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IMPROVEMENT OF THE SURFACING TECHNOLOGY FOR LARGE-SIZED BACKUP ROLLS OF HOT ROLLING MILLS

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It is shown that when surfacing large-sized backup rolls of hot rolling mills made of 90KhF steel, the limited weldability of steel leads to the need to select the thermal mode of surfacing that ensures the required performance of the deposited layer. The choice of materials and technology of deposition of the transition zone from the base metal to the working layer determines appearance of hardness dips and formation of a «soft interlayer», which leads to occurrence of spalling. Elimination of such dips depends on the choice of the deposition mode of each of the layers, in accordance with the composition and size of the electrodes used. It is shown that application of 1.0 mm thick 08kp, 30KhGSA, 25Kh5FMS strip electrode for surfacing makes it possible to obtain a smooth (without dips and bursts) change in hardness by the height of the multilayer composition, which contributes to an increase in spalling resistance when the height of the deposited layer decreases during the operation of the roll. The high efficiency of the surfaced backup rolls was confirmed during industrial development of the surfacing technology of the rolls and their long-term operation in the hot rolling mill. The developed and implemented route scheme for movement of the deposited and new backup rolls (the share of deposited rolls reached 30 %) in the roughing group of stands of mill 2000 of the Cherepovets Metallurgical Plant made it possible to ensure the operating time of surfaced rolls commensurate with that of new rolls as to the tonnage of rolled products. 12 Ref., 4 Tables, 2 Figures.

Keywords: backup rolls, 90KhF steel, surfacing, underlayer, transition zone, composition of layers, hardness, spalling of the surfaced layer, strip electrode, surfacing mode, hot rolling mill, roughing stand, roll route, operating time of surfaced rolls

When developing the surfacing technology for large-sized forming rolls with barrel diameter of 800–1600 mm and 1500–4500 mm length, it should be taken into account that the extent of wear may require deposition of not less than 12–15 layers [1–6]. The zone of transition from the roll material to the working layer should form in the first deposited layers of such a composition. The correspondence of mechanical properties of this zone to applied loads and its cracking resistance depend on the structure and properties of the near-weld zone of the HAZ, chemical composition of the deposited metal that forms the transition zone, absence of hardness dips and peaks here [7]. Therefore, the task of selection of materials and technology of deposition of the zone of transition from the base metal to the working layer is regarded as one of the main problems, as performance of the surfaced backup rolls largely depends on it.

In the thermal mode of deposition of large-sized backup rolls from high-carbon steel, selection of preheating temperature has the most important role, which it is rational to consider for several roll steels: 40Kh (40KhN), 55Kh (55KhNM) and 90KhF which differ by carbon content and weldability (cracking susceptibility). In order to lower the cracking susceptibility of the roll, thermal mode of surfacing is used which reduces the probability of formation of hardening structures in the HAZ metal, and surfacing materials are applied, which allow increasing the metal ductility, lowering diffusible hydrogen concentration and level of residual tensile stresses. Proceeding from cold cracking susceptibility, carbon equivalent C_c is a characteristic used for assessment of weldability [8]. Mathematical description of this value is proposed, with consideration of the minimum critical time of weld metal cooling, dependent on the cooling rate and required for a complete martensite transformation:

$$C_e = C + (Mn + Si)/6 + (Cr + Mo + V + W)/5 + + (Ni + Cu)/15.$$

Results of calculation of carbon equivalent values by the dependence proposed by IIW, are given in Table 1.

Long-time process of concurrent heating results in thermal equilibrium of the roll being surfaced, and its cooling rate becomes considerably lower than the critical value. For forming rolls, the concurrent heating temperature is selected significantly higher than that of martensite transformation M_s (see Table 1). For 90KhF steel having a high stability of overcooled

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Table 1. Carbon equivalent of roll steels

Steel grade	Carbon content, %	Carbon equivalent C_c	Temperature of martensite transformation M_s, °C	Critical cooling time Δt_m, s*
40Kh	0.36–0.44	0.74	280	–
50KhNM	0.50–0.60	0.98	260	2000
90KhF	0.80–0.90	1.35	240	–

*By calculated data of [8].

austenite, the concurrent heating temperature of 380–400 °C provides isothermal conditions for complete decomposition of austenite and determines formation of pearlite structure [6].

