TECHOLOGY DIGEST
Timely Technology Transfer — 99-025

Field Evaluation of Welding Materials for High Angle AMS Frog Repair

by Jian Sun and David D. Davis

Summary

Recent evaluations of commercially available welding materials for the repair of frogs cast from austenitic manganese steel (AMS) indicate welding procedures used and the railroad's policy on providing track time for frog repair has a greater effect on the performance of weld repairs than does the welding material. This finding came from field tests conducted by Transportation Technology Center, Inc. with the cooperation of Indiana Harbor Belt (IHB) Railroad, on an IHB-maintained high-angle crossing at Dolton, Illinois. Four weld materials were used to repair AMS castings on four high-angle crossing diamonds at this busy interlocking. The same welder made all welds according to the recommended practices in AWS D15.2. All test welds, regardless of welding material used, exhibited much longer service lives than the non-test welds IHB made on similar AMS frogs.

Other findings are:

- Welds made with a low-carbon / high-alloy electrode performed better than welds made with other test electrodes.
- In general, welds made with low-carbon electrodes performed better than welds made with electrodes of higher carbon content. The high-carbon-content welds had a significant number of early life failures.

Maintenance of AMS crossing diamonds is of great importance to North American railroads. Approximately 5,800 turnout frogs and 1,000 diamond crossing frogs are replaced and $120 million is spent on turnout- and crossing-frog maintenance each year. The average life of frog castings and frog-weld repairs is quite short compared to rail in standard track. However, through the use of weld repair, frogs may be kept in service well beyond the service life of the original casting's running surface.

Suggested Distribution:
- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads
July 1999©

INTRODUCTION AND CONCLUSIONS

To evaluate the performance of commercially available welding materials for repairs of frogs cast from austenitic manganese steel (AMS), TTCI, with the cooperation of IHB Railroad, conducted a field test at an IHB-maintained crossing at Dolton, Illinois. The same welder made all the test welds according to the recommended practices in AWS D15.2. Sufficient track time was given to enable the welder to follow the recommended practices. All test welds, regardless which welding material was used, exhibited much longer service lives than the non-test welds IHB made on other similar AMS frogs. According to the IHB track personnel, the service lives of the test welds are several times longer than the ordinary AMS frog repair welds. The finding implies that the welder's practice and the railroad's policy on providing track time for frog repair — not the welding material — has a greater effect on the performance of weld repairs on AMS frogs.

Other findings are welds made with a low-carbon, high-alloy electrode (coded electrode C in the tests) performed better than welds made with other test electrodes. And, in general, welds made with low-carbon electrodes performed better than welds made with electrodes of higher carbon content. The results indicate that increasing carbon content in the weld metal is not the best way to improve performance despite the fact that carbon is effective in increasing hardness and the rate of work-hardening. In this test, the high-carbon weld repairs had a large percentage of early cracking or infant mortality failures. The low-carbon welds have not had any early cracking. Test welds were followed up with inspections and measurements; therefore, initial metal flows were more likely to be ground more timely than were ordinary repair welds.

BACKGROUND

Industrywide, approximately 5,800 turnout frogs and 1,000 diamond crossing frogs are replaced and $120 million is spent on turnout- and crossing-frog maintenance each year. The average life of frog castings and frog weld repairs is quite short compared to rail in standard track. To extend the service lives of weld repairs, and therefore the service lives of the AMS crossing diamond frogs, is of great importance to North American railroads.

The frog is the key component in turnouts and crossing diamonds. It has the shortest life of any track component and also requires frequent maintenance. Weld repair of a frog can greatly extend the life of the frog and is conducted to repair cracks or to restore running-surface profiles that have worn or flowed beyond allowable limits. As a frog running surface wears and deforms, wheel impacts increase. This increases the damage done to the frog by each wheel and can further shorten the life of the frog. Recent studies of rail-bound AMS frogs in heavy-haul service have shown that the average frog receives many weld repairs over its life, with each frog in service averaging eight weld repairs. These repairs begin at about 1/4 to 1/3 (depending on frog angle) of the total life of the frog. Thus, the life of the frog is greatly extended by the use of in-track weld repairs.

