TECHNOLOGY DIGEST

Timely Technology Transfer

Squeeze Thermite Rail Welding

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Summary

Tests have shown that rail welds having mechanical properties approaching those of electric flash butt welds and of the base rail metal, can be made by squeeze thermite welding. The application of this approach offers the advantage of greater structural integrity in thermite welds at little increase in manufacturing cost.

Squeeze thermite rail welding involves the use of standard thermite casting practices to heat and clean the rail ends, after which a mechanical forcing system (rail puller) can be used to squeeze the rail ends together expelling the liquid metal and upsetting the rail ends.

However, even though improved properties have been achieved, much work remains to be done (slow bend, rolling load, and in-track tests) to demonstrate the reliability needed for revenue service applications. In addition, problems of rail alignment and metal clean up need to be addressed.

Association of American Railroads
Research and Test Department

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INTRODUCTION AND CONCLUSIONS

Rail thermite welds generally suffer from a significantly higher failure rate in track than do electric flash butt welds. This comes from the low ductility and toughness of the cast metal structure joining the rail ends together. The cast metal generally contains porosity and perhaps some shrinkage cracking that contribute to the poorer mechanical properties.

Measures can, in theory, be taken in the melting and casting practice to reduce the occurrence of porosity and shrinkage cracking. However, researchers at the University of Illinois wondered why not use the thermite weld metal as a source of heat and as a means to clean the rail ends prior to making a forge weld, much as the electric flash butt welding process does. The conceptual action of a high upset process is shown in Exhibit 1. This is not an entirely new concept; pressure welding with thermite as a source of heat was utilized for rail welding many years ago, but the amount of upset was minimal and the development of a bond was dependent upon solid state diffusion. The pressure (not really upset) welds were not likely to meet the demands of current day revenue service.

Research to examine the applicability of an approach using significant upset was undertaken along two paths: one at the University of Illinois using a closed loop servo controlled force application system; the other by the AAR using conventional rail pullers as a means of squeezing the rail ends together. The approach has come to be known generally as squeeze thermite welding.

A schematic of the laboratory apparatus is given in Exhibit 2. The force conditions needed for a successful squeeze weld were application of a peak force of 41,000 lbs within 20 seconds after the completion of the thermite pour. This caused rail end displacement of 1.6".

The volume fraction of inclusion and porosity was reduced as shown in Table 1. Longitudinal tensile specimens were prepared at the locations shown in Exhibit 3. The stress-strain curves are shown in Exhibit 4. The ductilities have been raised almost to a par with those of the base metal.

	Conventional Volume %	Squeezed Volume %
Porosity	1.53 ± 0.45	1.08 ± 0.41
Inclusions	0.40 ± 0.10	0.23 ± 0.13
Total	1.93 ± 0.45	1.32 ± 0.40

