

Suggested Distribution:

- Maintenance of Way
- Planning & Analysis
- Track Maintenance
- Safety

Laboratory Tests of Gas Pressure Rail Welds

by Jian Sun

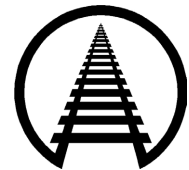
Summary

Test gas pressure rail welds exhibited excellent fatigue properties in both bending fatigue and rolling load tests performed by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR). The fatigue resistance of gas pressure welds exceeds those of both thermite and electric flash rail welds in bending fatigue tests. The welds also exhibited extraordinary ductility in the slow bend tests.

Two test welds had deflections of four inches (the machine limit) without fracture. Their strength and hardness, as indicated by the modulus of rupture in slow bend tests and internal hardness measurement in the railhead, are also satisfactory. Overall, the tested gas pressure rail welds have performed excellently in laboratory tests. These laboratory test results indicate that the gas pressure rail weld has the potential to perform well in revenue service.

In previous efforts, TTCI identified gas pressure welding (GPW) as a potential alternative process for rail welding in North America. To further evaluate its potential in service performance and to investigate the feasibility of using GPW in North American railroads conditions, TTCI has tested sample gas pressure welds made of AREMA head hardened rails.

In application, GPW has the potential to complement the current rail welding processes in North America in certain situations. Compared to mobile electric flash welding, the GPW has substantially lower equipment cost and better portability. The quality of gas pressure welds is expected to be comparable to that of electric flash welds, based on the satisfactory full-scale laboratory test results. However, the productivity of GPW is believed to be lower than that of electric flash welding. It was observed that it took about 26 minutes to complete the GPW welding and post-welding heat treatment process in trackside (not in-track) operations in Japan. Considering those factors, GPW could be the favorable welding process should a limited number of high quality rail welds be needed at a specific location, such as CWR renewal in curved tracks.



TTCI
Transportation
Technology Center, Inc.

Work performed by
a subsidiary of the Association of American Railroads

©November 2002

INTRODUCTION AND CONCLUSIONS

In searching for ways to improve the service performance of rail welds and to reduce the cost for rail welding, TTCI has identified gas pressure welding (GPW) as a potential alternative process for rail welding in North America.¹ To further evaluate its potential in service performance and to investigate the feasibility of using GPW in North American railroad conditions, TTCI has contracted with Hakusan Manufacturing Company of Japan, a GPW equipment and service supplier, to manufacture six gas pressure rail welds for an independent laboratory examination.

Laboratory test results show that GPW can produce very high quality rail welds. Overall, the gas pressure weld performance in full-scale laboratory tests has exceeded the requirements for electric flash rail welds. Two gas pressure rail welds were tested in American Railway Engineering and Maintenance-of-Way Association (AREMA) slow bend tests. Neither weld broke when the deflection reached four inches — the machine limit. The test welds also exhibited superior fatigue properties in laboratory bend fatigue tests and rolling load tests. The very satisfactory laboratory test results indicate that the gas pressure rail welds have the potential to perform well in revenue tracks, even under North America's heavy axle loads. This prospect encourages further evaluation of GPW through in-track testing at the Federal Railroad Administration's (FRA) Facility for Accelerated Service Testing (FAST) near Pueblo, Colorado.

At present, two processes (electric flash and thermite) are used for rail welding in North America. The high quality as well as efficiency of electric flash rail welding makes it the preferred process for rail welding plants. In fact, electric flash is the only in-plant rail welding process currently used in North America.

When rails are joined in the field, either mobile electric flash welding or thermite welding is used. The quality of mobile flash welds approaches that of plant flash welds, and it can be cost effective when a large number of welds are to be made in the vicinity. However, the high equipment cost and less-than-ideal portability make it less suitable when only a small number of rail welds need to be made at one location. In addition, mobile electric flash butt welding requires 1.5- to 2-inch rail consumption and the resulting longitudinal rail movement during the welding procedure. These disadvantages have limited the use of electric flash welding in the field.

Comparatively, thermite welding has low equipment cost and excellent portability. There is no net rail consumption in thermite rail welding, and it does not require rail movement during the welding process. These

favorable characteristics make thermite welding the predominant field welding process for joining rails in North America. The service performance of thermite rail welds, however, has been lower than electric flash welds although improvements have been made in recent years. The strength, ductility, and fatigue properties of thermite weld metal have been lower than those of parent rail steel attributed to the cast structure, porosity, and inclusions in the weld metal.

In certain applications, GPW has the potential to complement the aforementioned shortcomings of thermite welding and electric flash welding. Compared to mobile electric flash welding, the GPW has substantially lower equipment cost and better portability. The quality of gas pressure welds is expected to be comparable to that of electric flash welds, based on the full-scale laboratory test results. The productivity of GPW is believed to be lower than that of electric flash welding. It was observed that 26 minutes are needed to complete the GPW welding and post-welding heat treatment process in trackside (not in-track) operations in Japan.