Many welding materials have been developed for weld repair of AMS frogs. Welding material manufacturers often claim that one product or one type of products performs better than others, but there is little experimental evidence to support the claims. Earlier TTCI laboratory test results show that weld metal with high-carbon content has high initial hardness and performed well in keeping their original geometry, but is vulnerable to cracking, especially under impact load. On the other hand, the low-carbon weld metal exhibits better resistance to cracking, but is less resistant to deformation (metal flow) because of its relatively low hardness both in initial stage and after work-hardening. The repair welds, especially when weld metal is comparatively softer, should be profiled to allow for metal flow and the flow must be ground off before cracking starts. A field evaluation was desirable to validate the laboratory test results and compare the performances of different welding materials. IHB Railroad had the same interest and agreed to cooperate with TTCI in conducting these tests.

THE TESTS

The test site was an IHB/Union Pacific double track crossing, as shown in Exhibit 1, with an angle close to 90 degrees. Traffic rates are approximately 20 MGT/track and 5 MGT/track on the IHB and UP respectively. The allowable track speed is 20 miles per hour, but many trains travel slower due to the site's proximity to major yards to the west and south.

Exhibit 1. The Test Site

A double-track crossing consists of four diamonds and each diamond has 16 "corners" (4x4). Of the 16 corners for each diamond, four of them never touch a passing wheel. Weld repair at each of the remaining 12 corners can be treated as an individual test. So the maximum number of tests at the crossing is 48. The wheel-load mode on each corner can be different, with some corners where wheels mostly depart and run into the flange gap (i.e. "approaching" corners), to some corners mostly receiving wheels rolled across the flange gap (i.e. "leaving" corners). The leaving corners are subject to high impact loads. Some corners only interact with wheels of trains in one direction while others interact with train wheels in both directions. The 48 corners are divided into groups according to the traffic and wheel-load mode. An ideal test would have welds in each group installed at the same time. In practice, however, IHB determined to make a weld repair only when it is needed because of the nature of the railroad operation. Exhibit 2 illustrates the repair welds made at the crossing as of November 20, 1998. Each weld is categorized by whether traffic is approaching or leaving.

Four welding electrodes, one each from four major suppliers in North America, were selected for the test. The nominal weld-metal compositions of the electrodes are shown in Exhibit 3.

An experienced welder from IHB Railroad was selected to perform all the welding-repair work for the test crossing to eliminate the variable of welder's skill on the weld quality. The welder was thoroughly retrained in the recommended practices for AMS frog-welding repair as illustrated in AWS D15.2.

Thirty test welds have been made since February 1997. Installation dates were recorded by IHB and the histories of traffic tonnage on each track were obtained from both IHB and UP. It has been difficult for TTCI researchers to measure and record all the test welds due to the remoteness of the test site and the unpredictable installation schedule. The busy train traffic and track conditions at the site make it very difficult to accurately measure the geometry and deformation of the welds. In many circumstances, qualitative records such as visual observation and photography were adopted instead of quantitative measurement.

Of the 30 installed welds, only two (Weld 21 and Weld 26) had been further repaired by November 1998, while a few others had cracks and various amounts of metal flow. The majority of the remaining repair welds are in good condition. According to IHB personnel, all of the test welds, regardless of the welding electrode used, lasted much longer than previous welds on the crossing and welds made at other locations. The railroad uses electrode A as its standard electrode for AMS frog weld repair.