It is advisable to consider the influence of metal composition and surfacing technology on the properties of the zone of transition from the base metal (90KhF steel) to the working layer, having, first of all, more precisely determined the real content of carbon in the first deposited layers. With this purpose, it is necessary to determine the degree of weld dilution by base metal (previous layer) for the applied wire and strip electrode dimensions, as well as parameters of the mode of backup roll deposition (Table 2). At deposition of an underlayer on 90KhF steel, using 5 mm Np-30KhGSA wire the carbon content in the underlayer is equal to 0.64 %, and at the possible application of split electrode it is not less than 0.42 % (Table 3). Even with thorough following of the surfacing technologies, which become much more complicated, as well as the required preparation of surfacing materials, it is difficult to ensure the necessary technological strength, while preventing cracking. In the structure of 30KhGSA underlayer, deposited on 90KhF steel, at a high content of carbon, the martensite is characterized by a higher dislocation density and lower ductility. Such a structure of the underlayer fails in the intergranular cleavage mode with regions of tough pit fracture through the grain, then in 90KhF steel the fracture runs along the boundaries of surface-melted grains, and then it goes into intragranular cleavage [9].

Table 3. Carbon content in 1–3 layers at deposition on 90KhF steel (γ = 0.55)

Layer number	Carbon content, %	
	Np-30KhGSA	Sv-18KhGS
1	0.64	0.57
2	0.48	0.39
3	0.40	0.30

Cracking susceptibility decreases noticeably at deposition of an underlayer on a roll from 90KhF steel, using Sv-18KhGS wire. Compared to application of Np-30KhGSA wire, lowering of carbon content in the underlayer (below 0.60 %) (Table 3) does not lead to appearance of hardness dip at transition from bainite-martensite structure of the underlayer to pearlite structure of 90KhF steel. Carbon content of 0.18–0.22 % in the electrode is probably the maximum admissible one in the case of deposition of an underlayer on 90KhF steel. Note that a smooth transition from 40Kh steel to the deposited working layer of 25Kh5FMS without dips was obtained at application of PP-Np-12GKhMF wire for underlayer deposition [10]. In the case of application of this wire for surfacing of 90KhF steel the carbon content (at share of participation γ = 0.37) is equal to 0.35 % in the first layer, and 0.15 % in the third layer. At the same time, at deposition on steel with 0.67 % C, up to 1.20 % Mn, 0.40 % Si, and 0.15 % V, using flux-cored wire PP-AN-180MN (12Kh1NMFS), the deposited layer is characterized by finely-dispersed bainite-martensite structure, and high crack resistance [11]. Here, for 50KhS, 40KhGS, 35KhGS, 32Kh2GMS, 30KhG3MF, 30Kh2M2NF metal compositions, which form in the underlayer at surfacing of high-carbon or medium-carbon steel, the temperature of the start of martensite transformation is markedly lower than that of concurrent heating at surfacing of large-sized forming rolls [4, 6].

Appearance of deposited layer spalling on two backup rolls of hot rolling mill 1700 of Mariupol Ilich Metallurgical Works [7], is associated with metal hardness dip as a result of formation of a «soft inter-

Table 2. Parameters of the mode of underlayer deposition on backup roll from 90KhF steel

Electrode grade	Electrode dimensions, mm	Current, A	Penetration depth h_p, mm	Ratio of penetration depth to layer thickness h_p/δ	Share of dilution γ
08kp (rimmed)	50×0.5	450–550	1.5	0.37	0.23
08kp	40×1.0	500–600	1.9	0.47	0.45
30KhGSA	40×1.0	500–650	2.3	0.48	0.45
Sv-18KhGS	Ø5	600–700	9.0	1.50	0.55
Np-30KhGSA	Ø5	600–700	9.0	1.50	0.55
Np-30KhGSA	2×Ø4	700–850	6.0	1.20	0.37
PP-Np-12Kh1G1NM	Ø3.6	350–400	3.0	0.60	0.37

Note. Voltage of 30–32 V; υ_s = 15 m/h (for strip); υ_s = 30 m/h (for wire).

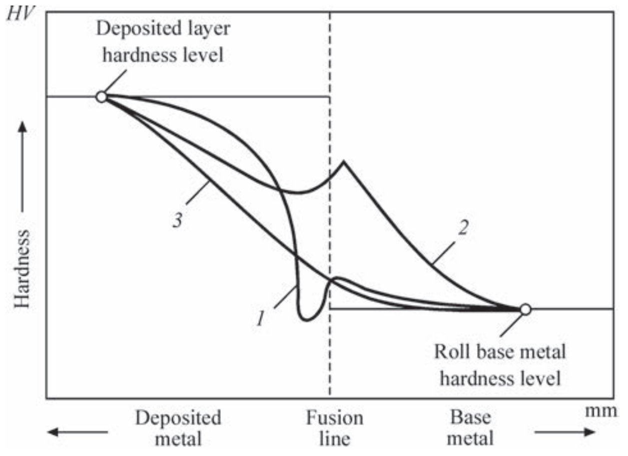

Figure 1. Nature of hardness distribution by the depth of the transition zone: *1* — with hardness dip in the underlayer region; *2* — with hardness increase near the fusion line; *3* — with smooth change of hardness from the underlayer to the working layer

layer» in the transition zone. Such a dip was observed both on the roll and on the reference sample (base metal is 90KhF steel, 08kp strip electrode of 50×0.5 mm cross-section was used in both cases for underlayer deposition). It should be noted that while in the reference sample reliable penetration was ensured and absence of lacks-of-fusion was controlled, during the process of underlayer deposition on the backup roll appearance of lack-of-fusion was quite probable that can provoke spalling. Thickness of «soft interlayer», as one can see from work [7, Figure 1], is not more than 3.5–4.0 mm, its hardness is lower than that of the base metal, which is followed by its abrupt increase up to the level of working layer hardness. Unlike the surfacing process, formation of «soft interlayer» in welds is related to the nature of the welding process, or to application of electrodes, for instance, of austenitic class, when the mechanical properties of weld metal differ markedly from those of the base metal (high-strength steel). In a multilayer composition, deposited on a backup roll, formation of a «soft interlayer» is not related to the nature of the process, but it caused by disadvantages of the surfacing technology. So, it was not taken into account that in case of deposition of an underlayer by a thin strip electrode, the penetration is minimal, and it is difficult to ensure reliable fusion with the substrate material. More over, the mode of deposition of the next layers, which ensures absence of dips in the zone of transition from the underlayer to the working layer, was not specified.

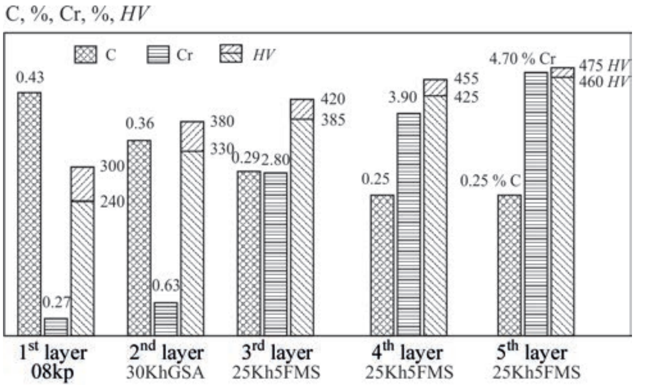

Figure 2. Chemical composition and hardness of transition zone layers at deposition with 40×1.0 mm strip electrodes on 90 KhF steel

When 1.0 mm strip electrodes are used, the substrate penetration depth (compared to 0.5 mm thick strip) becomes 1.5–1.7 times greater [5] that improves the fusion reliability, and abruptly lowers the probability of appearance of both defects of lack-of-fusion type, and hardness dips in the transition zone. At deposition of an underlayer on 90KhF steel by 08kp strip electrode the ferrite-pearlite structure fails in the viscous pit mode with tear regions. Deposition of the second layer by 30KhGSA strip, and then by 25Kh5FMS strip ensures a smooth transition of hardness from the underlayer to the working layer (Figure 1, curve *3*). The obtained layer compositions are characterized by satisfactory weldability that at the temperature of concurrent heating of the roll (up to 400 °C) allows preventing the deposited metal cracking.

