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Continuous welded rail using mobile flash butt welding

Figure 1 *Plasser & Theurer K355 APT flash butt welding machine*
Figure 2 *Welding phases on printout*
Figure 3 *Welding upset visible shortly after shearing*

The introduction of continuous welded rail has vastly improved the geometric stability of the track structure. Nevertheless, the localised change in the metallurgical character of the rail in the vicinity of welds can ultimately initiate damage to fastenings and sleepers. This has, however, improved quite dramatically with the development of the flash butt welding process

FISH BOLTED RAIL JOINTS have been one of the major locations and causes of maintenance on rail track since the first railway line was built. Discontinuity of the track running surface produces dynamic impact loads battering the rail joint ends and bending the rail. This causes greater stress on the ballast and subgrade, which in turn increases ballast settlement and produces uneven track. The pumping action at the joints also accelerates rail failure, sleeper wear, and fouling of the ballast at the joint.

The introduction of continuous welded rail has vastly improved the geometric stability of the track structure. Nevertheless, the localised change in the metallurgical character of the rail that can occur in the vicinity of welds can ultimately lead to a loss of running smoothness which can initiate corrugations and promote the development of localised track geometry irregularities, pulverisation and movement of the ballast, and damage to fastenings and sleepers.

This has, however, improved quite dramatically with the development of the flash butt welding process. This process, with its limited change to the metallurgical character of the rail, reduces the possibility of loss of running smoothness dramatically, thus producing a high-quality continuous welded rail.

The process charges the two rails to be welded with very high amperage at low voltages. The resistance of the current flow between the two rails causes rapid heating of the two rail ends. Based purely on a time controlled system, the heated rail ends are forced together at a high pressure during which all impurities are forced out. Flash butt welding does not require any additional welding material, as the rail itself is used as a welding compound. The result is a near flawless weld of which the strength exceeds that of the rail material.

Flash butt welding has been used by railways since around 1930. Initially, a drawback was that flash butt welding was only used in stationary depots, which then required the arduous transport of the long welded rail, thus setting constructional limits for the production lengths.

If it was possible to perform butt welding on rails in situ, near perfect continuous welded rails could be possible. Plasser & Theurer, as the world leader in track maintenance and construction machinery, therefore developed the first mobile flash butt welding machine in 1973 using a welding head, the K355, developed at the J O Paton Institute in Kiev, Russia.

Today mobile flash butt welding is used in all modern railways for construction, removing old joints or fatigued welds, rail replacement programmes, etc.

K 355 APT FLASH BUTT WELDING MACHINE

A three-phase 50 Hz alternator with a rated output of 150 kVA is designed as a revolving field generator, that is with a fixed anchor and a revolving magnet wheel. The primary voltage is set between 340 V and 380 V depending upon the cross-section of the rail being welded.

The secondary circuit of the power plant is integrated in the welding head in order to transform the welding current from 380 V to approximately 6 V and the welding amperage from 395 A to more than 20 000 A.

In contrast to other welding methods, the electric flash butt welding machine can produce a graph report of each welding sequence. This produces a document for every weld which enables an immediate assess-

the machine

ment of the welding quality.

The welding machine is equipped with a three channel recorder which records the parameters:

- Welding current intensity
- Compression force
- Displacement (feed travel). This recording shows the movement of the two halves of the welding unit relative to one another. This indicates the burn-off, the compression displacement, the total material consumption and the shearing process

THE FLASH BUTT WELDING PROCESS

During welding there is a consumption of material as a result of the burn-off and compression of the rails. The consumption of material amounts to approximately 35 mm. To allow the welding head to move the rails without hindrance, rail fastenings of the entire section have to be removed and the rail laid on rollers so that the frictional resistance between the rail base and the sleeper can be reduced to a minimum. These rollers are inserted at approximately every 20 sleepers.

The machine's rail-pulling device will be used to pull the rail with the least resistance towards the other. A gap of 3–5 mm must be left between the rails. They should not make contact. Good alignment is crucial for a quality weld because if the rails are aligned at an angle, uneven preheating will result.