Exhibit 4 shows the condition of the test welds as of November 20, 1998. Weibull analysis was used to project an average cracking life for each consumable, as shown in Exhibit 5. Electrode C, a low-carbon/high-alloy electrode,

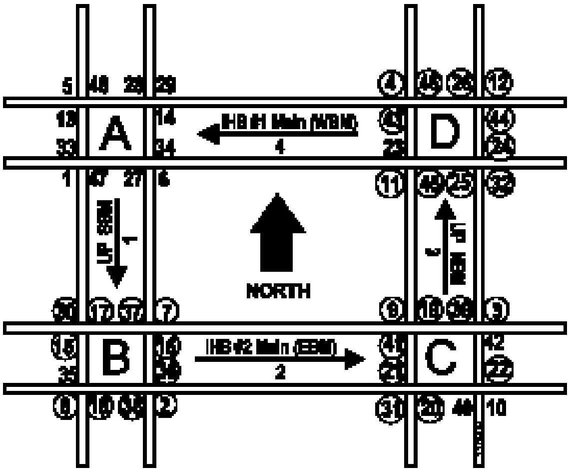

Exhibit 2. Locations of Test Welds. Welds Were Made on the Corners with a Circled Number

Electrode	C	Mn	Cr	Ni	Mo
A	1.0	19.5	5.0	-	-
B	0.56	17	-	3.9	1.2
C	0.35	14	15	-	-
D	1.0	15	4.9	0.7	1.0

Exhibit 3. Weld Metal Composition of the Electrodes

performed better than welds made with other test electrodes. And, as a group, low-carbon electrodes, electrodes B and C, performed better than welds made with electrodes of higher carbon content (A and D). Although carbon is effective in increasing hardness and the rate of work-hardening, the results indicate that increasing carbon content in the weld metal is not the best way to improve its performance. This is in agreement with earlier laboratory test results. Higher hardness achieved by means other than high carbon content, such as alloy-strengthening, may be more desirable in application of AMS frog repairs. One concern would be the higher cost of high-alloy electrodes. However, electrode C, which has a higher alloy content, cost virtually the same as two of the other test electrodes. The fourth costs about 20 percent less than the others do.

Exhibit 5. Projected "Average" Weld Life from Each Electrode from Weibull Statistics

Electrode	Number of Samples	Number Failed (replaced, cracked or heavy flow)	Weibull Characteristic Life (MGT)
A	9	3	52
B	8	2	98
C	8	1	138
D	9	2	54

Exhibit 4. Condition of the Test Welds as of November 20, 1998

Corner	Electrode	Number Leave, Approach	Total MGT 11/20/98	Condition 11/20/98
2	B	2,0	11.7	flow
3	C	2,0	14.5	good
4	D	2,0	34.5	light flow
7	C	1,1	11.8	good
8	D	1,1	33.3	heavy flow
9	A	1,1	12.3	good
11	C	1,1	40.0	flow
12	D	1,1	1.2	light flow
15	C	1,0	7.3	crack
16	D	1,0	1.5	crack
17	A	1,0	41.2	good
19	C	1,0	10.6	good
20	D	1,0	12.6	good
21	A	1,0	2.1	replaced
21	A	1,0	4.9	crack
22	B	1,0	1.2	crack
24	D	1,0	1.9	good
25	A	1,0	32.7	crack
26	B	1,0	13.1	replaced
26	B	1,0	1.0	good
30	B	0,2	43.7	flow
31	C	0,2	28.8	good
32	D	0,2	14.5	good
36	D	0,1	1.5	light flow
37	A	0,1	10.3	good
38	B	0,1	10.8	good
39	C	0,1	12.6	good
41	A	0,1	1.5	good
43	B	0,1	6.0	good
44	D	0,1	1.9	good
45	A	0,1	32.8	light flow
46	B	0,1	28.5	good

ACKNOWLEDGMENTS

Mike Markase, formerly Welding Supervisor and Tom Dinger, formerly Chief Engineer, IHB Railroad, were essential in developing and executing this test. Bill Reno, Track Supervisor, IHB, also assisted in inspection and measurement of the diamonds. Bill Gemeiner, Manager Research and Methods, Union Pacific, provided the UP tonnage records.

Note: Contact Jian Sun at (719) 584-0698 or David Davis at (719) 584-0754 with questions or comments about this document.

E-mail: **jian_sun@ttci.aar.com**
dave_davis@ttci.aar.com

Web site: **www.ttci.aar.com**

Disclaimer: Preliminary results in this document are disseminated by the AAR/TTCI for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR/TTCI makes no representations or warranties, either express or implied, with respect to this document or its contents. The AAR/TTCI 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.

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.