TECHOLOGY DIGEST

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A Review of Gas Pressure Rail Welding

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Summary

In many aspects, the utility of gas pressure welding (GPW) is rated somewhere between thermite welding and mobile flash-butt welding. It is not likely to replace either of the current welding processes, but may complement current welding processes in certain applications.

Even though North American railroads no longer use GPW to join rails in the field, the process is still being used in other parts of the world. The process has been further developed and is being used most extensively in Japan.

Under the Association of American Railroads'(AAR) Strategic Research Initiative Program, Transportation Technology Center, Inc. has conducted a review of the current status of GPW technology in rail welding. The major findings are:

- GPW is extensively used for rail welding in the Japanese railway system, especially in the Shinkansen, Japan Railway's high-speed lines.
- GPW weld quality is well regarded in Japan.
- GPW welds have performed well at the Facility for Accelerated Service Testing and in rolling load tests.
- The GPW welds made of 136RE rail performed well in bend tests.
- The GPW equipment is more portable and less expensive than electric flash-butt welding equipment.
- In Japan, the GPW process is mostly used for depot or track-side welding. Its application for in-track rail repair welding has been limited.
- GPW consumes 1 to 1.2 inches (25-30 mm) of rail making a weld; a typical flash-butt weld consumes 1.5 to 2.0 inches (38-51 mm).

In North America, rails are joined by either thermite welding or electric flash-butt welding. Both processes have advantages and certain limitations in field rail welding applications. Thermite welding has been used extensively for field rail welding because of its easy portability, low capital investment, and its suitability for the rough conditions in the field. It is especially suitable for rail defect repair welding because it does not consume rail during the process. But the strength, ductility, and fatigue properties of the thermite weld do not meet those of rail steel or flash-butt welds. Mobile flash welding produces high quality welds, but its equipment cost is high, and it consumes rail during the process.

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

INTRODUCTION

Supported by the AAR's Strategic Research Initiative Program, TTCI has conducted a review of gas pressure welding (GPW) technology in rail welding. Reviewers found that:

- GPW is extensively used for rail welding in the Japanese railway system, especially in the Shinkansen, Japan Railway's high-speed lines.
- GPW weld quality is well regarded in Japan.
- GPW welds have performed well in FAST and in rolling load test.
- The GPW welds made of 136RE rail performed well in bend tests.
- The GPW equipment is more portable and less expensive than electric flash-butt welding equipment.
- In Japan, the GPW process is mostly used for depot or track-side welding. Its application for in-track rail repair welding has been limited.
- GPW consumes 1 to 1.2 inches (25-30 mm) of rail; a typical flash-butt weld consumes 1.5 to 2.0 inches.

In North America, rails are joined by either thermite welding or electric flash-butt welding. Both of these processes have advantages and certain limitations in field rail welding.

Thermite welding has been extensively used for field rail welding because of its easy portability, low capital investment, and its suitability for the rough conditions in the field. In thermite welding, there is no net consumption of rail, and longitudinal rail movement is generally not needed. However, the strength, ductility, and fatigue properties of thermite welds have not met those of rail steel or flash-butt welds. These lower grade properties of thermite welds are mainly attributed to their dendritic cast structure, porosity, and inclusions. Various attempts, including squeezing the thermite metal out of the weld or stirring the thermite metal during solidification, have been made to improve the properties of thermite welds, but success has been limited. In addition, thermite welding is more of an operator-dependent process than flash-butt welding, resulting in some inconsistencies.

The other rail welding process used in North America is electric flash-butt welding. The failure rate of flash rail welds has been low compared to that of thermite welds. It is the only plant rail welding process used in North America, and the industry is generally satisfied with its quality and service performance. Flash welding is also applied for in-track welding by using mobile electric flash welders. The rail aligning, welding, and shearing processes can be controlled by computer program and consistent quality is usually achieved. 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 within the vicinity. The process found applications in joint elimination, yard reinstallation, CWR renewal, and other occasions. However, flash welding does consume 1.5 to 2 inches (38-51 mm) of rail, which makes the process less suitable for rail and weld defect repair welding. Its application is also limited by the relatively high equipment cost and less-than-ideal portability.

