Repair of rails on-site by welding

by Bengt Dahl and Björn Mogard, Banverket (Swedish National Rail Administration), Bibi Gretoft and Björn Ulander, Esab AB

Esab AB and Banverket (Swedish National Rail Administration) co-operate to develop welding procedures and consumables to repair damaged track components. Techniques are specific to the welding process, rail material and component undergoing repair.

Figure 1. By weld surfacing of track components such as crossings, switch blades and so on, length of service can be substantially prolonged at a lower cost than to replace the worn component with a new one.

Regular track repair and replacement of components amount to a substantial cost for any railway. Additional costs like those caused by delays and extra work due to failure. have to be considered also.

Maintaining the track to keep the ride as smooth as possible will also reduce the maintenance requiremcnts of the rolling stock and consequently reduce further damage to rails and crossings.

The wear of the rail starts soon after installation into the track no matter what kind of traffic. The regular ponding of rail joints which the passenger hears during a journey is the audible manifestation of impact working which eventually results in deformation of rail ends. A similar phenomenon occurs when passing through crossings. The service life of the rail before it needs repair may be as short as a few months or it may last for several years depending on what type of traffic the route carries.

By weld surfacing of track components. crossings, switches and so on, which arc subject to higher wear than the plain rail, length of service can be substantially prolonged at a lower cost than to replace the worn component with a new one. The weld repair cost of a crossing is about 20% compared to installation of a new one. In the Swedish track system there are about 20,000 crossings of which about 2,000 are repaired each year.

Encouraged by the economic advantages of semi-automatic welding Esab AB and Banverket have carried out an important development work with this process during the last years.

Rail grades

The rails arc designed for strength and wear resistance. This is achieved by using high carbon manganese steels (C/Mn-steel). The rail grades generally used in western Europe correspond to UIC 860 standard. The standard grade has typically 0.7 % C and 1.0 % Mn and a pcarlitic microstructure.

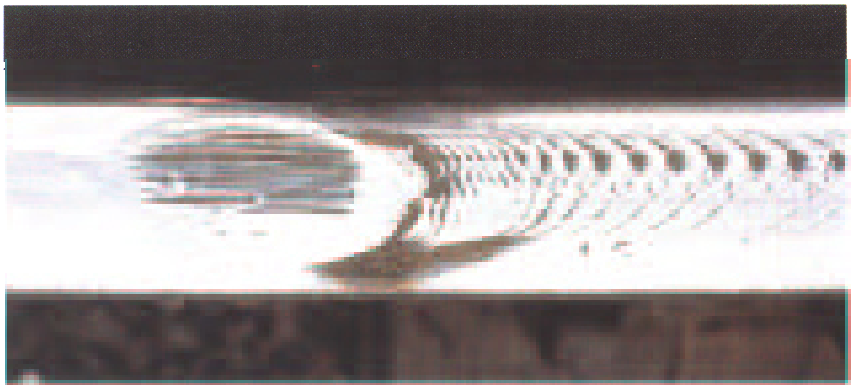


Figure 3. "Wheel burns".

Figure 4. "Squats" due to rolling contact fatigue.

Complex crossings are made from C/Mn steels. The crossings arc constructed by welded bolted rails. The crossings are subject to much higher wear than any other track component so the use of austenitic manganese steels (AM-steel) has become popular due to their good combined wear and impact properties especially after the first weld resurfacing.

The weldability of the rail material is an important consideration since welding is a significant process in the production of track components and their subsequent repair and maintenace. The desirable wear properties and strength of the rail are achieved at the expense of the weldability and toughness. Because of this the rail material has to be classified to steels with reduced weldability. Consequently welding procedures for both construction and repair have been developed as well as training of welders to produce high weld quality.

Rail and track length

The rail produced in Sweden has a standard length of 40 meters and is then flash-butt welded in the workshop to produce long rails (LWR). A common length of LWR in Sweden is 360 m.

The LWR are then transported on special wagons out into the track where they can be welded into continuous rails.

Nowadays most of the tracks are continuously welded. The total track length in Sweden is approximately 10.000 km, of which 6,500 km are continuously welded. The joining is either performed by Thermit welding or by so called mould welding using the manual metal-arc process.

Rail damage

This occurs all over the rail system. It is mainly caused by repeated impact, fatigue and wear from running traffic, but also spontaneously by locked wheels or locomotive driving slip (wheel burns). Material imperfections such as flaws, porosity or non metallic inclusions often take part in and accelerate the damage.

