Standards struggle to keep up with the welders

Attempts to standardise welding processes in Europe are failing to keep up with changes in track technology and the natural evolution of thermite welding techniques, posing problems for rail producers and welders. **Dr-Ing Robert Gehrmann** and **Dr-Ing Jörg Keichel**, of Elektro-Thermit, outline these challenges.

ALUMINOTHERMIC welding, which provides a continuously welded rail, is a well-established process that has been deployed on railways around the world for decades. While the process looks old-fashioned when executed at track construction sites, the underlying technology has undergone continuous improvements to the extent that today a large range of welding processes exists for a variety of rail types, profiles and grades (pictured below).

In 2006 the European Standard EN 14730-1 was published, which changed the landscape for aluminothermic welding in Europe almost overnight. In addition to outlining the requirements for the mechanical properties of an aluminothermic weld, the ruling also called for the standardisation of the welding process for flat bottom rails. Consequently, this standard became a general measure of the properties of track welds regardless of boundary and regulatory conditions defined by railway authorities, established track working conditions and the rail producers' latest developments.

As a result welding processes had to be adapted to the changing boundary conditions while still satisfying the

Aluminothermic welding might look old fashioned but it is a process that has evolved over time and remains extremely effective.

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demands of EN 14730-1. However, with the standard issuing strict physical boundaries that cannot be easily avoided or overcome, it was no longer possible to easily transform the welding process to meet new conditions and evolutions in rail technology.

The issues that have arisen since the ruling are posing challenges to the rail producers and welding service providers, and are affecting the continuing development and application of the aluminothermic welding to meet changing track technologies.

The first of these issues is the increasing desire from railways to conduct track welding without the use of oxygen due to safety concerns and ergonomic issues with the use of cumbersome bottles at the trackside.

Oxygen and propane are the standard preheating method for aluminothermic welding because they offer preheating times of two minutes or less, while producing an excellent weld in combination with the heat energy of the thermite steel. In order to address these safety and ergonomic concerns some alternatives have been developed, although their performance remains in question.

Petrol-compressed air is one preheating method that has been shown to produce a good weld quality when used instead of oxygen or propane, and also offers a reasonable cost saving. However, the method is restricted by comparatively longer preheating times and there is not much of an ergonomic argument for replacing heavy gas bottles with a similarly heavy preheating device.

Another preheating method that does not require oxygen bottles is propane-air. Like the standard preheating method, this is quite easy to use and only requires propane. However, the absence of oxygen makes this preheating method very weak, meaning that the flame is not very powerful and the temperature reached at the rail ends during the preheating process is comparatively low. As a result to generate welds of high quality in these conditions the aluminothermic welding process must be highly developed and specially designed to compensate for the weak heat input.

While these welding processes are used, the robustness of the preheating process, and consequently the whole welding process, will suffer if it is deployed in restrictive conditions such as poor weather or in low rail temperatures. Nevertheless, as welds executed in the laboratory have shown, it is possible for these modifications to fulfil the demands of EN 14730-1. It is hoped that a new preheating process which uses propane and air might offer better results, with the injected air offering a more powerful and effective preheating method.

High-strength rails

The weld properties for break load and deflection are more critical when welding high-strength rails as long as the standard requirements, or those offered by the railway authority, remain consistent. If a certain deflection has to be reached, it can limit the aluminothermic welding process.

It is generally understood that materials with increasing hardness and strength show a decreasing ductility and a capacity for a plastic deformation. With respect to the properties of an aluminothermic weld this means that the measured deflection during a three-point bending test will typically decrease when the rail steel strength increases. As a result, with the hardness of the thermite steel adjusted according to the hardness of the rail, there is little chance of achieving the same test results for the complete range of steel grades.

This means that requirements for the properties of aluminothermic welds will differ depending on specific steel grades. However, it is difficult to adjust these standards, and changes to these requirements arise only when new high-strength steels are available in the market for a certain period. Indeed only the experience gained from installing these new steel grades in track under realistic conditions will identify the requirements for a specific aluminothermic weld standard.

But with railway authorities responsible for track safety, they are presumed to favour the highest minimum requirements as long as there is no proof given that another lower requirement is sufficient. As a result contractors providing aluminothermic welding services are facing significant challenges to offer both a suitable weld and to meet these requirements.

For example certified welding processes used for new high-strength rails that have certain minimum requirements will become more and more difficult to carry out without the development of new technologies to simplify this process. Indeed certification of welding processes for new high strength rails might be hindered if there is no clear evidence about the weld properties, and if railway authorities fail to understand that it is not possible to transfer the fixed requirements for standard rail grades to new high-strength rails. Moreover, railway authorities should provide clear statements outlining their realistic expectations for the performance of thermite track welds.

