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Study into the process of defective railtrack arc-hardfacing

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Abstract. The paper focuses exclusively on the manual arc hardfaced layers of railtrack repairing. The study is conducted in two stages- structural analysis of layers and mechanical characteristic(hardness) study. Two types of technologies for defective areas rebuilding are developed. The first one is hardfacing without a buffer layer, and the second one is with a buffer layer. The process is carried out using electrodes particularly appropriate for this purpose, namely OK 83.28 and OK 67.45, and is designed to achieve the original hardness of the railtrack. All in all, the desired hardness value and magnitude can be achieved by hardfacing the defective areas without a buffer layer, and with the use of OK 63.28 electrodes.

Keywords: railway, deep water, towing tank, carriage, arc deposition, microstructure

1 Introduction.

Deposition, also known as hardfacing, is a widely used process for extending the lifespan of metal constructions and elements. This process is particularly applicable in heavy industries where the cost of new elements or products is high.

In (Mortazavian,2022) the hardness and microstructure of worn repaired rails were examined using laser powder deposition. Prior to deposition, the hardness of the rails was 85 HRB, but after deposition, it significantly increased to 103 HRB.

The effect of laser cladding on the improved wear of rails is studied in (Seo, Kim 2019). To that effect, the authors evaluated three types of laser cladding- Stellite 21, Inconel 625 and Hastelloy-C and found that Stellite 21 had the best wear characteristics despite the lower hardness, while the other two types were more suitable for both wear and rolling contact fatigue.

Ways for increasing the brittle-fracture resistance of the metal in the heat-affected zone formed as a result of repair surfacing of the rolling surface of railroad wheels were fully examined by (Ostash, O.P.,Kulyk, V.V.,2020). They studied the influence of various heat treatment modes, including the traditional and modified Q-n-P-treatments, on the mechanical properties of 65G steel regarded as a model wheel steel. Their investigation showed that, after the modified Q-n-P-treatment, the mechanical characteristics of steel increased to a greater extent than after the traditional treatment.

The fracture of railtrack steel under cyclic loading of beam specimens with lateral cracks is thoroughly explored in (Lenkovs'kyi, T. M,2015), and determined experimentally is the friction coefficient of crack faces for specimens made of steel with troostite structure, in addition to the accurately plotted kinetic diagrams of fatigue fracture. Established, further, in the study is the influence of the crack test on the cyclical loading for troostite and sorbite structures, depending on the growth rate of fatigue cracks.

Hardening of railtracks steel through electrolyte-plasma surface treatment, conducted in a solution of 20% sodium carbonate, in a mode similar to 850°C for 2 seconds, and 1200° C for 3 seconds is found to significantly increase the hardness of the steel. Prior to hardening, the railracks steel consisted of pearlite and cement structure, but after treatment, the structure of the same steel was found to consist of carbide particles and martensite phase components. The hardness of the steel increased by 1.3 times for the 2s-treatment span (Rakhadilov, B.V.,2016).

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By implementing the results of the research into the influence of heat treatment of 65G steel, simulating the thermal and deformation cycle of reconstruction welding of railway wheels, it becomes apparent that the resistance to brittle fracture of the wheel metal in its heat-affected zone can be increased to the level of the base metal by forming a bainite-martensite structure in this zone and holding it for 2-3 h at 100°C in the course of its cooling after welding. Accordingly, the plasticity of the metal, its impact toughness, fatigue threshold of cracked specimens, and cyclic fracture toughness increased by 1.8, 2-3, 1.6, and 1.8 times respectively, while the strength remains almost constant. This is due to the fact that the stresses of the second kind and local strains in the bulk of bainite and martensite strips become 1.5 times lower (Haivorons'kyi 2016).

Deposition processes can be divided into five groups (Afrox Product Reference Manual):

- Arc methods;
- Arc and gas methods;
- Gas methods;
- Powder spraying methods;
- Laser methods;

Although, these methods are altogether used in heavy industry and partly in shipbuilding and ship repairing, some of them require special equipment and operator skills. It should be noted, though, that the most widespread method is the arc method.