Significantly damage on plain rail are cracks of different sizes caused by bending and rolling contact fatigue. Deformed rail ends are also found, caused by impact when the wagon wheels pass over eventual rail gaps.

A lot of damages are related to the switches. Crossings are subject to impact loading. This is concentrated to the tip section and adjacent wings where the wheel rolls from the narrowing tip onto the wing rails or vice versa.

The switch blades are exposed to and damaged by the flange pressure from the wheels. The blades are worn down gradually.

The same applies to the stock rail (the part of the rail that is supporting the switch blades).

MMA welding

During the so called "golden age of railways", i.e 1910-1935. welding processes of many types were applied and the benefits of using welding were very quickly appreciated.

The welding together of rails i.e. to eliminate the joint. was at this time carried out by the mit welding process, but also oxy-acetylene and manual metal arc welding processes (MMA). In the mid 1920s the MMA welding process was first applied to the resurfacing of worn parts in crossings.

Figure 2. Black area of crossing exposed to wear. Damaged parts are deformed and often cracked.

From then on MMA has been the successful process.

FCW welding

Since there is a long and positive experience of the MMA welding alloys, it was logical to transfer these alloys into semi-automatic welding processes. Considerable work has been undertaken to evaluate different materials and procedures using flux cored wire welding (FCW) and self shielded cored wires.

The semi-automatic process reduces the number of passes and restarts, and thereby minimises the amount of failures and defects. With a small wire diameter, Ø 1.6 mm, it is easy for the welder to control the weld pool and to have a better influence on the welding. Furthermore the metal deposition rate is higher and conscquently the welding speed. This in its turn means a faster job and less labour cost.

The cost of repairing a crossing can be reduced by 50% compared with previously used MMA process. Of course FCW can not replace MMA in all repair. There will always be repairs that due to different circumstances, are more suitable for MMA welding, for instance small repairs and where accessability is limited.

On-site machines

During the last few years the semi-automatic weld process with self shielded wires has been successfully adopted by Banverket because this process can operate from the same existing portable power supply as used for MMA welding. ESAB LUA 400 and NOMAD 400 Silenced are universal rectifiers for MMA and with wire feeder units MED 304, they arc ready for FCW.

Welding procedures and techniques

Track material is made of either carbon manganese steel or austenitic manganese steel. The welding of these steels must be treated quite differently. Carbon manganese steel rails are susceptible to air hardenability and particular attention must be directed to the attainment and maintenance of preheat, interpass temperature and cooling rates. Contrary to this, the austenitic manganese steels are sensitive to carbide precipitation and will readily crack if subjected to temperatures in excess of about 200°C.

Welding is limited to dry weather and shielding must be used in strong winds. Weld repairs on rails, rail ends, switches and crossings require removal of deformed and cracked material to expose sound base metal. When grinding, light pressure must be used to avoid overheating of the base material. Areas to be resurfaced should be ground to a minimum depth of 2 mm and finishing diagonally across the rail. Transition to the rail surface must be gradual, about 45°. Removal of all damaged material from the repair area is checked by liquid penetrant examination (PT).

Deep cracks or heavy deformation in C/Mn steel are removed by oxy-fuel gas cutting or flame gouging. A preheat of 100°C should be applied. Contrary to this, such defects in AM steel are removed by grinding without pre-heating.

To avoid shrinkage effects. workers release rail mountings from one to three sleepers on each side of the repair. Wedges are inserted under the rail to raise it 5 mm. Welders preheat C/Mn steel materials 100-200 mm on both sides of the repair site and begin welding after therequired preheat temperature stabilizes. Preheat temperatures along the rail must hold within plus 150°C or minus 50°C from the recommended temperature (400-450°C). If stringer beads < 30 mm width are used. the temperatures should be raised by 50°C.

European welding procedures for weld repair on rail components of C/Mn steel commonly specify weld travel in the longitudinal direction and electrode weave of 30 to 35 mm. Each weld pass must be deslagged and brushed before welding the nest run. The start and finish of each run should always be staggered to each other. Last made layer is hammered and ground immediately after the welding.

Figure 5. Worn and damaged switch blade.

