Innovative weld deposition process for cost effective restoration of grooved rails

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Format of presentation

- Background to Sheffield Supertram’s experience
- Corus Rail Technologies involvement
- Trials performed
- Site welding
- Conclusions

Stagecoach Supertram Maintenance Ltd. made a significant investment in a weld deposition technology developed by Jinpo of the Czech Republic to enable weld repair of grooved rails to extend rail life and permit more cost effective maintenance of the Sheffield network.

The Jinpo Plus Rail Walker was purchased and this is a rail mounted Welding Trolley with a submerged Arc Welding Head and flux recovery unit as shown in the next slide

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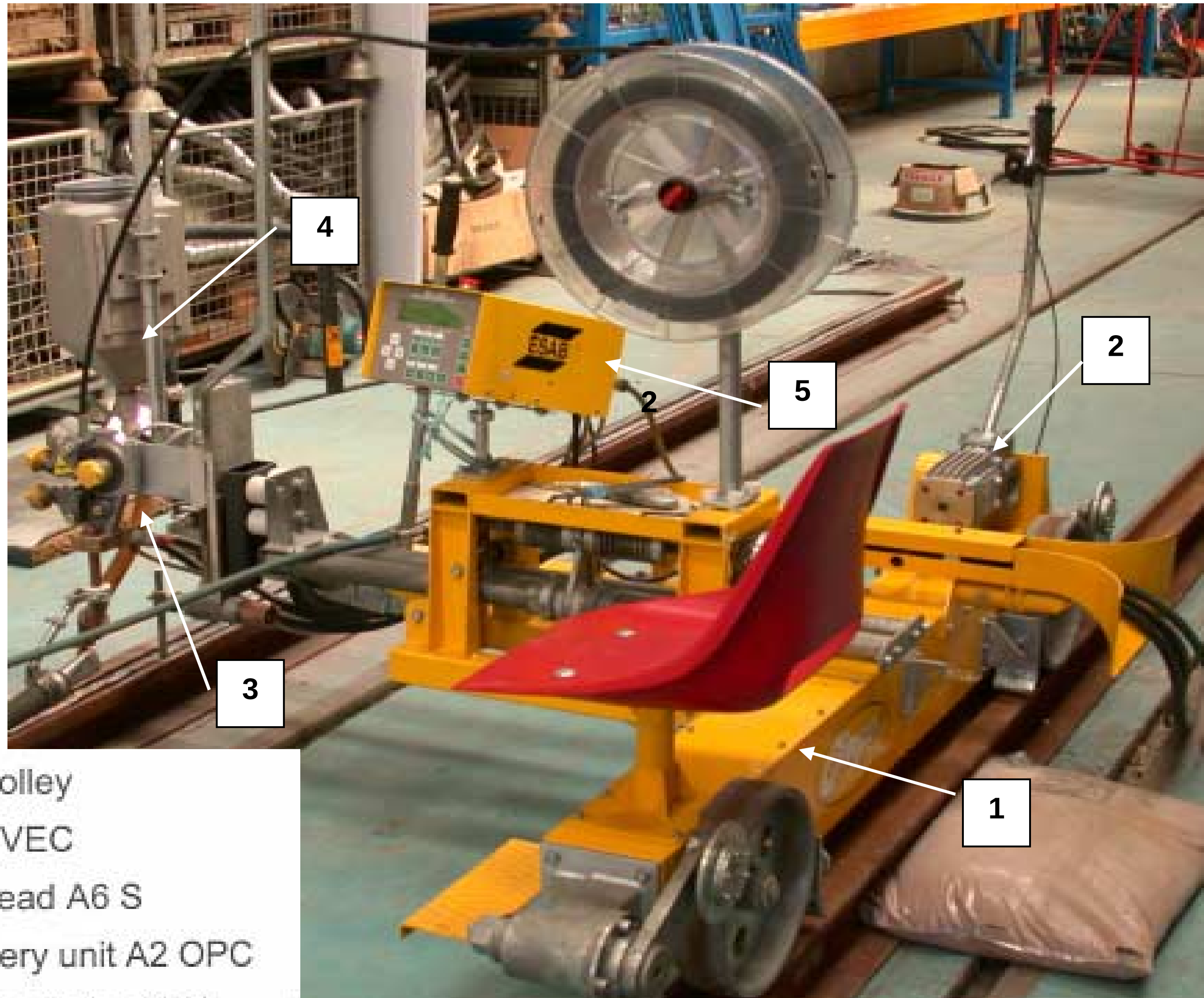

