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DEVELOPMENT OF TECHNOLOGY FOR SURFACING WORKING LAYER OF VARIABLE COMPOSITION ON CRIMPING ROLLS

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It is shown that development of the technology for surfacing crimping rolls with the working layer of variable composition and mechanical properties along the body length makes it possible to minimize the unevenness of wear, especially in the area with its greatest depth. Application of this technology involves the use of a control system that provides separate control of the feed drive for each of the electrodes. It is shown that during surfacing of the crimping rolls with a layer of variable composition of the C–Cr–Mo–V alloying system, it is advisable to limit the content of elements within the ranges of 15Kh3GSMF – 24Kh4MFBS. It was demonstrated that the technology of surfacing crimping rolls with the working layer of variable composition is realized by feeding two strip electrodes LN-15Kh3GSMF and LN-24KhMFBS into the common weld pool. It was found that to obtain the required law of the change of the layer composition along the body length, the ratio of feed rates of the strip electrodes is changed in accordance with the carbon equivalent value of the metal of strip electrodes. It is shown that during operation of horizontal rolls of the slabbing mill, surfaced with a layer of variable composition, the unevenness of body wear decreases, and the operating time of rolls per 1 mm of wear of the working layer also increases. 9 Ref., 3 Tables, 2 Figures.

Keywords: surfacing, working layer, variable chemical composition, carbon equivalent, strip electrodes, crimping roll, uneven wear, law of hardness change

Improvement of the technology for surfacing crimping rolls is caused by the need in reducing the intensity and unevenness of the wear of the working layer, increasing in its resistance to wear and cyclic heating changes [1, 2]. The depth of the wear is uneven along the length of the body of the horizontal slabbing mill roll [3] and grows while moving further from the edge of the body, reaching the maximum value in the zone of slab edges location (30–450 mm from its edges), after which slightly decreases (Figure 1). Uneven wear leads to a change in the shape and sizes of the slab, causing a need in frequent roll changing and remachining. It is possible to minimize unevenness of the wear of a body by using the technology of electric

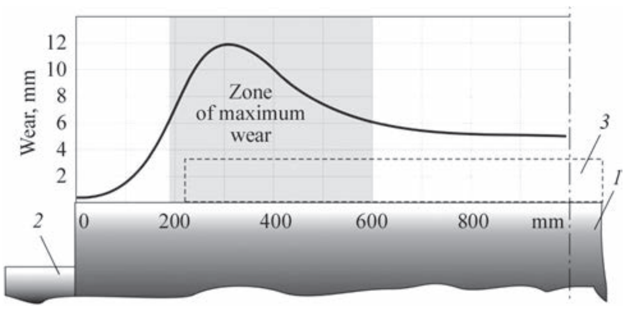

Figure 1. Nature of wear of a horizontal slabbing mill roll: *1* — body of a roll; *2* — neck; *3* — slab

arc surfacing of the layer of a variable chemical composition [4]. This is carried out by feeding two electrodes, differing in the content of alloying elements evaluated by carbon equivalent and hardness, at a programmable rate into a common welding pool. Thus, in accordance with the profile of the wear of the roll, the dependence of the change in the deposited metal and its properties is provided.

Changing the content of alloying elements in the deposited working layer and its mechanical and operational properties not only reduces the unevenness of the wear to the minimum, but is also accompanied by the formation of areas on the surface of a body, that differ in composition and hardness from surrounding metal. This allows improving clamping of a billet by rolls. The technology of surfacing crimping rolls by the layer of variable chemical composition, which fully meets these requirements, involves the creation of a control system [4], which provides a separate control of drives for electrode feeding, and therefore, the necessary change in the composition and hardness of the deposited layer. The system also provides a trajectory of movement of the surfacing apparatus relative to the surface of the roll.