Considering all the factors, GPW could be the favorable welding process should a limited number of high quality rail welds be needed at a specific location. CWR renewal in track curves is one of the scenarios in which GPW may find its application.

TEST WELDS

Exhibit 1 lists major welding parameters for each of the sample welds. The welds were made at a Hakusan shop in Japan using a TGP-136 gas pressure welder and Nippon Steel 136RE DHH370 rail (see Exhibit 2). A set of welding parameters was developed for the 136RE rail and was used in making the six sample welds. The rail ends were butted against each other and a pressure force of 208 kN (23.38 tons) was applied. Oxyacetylene flames around the rail contour heated the rail ends until a predetermined upset distance of 30 mm (1.2 inches) was reached. The rail ends started to deform after a flame time of 4 to 4.5 minutes and the welding was completed within 8 minutes.

Exhibit 1. TGP-136 Gas Pressure Welder and Post-Heat Treatment Apparatus

Weld ID	Flow rate (l/min)		Force (kN)	Upset (mm)	Deform start (min, sec)	Welding time (min, sec)
	O ₂	C ₂ H ₂				
1	120	130	208	30	4'17"	7'39"
3	120	130	208	30	4'17"	7'19"
4	120	135	208	30	4'23"	7'37"
6	120	131	208	30	4'24"	7'47"
7	120	130	208	30	4'26"	7'54"
8	120	131	208	30	4'25"	7'46"

1 liter = 0.0353 ft³, 1 kN = 224.8 lbf, 1 inch = 25.4 mm

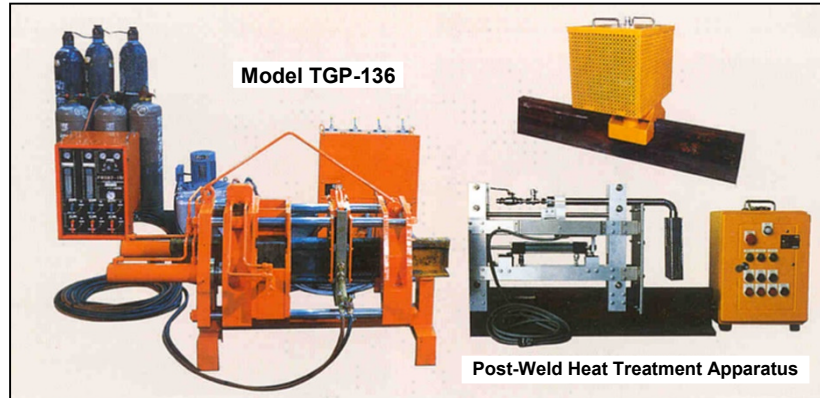


Exhibit 2. TGP-136 Gas Pressure Welder and Post-Heat Treatment Apparatus

The upset metal on the rail contour was immediately trimmed upon completion of welding. The rail alignment was then adjusted using a special tool when the weld was still hot.

To re-establish the hardness in the railhead, a post-welding heat treatment was performed for each of the six welds. Exhibit 2 also shows the heat treatment apparatus. The railhead in the weld area was reheated using a swing burner of oxyacetylene flames for 130 seconds and was cooled using an air blower for about 7 minutes.

RESULTS OF LABORATORY TESTS

Non-destructive Tests

TTCI has conducted nondestructive tests for all six welds to examine the integrity of the GPW samples using both dye penetrate and magnetic particle tests to check for surface and subsurface defects. These tests were important for gas pressure welds because, if not properly operated, the hot shearing procedure used to remove the upset metal may produce surface or subsurface defects. The welds proved to be free of surface or subsurface defects.

Ultrasonic tests were used to check the weld internal integrity using 0-, 45-, and 70-degree probes. No internal defect was found in the tests.

Rolling Load Tests

The rolling load test is a full-scale fatigue test in which a wheel is repeatedly rolled on the test weld that sits on two supports to form a cantilever loading arrangement. Weld Number 1 was tested in one of TTCI's 12-inch stroke rolling load machines. The weld was setup on the machine according to ANSI/AWS D15.2-94, "Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles." The weld endured more than two million cycles under a wheel load of 59,400 pounds without failure. The test was deemed successful and the test weld was sectioned

for subsequent internal hardness testing and macrostructural examination.

Macrostructure and Hardness

Weld Number 1 was sectioned across the weld center. The macro-etching and hardness measurements were performed according to AREMA requirements. The weld cross-section macrostructure shows the existence of very large heat affected zones (more than 5 1/2 inches total width). If not heat-treated after welding, the metal in the heat affected zones would be softer than parent rail and would wear at a faster rate. It would lead to larger weld dip, larger dynamic wheel forces, and shorter weld life. Post-welding heat treatment is therefore necessary for gas pressure welding in high strength rail. The test welds were heat treated after welding and their hardness was re-established over the majority of the railhead (Exhibit 3). However, the hardness of one spheroidized edge of the examined weld heat affected zone (right side in Exhibit 3) apparently was not fully affected by the post-welding heat treatment. To achieve a high and uniform hardness in the railhead, it is desirable to ensure the post-welding heat treatment covers the entire heat affected zone at the railhead.