1. welding trolley
2. motor A6 VEC
3. welding head A6 S
4. flux recovery unit A2 OPC
5. process controller PEH

The cold rail re-surfacing, as developed by the Czech company Jinpo plus, had been identified as a process that would allow weld repairs to be carried out on worn rails **without the necessity for pre-heating of the rail.** Pre-heating of the rail would damage the electrometric polymer that surrounds the tram rail and would cause the polymer to release harmful gases.

This technique was initially used at Sheffield but the outcome was not a success since after a short period of time, the rail began to crack. Sheffield Supertram asked Corus Rail Technologies to investigate.

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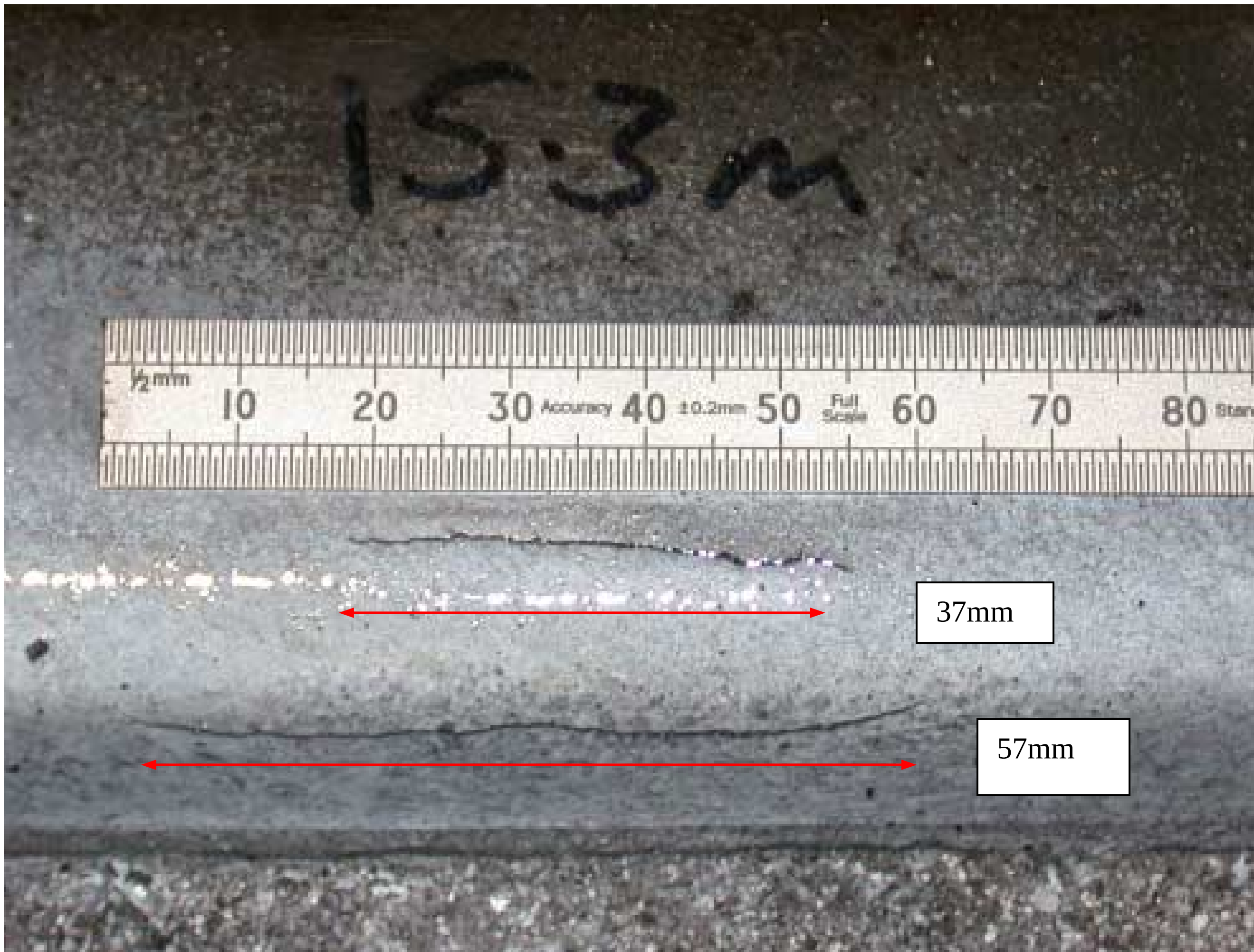
15.3m
½mm 10 20 30 Accuracy 40 ±0.2mm 50 Full Scale 60 70 80
37mm
57mm

