

AG60 Rail welding

INNOTRACK reports from WP4.6

D4.6.1 The influence of the working procedures on the formation and shape of the HAZ of flash butt and aluminothermic welds in rails

Difference in hardness between HAZ and base metal gives additional wear in HAZ -> weld batter -> higher impact loads.

Interest in reducing the HAZ

Flash butt welding

- As low a heat input as possible to achieve adequate weld consolidation
- As low a conduction of heat away from the weld interface into the body of the rail as possible

This is achieved by

- A slightly longer initial flash duration giving a longer localised heating cycle
- A considerably lower number of preheats aimed at reducing the total heat input
- Significant reduction in the durations of the preheat On and Off periods aimed at reducing both the overall heat input and the total time for the heat to be conducted away from the weld interface
- A shorter final flash duration giving a shorter localized heating cycle and reducing both the heat input and the heat conduction time
- Lower forging (upset) distances - this is a direct consequence of the significantly reduced heat input levels

Aluminothermic welding

The following factors influence the shape and width of the HAZ

- Profile and type of rails
- Gap width between the rails prior to welding process
- Temperature of the rails
- Weather conditions
- Preheating
 - Preheating time
 - Gas pressure
 - Burner type
 - Burner height
 - Quality of used gas (caloric value)
- Pouring system / mould geometry
- Temperature of superheated liquid steel at the beginning of the welding process
- Mass of liquid steel that is used to fill the gap between the rails

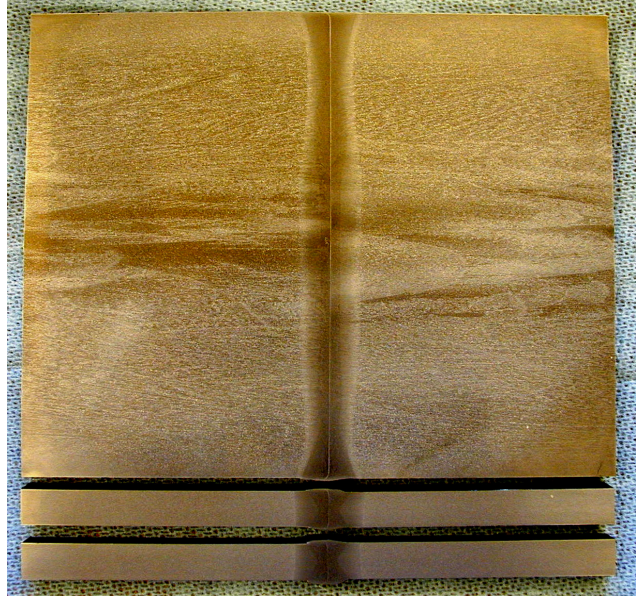
			
Standard Weld		Narrow HAZ Weld	
Position	HAZ Width (mm)		
	Standard Weld	Narrow HAZ Weld	
Rail Running Surface	37	26	
20 mm Below Rail Running Surface	35	21	
86 mm Below Rail Running Surface	37	23	
20 mm Above Rail Foot Base	38	20	
Rail Foot Base	38	23	
Rail Foot Tips (A and B)	32, 36	24, 24	

Table 2 - HAZ Profiles

3.2.2 Hardness Profile

The hardness profiles from the 350HT, 60E1 rails for the standard (post weld enhanced cooled using compressed air) and Narrow HAZ (normal air cooled) welds are shown in Figure 2 below.

3.2.3 Bending Fatigue Strength

Strength in bending fatigue is an important requirement in the welding specification of all railways and consequently, it was necessary to demonstrate that the changes in welding parameters deployed to achieve narrow HAZ width had not compromised this important attribute. The data shown in Figure 3 below clearly demonstrates that the fatigue performance of Narrow HAZ welds is very similar to that of the standard welds.