The primary purpose of the present paper is to explore the hardness, macro and microstructural analysis of the hardfaced layer of railtrack.

2 Problem description.

The paper addresses the technological challenges associated with defects in hardfacing on towing carriage railtrack in deep water towing tank. The railtrack is 200m in length and is comprised of thermal welded separate parts, each measuring 10m in length and a cross-section as depicted in Fig.1.

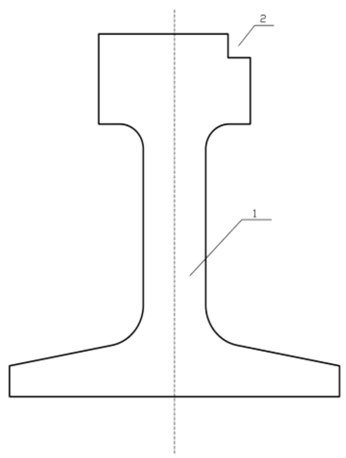

Fig. 1. Transverse railway section- 1- railway profile, 2- defects

Due to incorrect welding techniques and inappropriate welding parameters, angular deformation in the railtrack is likely to occur, as illustrated in Fig2.

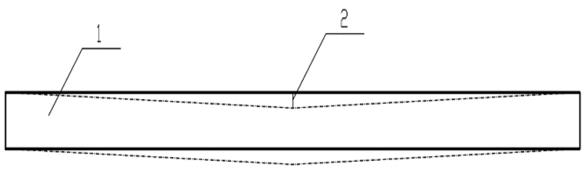

Fig. 2. Angular deformation of railway

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Deviations from the straight line (number 2 in Fig.2) along the railtrack range between 0.3-3.5mm. As a result of carriage movement and height deformation value, shock loads on the railway in welded areas have emerged (Welding Alloyed Group,2018). The number and magnitude of defects are directly proportional to the deviation magnitude.

The maximum allowable speed of the carriage ahead and astern is 6m/s, with the carriage wheel arrangement being shown in Fig. 3 and specific rail track defects depicted in Fig. 4.

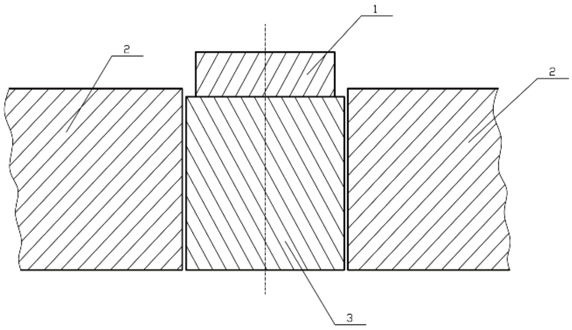

Fig. 3. Arrangement of carriage wheel

Fig. 4. Rail track specific defects

The repaired areas after the hardfaced process are shown in Fig.5.

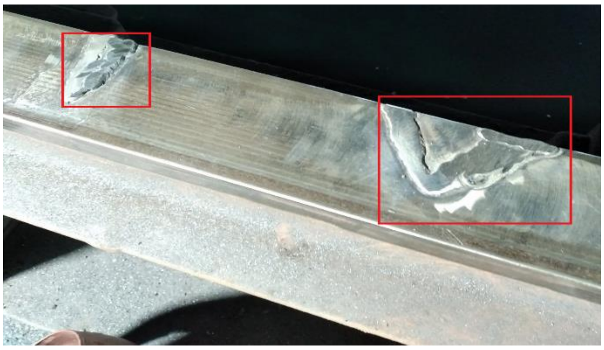

Fig. 5. Depositional areas of carriage railway

Subsequent to the process of hardfacing, abrasive treatment and grinding are necessary to achieve nominal railway dimensions, as shown in Fig.6.

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Fig. 6. Abrasive treatment of deposition areas

3 Selection of deposition materials

The principal objective of the present paper is to develop technological processes for hard facing defective rail track areas of towing carriage railways in deep water towing tanks. The chemical composition of the main metal is reported in Table.1

Table 1. Chemical composition (Peev,2021)

Chemical element	C	Si	Mn	P	S	Cr	Ni	Al	Co	Cu	N
Value, %	0,72	0,17	0,93	0,02	0,03	0,03	0,1	0,02	0,02	0,02	0,01

The main metal hardness is HV5= 256 and the carbon equivalent, according to (Бельчук1971) is 0.89%.

$$Ceq = C,\% + \frac{P}{2}\% + \frac{Mo}{4}\% + \frac{(Cr+V)}{5}\% + \frac{Mn}{6}\% + \frac{Ni}{15}\%, [\%] \quad (1)$$

The steel with 0.89% Ceq is a hardening steel that requires preheating.

The heated temperature is calculated according to Seferian formula (Serefian, 1992):

$$T_0 = 350\sqrt{(C'_{eq} - 0.25)}, °C \qquad (2)$$

where:

$$C'_{eq} = C_{eq} * (1 + 0.005 * t) \quad (3)$$

The railway thickness is 40mm and as stated by the Seferian formula, the heated temperature should be approximately 316°C. This temperature is specific to highly quenched steels.

According to thermokinetic diagrams, a hardness value of HV30= 250-270 in the heat- affected zone for this type of steel corresponds to a cooling speed of ≤5°C/s. The heat affected zone structure is around 3%F and 97%P.

The first hardfaced technology process in defected areas utilizes basic electrodes of the OK 83.28 ESAB type, which are alloyed with Cr, Mn and Si, and are applied to defected areas using AC/DC current. The chemical composition is detailed in Table2.

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Table 2. Chemical composion of electrodes OK 83.28 ESAB

Chemical elements	C	Si	Mn	Cr
Chemical composition,%	0,1	0,7	0,7	3,2

The second technology refers to the hard facing of main metal with OK 83.28 electrodes and involves the application of a buffer layer using OK 67.45 electrodes. The chemical composition of the buffer (middle) layer electrodes is shown in Table 3, while Table 4 describes their mechanical properties.

Table 3. Chemical composition of OK 67.45(ESAB,2001; ESAB)

Chemical elements	C	Si	Mn	Cr	Ni
Chemical composition,%	0,1	0,5	6.0	18.5	8.5

Table **4.** Mechanical characteristics of welded metal

Type of electrode		Characteristic			
		Rm, MPa	Re, Mpa	A, %	WRC FN
1	OK 67.45	620	430	40	<5

4 Hardfaced layer mechanical characteristics.

The hardness achieved in a single layer of hardfacing using OK 83.28 electrodes without advance heating is illustrated in Fig.7. The hardfacing parameters without a buffer layer are: welding current of 80A, electrodes diameter de=2,5mm and voltage=65V.

The heat-affected zone hardness is about 340-380 units, while the fusion limit hardness is 410-412 units. These values correspond to a cooling speed of about 5°C/s, as indicated by the thermokinetic diagrams.

The hardness distribution of the buffer layer hard faced with OK 67.45 electrodes and the hard faced layer with OK 83.28 is displayed in Fig.8. The hardfacing parameters for the buffer layer are: OK 83.28type of electrodes, a welding current of 80A, electrode diameter de=2,5mm and voltage=65V. For the second layer (hadrfacing metal) OK67.45 electrodes, a welding current of 80A, electrode diameter de=3,0 mm and voltage=65V.

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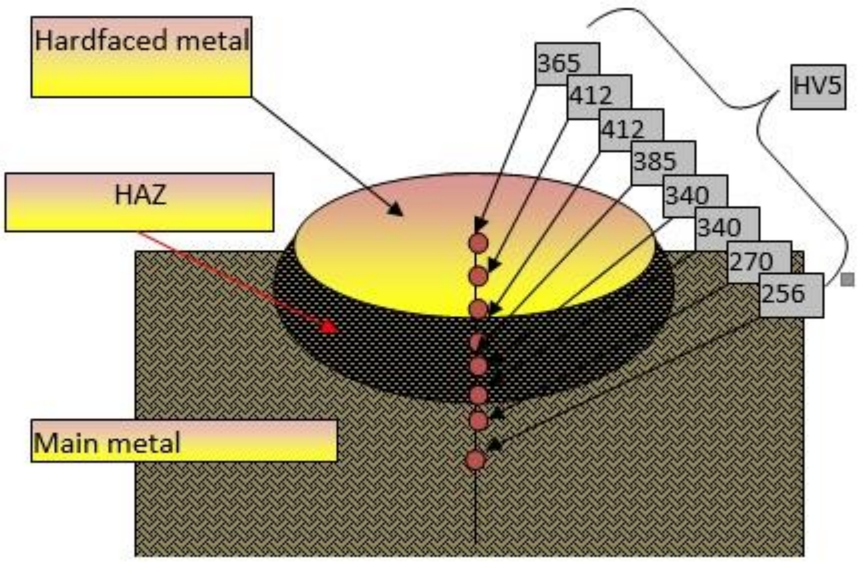

Fig. 7. Hardness of deposition layers without middle layer

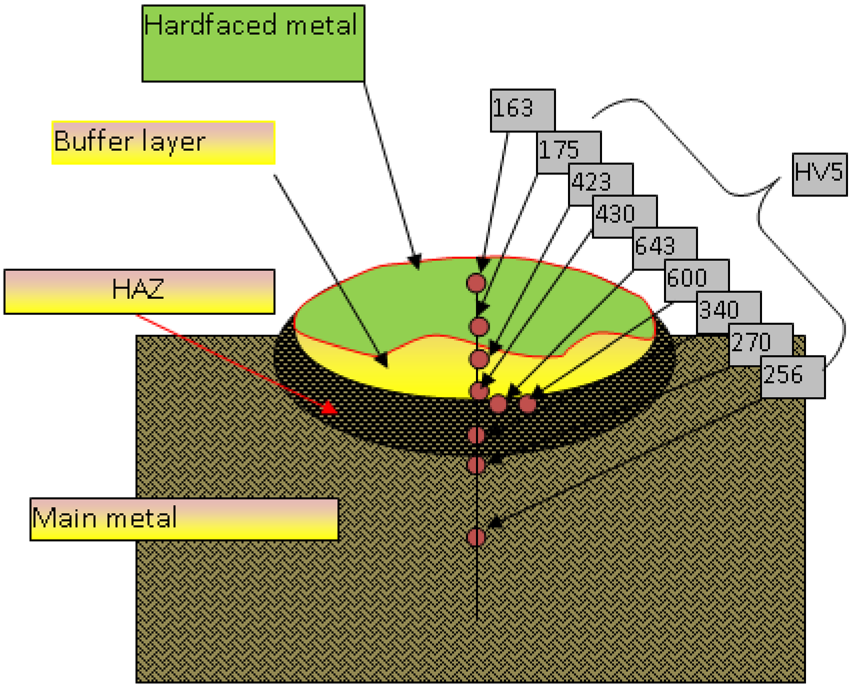

Fig. 8. Hardness with middle layer

The buffer layer hardness ranges from 420-430 HV5 which is relatively higher than that of the main metal. The fusion limit of the main metal hardness HV5 is normally between 600-650 units, which pursuant to the thermokinetic diagrams, corresponds to 5-10% P and unbalanced structures. The cover

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layer (hardfaced layer with OK 83.28) has a hardness HV5 of 160-180 units. When it comes to railway repair, it is recommended to use OK 83.28 electrodes without a middle layer.

5 Macro structural and micro structural analysis.

Macro structural analysis shows that the hardfaced metal is well-formed, as seen in Fig.9 and Fig. 10. There are no defects found in the alloying limit and heat affected zone (HAZ), Fig.10. However, in the depositional metal area hardfaced with OK 83.28, a pore has emerged, which has a random character and small dimensions. The microstructural analysis of deposition with a buffer(middle) layer is pictured in Fig.11.

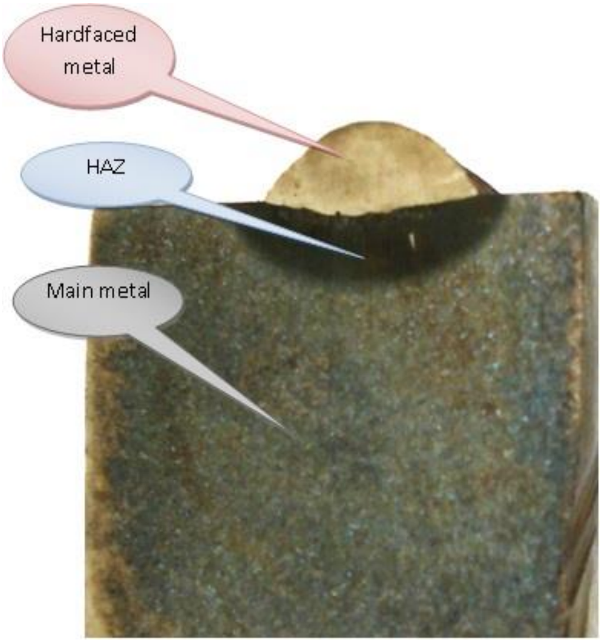

Fig.9. Depositional area without buffer layer

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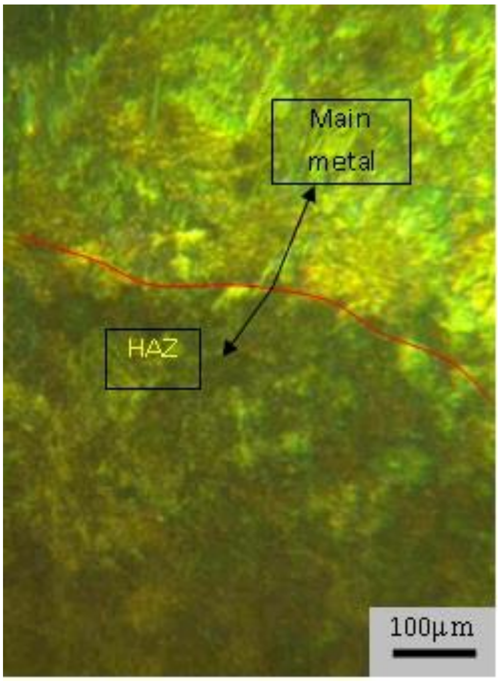

Fig. 10. HAZ microstructure in alloying limit

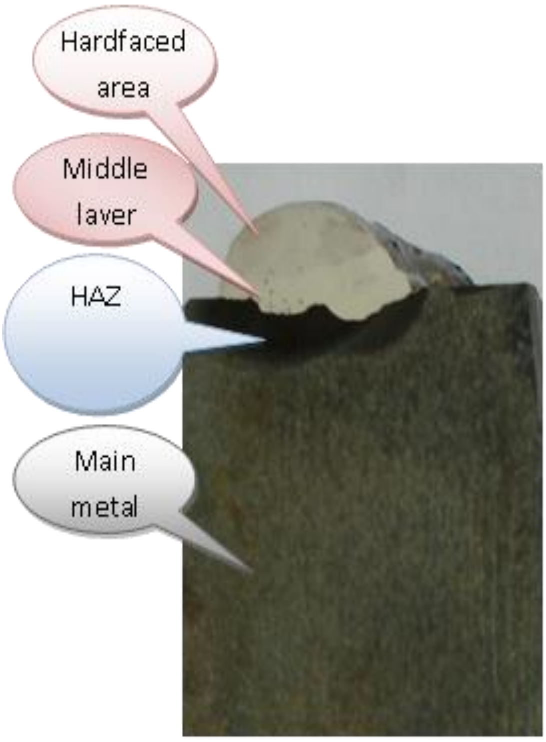

Fig. 11. Microstructure of deposition metal with a buffer layer

Represented in Fig.12 and Fig13. are micro-structural analyses of the deposition metal, the main metal and the heat-affected zone.

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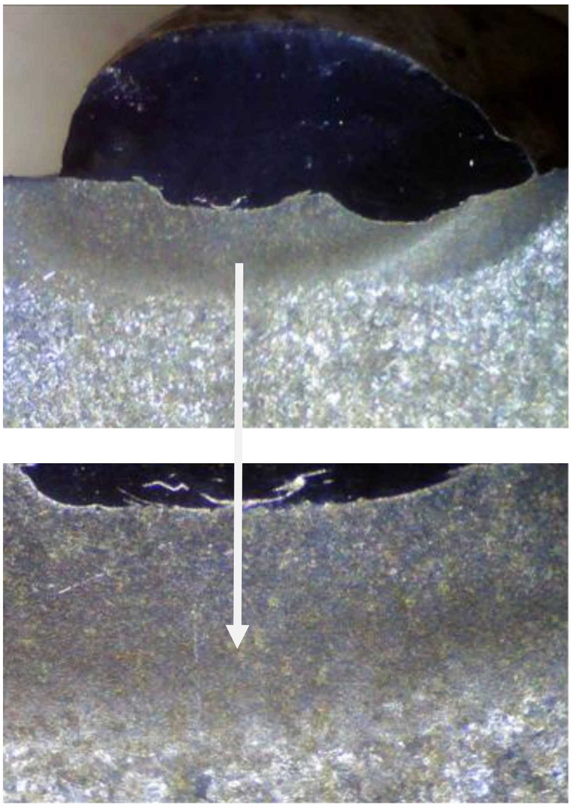

Fig. 12. Microstructure of depositional single layer welded seam in the main metal area

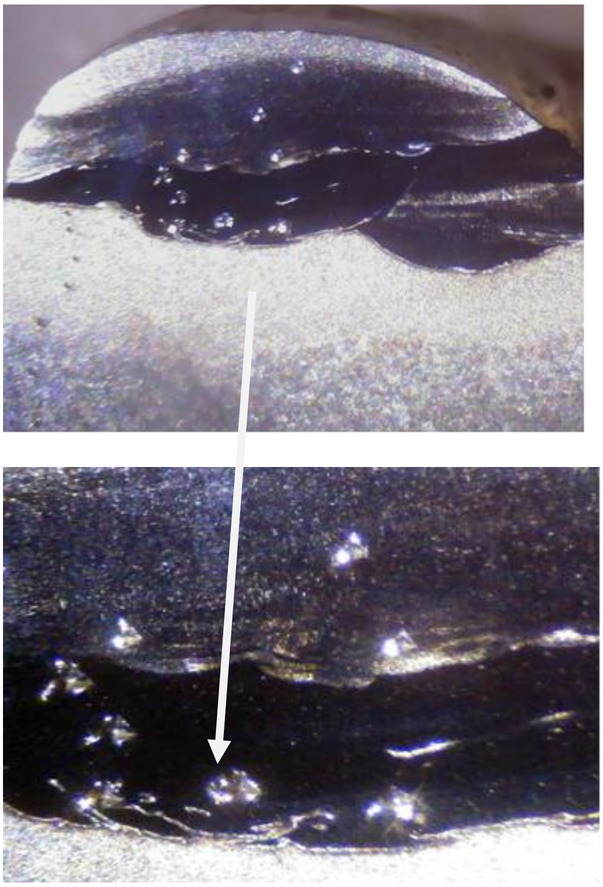

Fig. 13. Microstructure of depositional single layer welded seam at HAZ

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6 Conclusions.

Deposition of towing carriage railway in deep water towing tank is a complex and responsible process. Proper deposition process and material selection are the main elements for achieving the desired outcome.

The hardness of HAZ in deposition without a buffer layer is about 340-380 units, while in the deposited metal, it is 360-400 units. These hardness values were achieved by using OK 83.28 electrodes.

The HAZ hardness in deposition with a buffer layer is 270-340 units, while in the buffer layer and fusion limit, the hardness is about 600 units by using OK 67.45, and in the deposition layer, it is 160-180 units by applying OK 83.28. These hardness values correspond to lower hardness, which is not due to cooling temperature but rather to the characteristics of the electrodes and their mixing with the main metal. The cooling temperature is generally calculated for the hardfaced area.

In such a case, considering the relevant operating conditions, it is preferable to hardface without a buffer layer.

Our future research endeavours will concentrate on an in-depth analysis of the hardfaced layers with preheating of the main metal.

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