence (Appendix A), the plate displayed definite inconsistency between the two leg welds during ballistic testing, and it was requested that a metallurgical examination be carried out to see if any difference in the metallurgical structure was evident to account for this inconsistency.

Welding materials and procedure, and results of radiographic and ballistic testing of the plate were reported in Armor Test No. AD-754, 22 July 1943 by the Proving Center (Armor Branch), Aberdeen Proving Ground.

The plate was welded with four hand passes at the root, deposited with Lincoln Armorweld manganese modified 18/8 and two Unionmelt passes, one from each side of a 45° included angle double V bevel, with Linde Oxweld 42 austenitic electrode, on Carnegie Illinois 1-1/2 inch thick rolled homogeneous armor plate of the following analysis: .25 C, 1.09 Mn, .19 Si, .57 Cr, .87 Ni, .20 Mo, and .002% B.

The plate was judged unacceptable in weld radiographic report because of a 3/8 inch weld metal crack at junction of right leg and crossbar and 1/8 inch weld metal crack at left end of crossbar.

The first ballistic impact (75 mm. T-21 proof projectile) hit on right leg 7-1/2 inches above crossbar and produced 17-5/8 inches of heat-affected zone cracking. The second impact hit 5/8 inch right of left leg 6-5/8 inches below crossbar and produced 4-7/8 inches of heat-affected zone cracking. A third impact hit 3/4 inch left of left leg, 8-1/4 inches above crossbar, produced 18 inches of heat-affected zone cracking and extended crack below crossbar to 5-7/8 inches all heat-affected zone.

TEST MATERIALS AND PROCEDURE

The samples received for examination were taken from the right leg through the first impact and from an undamaged portion of the lower left leg. The right leg sample, consisting of one piece from each side of the ballistic fracture, was photographed to show fracture surface and a specimen was taken through the weld for hardness survey, macroetching and microscopic examination. The left leg sample was notched with an abrasive wheel and fractured across the weld joint with a sharp blow of a steam hammer. A sample was then taken through the weld for hardness survey, macroetching, and microscopic examination.

DATA AND DISCUSSION

1. Examination of Fractured Surfaces

Figure 1A is a photograph of the surface of the ballistic fracture of the sample from the right leg weld. Most of the fracture is in the weld heat-affected zone of the armor plate parallel and within a few hundredths of an inch of the weld fusion line. A part of the fracture extends into the armor plate along a shelf parallel to the plate surface for a distance equal to the width of the weld heat-affected zone (approximately $\frac{1}{8}$ inch) and then breaks to the back surface of the plate at an angle. The shelf appears to be along a lamination in the armor plate as shown in Figure 1B which is a photograph of a macroetched section taken through this part of the ballistic fracture. The appearance of the macroetched surface indicates acceptable steel quality. The fracture near the point of impact shows no sign of plate metal defects and it is impossible to determine whether the lamination affected the propagation of the ballistic fracture.

Figure 1C is a photograph of a nick-break fracture surface through the weld joint of the sample from the left leg weld which was not damaged by ballistic impact. The entire heat-affected zone shows a crystalline type of fracture surface with large facets near the weld fusion line in the area corresponding to that of the path of ballistic failure in the right leg sample. A crystalline type fracture is typical of steel which is of unsuitable metallographic structure because of inadequate hardenability or unsuitable heat treatment and which tends to fail brittlely, without deformation, at relatively low energy values under severe ballistic impact.

2. Macroexamination

Figure 2A is a photograph of macroetched cross section through sample from right leg weld. Figure 2B is a photograph of macroetched section through left leg weld. No significant differences are apparent between the macrostructures of the two leg welds.

3. Hardness Surveys

Figure 3 shows results of Vickers hardness surveys on polished surfaces of cross sections taken through samples from each leg weld. No significant differences are apparent between hardnesses of the weld metal, heat-affected zone, or base plate of the two leg welds.

4. Microexamination

Microscopic examination of polished cross sections taken from the two leg welds indicates no significant differences in microstructures between the two leg welds. As shown by the photomicrograph of Figure 4, the structure of the heat-affected zone of each leg weld, in the area near the fusion line which corresponds to the region of greatest ballistic cracking, consists of high transformation temperature carbides with a large amount of free ferrite.