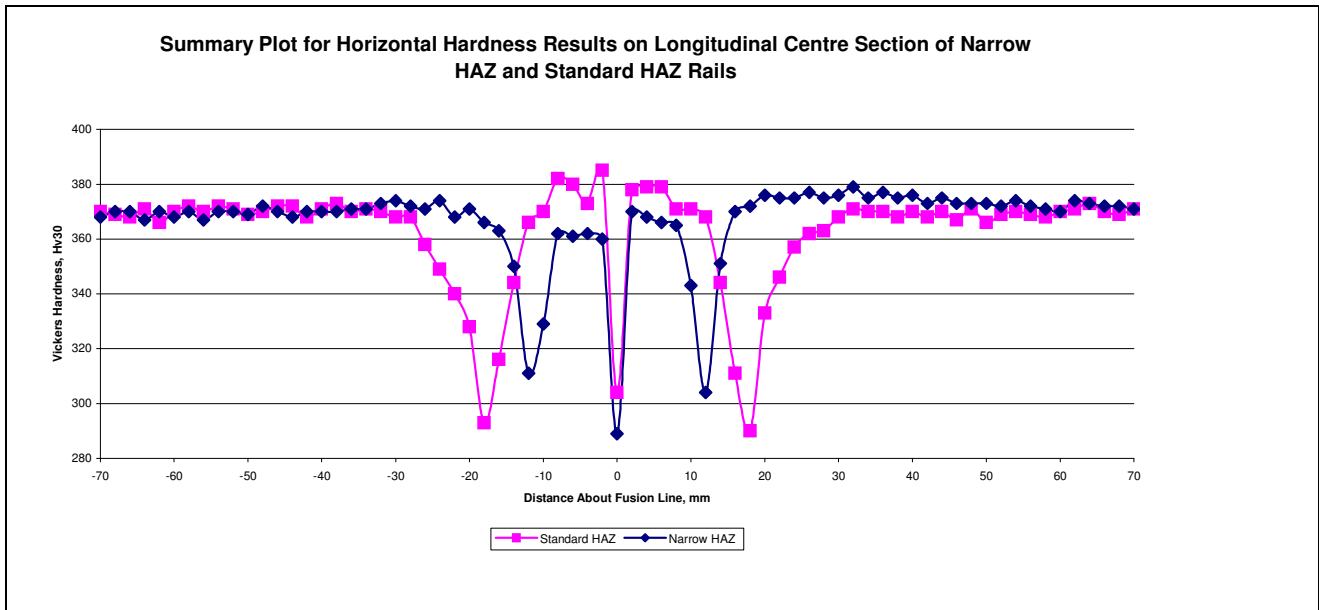


Figure 2 - Hardness Profiles of Standard and Narrow HAZ Welds

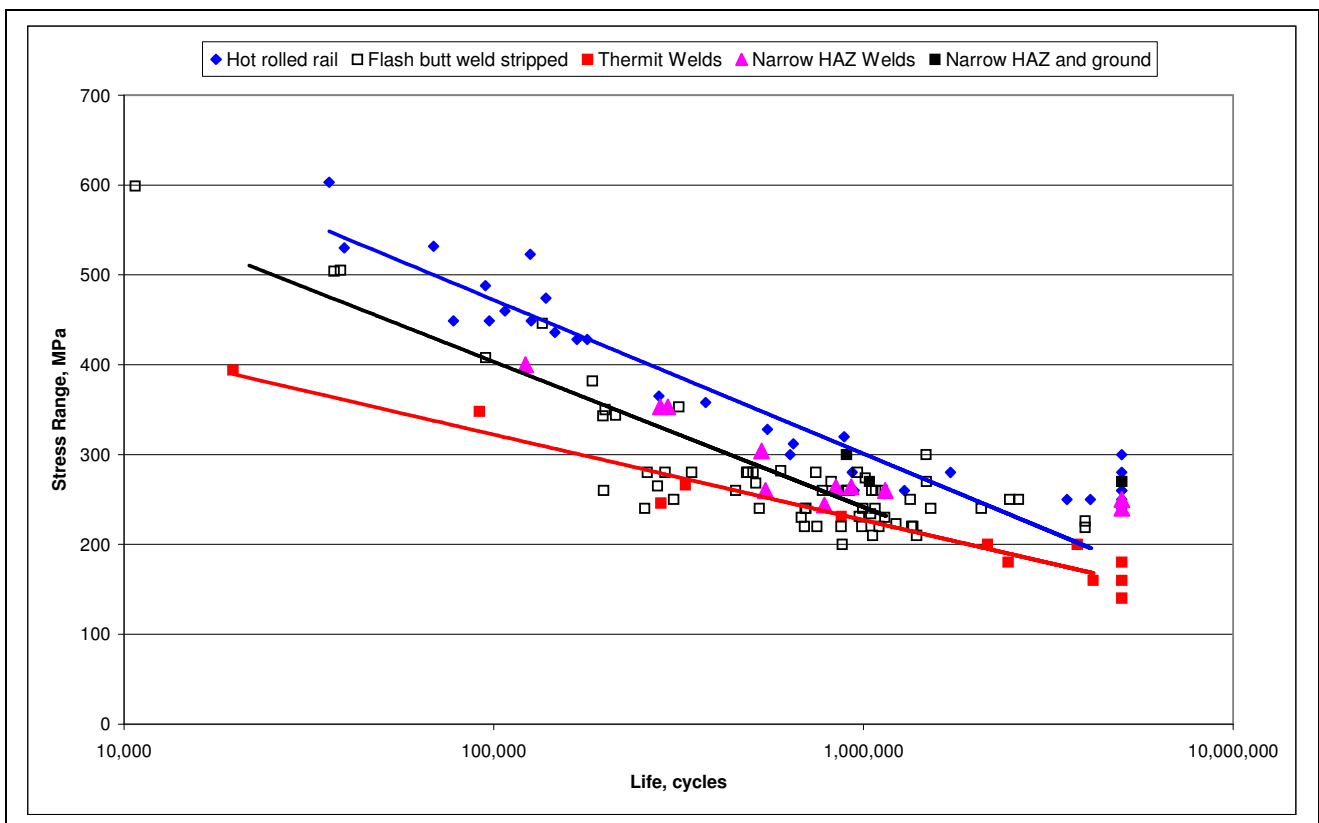


Figure 3 - Strength in Bending Fatigue of Welds

In Figure 4 longitudinal sections of welds are given that are generated by the use of different welding procedures (HPW, SkV-Elite and SoW-5). Based on the experience up to now the welding process SkV-Elite results in the smallest HAZ compared with e.g. HPW or SoW-5.

This knowledge may not lead to a separation of welding processes with a comparatively large HAZ and a comparatively narrow HAZ. This kind of separation would not be helpful because the properties of the weld are not only determined by the width of the HAZ. The properties of the weld need to be regarded along the complete weld (parent rail – HAZ – weld metal – HAZ – parent rail).

