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Gas Pressure Welds and Hollink Slot Welds Testing at the Facility for Accelerated Service Testing

SUMMARY

In 2006, two new weld tests were installed in the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST) located at the Transportation Technology Center (TTC) in Pueblo, Colorado. Two rail strings containing a total of 10 gas pressure welds (GPWs) were installed in Section 3 at FAST in January, and in June, the Holland Company sent one of its Hollink® slot weld vehicles to make several robotic gas-metal-arc railhead repair welds for in-track testing in a 5-degree curve with a 4-inch superelevation. A total of 14 slot welds were installed in Section 3 at FAST for testing. The primary objective of these tests was to improve field weld performance under heavy axle load cars.

As of June 2007, the GPW test accumulated 263 million gross tons (MGT). Three of the welds required maintenance at 84 MGT due to weld batter (approximately 0.065 inch). Rails adjacent to the welds were taper-ground to minimize impacts on the welds. Three additional welds failed due to subsurface shells that broke out on the gage face at 150, 193, and 216 MGT. Another weld failed at 165 MGT due to web cracking which originated at a rail manufacturer's stamp located in the weld heat affected zone.

The GPW test outlived both the first and second generation of thermite welds used for the test in track. The heat-treated process needs to be improved further. Currently, the Jinzhou Institute in China is improving and automating a welding process to produce a product suitable for North American railroads.

The Hollink slot weld equipment was not capable of performing slot welds in a 5-degree curve with a 6-inch superelevation because of the physical limitations of the weld dam consumables. One plant weld was successfully slot welded. Two welds experienced horizontal fractures that originated at the weld fusion line in the railhead at 124 and 127 MGT. A third weld failed due to shelling of the gage corner at 171 MGT. As of June 2007, the slot weld test accumulated 192 MGT.

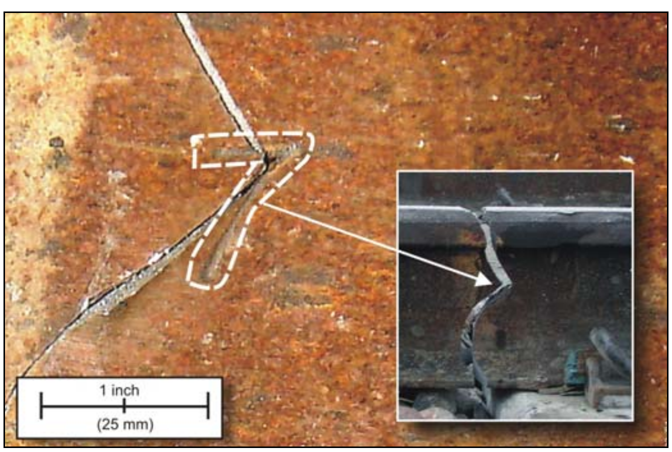

Figure 1. Example of GPW Break at Rail Manufacturer's Stamp. Inset shows the Full Break in Track.

BACKGROUND

In 2006, the installation of two weld tests, GPWs and slot welds, was implemented at FAST. Figure 2 shows the relative locations of the weld test beds within Section 3 of the HTL.

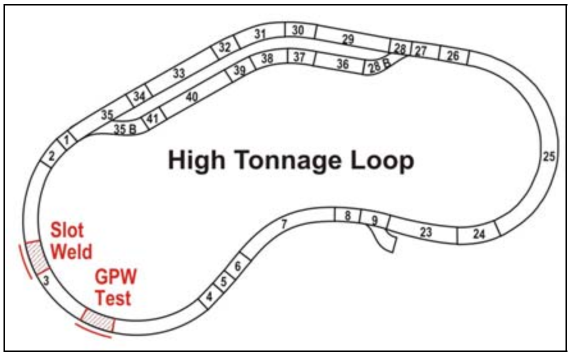

Figure 2. GPW and Slot Weld Test Zones on the HTL at FAST.

GPW BACKGROUND

In 2002, due to the strong performance of GPWs in initial laboratory slow bend tests, the Transportation Technology Center, Inc. (TTCI) identified GPW as a potential alternative welding method to traditional thermite and electric flash-butt methods for field maintenance welding [Ref. 1,2]. In 2005, TTCI began working with the Jinzhou Institute in China to test and develop a GPW system suitable for use on North American railroads. In October 2005, Jinzhou Institute personnel traveled to TTC to train TTCI welders in the operation of their equipment to manufacture GPW. At that time, TTCI and Jinzhou Institute personnel installed two sets of track-side welds in test strings for later installation at FAST. In January 2006, the welds were heat treated and placed in Section 3 of the HTL at FAST.