APPENDIX A

Basic Correspondence

WAR DEPARTMENT
ABERDEEN PROVING GROUND
MARYLAND

A.P.G. 470.5/1162

Armor Branch
Roth/jm
Ext. 4165

20 August 1943

Subject: Samples from New York Air Brake Welded Plate No. 47

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Attn: Colonel Cox

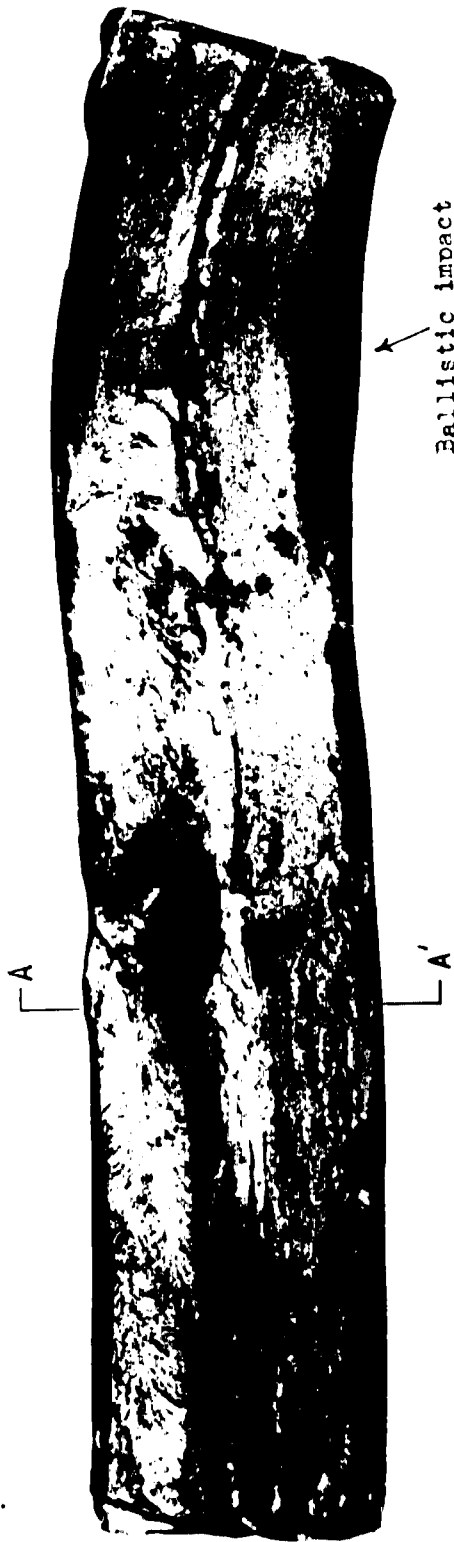
1. This station is shipping to Watertown Arsenal two samples from New York Air Brake welded plate No. 47. This plate on ballistic testing displayed definite inconsistency between the two leg welds. Samples have been cut from each of the leg welds and labeled 47R for the sample taken from the right leg and 47L for the sample taken from the left leg. These samples have been forwarded to Watertown Arsenal for metallurgical examination to see if there is any difference in the metallurgical structure of the welds which would cause this inconsistency.

2. The results of the testing of these plates was reported in Armor Test Report No. AD-754, of which Watertown Arsenal received a copy.

3. It is requested that metallurgical examination be conducted on these plates and the findings sent to this station in a letter report.

For the Commanding General:

(s/t) G. E. Philipsen
Major, Ord. Dept.
Chief, Armor Branch



Ballistic impact

FIGURE 1A SURFACE OF BALLISTIC FRACTURE - RIGHT LEG WELD SAMPLE

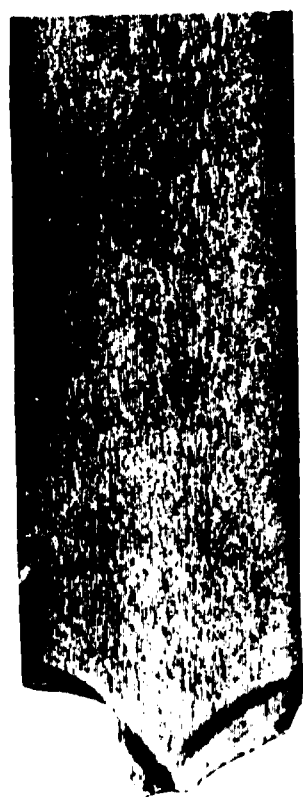


FIGURE 1B MACROETCHED CROSS SECTION (100X) THROUGH HALF OF BALLISTIC FRACTURE SURFACE - RIGHT LEG WELD SAMPLE

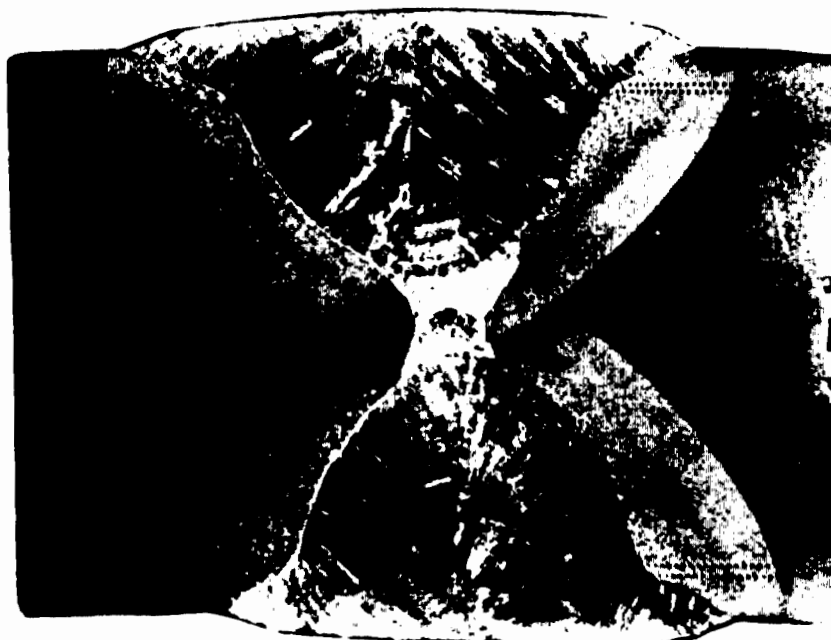
FIGURE 1C MACROETCHED CROSS SECTION (100X) THROUGH HALF OF BALLISTIC FRACTURE SURFACE - RIGHT LEG WELD SAMPLE



X2

Etch: 4% picral followed by
10% chromic acid (electrolytically)

FIGURE 2A MACROETCHED CROSS SECTION THROUGH RIGHT LEG WELD SAMPLE



MTN.03-0050

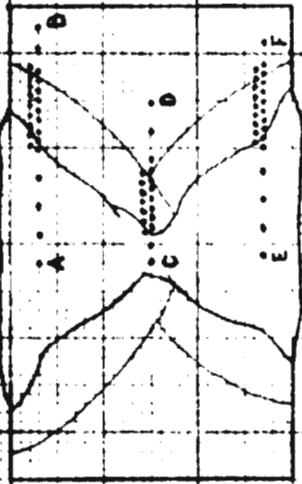
X2

Etch: 4% picral followed by
10% chromic acid (electrolytically)

FIGURE 2B MACROETCHED CROSS SECTION THROUGH LEFT LEG WELD SAMPLE

METHOD OF MAKING SURVEYS

.05" spacing in weld metal and unaffected plate
 Impressions in heat-affected zone staggered to give .01" spacing



Right Leg Sample

Left Leg Sample

AB

AB

CD

CD

EF

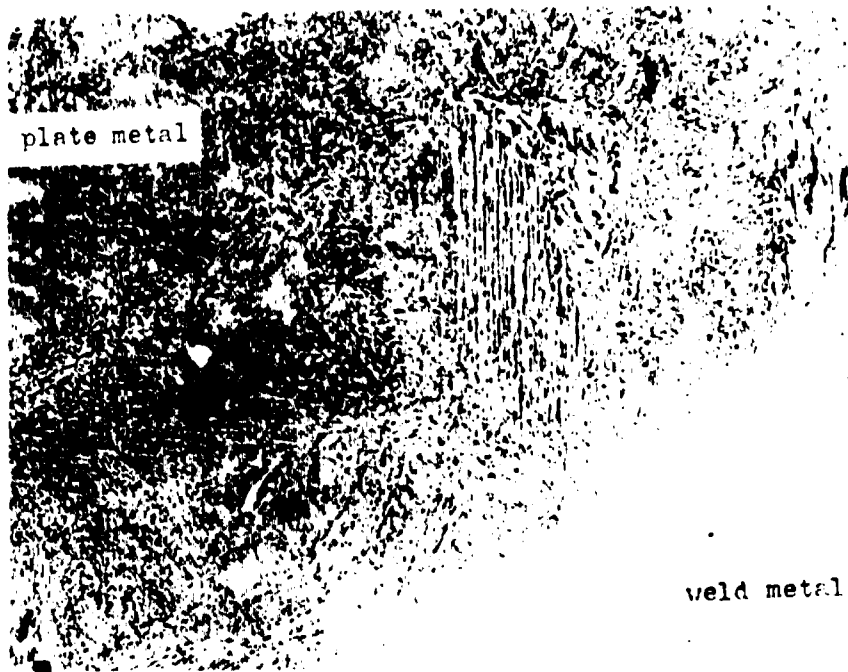
EF

Fusion Line

Vickers-Griffith Hardness

0 .20 .40 .60 .80 Inches 0 .20 .40 .60 .80

FIGURE 3 HAZ/HAZ SURVEYS



X250

Picral etch

Right leg weld sample



X250

Picral etch

Left leg weld sample

WITNESS PHOTO

FIGURE 4 MICROSTRUCTURE NEAR FUSION LINE OF LAST PASS
MIDWALL OF PLATE