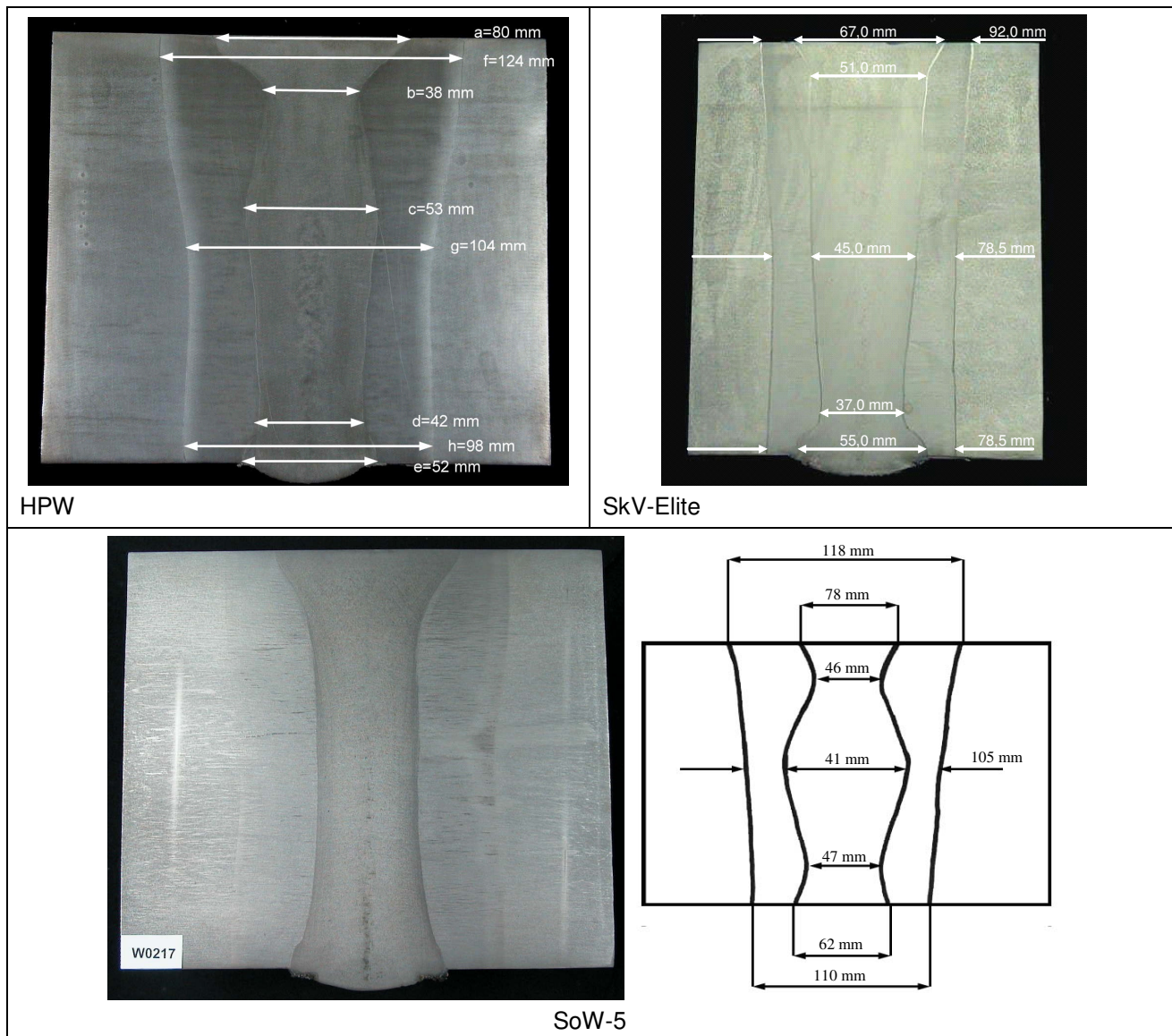


Figure 4 - Shape and Geometry of Different Aluminothermic Welds

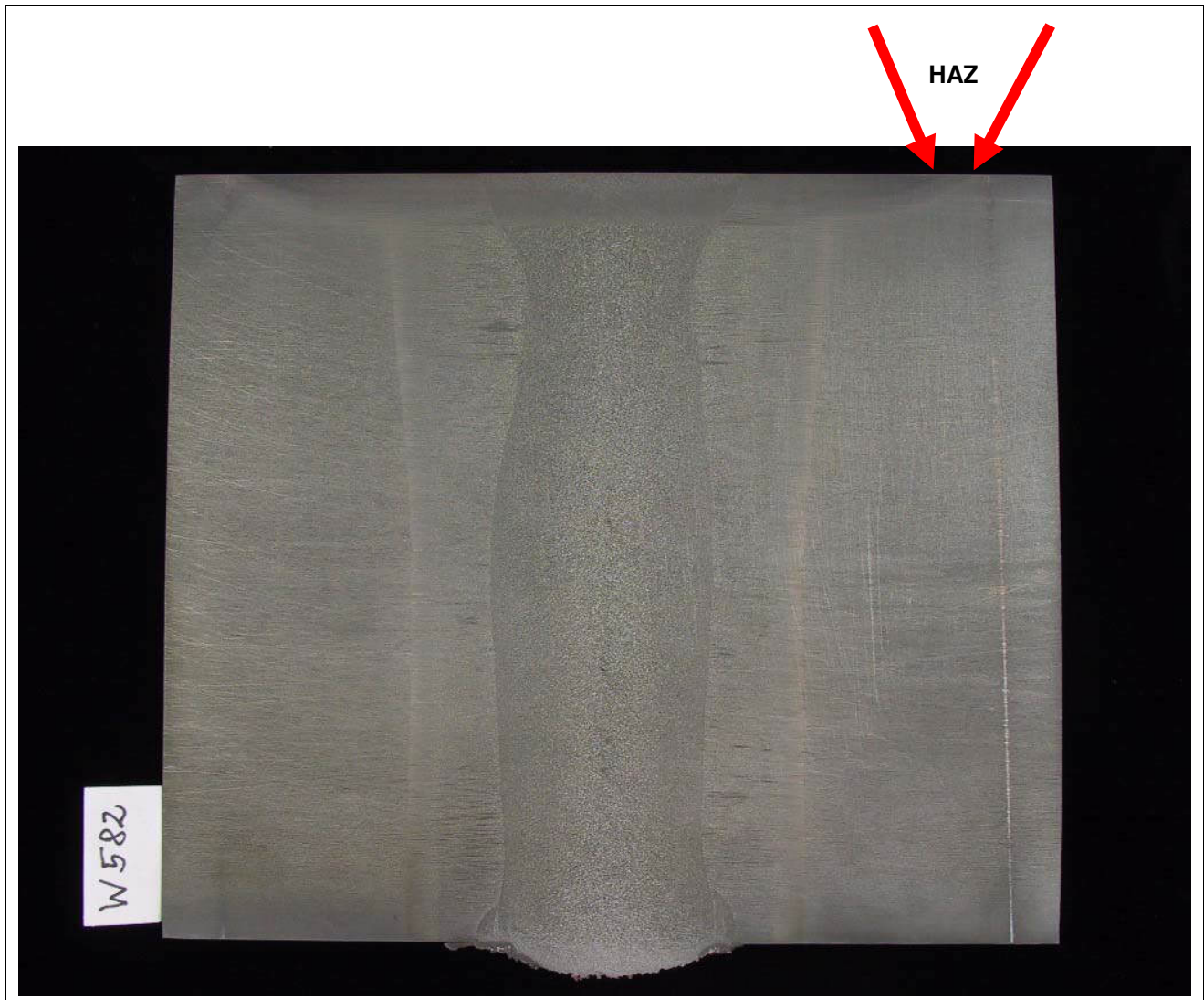


Figure 5 - Longitudinal Section of SkV-Weld With Additional HC-Treatment

As mentioned above, an additional heat treatment can be performed in order to modify the initial microstructure. This so-called HC-treatment causes the formation of a very fine pearlitic microstructure and an increase of hardness. However, this second heat treatment somehow covers the HAZ that has been created before, and a new HAZ will be formed at the borders from the area that is affected by the heat treatment.

Figure 5 shows a longitudinal section of a SkV-weld with this additional heat treatment. On the one hand the fusion line and the HAZ of the aluminothermic weld are clearly visible; on the other hand a dark shaded, crescent shaped area below the running surface becomes visible. This is the area where the heat treatment causes the formation of the fine pearlitic microstructure, and (indicated by the arrows) a second HAZ has been formed.

The additional heat treatment is superimposed to the heat treatment that was caused by the initial welding process, but as it can be seen in Figure 5 the location of the initial fusion line and the HAZ still remain visible in the longitudinal section.