Based on the operating conditions, the working layer of the crimping rolls of steel of type 60KhN

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is characterized by hardness *HV* 270–290, strength $\sigma_{0.2}$ = 520–540 MPa, ductility ψ = 30–35 % and impact toughness of 0.20–0.25 MPa [5]. Higher requirements to the properties of the deposited layer provide a combination of optimal hardness values (*HV* ≤ 400), technological strength (A_{cr} ≥ 10–12 mm/min), ductility (ψ ≥ 40–45 %), dynamic crack resistance (impact toughness *KC* ≥ 0.30–0.33 MJ/m^2 and coefficient of stress intensity K_{1D} ≥ 26.0–28.0 MPa·m$^{1/2}$). These properties are characteristic for steels 15Kh3M1F, 20Kh2M2FN, 25Kh5FMS, which are deposited by corresponding electrode materials [6]. At the same time, producing the layer of variable chemical composition with a continuous change in the content of alloying elements, it is advisable to use surfacing materials of the alloying system C–Cr–Mo–V, limiting the content of chromium (2.5–5.0 %), carbon (0.15–0.25 %), molybdenum (0.6–1.3 %), vanadium (0.15–0.40 %) and niobium (0.15–0.25 %). In [7], as a lower limit of this area, the composition 16Kh4GMFS (carbon equivalent C_e = 1.273*, hardness *HV* 345) is proposed. At the same time, the upper limit is the composition 25Kh5FMS (C_e = 1.707; *HV* 420), which is characterized by a high wear resistance in combination with a sufficient ductility.

However, taking into account the variable high intensity thermal power loads that affect the crimping roll, for surfacing of the working layer, it is advisable to use materials with a higher ductility and crack resistance. Therefore, for the lower limit of the area of alloying, a deposited metal 15Kh3GMFS (C_e = 1.066, hardness *HV* 305) was selected. At the same time, for the upper limit, the deposited metal 24Kh4MFBS (C_e = 1.45, *HV* 400), in which as compared to the deposited metal 25Kh5FMS the content of chromium and carbon is reduced, as well as niobium introduced. In this case, the change in carbon equivalent C_e in the range of 1.07–1.45 is accompanied by an increase in the metal hardness *HV* from 305 to 400, but to a lesser extent — a decrease in impact toughness (Table 1). The latter is explained by the presence of batch martensite in the structure, which affects the energy-intensive destruction mechanism — transcrystalline chipping and microtough pit one.

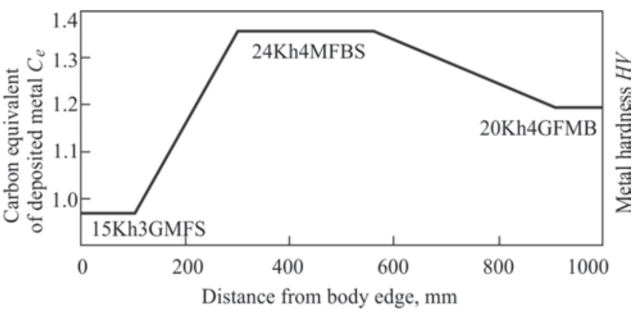

Figure 2. Change in carbon equivalent C_e and hardness of deposited metal

In steel 15Kh3GMFS, containing (wt.%): 0.15 C; 3.2 Cr; 0.3 Mo; 0.08 V; 1.2 Mn; 0.5 Si (C_e = 1.066), after surfacing and thermocyclic tempering, a ferrite-cementite structure is formed, in which ~ 10% of free ferrite is formed, and carbide phase is represented by large plates of cementite [7]. Such a structure is characterized by a low hardness *HV* 305 (HSD 46), high ductility, impact toughness and crack resistance during cyclic heat changes (see Table 1). The mechanism of destruction of such a structure is mainly microtough pit one. At the same time, as a result of the limited resistance to friction wear at elevated temperatures, it is rational to use the composition 15Kh3GMFS for surfacing the edge of a body (Figure 2). Moving further from the edge, the composition and hardness of the deposited layer are changed by the law, given in Figure 2 in such a way, that the maximum value of the carbon equivalent and metal hardness can be achieved on the area of the most intensive wear. This area on the body of the roll is located in the zone of the slab edge (for a horizontal slabbing mill roll it is ~ 400 mm from the edges of the body) (Figure 2). To such a value C_e, the composition 24Kh4MBFS corresponds, which contains (wt.%) 0.24 C; 4.2 Cr; 0.8 Mo; 0.40 V; 0.25 Nb; 0.8 Mn; 0.5 Si, which provides the hardness *HV* 400 (HSD 57) and a high wear resistance. These characteristics are remained unchanged on the body area (Figure 2), and