The results of measurement of the transition zone extent on the deposited samples correspond to the presented in Figure 1 nature of hardness change for different variants of the technology of transition zone surfacing (Table 4).

Figure 2 presents the data for evaluation of changes in carbon, chromium content and hardness in the deposited layers of the transition zone at surfacing with 08kp, 30KhGSA, 25Kh5MFS strip electrodes of 40×1.0 mm cross-section (base metal share $\gamma = 0.45$).

Application of 25Kh5FMS strip for working layer deposition allows producing deposited metal with the structure of batch martensite with rather dispersed martensite racks. Hardness after deposition was *HV* 410 (*HSD* 58), impact toughness — 0.33 MJ/m^2, dynamic coefficient of stress intensity — 28.4 MPa·m$^{1/2}$, and fracture mode was transcrystalline

Table 4. Parameters of the transition zone for different variants of hardness distribution

Variant number	Nature of hardness distribution in the transition zone	Dimensions of the transition zone, mm
1	With hardness dip in underlayer region	4.0
2	With hardness rise near the fusion line	5.0
3	With a smooth change of hardness from the underlayer to the working layer	6.0–7.0

cleavage [9]. When this material is used for roll surfacing, it is necessary to take into account the effect of tempering after surfacing on hardness and crack resistance. Conducted studies show that the optimum tempering temperature was 600 °C. At this temperature the deposited metal hardness rises up to *HV* 450 (*HSD* 62). On the other hand, impact toughness is equal to 0.35 MJ/m^2, and the dynamic coefficient of stress intensity is 30.0 $MPa{\cdot}m^{1/2}$.

Technology of surfacing large-sized backup rolls that ensures a smooth change of hardness by the deposited layer height became widely accepted in the Cherepovets Metallurgical Plant [4]. It required mastering Plant's own production of standard and new compositions of the surfacing strip [12]. Mastering the technology of surfacing large-sized backup rolls, their operation experience in the roughing stand of hot rolling mill 2000 of the Cherepovets Metallurgical Plant, allowed bringing the share of deposited rolls to ~30 % of the entire fleet. Considering the performance of the surfaced and new backup rolls, and correspondence of load distribution in the roughing stand, an optimal ratio of the surfaced and new rolls was selected. The Plant proposed, developed and realized the optimal route of the roll moving on the stands. Due to that the average operating life (in rolled stock tonnage) of the surfaced backup rolls of hot rolling mill 2000 is equal up to 85 % (by the Plant data) relative to new rolls produced by NKMP and UHMP.

Conclusions

During the research it was found that:

1. At multilayer surfacing of backup rolls formation of the transition zone from base metal to the working layer is determined by an optimum combination of the deposited layer composition and mode of each layer deposition. Substantiated selection of such a combination that allows for the surfacing method and mode, electrode composition and geometry, influences the degree of underlayer dilution by the base metal, and by the previous and next layers for the second and third layer. It allows preventing the hardness dips in the entire extent of the transition zone.

2. The proposed and realized scheme of formation of a multilayer composition, deposited by strip electrode on large-sized backup rolls for hot rolling, provides a smooth distribution of hardness by the deposited metal height.

3. Development of the technology of surfacing large-sized backup rolls, mastering the production of strip electrodes, and long-term operation of the surfaced rolls confirmed their ability to ensure a high level of surfaced roll operating life in rolled stock tonnage. Obtained experience of development and realization of the route of movement of the surfaced and new backup rolls in mill 2000 at the Cherepovets Metallurgical Plant should be further analyzed and disseminated.

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