4.2 HPW welding procedure

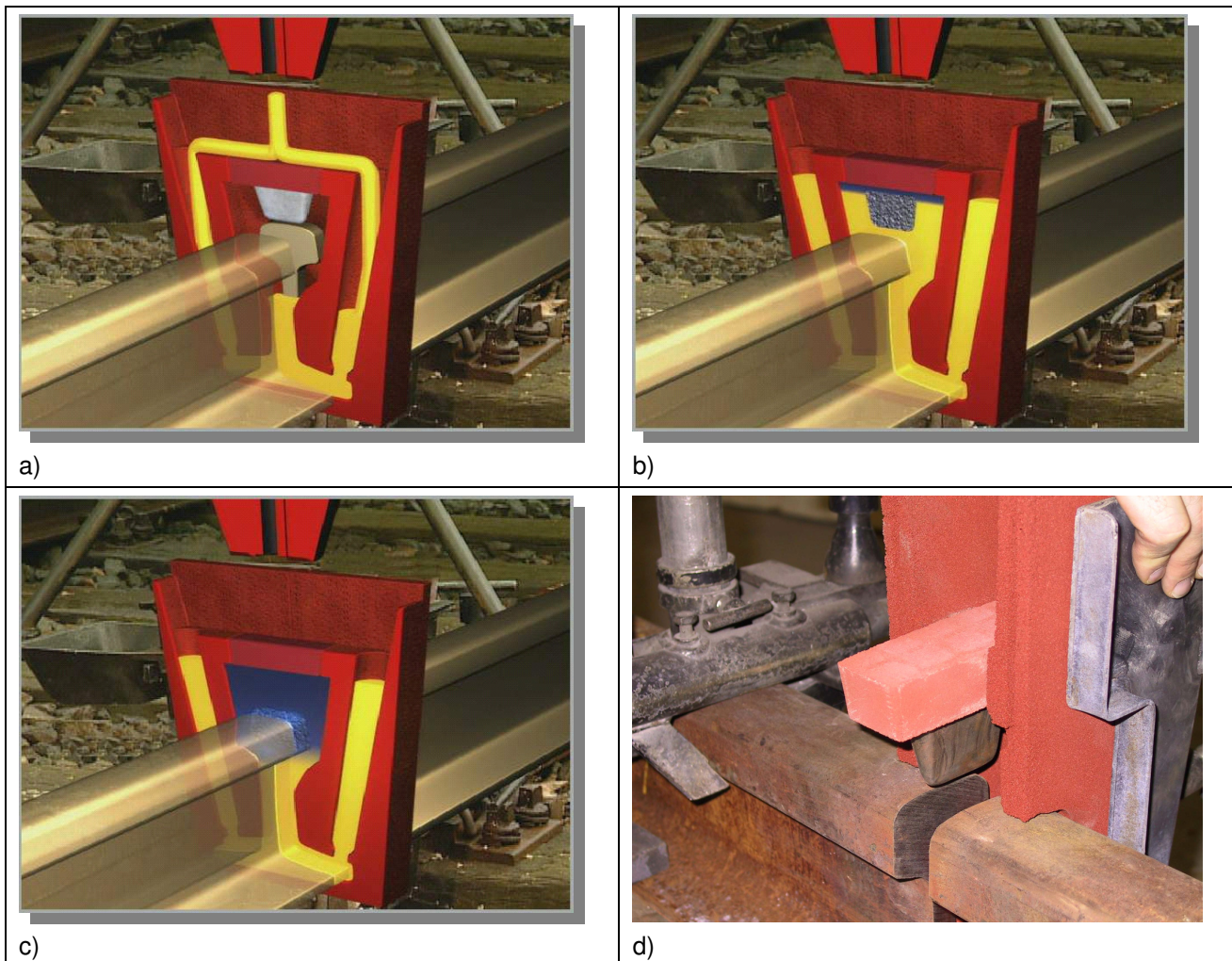


Figure 7 - Schematic presentation of the HPW process

A high performance weld (HPW) is characterised by a distinct difference of hardness between head and base. The high hardness of the head is achieved by using a small container with alloying elements that is attached under the plug (Figure 7d). The welding process is given schematically in Figure 7a to c. Here it can be seen that the liquid metal reaches the container with alloying elements at a late stage of the casting process. The container dissolves and the alloying elements are released. A homogeneous distribution of the alloying elements in the head of the weld causes an increase of hardness. The required hardness level is dependant on the grade of the rail and can be controlled by the amount (or concentration) of alloying elements. For example for welding R350HT rails then a base portion Z90 (normally used for welding R260 rails) is used with the head being selectively alloyed to increase the hardness to match that of the parent rail head. Typical alloying elements that can be used to influence the hardness level are e.g. Vanadium and Carbon.

