

"LABORATORY INVESTIGATION OF MANGANESE STEEL WELD DEPOSITS"

by Jian Sun
TD96-008

Summary

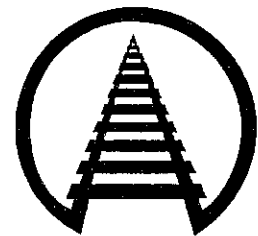
As part of a cooperative effort to increase the service life of weld repairs on manganese steel frogs and crossings, the Association of American Railroads and Edison Welding Institute conducted laboratory experiments on manganese steel weld deposits produced by flux cored arc welding (FCAW) and shield metal arc welding (SMAW). Results indicate that the impact toughness of manganese steel weld metal deposits produced by FCAW is much lower than that of deposits produced by SMAW, whether or not the interpass temperature and bead width were controlled. This is attributed to the carbide precipitation in the FCAW weld metal and to the difference between the chemical composition of SMAW and FCAW deposits.

Because the service life of weld repairs is usually much shorter than that of the original casting, there is a great interest in improving it. The generally accepted practice for manganese steel frog/crossing repair welding recommends a maximum interpass temperature of 500 °F and a maximum bead width of 5/8 inch. The impact test results show no detrimental effect on the toughness of weld metal when higher interpass temperatures and wider beads are employed.

Test results presented in this document are limited to the microstructure and impact toughness of weld deposits. The effect of welding heat on the heat affected zone in the manganese steel substrate material will be investigated with specimens of welds made on cast manganese steel microstructurally similar to frogs and crossings.

Suggested Distribution:

- Maintenance of Way
- Research and Development
- Track Maintenance
- Maintenance Planning



Association of American Railroads
Research and Test Department

April 1996



INTRODUCTION AND CONCLUSIONS

As part of a cooperative effort to increase the service life of weld repairs on manganese steel frogs and crossings, the Association of American Railroads and Edison Welding Institute conducted laboratory experiments on manganese steel weld deposits produced by flux cored arc welding (FCAW) and shield metal arc welding (SMAW). Results indicate that the impact toughness of manganese steel weld metal deposits produced by FCAW is much lower than that of deposits produced by SMAW, whether or not the interpass temperature and bead width were controlled. This is attributed to the carbide precipitation in the FCAW weld metal and to the difference between the chemical composition of SMAW and FCAW deposits.

Results show that failure to control interpass temperature and weld bead width was not detrimental to weld metal toughness for either SMAW or FCAW deposits. While a significant amount of carbide precipitation was found in the weld metal of FCAW welds, the quantity found in SMAW welds was minimal.

BACKGROUND

Repairing manganese steel frogs or crossings using SMAW or FCAW is a common practice on North American railroads. Because the service life of the weld repairs is usually much shorter than that of the original casting, there is a great interest among the railroads to improve it. While there is a recommended practice for weld repair, actual practice can vary substantially. A wide range of maximum interpass temperatures is employed, and heat input control, primarily through control of weld bead width, also varies substantially. The generally accepted practice recommends

a maximum interpass temperature of 500 °F and a maximum bead width of 5/8 inch.

Most engineers believe that failure to adhere to the recommended practice increases the risk of carbide precipitation with possible loss of toughness/ductility in the weld repaired region. The subsequent service performance of repairs could be affected adversely by the increased potential for cracking associated with carbide precipitation.

EXPERIMENTAL PROCEDURE

A constant current power source was used for SMAW, and a constant voltage power source was used for FCAW. Welding consumables, with a manganese content in the range of 15 to 20 percent were purchased from a major railroad industry supplier. They included 3/16-inch electrodes for SMAW and 3/32-inch flux cored wire for FCAW. Flux cored wire, the most common FCAW consumable type in both shop and field, was a self-shielded type without external gas shielding.

The base material for each weld pad was a 4.5-inch × 12-inch × 1-inch piece cut from a wrought austenitic manganese steel plate section using plasma arc cutting. To simulate the restraint conditions of a track casting and minimize distortion in the weld pad, the austenitic manganese plate was welded to a section of thick steel plate. Refer to Exhibit 1 for the welding processes, parameters, and practices employed for each weld pad.

The thickness of weld metal deposits was 1/2 inch for all the welds. Interpass temperatures of W1, W3, and W4 were controlled to a maximum of 500 °F. Although there was no control on the interpass temperatures of W2 and W5, temperatures were still measured and recorded.