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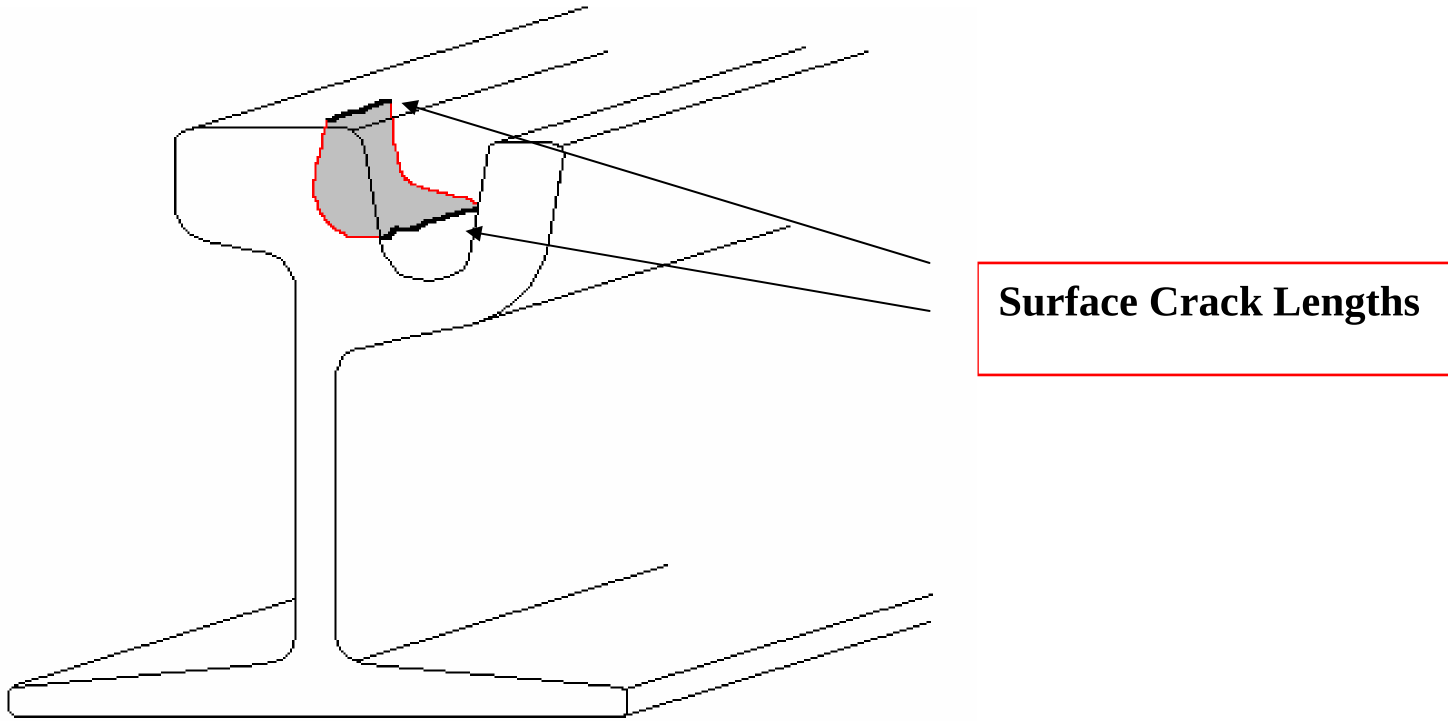