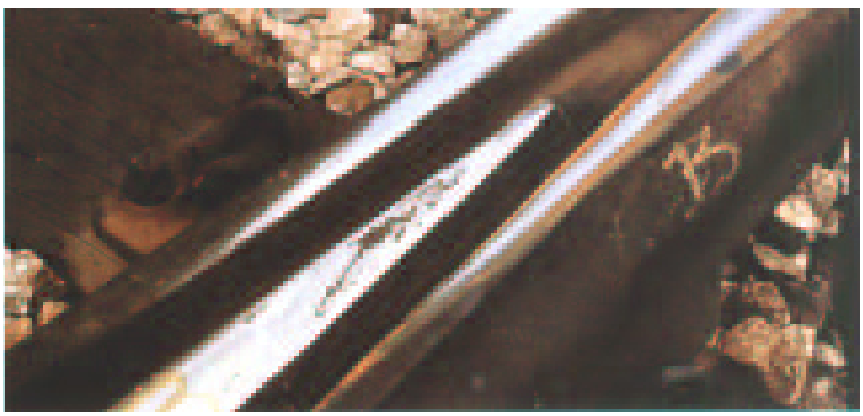


Figure 6. Cast defect in austentic-manganese crossing.

Figure 7. Mounting of backing. OK Backing 21.21.

Figure 8. Welding of the foot using electrode OK 74.78.

Figure 9. Coppershoes mounted for mould welding web and head with electrode OK 74.78. OK 83.28 is used for the cap layer.

Figure 10. Complete weld before grinding.

Switch blades and stock rails

When a wagon passes turn-outs onto a side track, it is guided by a switch blade. In this case the directive forces which occur between the flanges of the wagon wheels and the switch blade cause wear to the latter. The stock rail to which the blade is directed is also subjected to wear.

Very thin parts of the blade or where pieces have been broken away should be ground. Area to be repaired and adjacent rail, 100 mm either side, are preheated. Welding is carried out vertically. Subscqucnt beads arc finished off on the first made bead. When ready, the beads are ground while still hot. New beads arc made in the same way until the end of the blade is reached. After cooling the blade is finally ground and adopted to the stock rail.

In connection with reconditioning of the switch blade, the stock rail is inspected. If it is damaged, welding is carried out in the same way as for switch blades.

Joining of rails-mould welding

The rail ends are raised 1.5-2 mm to avoid shrinkage effects. A backing bar is inserted under the two rail ends, which have a gap of 15 to 18 mm Preheating is made to a distance of 200 mm from rail ends.

Configuration of the rail-to-rail joint-ail foot, web and head-requires shifts in weld pattern as the joint fills. Using the MMA process, welders deposit one stringer bead along the foot of one rail end, then another bead along the opposite rail foot. A third bridging-filler pass joins both stringer beads to complete the first weld layer. Overlapping beads should be smooth and without undercut. Welders remove the backing bar and visually inspect the back of the weld using a mirror.

Copper shoes installed alongside the rail joint support the weld pool during filling of web and head portions of the joint. Weldcrs deposit filler metal in a square pattern, making short stops at joint corners. They keep arc lengths short to avoid porosity. MMA requires quick electrode changes in order to prevent solidification of the slag. Welders weave electrodes to fill the rail head and the final weld metal hardness matches that of the base metal.

While the weld is still hot the copper shoes are removed, then the joint is hammered and roughly ground. Stress relieving is undertaken before the tempera ture has reached 350°C on cooling. The joint and adjacent material are heated to 600-650°C and hold for 10 minutes. Uniform slow cooling is achieved by surronding the area by mineral wool pads. Once cool. workers grind the rail to the correct profile.

Multiple passes repair rail crossings

Weld repair to x-shaped rail crossings is preferably carried out before wear exceeds a depth of 6 mm. To begin. workers release sleeper mountings under the damaged part and insert wedges to raise the part 5 to 10 mm. Crossings of carbon-manganese steel require preheat 100 mm on either side of the repair site. When using the MMA process, welders weave beads back and forth across the rail.