One particular development that is proving problematic to the certification process is the current focus of rail producers on bainitic steel grades which offer the benefits of harder wearing rails. Yet with no regulation in any European standard of bainitic rails and their properties, there are currently no set rules for aluminothermic welding for these new rails.

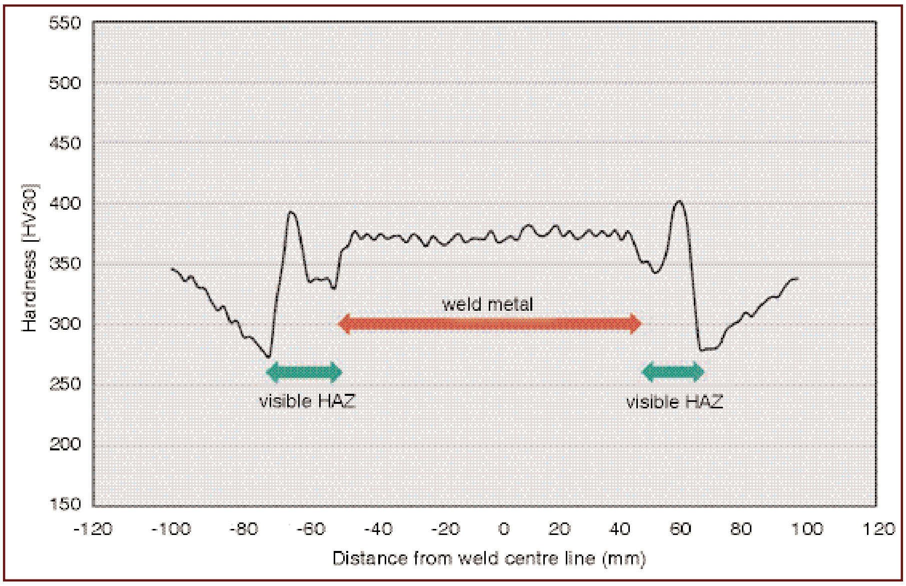

Figure 1: example of hardness profile of bainitic rail steel thermite portion measured 5mm below running surface.

Welding grooved rails for light rail applications has proved challenging with no European Standard yet established for this process.

The underlying problem with developing a standard is that at present various production methods and different alloying concepts are used to produce bainitic rails. As a result when welding a bainitic rail the microstructure in the heat affected zone (HAZ) will be affected by the heat generated by the thermite steel differently depending on the type of bainite used. Indeed the welding process is either executed without any consideration, or the cooling rate in the HAZ is decelerated or even accelerated in order to achieve the desired microstructure and corresponding mechanical properties in the HAZ.

Inevitably this makes it almost impossible to identify 'the one' welding procedure that fits all bainitic rail types and it is very likely that a differentiation will be necessary in future, requiring welding companies to undertake comprehensive training of how to effectively handle the various bainitic rail steels available in the market.

A second problem that arises in welding bainitic rail grades is an unsatisfactory fatigue strength, which has been shown in laboratory tests. Figure 1 shows an example of a hardness profile of a bainitic aluminothermic weld. An extraordinary constant hardness level within the weld metal is achievable and the weld shows no obvious irregularities. However, the expected fatigue strength is still not as good as standard pearlitic rail grades and the HAZ is visible without any specific treatment. As a result this phenomenon must be overcome for successful certification and market launch.

Grooved rails

Despite the fact that welding grooved rails is based on the same technology as welding flat bottom rails, there is no specific European Standard for this process with the regulations for flat bottom rails simply expanded to include grooved rails. However, on some light rail lines where grooved rails are deployed, the welds have been shown to be dipping despite their execution according to the code of practice (pictured above).

At present this phenomenon is not completely understood, although a possible explanation given is that the yield strength of the weld metal is too low compared with the yield strength of the adjacent rail steel. This would explain an earlier plastic deformation of the weld on the running surface under load conditions.

However, this effect is not a general phenomenon, which makes it very difficult to identify the root cause. Indeed in instances where the weld shows no defects the thermite weld may have the desired hardness.

Nevertheless, for certain rail profiles an undesired dipping of the welds starts after a certain time in track. Raising the hardness of the weld can diminish this effect, but it may not address other problems such as the condition of the superstructure, and the effect of the wheels and the passing load. At present it is not possible to quantify this contribution. But with tramways and light rail networks requiring a complete and even track to reduce undesirable noise and vibrations, investigations are underway to reach an understanding of the phenomenon and the required counter measures.

Aluminothermic welding might appear to be an old-fashioned process, but it is neither out-of-date nor is the welding technology inadequate for the current range of applications. On the contrary, aluminothermic welding is a reliable and highly-dependable technology. Nevertheless challenges remain for both rail producers and the providers of welding technology, and while great efforts are being made to master these challenges, only a combined understanding of them will produce successful solutions. **IRJ**