Table 1. Metallurgical Discontinuities in Weld Metal

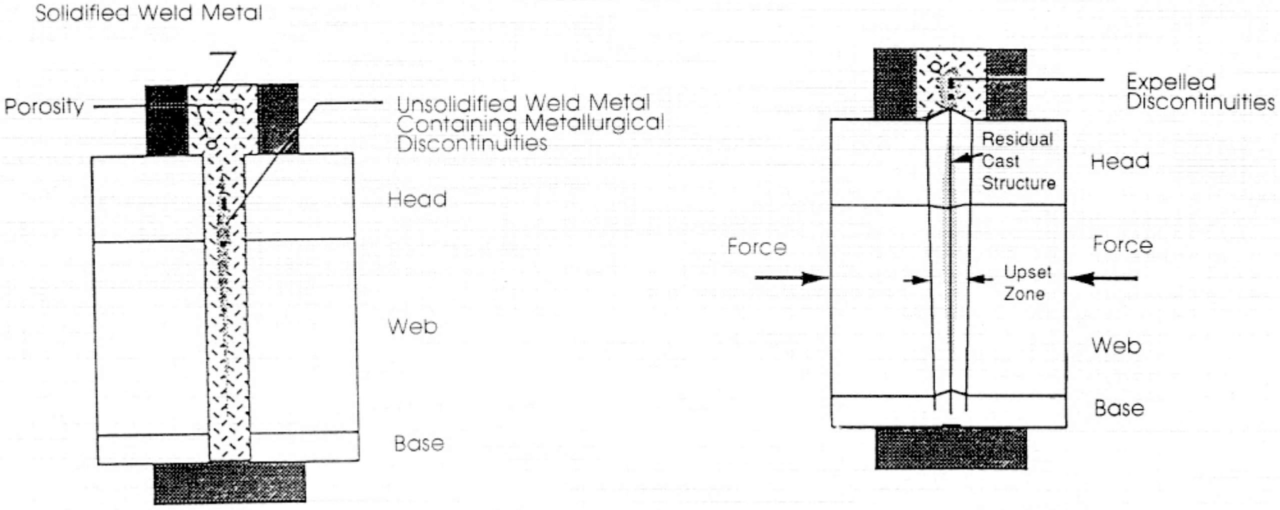


Exhibit 1. Schematic Drawing of Modified Thermite Welding Procedure

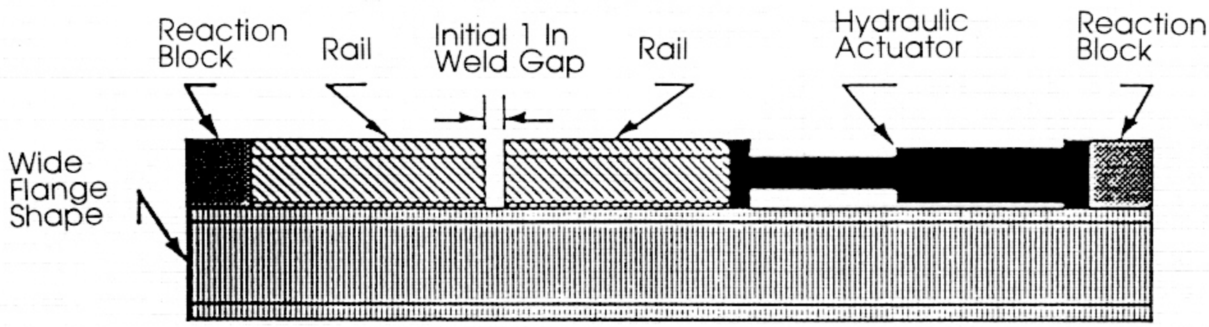


Exhibit 2. Schematic drawing of experimental weld fabrication apparatus.

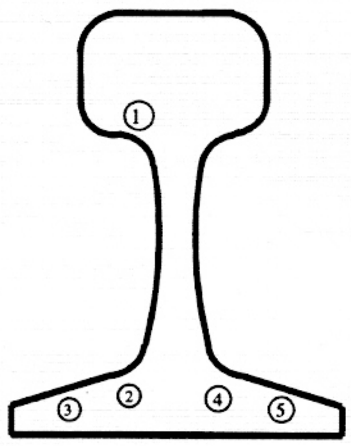
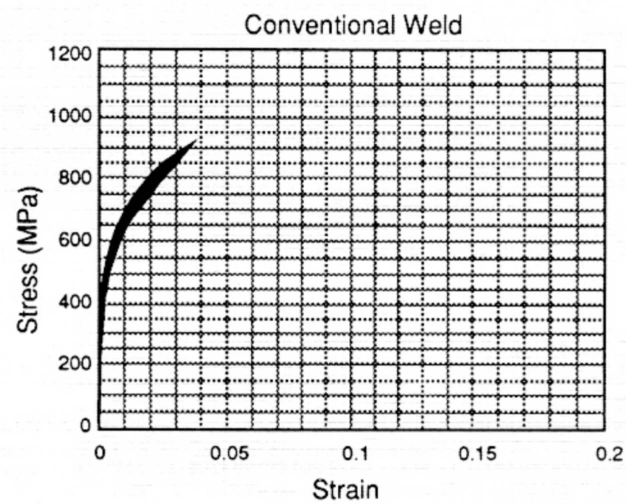


Exhibit 3. Locations of tensile specimens.