The results of the site inspection using a variety of NDT techniques had shown that the defects were emanating from within or adjacent to the rail weld deposit.

Conclusions from the ultrasonic examination had highlighted that the rail defects had propagated through the rail to a point where they exit the running surface of the rail and gauge face of the rail. The longest running surface crack length of 37mm also had a gauge face crack length of 57mm, in this case the material will fatigue further until it detaches from the rail. The Ultrasonic depth readings for this location indicate that the crack was 9mm from the gauge face and extended to a vertical depth of 14mm below the running surface of the rail.

Network Rail Standard NR/SP/TRK/132 Issue (formerly RT/CE/S/132) "Weld repair of Rails" states that the temperature of rail over the area to be welded, including 75mm at each end, shall be subjected to an initial preheat of 343°C, maintained throughout welding.

This procedure applies for both 220 and 260 grade of steel.

For the weld repair of tramways, the street running part of the rail is encased in a polymer which breaks down to evolve hydrogen cyanide at around 160°C thus making it impossible to weld repair these rails to the above procedure.

Corus have developed a new weld procedure for Grades 220 and 260 that uses a propane based chill removal burner unit to raise the temperature of the running surface of the rail . The deployment of this procedure and the deviation from conventional weld repair procedures for such medium and high carbon steel grades is supported by detailed consideration of the metallurgical transformations that occur on cooling as explained

The traditional approach to the selection of a given preheat temperature e.g. of around 350 ^{0}C for the repair welding of Grade 260 rails was based on the concept of reducing the post weld cooling rate of the heat affected zone (HAZ) to such an extent so as to allow the austenite to pearlite transformation to go to completion during cooling of the weld, thus avoiding the formation of very hard and brittle martensite in the microstructure subsequently developed within the heat affected zone of the weld. In the absence of a preheating stage, the heat sink provided by the rail mass would result in a more rapid cooling rate leading to transformation of significant quantities of austenite to brittle martensite.

The novel concept of the application of a low temperature "chill" removal treatment prior to repair welding of rails is based on not allowing the austenite to martensite transformation to go to completion during cooling of the first weld bead, with the result that the microstructure of the heat affected zone comprises almost equal proportions of hard and brittle martensite intermingled with soft and ductile retained austenite.

An optimum "chill" removal temperature was arrived at following the calculation of the martensite start temperature of the Grade 260 rail steel of around 158 ^{0}C, using the well known and widely utilized equation:

$$Ms\ (^{0}C) = 561 - 474\ (\%C) - 33\ (\%Mn) - 17\ (\%Ni) - 17\ (\%\ Cr) - 21\ (Mo)$$

There is no recognized equation for calculating the martensite finish temperature (Mf), but it is widely accepted to be of the order of 150 ^{0}C below the Ms temperature of a given steel. As such, the Grade 260 rail steel is accepted to have an Mf temperature slightly below ambient temperature of around 20 ^{0}C. Additional support to this is provided by the fact that upon rapid water quenching of the steel to ambient temperature, the austenite to martensite transformation does not go to completion, but instead results in the generation of a microstructure comprising around 95% martensite and 5% retained austenite.