Typically, this welding procedure is used to weld head hardened rails of grade R350HT or 370LHT. Using a base weld metal with low hardness (e.g. corresponding to rail grade R260) the alloying systems allows achieving the hardness of R350HT or 370LHT rails in the head of the weld.

5. Conclusions

5.1 Flash Butt Welding

1. The process parameters of flash butt welding that contribute towards the formation of the heat affected zone have been critically examined and optimised with the aim of significantly reducing the HAZ width towards the narrower end of that specified in EN 14587-1.
2. The process has been applied to all the commonly used rail steel grades and a number of rail sections.
3. The success of the new process has been demonstrated through the results obtained for Grade 350 HT, 60E1 rail. Data for bend strength, hardness profile, and bending fatigue strength all demonstrate full compliance with EN 14587-1.

5.2 Aluminothermic Welding

1. Aluminothermic welding processes have not been optimized up to now with the aim to minimize the width of the HAZ. Experience has shown that SkV-Elite is the welding process that creates the narrowest HAZ compared to the other aluminothermic welding processes from Elektro-Thermit GmbH & Co. KG.
Regarding aluminothermic welding the preheating time (besides other preheating parameters such as gas pressure, positioning of the preheating burner, etc.) seems to be the process parameter that has the largest influence on the width of the HAZ. A very short preheating time of about 1.5 minutes combined with an optimized mould design results in the narrow HAZ of the SkV-Elite process. For the HPW process a longer preheating time of about 3.5 minutes is used and consequently the width of the HAZ slightly increases. The usage of longer preheating times will further lead to a broadening of the HAZ.
2. Due to the demand for a sufficient bonding between rail steel and weld metal a preheating process is always required for aluminothermic welding. As long as similar preheating parameters (e.g. short preheating times) are used the width of the HAZ cannot be reduced any more to a large extent.
3. The width of the HAZ cannot solely be regarded if assessing the service performance of an aluminothermic weld. Both the width of the weld and the width of the HAZ need to be considered with regard to the properties. The change of properties along the complete weld has to be controlled to optimize the service performance.
4. Within this project HPW has been chosen as welding process because of its innovative welding procedure, that a selective alloying technique allows decoupling the properties of head and base of the weld. The high wear resistance of a hard head can be combined with the higher ductility of a base with lower hardness.

Gas pressure welding

All the defined number of welds have to be manufactured consecutively using rail of the same grade and profile. Welding parameters must remain unchanged during production. Rail end preparation must be in accordance with the process requirements – in the case of gas pressure, the procedure is defined in the operating instructions to include rail end grinding, and solvent cleaning to remove surface films. If recording equipment is provided, a full record of each weld must be taken; otherwise details must be recorded manually for each of the process parameters.

For Gas Pressure welding these include:

- Initial alignment (see later)
- Clamping pressure
- Forging Pressure
- Gas Pressures, Gas Flow and flame condition (flame length)
- Heating distance (burner movement)
- Forging distance (total stroke/material loss)
- Welding time – start of heating to end forging

Conclusions:

The development work summarised in this report has demonstrated that, properly executed, the Gas Pressure Welding process is capable of producing welds that meet the requirements established for other methods, subject to small concessions to allow for the different metallurgical properties of the Interface and heat affected zone. With minor amendments the current EN standard for approval of Flash butt welds could be adapted to include provision for Gas Pressure welds.

The Welding process as used for development relies heavily on the skills of the operator, and careful pre alignment of the rails in order to achieve acceptable alignment tolerances –An improved clamping and forging unit should incorporate some form of automatic alignment.

The main deficiency of the process – as identified when welding 60E1 rail – is the requirement to control the deformation processes in the foot tips in order to avoid interface defects. The research completed indicated that maintaining a narrow Heat affected area, which a high forging pressure minimises the non linear deformation with better geometry across the rail foot, and reduces the likelihood of lack of bonding defects.

The limitations of forging capacity, and burner design in the GPW unit selected for the approval investigation resulted in difficulty is reproducing the optimum welding conditions for the required deformation process while maintaining alignment.