The heat-treating equipment and process used by the Jinzhou Institute was not readily applicable for use on North American railroads, so TTCI chose a provisional heat-treatment process that used compressed air as the quenching agent. Several brief experiments were performed to determine appropriate treatment variables for the equipment used. As a result, the heat-treatment process was not fully developed at the time of application.

Installation Process Evaluation

After in-track installation, the welds were monitored for hardness and longitudinal profile changes. Hardness measurements were taken on the rail running surface for each of the parent rails, for weld heat-affected zones, and for the weld centerline. Figure 3 shows the measured readings for each location and tonnage through 150 MGT.

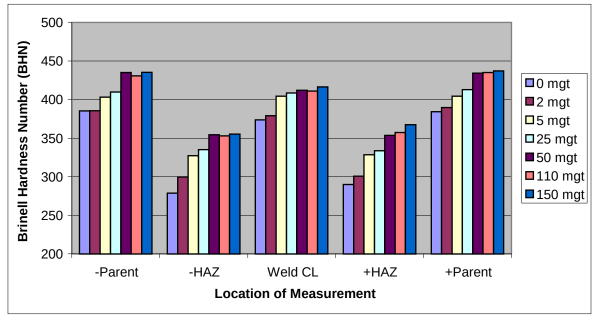

Figure 3. GPW Average Running Surface Hardness Measurements.

At 150 MGT, the TTCI rail flaw detector car indicated a flaw in GPW No. 08. On the gage face of the weld at a depth of 0.3 inch, examination revealed 3- by 1-inch internal shelling. The weld was loosely barred with a special insulated bar to allow for monitoring of flaw growth. Within 5 MGT, the flaw developed a vertical component near the weld centerline comprising approximately 6 percent of the railhead region. After a total of 15 MGT from the first detection, the shell grew to 5 inches long by 1.75 inches wide and the vertical component had grown to 17 percent of the railhead. The weld was removed at 165 MGT.

The test experienced its second weld failure at 165 MGT when GPW No. 05 fractured during train operations. Examination revealed that the fracture originated in the web of the rail in the heat-affected zone. Further examination identified the origin of the failure as being a rail manufacturer number stamped in the rail, which acted as the crack initiation site. Figure 1 shows the fracture origin. Similar failures have been noted recently at FAST involving electric flash-butt welds in which rail manufacturer stamps located in the heat-affected zone have acted as the initiation site for fatigue cracking.

The experiment suffered its third and fourth failures at 193 and 216 MGT, respectively — both due to shelling on the gage corner. It should be noted that none of the welds in this test failed as a result of flat fractures or paste welds similar to the oxy-acetylene plant welds produced in North America between the 1940s and 1970s. This is significant because it suggests that once the current post-weld heat treatment is optimized, these welds may be able to withstand higher tonnage demands of modern North American railroads. Table 1 shows the status of the GPW at FAST.

Table 1. Status of GPWs at FAST, June 2007.

Weld ID	MGT	Status
GPW No. 01	263	In service
GPW No. 02	193	Shelled – gage corner
GPW No. 03	263	In service
GPW No. 04	263	In service
GPW No. 05	165	Fractured at manufacturer stamp in weld heat-affected zone
GPW No. 06	193	Removed along with GPW No. 2
GPW No. 07	167	Removed along with GPW No. 8
GPW No. 08	167	Shelled – gage corner
GPW No. 09	263	In service
GPW No. 10	216	Shelled – gage corner

The Jinzhou Institute, merged with the Shengyang Institute, is continuing its efforts to produce a portable GPW system capable of meeting the requirements of the North American market. The Jinzhou Institute continues to make progress toward automation of its portable GPW equipment, thereby reducing the number of needed operators as well as reducing the overall time required to produce a weld.

HOLLINK SLOT WELD BACKGROUND

Slot welds have been previously tested by TTCI both in the laboratory and at FAST, from 2004 to 2005 [Ref. 3, 4]. The original testing at FAST was performed using a string of 7/8-inch-deep test welds that were welded out of track by Holland Company and then sent to TTC for in-track testing. In 2005, Holland Company sent a slot weld vehicle to FAST to test the in-track installation of slot welds. At that time, the process was not able to satisfactorily weld in 4-inch superelevation. Holland Company then consulted with a weld engineering firm to refine and improve the slot weld process. The process improvements that Holland Company subsequently implemented provided the impetus for a new round of testing at FAST. In June 2006, Holland Company sent a Hollink® Slot Weld vehicle to FAST to install new 1 1/8-inch depth slot welds in track. This latest installation is the focus of the following discussion.