Gas pressure welding (GPW) is a solid welding process in which the rails are joined by applying heat and pressure.[1] Like electric flash welding, no filler metal is used in GPW. The rail ends are butted against each other, and an axial pressure (19 tonnes for Japanese Industrial Standards (JIS) 60-kg rail) is applied on the rails during the welding process. The butted rails are heated up to 2400°F by oxyacetylene flames around the rail contour until a predetermined upset distance (0.94 inch (24 mm) for standard JIS 60-kg rail) is achieved. The upset metal is then trimmed. Figure 1 shows a complete set of Hakusan TGP-5 gas pressure rail welding equipment. Post-welding heat treatment (oxyacetylene flame heating plus enforced air-cooling) is generally performed for head hardened rail. Besides Japan, GPW is also employed in certain other Asian countries and in Europe.[2]

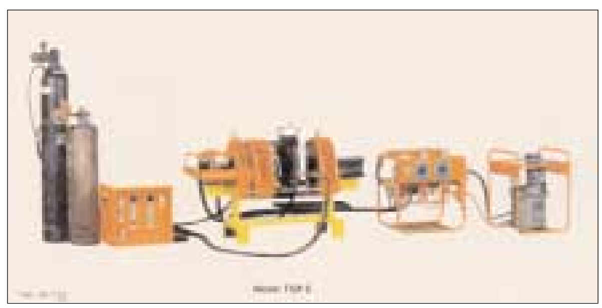

Exhibit 1: Hakusan TGP-5 System for Gas Pressure Rail Welding

In North America, GPW was used to join rails from the 1930s to the 1970s, mostly for plant or depot rail welding.[3,4] The failure rate of gas pressure welds increased dramatically with the increase of axle load in the 1980s, and the performance of gas pressure welds became unsatisfactory. The process was replaced by electric flash welding, and now there are few gas pressure rail welds still in service in North America.

Gas Pressure Rail Welding in Japan

GPW is extensively used in Japan railway systems for rail joining. In recent years, gas pressure welds consist of about 30 percent of all rail welds in the JR group. In

TTCI = Transportation Technology Center, Inc.; AAR = Association of American Railroads the high-speed Shinkansen lines where thermite welds are not allowed, the percentage of gas pressure welds is much higher. Other rail welding processes used in Japan are thermite welding, electric flash welding, and enclosed arc welding. In Japan, gas pressure welds are regarded as high quality welds, as are electric flash welds.The GPW process is primarily used for track-side rail welding and in-shop rail welding. Experience with rail/weld defect repair welding has been limited. The Railway Technical Research Institute (RTRI) developed the Japanese GPW process and the Hakusan Mfg. Co. supplies the GPW equipment. The process is used in Japan and a number of other Asian countries. It is also available in Europe.

A TTCI engineer observed a few track-side and in-shop GPW trails while in Japan in November 2001. A track-side GPW crew typically consists of seven or eight members — GPW operators and a crew to conduct rail preparation, post-welding grinding, and non-destructive tests. In track-side operations, it took about 15 minutes to make a weld or about 26 minutes if post-welding heat treatment was needed. In Japan, dye-penetrate test, or mag-particle test, or both are performed on the finished welds. In some occasions, ultrasonic testing is also required. According to RTRI researchers and a quality control manager of a GPW contractor, the rejection rate for gas pressure welds has been very low (0.05 - 0.1% for that GPW contractor).

GPW appears to be a highly operator-dependent process. The GPW welders in Japan are well trained to achieve the consistency of weld quality. The GPW process was introduced to a Southeast Asian country in April 2001, and the weld rejection rate was about 1 percent at the initial stage, according to RTRI researchers. The primary defect for rejection was surface cracking caused by oxide inclusions on the weld interface formed during the trimming process. Weld quality is mostly affected by the heating temperature and the upset distance. Generally, the higher the heating temperature and the larger the upset distance, the better and more consistent the weld quality. In addition, the rail ends preparation is also important for weld quality.

Hakusan also has a GPW product designed for the North America market. TGP-136 was designed for in-shop or depot welding for rail sections from 132RE to 136RE. RTRI and Hakusan conducted preliminary experiments of welding 136RE rail using the TGP-136 GPW equipment. The welds were tested in a three-point bend fixture. The loading point is on the weld interface while the two support points have a 39.4-inch (1-meter) span. Table 1 lists the bend results. It shows that the welds made with an upset distance of 1.2 inches (30 mm) performed better than the weld (No.1 in the table) made with an upset distance of 1.1 inches (28 mm) in the bend tests.