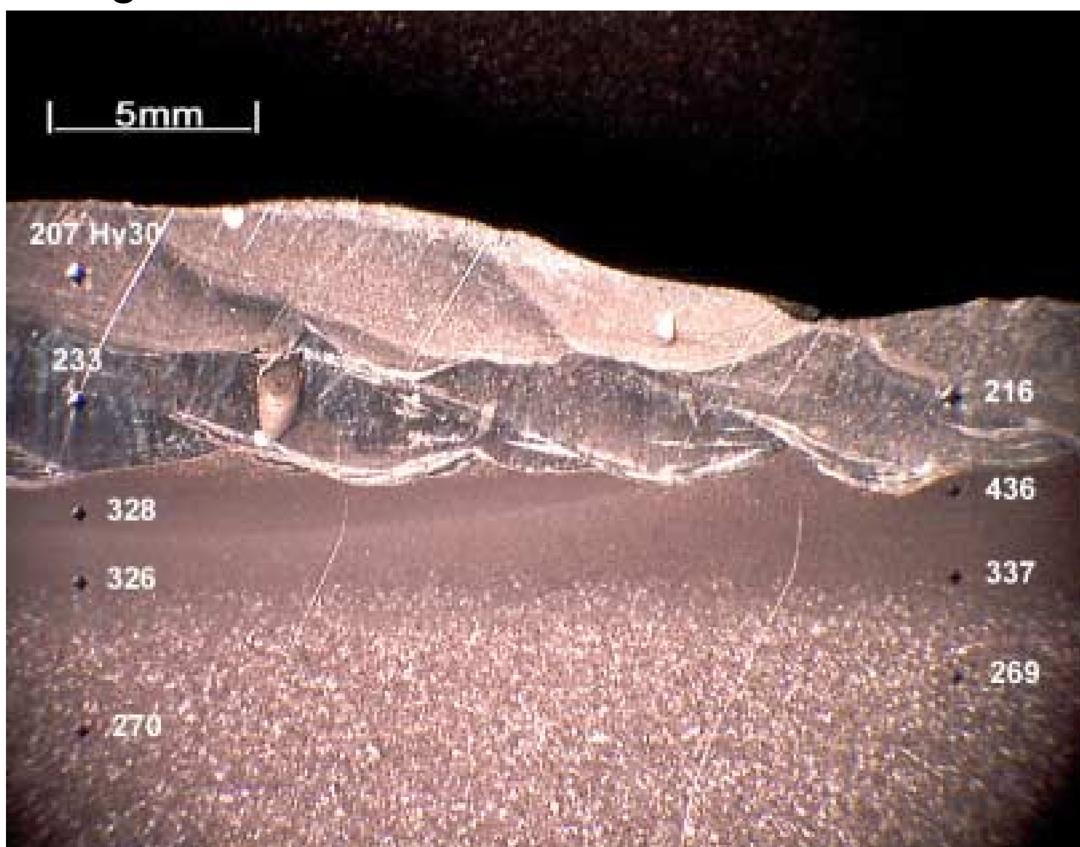
The concept of not allowing the austenite to martensite to go to completion i.e. retaining a relatively large proportion (40/50 %) of austenite within the microstructure of the heat affected zone (HAZ) after laying of the first weld bead is based on the following foreseen advantages:

1. An overall softer and tougher HAZ, less prone to cracking as a result of the relatively high tensile residual stresses generated following the solidification of the weld metal. The resulting structure is also less prone to hydrogen related "cold" cracking, which is generally at its most pronounced at temperatures close to ambient.

2. An HAZ capable of tolerating relatively high amounts of embrittling hydrogen diffusing across the weld metal HAZ interface, due to the fact that the solubility of hydrogen in austenite is known to be several magnitudes higher than that in martensite/ferrite).

3. The recognition that the deleterious martensite present within the HAZ microstructure following laying of the first/root weld bead would subsequently be heavily tempered (breaking down into a significantly tougher aggregate of ferrite and carbide) during the laying of the second weld bead.

This aspect is illustrated below where a moderately high hardness of 436 HV (on the R.H.S of the macrograph) within the coarse grained HAZ of the first weld bead is reduced to a perfectly acceptable HAZ hardness level of 328 HV (on the L.H.S of the macrograph) as a result of the tempering effect of the second weld bead.