The test installation was divided into two main portions. First, the test evaluated the installation process in superelevated track. Specifically, this test was concerned with the ability to make a sound weld in superelevated track and not with the accurate location and removal of defects of various orientations and sizes. Second, the ongoing test is evaluating the weld performance of the slot welds under heavy axle load (HAL) conditions.

Slot Weld Installation Process Evaluation

Average slot weld installation time was less than 25 minutes. This included slot milling, preheating, and welding, but not cooling time or post-weld grinding.

One slot weld was installed in a 6-inch superelevated track and 14 welds were installed in a 4-inch superelevated track. Of the welds made in the 4-inch superelevated track, two were made in 136 Railroad Engineering (RE rail with the remainder in 141 RE rail. The weld made in the high rail of 6-inch superelevated track had low spots in the running surface after the final rail grind was performed. These low spots occurred due to the existing weld containment not being designed to hold the molten weld pool at the high cant. Slot welds were, however, successfully installed in the 4-inch superelevation in both the high and low rails without surface defects.

After the welds received finish grinding and had sufficiently cooled, TTCI performed an ultrasonic (UT) inspection. Three welds contained 1/8-inch indications near the weld centerline when examined using a 70-degree probe, but were free of indications when examined with 0- and 45-degree probes. One weld had a small void on the gage face of the rail. This weld, along with one of the above-mentioned welds, was selected for re-slotting. Additionally, a plant weld that had a 3-percent indication in the head was slot welded. After welding, the welds were found to be free of UT indications.

HAL Performance

Six of the welds in 141 RE rail were selected for ongoing performance monitoring under HAL conditions. Initial longitudinal profiles and hardness measurements were taken on each of the welds. The welds were monitored subsequently every 50 MGT. As of June 2007, a total of three welds had failed; two were from horizontal fractures in the railhead and one was from shelling of the gage corner.

Figure 4 shows the first failed slot weld that occurred at 124 MGT. The left inset of Figure 4 shows the barred weld in track and the right inset shows the fracture surface after opening the break for inspection. The fracture initiated at the weld fusion line approximately 0.9 inch from the gage face and at a depth of 0.5 inch. The arrow in the right inset indicates the origin of the crack and the dashed lines show the approximate fusion line location. The slot welds were examined approximately weekly for UT indications. Table 2 details the UT inspection findings during HAL operations.

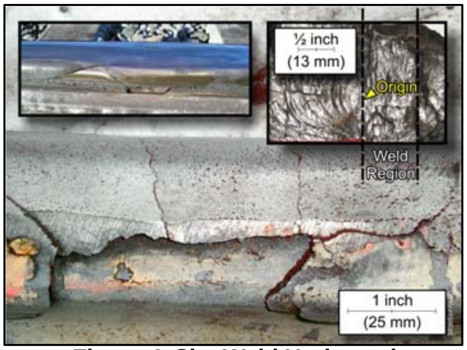

Figure 4. Slot Weld Horizontal Fracture in the Railhead.

Table 2. Ultrasonic Inspection Results.

MGT	Weld No.	Inspection	Status
16	HW 207	7 percent unchanged since detection	In service
51	HW 206	4 percent unchanged since detection	In service
151	HW 203	2 percent unchanged since detection	In service

SUMMARY OF FINDINGS

Gas Pressure Rail Weld Summary

A provisional heat-treating process was chosen as the process developed by the Jinzhou Institute was not practical for use on North American railroads. This provisional process was not optimum for the treatment of the welds and was subsequently reflected in weld performance.

Several welds required taper grinding to reduce impacts from weld batter. Three welds failed as a result of shelling in the gage corner. One weld fractured at a rail manufacturer stamp located in the weld heat-affected zone.

Unlike previous generations of oxy-acetylene welds made in North America from the 1940s to the 1970s, the Jinzhou Institute developed GPWs did not experience any failures due to a flat fracture at the bonding surface.

The Jinzhou Institute continues to develop and automate the GPW equipment to produce a product suitable for use on North American railroads.

Hollink Slot Weld Summary

The Hollink slot weld process was able to successfully weld up to a 4-inch superelevation. A portion of these welds was also successfully made under adverse weather conditions involving sustained crosswind speeds of 23 miles per hour.

Several welds were re-slotted to successfully remove 1/8-inch UT indications. One of the reslotted welds later developed new UT indications at approximately 16 MGT, but has remained unchanged throughout the following 174 MGT.

A total of three welds failed during HAL performance testing due to horizontal fractures in the railhead and shelling of the gage corner.

ACKNOWLEDGEMENTS

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