Tests of Gas Pressure Rail Welds at FAST

In 1996, RTRI contracted TTCI for a proprietary test of six gas pressure rail welds at FAST. As a courtesy, RTRI is now allowing TTCI to publicize the test results. The test welds were made in Japan using JIS 60-kg rails. Two 25-meter rail sections, each containing three gas pressure welds, were installed at FAST in Section 5 (a tangent section of track located between 5-degree reverse curves) of the High Tonnage Loop. The two JIS 60-kilogram rail sections were joined to AREMA 132RE and 136RE rails with compromised joint bars — one rail section to the inside rail and the other to the outside rail.

The six welds endured 185 MGT of heavy axle load and performed well, except for metal flow occurring at the welds and on the rails. There were no detectable discontinuities in the six welds after 185 MGT. The metal flow could be expected for the softer and smaller rails under heavy axle loads. The measured initial hardness of the tested JIS 60-kg rails was 226-265 Bhn, while the measured rail hardness in the work-hardened condition, after 185 MGT, was 301-320 Bhn, considerably softer than current AREMA 136RE rails.

Table 1. Bend Test Results of Gas Pressure Rail Welds Made of 136RE Rail

			Bend Tests Results		
Weld No.	Upset (mm)	Welding Time	Position	Load (kN)	Deflection (mm)
1	28	8'18"	Head down	1852	21.0
2	30	8'09"	Head down	2273	39.0
3	30	7'43"	Head down	2224	35.5
4	30	7'38"	Head up	2207*	27.0*

* Weld did not break

TTCI also conducted a rolling load test of a gas pressure weld made of JIS 60-kg rail. The weld passed the required (ANSI/AWS Standard D1J.2-94) 2-million load cycle without failure.

Promises and Limitations

Is GPW suitable for the rail and the heavy axle load in North America? While there are no conclusive answers without comprehensive laboratory and in-track tests, the experiences in Japan and at FAST of JIS-60 kilogram rail welds indicate that the possibility is good. RTRI and Hakusan conducted trial welding of 136RE rail in Japan. It was found that the upset amount needed to be increased to 1.2 inches (30 mm) for 136RE rail to ensure the soundness of the welds. The 136RE welds performed well in the bend tests conducted at Hakusan.

Compared to mobile flash welding, the GPW has the potential advantages of lower equipment cost and better portability. The portability of GPW also helps its competitiveness in applications of track-side or in-track welding, especially when the number of welds is limited. However, the productivity of GPW is believed to be lower than that of mobile flash welding, and it is not certain that the quality of gas pressure welds can reach the level of that of mobile flash welds in North America. Unlike mobile flash welding, GPW is not an automatic process, and the weld quality is dependent on the skills of the operators.

Compared to thermite welding, GPW has the potential to produce better quality welds. However, it does consume rail and needs the help of a rail puller to make a closure weld in track. The consumption of rail makes GPW a less desirable process in rail defect repair welding in which a plug rail is welded into track to replace the defective rail section. In Japan, GPW has only limited usage for rail defect repair welding in Shinkansen. The other welding process used in Shinkansen for rail defect repair welding is enclosed arc welding. In North America, thermite welding, despite its less consistent quality, is still a preferred process for defect repair welding because of its advantages mentioned earlier.

In many aspects, gas pressure welding is rated somewhere between thermite welding and mobile flash welding. It is not likely to replace either of the current welding processes. If used wisely, it can complement the shortcomings of current welding processes in certain applications.

FUTURE WORK

To further investigate the feasibility of using GPW for rail welding in North America railroad tracks, TTCI has requested Hakusan to manufacture six gas pressure welds for an independent examination at TTCI laboratories. The welds will be made using Nippon Steel 136RE DHH370 rails and the Hakusan Model TGP-136 gas pressure welder. The planned laboratory tests include nondestructive tests (dye penetrate, mag-particles, and ultrasonic), macro/microstructure analysis, hardness tests, AREMA slow bend tests, and rolling load tests. The results will be compared with those of previous TTCI tests for thermite rail welds and electric flash rail welds. Future in-track tests at FAST will be considered if laboratory test results are satisfactory.

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