The subsequent inter-pass temperature should be measured on the rail head using a contact pyrometer, prior to starting each weld deposition pass. If the interpass temperature is found to be have risen to above the **maximum specified interpass temperature of 130 °C**, the weld deposition process should be stopped until the rail head temperature has dropped to below this value.

A trial was conducted on a ~9 m long Grade 900A grooved rail with a machined facet having a width of 10 mm and a depth of 20 mm to simulate the profile of a worn gauge face during service in track

The first stage of the trial involved uninterrupted weld deposition in 9 passes over the first half (~4.5m) of the 9m rail at ambient temperature (11.5°C), which was just above the minimum air temperature of 10°C originally recommended by the equipment manufacturers.

The second stage of the trial utilised the remaining 4.5m of the rail and involved a “chill removal” treatment using an oxy-propane burner with oxygen and propane pressures of around 25 and 5 psi respectively. The objective of this treatment was to raise the temperature of the rail prior to starting the weld deposition.

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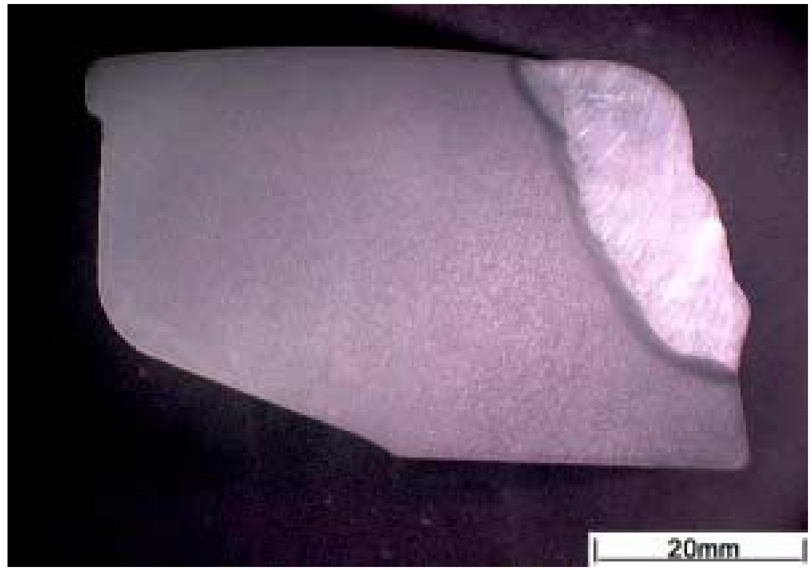
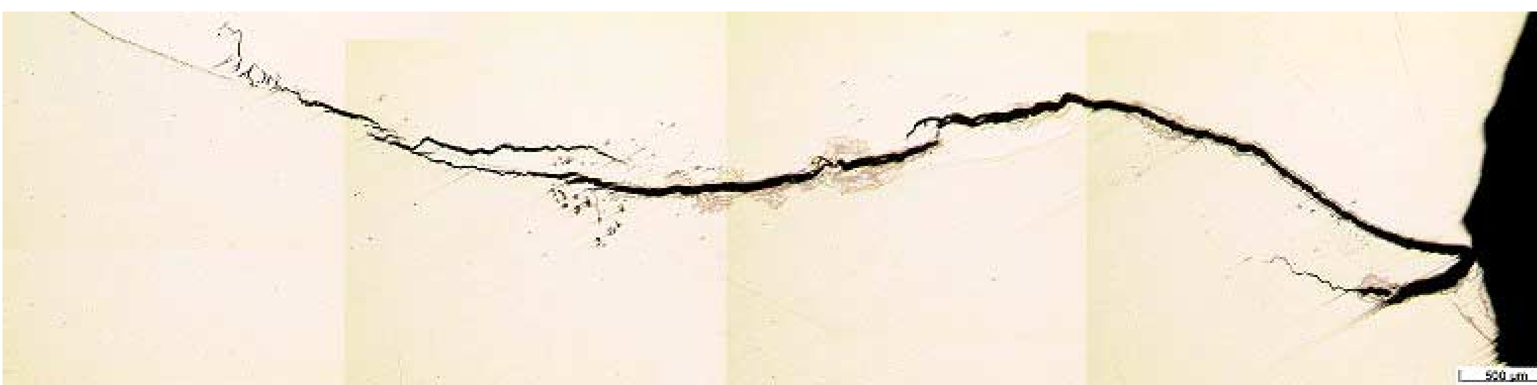