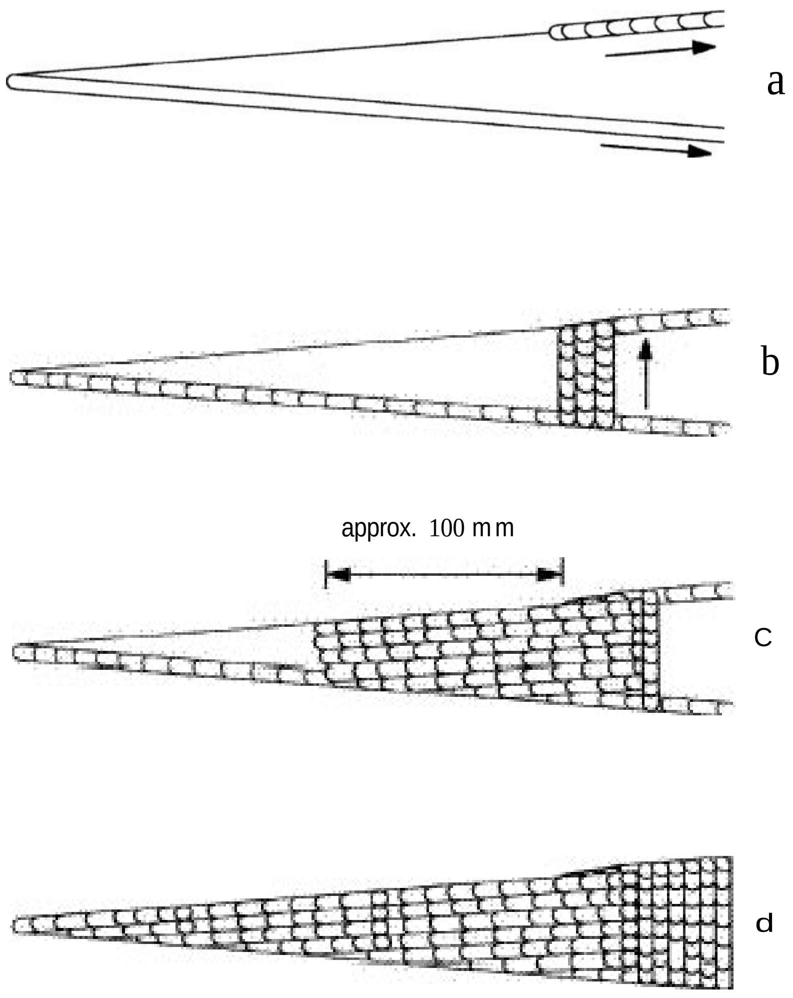
With FCW. welders first lay down a longitudinal bead along edges of the rails making up the crossing. These beads support weld metal during subsequent weaving across the entire surface of the rail. The last layer is hammered and ground while the metal still is hot. Upon cooling. workers remove wedges. make the final grinding and remount the rail on the sleepers.

Rail crossings of carbon-manganese steel take transverse weld patterns with electrode weave of 30-35 mm

Austenitic-manganese steel crossings do not require preheat. The interpass temperature must not exceed 200°C. Stringer beads and maximum bead lengths of 100 mm for MMA welding and 600 mm for FCW welding limit heating of the base material. Welders grind all starts and stops and peen each weld bead lightly while the weld metal still is hot.

11. Rail crossings of carbon-manganese steel take transverse weld patterns with electrode weave of 30-35 mm.

Rectification of the tip and the rail wings are principally made in the same way. Support beads extending along rail crossing edges are necessary before welders lay three weld beads across the widest region of the crossing tip. Welders then deposit longitudinal MMA stringer beads starting 100 mm from the three transverse welds and travel away from the crossing tip to end at the transverse beads. Similar stringer beads 100-600 mm long deposit for FCW. Each pass is parallel to one side of the rail. When weld-repair is complete, workers grind welds smooth, remove support wedges, and grind to the correct profiles.



12. Bead sequence when repairing an austenitic manganese crossing by MMA welding. The arrows show the welding direction.

Summary

There is no doubt that track repairs by welding has considerable cost saving advantages compared to replacement by new components.

In general it can be assumed that 40% of the total cost of the materials for a kilometer track is that of the rail itself. Such a high proportion of cost therefore indicates that anything that can be done to prolong the life of the rails will impart considerable financial savings.

About the authors:

Bengt Dahl is Chief Welding Engineer Banverket Swedish National Rail, Borlänge, Sweden.

Björn Mogard is Metalurgist Banverket Swedish National Rail.

Bibi Gretoft is Product Manager, Repair & Maintenance, Esab AB, Göteborg, Sweden and

Björn Ulander is Development Engineer, Repair & Maintenance, Esab AB.