Exhibit 1. Welding Conditions

| Pad No. | Process | Welding Current (A) | Welding Voltage (V) | Wire Speed (in/min) | Travel Speed (in/min) | Layers | Beads/ Layer | Interpass Temperature (°F) |
|---------|---------|---------------------|---------------------|---------------------|-----------------------|--------|--------------|----------------------------|
| W1 | SMAW | 190 | 24-25 | - | 6-7 | 7 | 9-10 | 300-480 |
| W2 | SMAW | 190 | 24-25 | - | 6-7 | 7 | 9-10 | 540-660* |
| W3 | FCAW | 340 | 28 | 185 | 12 | 6 | 8-9 | 360-490 |
| W4 | FCAW | 340 | 28 | 185 | 5-6 | 6 | 3 | 340-500 |
| W5 | FCAW | 340 | 28 | 185 | 5-6 | 6 | 3 | 550-640 |

* Reached 750 °F by the end of seventh layer.

An impact test and three metallographic specimens were prepared from each weld pad using wire electrodischarge machining (EDM). Machining was carried out with the weld pads immersed in oil, a standard operating technique which also prevents carbide precipitation through overheating.

RESULTS

Weld metal chemical compositions of W1 (SMAW) and W5 (FCAW) were determined using plasma emission spectroscopy (see Exhibit 2). The SMAW deposited weld metal contains 0.5 C, 3.9 Ni, and 0.98 Mo; the FCAW deposited weld metal contains 1.1 C, 0.76 Ni, and 0.2 Mo. Each of these weld metal compositions were found to affect the weld metal toughness.

Solidification cracking and significant carbide precipitation were discovered in all of the FCAW welds. The microstructure of SMAW weld metal exhibits minimal carbide

precipitation and no solidification cracking. The quantity of carbide precipitation present in SMAW and FCAW weld metals is clearly related to their carbon content. Higher carbon content is beneficial to weld metal hardness, but may harm the toughness, as shown in this test.

Results of the impact tests, which were conducted at -20 °F, are shown in Exhibit 3. The absorbed energy of SMAW weld metal was much higher than that of FCAW weld metal, regardless of the interpass temperature and bead width.

Subsequent examination of the fracture surfaces found that SMAW weld metal fractured in a ductile manner and FCAW weld metal fractured in a brittle manner. This is attributed to the large amount of carbide precipitation in the FCAW weld metal and to the difference in chemical compositions.



Exhibit 2. Weld Metal Compositions of SMAW Weld W1 and FCAW Weld W5

| Element | W1 (SMAW) | W5 (FCAW) |
|---------|-----------|-----------|
| C | 0.51 | 1.1 |
| Mn | 17.7 | 19.6 |
| Ni | 3.9 | 0.76 |
| Cr | 3.4 | 4.3 |
| Mo | 0.98 | 0.20 |
| P | 0.02 | 0.02 |
| S | <0.01 | <0.01 |
| Si | 0.09 | 0.08 |
| Cu | 0.09 | 0.03 |
| Sn | 0.01 | 0.01 |
| Al | 0.003 | 0.02 |
| V | 0.04 | 0.05 |
| Nb | 0.01 | 0.01 |
| Zr | -- | -- |
| Ti | 0.3 | 0.06 |
| B | 0.001 | 0.001 |
| Ca | 0.0005 | 0.0009 |
| Co | 0.02 | 0.02 |

DISCUSSION

Results were generated from weld metal testing only. The service life of welding repairs on manganese steel frogs or crossings is determined not only by the toughness, but also by the initial hardness and hardenability of the weld metal, and probably to a larger extent by the microstructure and property of the heat affected zones in the cast substrate. Thus, a prediction of service life of manganese steel frog/crossing welding repairs should not be made only from the results of this document.

Exhibit 3. Impact Test Results for SMAW and FCAW Weld Metal at -20 °F

| Weld | Welding Process | Energy (ft-lb) | Lateral Expansion (mm) | Percent Shear Fracture |
|------|-----------------|----------------|------------------------|------------------------|
| W1 | SMAW | 60.5 | 1.53 | 45 |
| | | 79.0 | 1.75 | 76 |
| | | 66.0 | 1.60 | 58 |
| W2 | SMAW | 78.0 | 1.77 | 72 |
| | | 84.0 | 2.01 | 72 |
| | | 66.0 | 1.47 | 66 |
| W3 | FCAW | 8.5 | 0.20 | 0 |
| | | 13.5 | 0.24 | 0 |
| | | 11.5 | 0.17 | 0 |
| W4 | FCAW | 8.0 | 0.12 | 0 |
| | | 6.0 | 0.06 | 0 |
| | | 8.0 | 0.13 | 0 |
| W5 | FCAW | 16.5 | 0.30 | 0 |
| | | 16.5 | 0.29 | 0 |
| | | 19.5 | .033 | 0 |

Subsequent experiments will use cast manganese steel as a base material. Carbide precipitation in the heat affected zones produced with different welding process, heat input, and interpass temperatures will be examined.

Note: Contact Jian Sun at (719) 584-0698 with questions or comments about this document.

Disclaimer: Preliminary results in this document are disseminated by the AAR for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR makes no representations or warranties, either express or implied, with respect to this document or its contents. The AAR assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk.