TECHNOLOGY OF RESURFACING MN-STEELS USED TO MANUFACTURE RAILS

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The track components that are the most heavily loaded from the axles of train units are the switch components and rail crossing parts. These parts can be refurbished by welding on suitable types of additional materials. Parts made of high-alloyed Mn-steel (Hadfield steels) need to meet specific conditions for their welding. For the experiment, ESAB OK Tubrodur 14.71 and ESAB OK Tubrodur 15.65 materials were used. The results show the feasibility of appropriate procedures under specific conditions due to the occurrence of metallurgical defects affecting the safety of operation on railway and tram lines. The aim of the experiment was to perform and assess the properties of two types of austenitic welds of different chemical composition on the rail head and rail grooves with the same welding parameters.

KEYWORDS

Manganese Steel, Hadfield Steels, Rails, Welding, Weld Deposit, Resurfacing, Microstructure

1 INTRODUCTION

Hadfield steel belongs to the group of austenitic manganese steels. The name of the steel is derived from the name of its creator R. A. Hadfield. For its specific properties, it is used in various fields of engineering. If sufficiently large shocks or pressures act on the surface of this steel, it is strengthened. The high hardness of the surface layers will then increase the resistance to abrasive wear, but the core of the component retains good strength. This steel is also used in the field of railway transport for the extremely stressed parts of the track superstructures, especially in the track crossing section, produced as cast monoblocks. Although the service life of these parts is significantly higher than that of traditional high-carbon steel, it also wears out [Dahl 1995], [Fucheng 2007].

The presented paper deals with the issue of welding frogs from MB steels on cast monoblocks using two types of austenitic welds [Jasenak 2005].

2 ANALYSIS OF THE ISSUE

Metallurgical processes provided at higher temperatures affect the weldability of austenitic manganese steels. The integrity of the authentic structure, even at the usual room temperature, is ensured by the austenite-forming alloying elements manganese and nickel, which reduce the temperature of martensitic transformation. Tab. 1 shows the chemical composition of the Hadfield steel used for the production of monoblocks.

The relatively high carbon content affects the required wear resistance. When increasing the content of this element in the steel, the resistance to abrasive wear increases. The carbon content results in a greater tendency to crack, and, at the same time, it promotes the excretion of more carbides along the boundaries of grains. Manganese improves the plastic properties of steel at the contents from 11 to 14 %. Another alloying element is chromium (up to about 1 %), which slightly increases the yield strength. However, it is necessary to take into consideration the formation of chromium carbides along the boundaries of austenitic grains, which reduce plastic properties. Chromium carbides can be dissolved in austenite at temperatures of 1,150 °C [Hrivnak 1989].

C	Mn	Cr	Si	P	S
(mass %)					
1.0-1.5	11.5-14.5	0.7-1.2	max. 1.0	max. 0.1	max. 0.05

Table 1. Chemical composition of Hadfield steel [Benes 1999]

The heat treatment of austenitic manganese steel is focused on dissolving annealing

(1,030 to 1,080 °C). During this heat treatment, we dissolve the double cementite, which is present after casting in the matrix of this steel and with the subsequent rapid cooling in water from a temperature of 1,050 °C, its separation is prevented. Mechanical properties and wear resistance depend on the size of the grains. By using steels with a fine-grained structure, not only its wear resistance increases, maintaining an extraordinary yield strength even with temperatures below -70 °C, but they also have better tensile strength [Sabzi 2019].

Austenitic manganese steel has the ability to strengthen rapid cold deformation if sufficiently high pressure or impact is used. During the plastic deformation of austenitic manganese steel, there is a movement of dislocations, in which new layered errors and twin lamellas are formed, see Fig. 1 [Schmidova 2016], [Benes 2001].

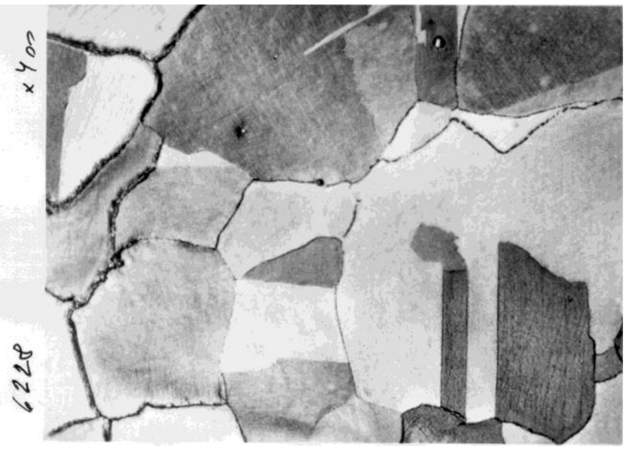

Figure 2. Occurrence of twin lamellas in the base material (400x) [Benes 2001]

The actual welding of austenitic manganese steel is always carried out without preheating with minimal heat input, so as not to anneal the heat-affected zone with the subsequent precipitation of the carbide phase. The Interpass temperature, max. 100 °C, is also important. In the case of a higher heat input,area the structure may break down due to intercrystalline cracks (Fig. 2), which can rise to the surface of the component in its pores (Fig. 3) [Hrivnak 1989], [Benes 2001].

For the above-mentioned reason, the use of so-called "cold" welding can be recommended as it is possible to check that the ambient temperature of the weld does not exceed 300 °C. It is welding and cladding with minimal heat input, and with an immediate cooling of the part after its welding. If the temperature is exceeded, it is necessary to interrupt the process of welding until the weld cools down, and subsequently inspect this weld surface [Mendez 2004], [Zorc 2013].

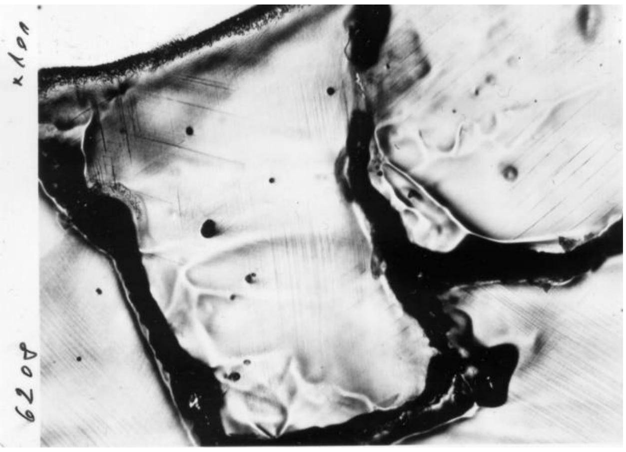

Figure 2. Microstructure of the base material below the limit of sample melting (100x) [Schmidova 2016]

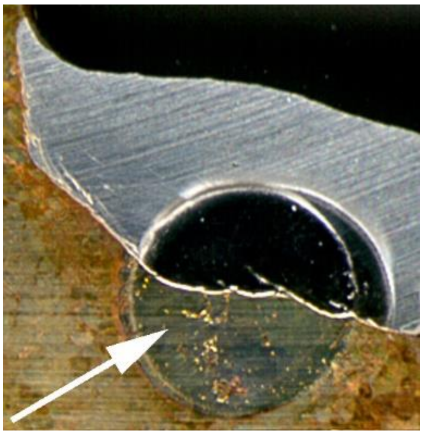

Figure 3. Detail of a pore with intercrystalline cracks (indicated by the arrow) on sample A (20x) [Benes 2001]

3 EXPERIMENT AND DISCUSSION ON THE RESULTS OBTAINED

The experiment itself builds on the results of the research presented in the publication [Benes 2001] when the heat introduced during cladding was from 8.97 $kJ.cm^{-1}$ to 10.38 $kJ.cm^{-1}$. Welded clads of samples C and D were made on a cast monoblock with wear of the welded surface reaching approx. 4 mm. In Tab. 2, the chemical composition of the monoblock is listed. To weld samples C and D, filled electrodes ESAB OK Tubrodur 14.71 (sample C) and ESAB OK Tubrodur 15.65 (sample D) were used following Tab. 3. The same welding parameters were used for both samples: welding current $I \approx 220$ A, welding voltage $U = 30$ V, welding speed $v = 34$ $cm.min^{-1}$). An ESAB LAF 1001 automatic machine (SAW) and ESAB A2 welding head were used for welding.

	C	Mn	Cr	Si	Ni	Mo	V	P	S
	(mass %)								
Sample C and D	1.16	12.62	0.19	0.86	0.06	0.01	-	0.028	0.010
OK Tubrodur 14.71	0.04	6.00	19.00	0.50	8.00	-	-	-	-
OK Tubrodur 15.65	0.30	14.00	16.00	0.55	1.70	0.80	0.60	-	-

Table 2. Chemical composition of basic and additional materials

Sample number Additional mat.	Input heat Q [$kJ.cm^{-1}$]	Welding conditions
C ESAB OK Tubrodur 14.71	10.38	Without preheating, Interpass 100°C Weld made on the rail head and in the groove
D ESAB OK Tubrodur 15.65	10.38	Without preheating, Interpass 100°C Weld made on the rail head and in the groove

Table 3. Identification of the samples used

The main objective was to assess the influence of higher heat input – degradation by welding using a filled electrode for austenitic manganese steel.

The samples were assessed using a metallographic evaluation of the weld HAZ, as was the base material, by evaluating the hardness values through the weld into the base material and assessing the hardness values in the areas with martensite, bainite and carbidic phases.

In the macro structural image of the sample C (Fig. 4), there is displayed the pore that was monitored. A similar pore is shown in Fig. 5, containing visible transversal cracks in the base material (Fig. 9). No cracks were observed in other areas.

Figure 4. Macrostructure of sample C with the pore

Figure 5. Macrostructure of sample C with the pore and cracks

In the image of sample D (Fig. 6), a pore in the weld was observed.

Figure 6. Macrostructure of sample D

From a microstructural point of view, in both samples, dark zones on the austenitic matrix caused by the carburization of the base material weld can be observed in the weld of the upper surface of the rail head in the area of the melting zone boundary [Mendez 2004]. The measured microhardness in these zones reaches values of up to 445 HV0.1 confirming the occurrence of finely tempered martensite (Fig. 7).

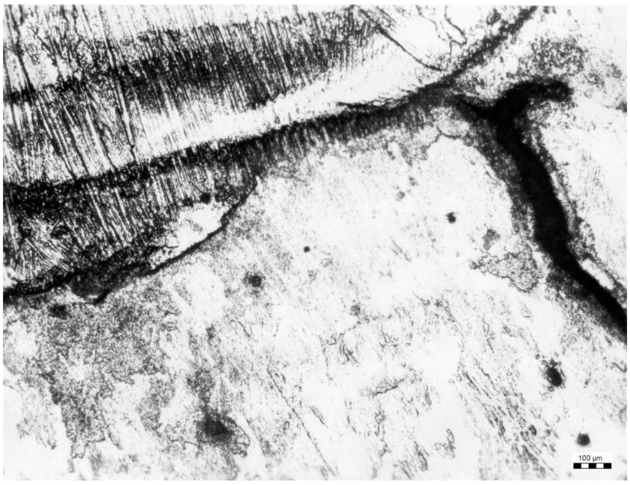

Figure 7. Microstructure of the weld deposit in sample C with a crack (on the right)

The microstructure of the weld boundary of the weld in the rail groove of both samples shows a characteristic austenitic weld with visible austenitic grain boundaries, coarsened the continuous exclusion of carbides at their boundaries (Fig. 8).

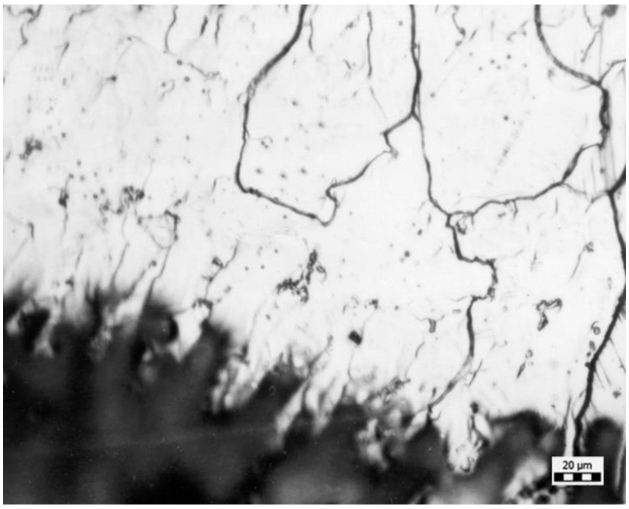

Figure 8. Microstructure of the weld deposit for a groove in sample D

To complete the evaluation of the individual areas, the hardness values were measured through the weld into the base material for both samples by 1 mm, see Fig. 9. Hardness values correspond to the properties of non-strengthen austenitic base material and austenitic clad (Fig. 10). The increased hardness of sample D is due to the additive material OK Tubrodur 15.65 with a higher manganese content (Tab. 2).

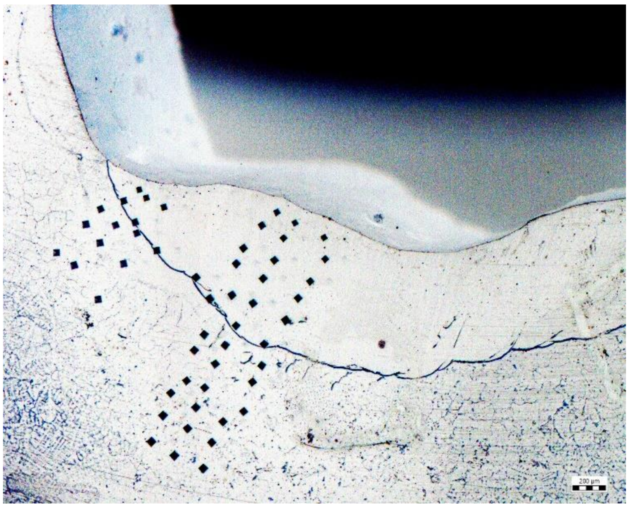

Figure 9. Method of hardness measurement done on sample D (a non-etched state with visible cracks)

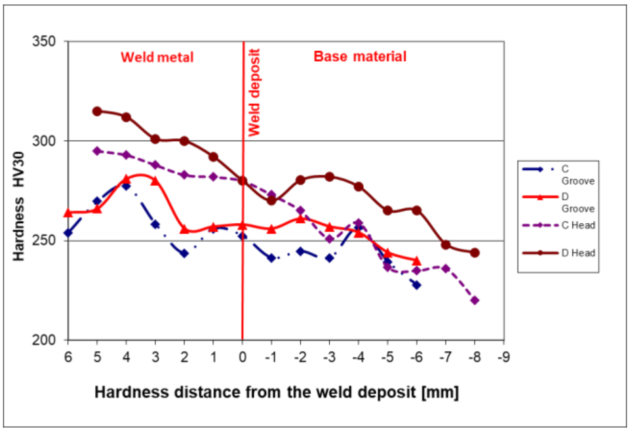

Figure 10. Hardness values depending on the distance from the weld deposit of samples C and D

4 CONCLUSION

One of the options to extend the service life of components is to weld clads on the worn parts of the railway track superstructure. However, this surface welding has certain limitations for the process of welding. It is necessary to bear in mind that defects on the railway track superstructure are closely related to the safety of the transport of passengers. When welding Hadfield-type steels (austenitic manganese steels), the welded monoblocks can be irreversibly damaged by several parameters.

The results obtained in the experiment can be summarized as follows:

- When welding austenitic manganese steel, it is always necessary to use the minimum welding parameters, in this case using a filled electrode smaller than 9 $kJ.cm^{-1}$. A value of 9 $kJ.cm^{-1}$ is recommended with a margin in accordance with other experiments conducted in the past [Jinpo 2002]. Even in this case, it is necessary to observe the inter-base temperature (Interpass temperature) up to 100 °C, regardless of the recommendations from the literature [Benes 1999] max. 300°C.
- If the Interpass temperature is not observed, intercrystalline cracks (Fig. 3 and Fig. 7) in the base material (HAZ) may occur due to an increase in the

cooling time for the austenitic matrix, from which carbon in the form of carbides is separated from the austenitic grains and thus the matrix is embrittled. At the same time, differences in hardness values HV10 can be observed (Fig. 9 and Fig. 10). In the base material, measured values below 240 HV10 can be observed. At the melting boundary, the values of the C and D samples were unified at the grooves of both samples and at the weld-on points on the heads of samples C and D in the areas of the melting boundaries. In the groove areas the values are about 255 HV10 and at the weld-on of the heads of both samples about 270 HV10. The difference in the measured values of the rail head and rail groove in the two samples can be attributed to the heat dissipation. A weld-on rail head cools faster than a weld-on in a rail groove. It is a spatially closed weld-on in the groove and it can therefore be stated that the heat dissipation is slower. The increasing hardness of the overlay of sample D is already influenced by the chemical composition of the consumant material OK Tubrodur 15.65 with a high manganese content (mass. 14%) and reaches values of about 316 HV10. For sample C, an authentic filler material OK Tubrodur 14.71 with nickel content (cca mass 8%) with a resulting hardness of overlay of about 296 HV10 was used.

- No cracks (only pores) were observed in the welds due to the lower carbon content compared to the carbon content in the base material. The difference in the carbon content of the base material and the weld metal (the so-called concentration gradient) results in the formation of dark zones in the weld above the weld deposit containing a fine martensitic structure, in which the crumbling of welds may occur. The overlay in the first layer is created by mixing the melted base material (≈ 20% weld deposit) and the melted filler material into the total volume of 100% of the overlay. This weld metal has an effect on the resulting properties of the weld.
- When welding clads on the worn parts, it is necessary to remove a layer from the surface of switches and crossings that is hardened by the operation, in which cracks may occur. Then, it is essential to provide a capillary test before the proper welding.

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