The welding sequence begins by clamping the rails in two pairs of contact jaws. Rails with a cross-section area of up to 10 000 mm^2 can be welded. S60 rails have a cross-section area of 7 702 mm^2. The lever system applied achieves a considerable clamping force of approximately 125 t. During clamping the rail is thus adjusted accurately in terms of level and line. These copper jaws are also the electrodes which are water-cooled.

The welding sequence is programmed for every type and profile of rail in terms of the primary voltage (between 340 V and 380 V) and the welding duration (between 130 and 170 seconds). Flash butt welding is therefore not subject to operator errors. Each weld passes through three distinct phases, which are controlled by the pro-

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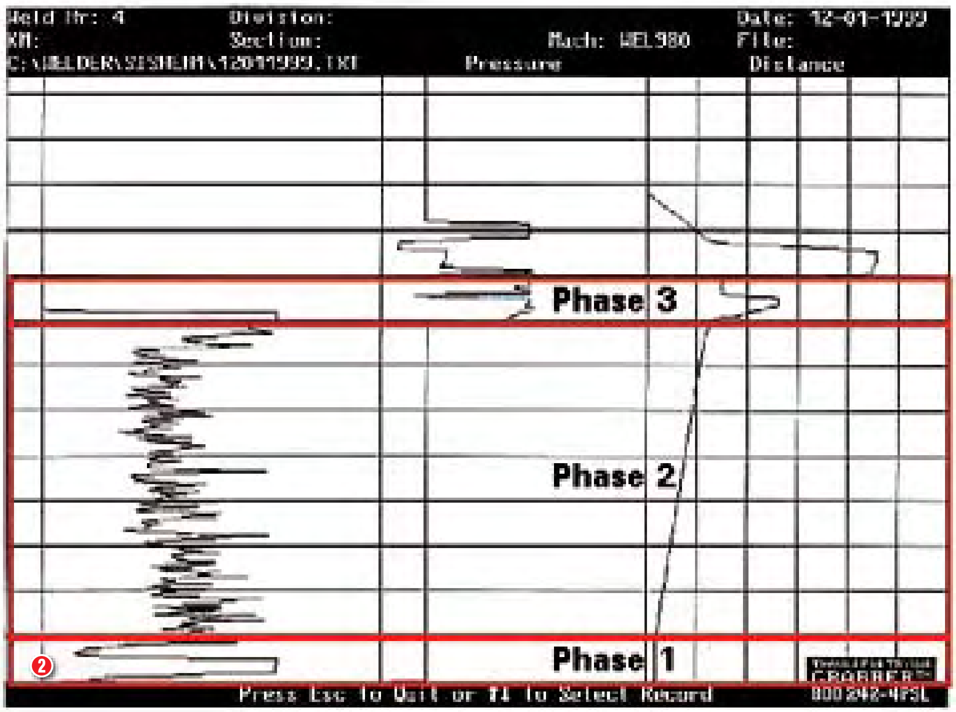

▶ ***Figure 4*** *Cross-section showing the spheroidised zone*

gramme unit. The three phases are clearly seen on the printout in figure 2.

Phase 1: Warming Up

The welding starts with the warming-up phase. At the start of this phase the welding head will bring the rail together to close the gap during alignment. This can be seen on the distance line. Once arcing starts the programme unit will start the timer sequence.

The warming-up phase is composed of repeated pulses of high amperage of more than 20 000 A at approximately 6 V. According to Joule's law, the maximum heat is produced on the points of maximal resistance. Maximum heat is therefore produced where the high current flows through a small area of contact when the rails are brought together.

Phase 2: Flash burning

During this phase the rails are pulled together at a constant rate of 0,22 mm/sec. The speed of approach rises in five steps to a final value of 1 mm/sec approximately 10 seconds before upset. The pulses of high amperage continue. Material consumption during this phase is in the order of 20 mm.

Phase 3: Upset

The third phase is the upset phase. Once the required upset temperature of approximately 1 100 °C has been reached, the rail ends are pulled and compressed together with a force that can reach up to 45 t. The temperature is not the trigger for the upset phase to start, however. It starts as the last phase of the fully automatic timed sequence.