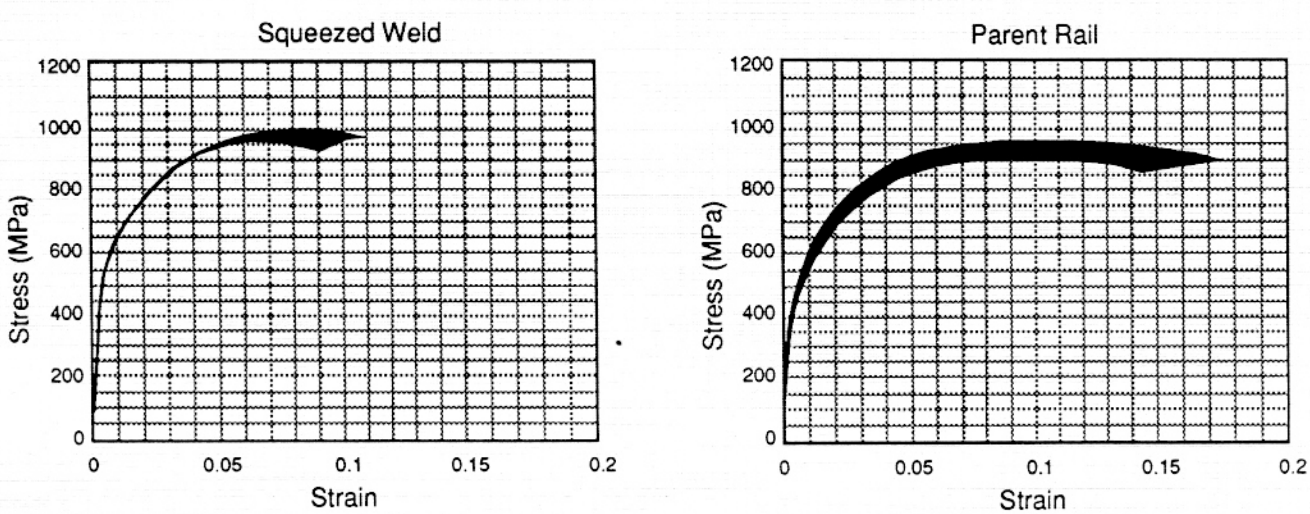


Exhibit 4. Stress-strain curves for conventional weld, squeezed weld, and rail base metal.

Note: The bands shown above encompass the stress strain behavior for all five specimen locations.

Further laboratory studies are underway at the University of Illinois to define the range of conditions under which successful squeeze thermite welds can be made. In addition, the experiment set up (Exhibit 2) permits the superposition of vibration on the solidification process. Research in other areas of solidification has suggested that the thermite weld columnar dendritic structure may be able to be modified by the presence of vibration to the benefit of the weld mechanical properties.

The longitudinal force needed to accomplish upset can be provided by a conventional rail puller albeit with much slower response than obtained with the closed loop servo system utilized at the U of I. A typical rail puller arrangement such as might be available to almost any track welding gang is shown in Exhibit 5.

Exhibit 5. Typical Rail Puller Arrangement.

Force levels up to 50 tons have been applied for 30 seconds after delay times from end of pour of four and eight seconds. Displacements up to nearly 1.2 inches were achieved. The best longitudinal properties achieved thus far using the rail puller approach are as follows:

	Yield Strength ksi(MPa)	Ultimate Tensile Strength ksi(MPa)	Elongation (%)	Reduction Area (%)
Head	86.8(599)	142.5(983)	*	40.9
Base	91.3(630)	149.0(1028)	11.5	40.0

* Broke in the heat affected zone at the gage mark

Thus it appears that squeeze thermite weldments can be made (even with conventionally available track equipment) that have mechanical properties that are comparable with the base rail properties. However, what is not clear yet is what stringency of control is necessary to produce a weld. Control of rail alignment and metal expulsion are known to be problems. Mold removal timing is critical; it must be removed right after upset if shearing is to be successful.

As yet slow bend and rolling load tests have not been done. One must eventually decide whether the additional effort is justified in the light of each railroad's experience with conventional thermite welding, even if the approach does produce a superior weldment. The process is a long way from optimizing the thermite heat source and the forcing system. Although thermite is a relatively inexpensive source of heat (on a capital investment basis), there may be other sources of heat (such as plate induction heating) that may be competitive even with electric flash. Ultimately the key to acceptance may be in the availibility of the weldment clean-up process (perhaps in the manner of in-track electric flash butt welders).

Note: Contact R. K. Steele at (312) 808-5875 with questions or comments about this document.

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