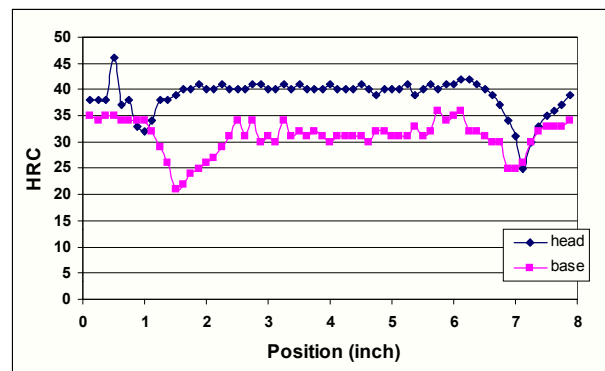


Exhibit 3. Hardness of Gas Pressure Weld Number 1

Slow Bend Tests

Slow bend tests were performed according to AREMA specifications using Weld Numbers 6 and 8. Both welds sustained four inches of deflection (the machine limit) without fracture — an achievement not seen for any welds made of high strength rail. Exhibit 4 lists the slow bend test results and comparison with the AREMA requirements for high strength rail electric flash butt welds. Since the gas pressure welds did not fracture during the tests, their moduli of rupture were calculated from the maximum loads during the tests. Exhibit 5 shows the gas pressure welds after slow bend tests.

Exhibit 4. Slow Bend Results

	Modulus of Rupture (psi)	Deflection (inches)
AREMA Requirements	125,000	0.75
GPW Number 6	199,106	4.005
GPW Number 8	186,178	3.997

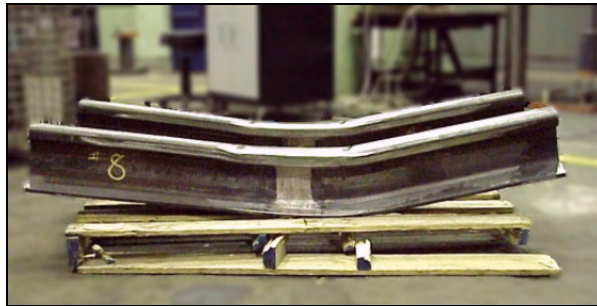


Exhibit 5. Gas Pressure Welds Number 6 and Number 8 after Slow Bend Tests

Bend Fatigue Tests

The rail bending fatigue test is a full-scale rail weld test scheme developed by TTCI to evaluate the fatigue performance at the rail base where cyclic bending tension stress occurs when a train passes.² Various rail welds have been tested by this method in recent years at TTC or contracted laboratories. In the tests, the rail base was under tension stresses produced by a four-point cyclic loading. The applied load cycles from a minimum of 5 kips to a maximum load (usually greater than 100 kips) and can be varied for each test rail weld. The fatigue performance of a rail weld is determined

by the total number of test cycles prior to weld fracture under a specific load. If a weld does not fail when 2,000,000 test cycles are reached, the test is regarded as completed (a run-out).

Gas pressure weld samples 3 and 4 were tested for a maximum load of 160 kips and 180 kips, respectively. Both welds sustained more than 2,000,000 cycles without failure. This is extraordinary performance compared to the bending fatigue performances of rail welds made using current welding processes. Under such load levels in previous TTCI tests, thermite rail welds typically failed between 20,000 and 450,000 cycles, and electric flash butt rail welds failed between 200,000 and 600,000 cycles.

SUMMARY AND FUTURE WORK

The test gas pressure rail welds exhibited excellent fatigue properties in bending fatigue and rolling load tests. The welds also exhibited extraordinary ductility in the slow bend tests. Their strength and hardness, as indicated by the modulus of rupture and internal hardness measurement in the railhead, are also satisfactory. Overall, the tested gas pressure rail welds have performed excellently in laboratory tests and warrant further evaluation — an in-track test at the TTC's FAST High Tonnage Loop (HTL). Ideally, the test welds should be made at TTC to demonstrate the feasibility of its application in North American railroad conditions. TTCI is attempting to obtain test specimens that will represent welds made in North American field conditions.

References

1. Sun, J., "A Review of Gas Pressure Rail Welding," *Technology Digest* TD02-008, Transportation Technology Center, Inc., Pueblo, Colorado, March 2002.
2. Sun, J. and Sawley, K., "Fatigue Bending Test of Thermite Rail Welds," *Technology Digest* TD00-007, Transportation Technology Center, Inc., Pueblo, Colorado, March 2000.

**Note: Jian Sun, (719) 584-0698 with questions or comments about this document.
E-mail: jian_sun@ttci.aar.com.**

Visit TTCI's website at <http://www.ttciaar.com>

©2002, Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads

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 expressed 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 AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. BOX 79780, BALTIMORE, MD, 21279-0780 <www.aarstore.org>