The upsetting distance should be sufficiently high to prevent micro-porosity and non-metallic inclusions in the welding seam. The upsetting distance is not set in terms of distance but rather in terms of pressure. Upsetting will continue until the pressure reaches its maximum when all the pasty metal consisting of slag and impurities has been squeezed out. The upsetting distance can be as much as 15 mm.

Immediately after the weld has been completed, a hydraulic shearing device integrated in the welding head removes the welding upset. The shearing device perfectly follows the contours of the rail. This ends the welding procedure; the clamping jaws are released and the welding head lifted. The loosened upset is removed from the rail using a steel bar.

POST WELDING TREATMENT

Chromium manganese rails

Standard rail types do not require any heat treatment after welding as their cooling rate between 800 °C and 500 °C is sufficiently slow to allow complete formation of a pearlitic microstructure.

Alloy rails retard the rate at which pearlite will form. To avoid the formation of martensite a controlled cooling cycle must be initiated.

Controlled cooling is achieved by postheating the rail within 30 seconds after the weld. Exothermic heating powder is poured into a steel clinker former and ignited using ignition blocs. The powder burns at a temperature of between 370 °C and 430 °C. The clinker former must stay on for approximately 30 minutes. This will retard the cooling sufficiently for complete pearlite formation.

Head hardened rails

Because of temperatures in the austenite range during welding, head hardened rails are softened in the heat-affected zone and the effect of heat treatment is lost. This softening can be reduced by rapidly cooling the rail head just after welding.

This rapid cooling is achieved by blowing dried and compressed air over the weld within 30 seconds after the upset. Forced cooling takes approximately 60–90 seconds. This ensures that a fine pearlitic microstructure is achieved, re-imposing the superior hardness of the crown to be similar to the rest of the rail.

FINALISING

Behind the welding machine the rail joints have to be ground according to the rail profile, true to shape and line.

When the sides of the rails are welded out of alignment up to a maximum of 0,8 mm, the joint is ground back at a slant not steeper than 1:500 on the running edge of the rail and to 1:50 on the field side. Welded joints which are out of alignment in excess of 0,8 mm in the crown are rejected, cut out and re-welded.

To allow for temperature expansion and contraction of the rail, the rail must be de-stressed after welding. De-stressing is accomplished simply by replacing all sleeper fastenings whilst the rail temperature is within the de-stressing range as specified for that specific track section.

THE CHARACTERISTICS OF FLASH BUTT WELDING

Static bending (deflection)

Every 500 welds two 600 mm lengths of rail are welded together for a static bending test performed by the Spoornet metallurgical laboratory.

The rails usually fail clear of both the heat affected zone and the weld seam in the parent material confirming the higher strength of the weld. Fatigue tests done by Plasser & Theurer and the former British Rail showed similar failure results. Under cyclic load, the fatigue life of flash butt welds is generally greater than those of the parent material.

Metallurgical examinations

Plasserail requests metallurgical examinations of a weld at the start of a new welding site to ensure correct machine set-up and weld quality.

Spheroidised zone

The spheroidised zones are the two light gray areas which are visible on the extremities of the heat-affected zone. Spheroidisation develops when the steel remains at a temperature of around 700 °C for a long time. The lamellae of cementite in the pearlite become round. This area will therefore also be softer.

On the outskirts of the spheroidised zone the temperature was below 723 °C and austenisation did not take place. The parent material was therefore not altered.

The spheroidised zones of flash butt welds are normally between 4 mm and 8 mm.

The welding seam

In the middle of the heat-affected zone the welding seam is visible as a thin line. The high temperature on the welding seam has burned away the carbon in the steel so that it returns to a ferritic state. The welding seam is therefore softer than the rest of the heat-affected zone.

CONCLUSION

Each weld failure requires the broken weld to be cut out and the insertion of a closure rail, thus needing two more welds. However, failure of in-situ K355 APT welds as a percentage of the total number of welds are negligible. Therefore the high quality of these welds provides greater savings in the long term. With flash butt welding the narrow heat affected zone shows metallurgical characteristics greater in strength than the parent material. The quality of flash butt welding is therefore superior to any other

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