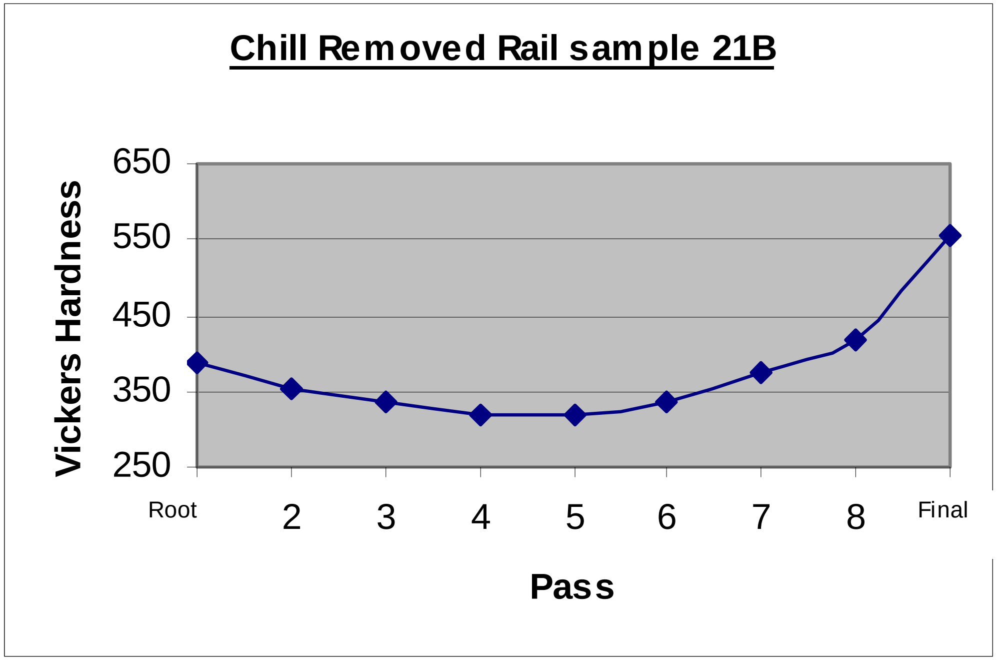


Conclusions from trial

A weld deposition technique, involving localised rail "chill removal" in conjunction with modified welding parameters and consumables, has been established that has been shown to produce a crack free and robust weld deposit on a consistent basis.

A localised “chill removal” treatment around the weld deposition area to be re-surfaced (and not the whole of the rail) to raise the rail temperature is recommended prior to the deposition of the first/root pass.

In order to avoid undesirable microstructure and levels of hardness at the wheel-rail interface, an additional "sacrificial weld deposit pass" is recommended. This final pass should be subsequently ground off to expose a weld deposit layer with more acceptable microstructure and hardness.



Site welding

Shalesmoor curve (both inbound and outbound) at Sheffield Supertram have now been welded by this process – a total of 120m of track !! With no problems !!

This has saved them lots of money as cost of rail replacement is of the order of £1,000/m for street running embedded track.

Corus and Grant Rail are in the process of buying a further machine to support tramways in the UK

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An Innovative weld deposition process for cost effective restoration of grooved rails has been developed by Corus Rail Technologies in conjunction with Sheffield Supertram.

Corus and Grant Rail are hoping to offer a weld restoration service early in 2007 which will help serve the light rail industry

Thank You for your attention