Table 1. Operational properties of deposited metal

Metal composition	A_{cr}, mm/min	KC^{**}, MJ/m^2	K_{1D}, MPa·m$^{1/2}$	Number of cycles heating-cooling until cracking	Relative wear resistance at 600 °C
15Kh3GMFS	11.9	0.46	29.5	1930	1.0
20Kh4GFMB	11.3	0.40	28.6	1800	1.3
24Kh4MFBS	11.0	0.37	28.5	1670	1.5
**Tests for determination of *KC* and K_{1D} were carried out at 20 °C.					

*Calculation of values of carbon equivalent C_e was carried out according to the dependence proposed by the International Institute of Welding.

Table 2. Influence of ratio of feed rates of strip electrodes LN-15Kh3GMFS and LN-24Kh4MFBS on the value C_e and metal properties

Ratio of rates	C_e	*HV* (HSD)	ψ, %	$\sigma_{0.2}$, MPa
100/0	1.066	305 (46)	57.0	680
40/60	1.297	365 (53)	53.0	740
0/100	1.453	400 (57)	48.0	780

then, reducing the carbon content to 0.20 %, a change in the composition of the deposited layer (20Kh4G-FMB) is provided. Here, C_e is reduced to 1.297, and the hardness of metal — to *HV* 365 (HSD 53), in its structure martensitic matrix with relatively large primary and dispersed secondary chromium, niobium and vanadium carbides is observed.

In accordance with the developed materials, at the Illich Steel and Iron Works an industrial production of cold-rolled alloyed strip of $1.0^{-0.2}$ mm thickness and 30 mm width and production of strip electrodes for surfacing of rolling mills were mastered [8, 9]. During strengthening of the horizontal slabbing mill roll, surfacing layer of variable chemical composition is provided by feeding of two strip electrodes LN-15Kh3GMFS and LN-24Kh4MFBS to a common weld pool at an adjustable rate. The ratio of the mass rate of their feeding (at a constant total rate) is selected based on the carbon equivalent value in such a way as to obtain the composition of the body with the minimum C_e value (to which steel 15Kh3GMFS corresponds). Further, changing the ratio of feed rates, an increase in C_e value to its maximum value is provided (to which steel 24Kh4MFBS corresponds). The mode of surfacing with two strip electrodes with a total cross-section of 60 mm^2 is the following: current of constant reverse polarity I_s = 700–740 A, U = = 34–36 V, v_s = 10.5 m/h; total volume rate of feeding two strips 0.9 cm^3/s.

Industrial operation of deposited horizontal slabbing mill rolls 1150 with the working layer of variable chemical composition showed that the unevenness of the body wear decreased, and also the work of 1 mm wear of the working layer increased (Table 3).

Thus, the use of the technology of surfacing the working layer of variable chemical composition and hardness for strengthening of the horizontal slabbing rolls provides stabilization of the output profiling due to a more even wear of bodies. This improves the slabs geometry, which during a further rolling on a broadstrip mill allows reducing the metal consumption associated with a tolerance to the width of the strip.

Table 3. Results of operation of deposited crimping rolls

Horizontal rolls of slabbing mill 1150	Volume of rolled metal, thou t	Operation per 1 mm of wear, t/mm
Rolls of steel 60KhN	825.0	22.0
Rolls, deposited by the layer of constant composition	927.0	38.4
Rolls, deposited by the layer of variable composition	1050.0	43.5

Conclusions

During investigations it was established:

1. It is rational to perform the development of the technology of surfacing mill rolls by the layers of variable composition at a given alloying system, choosing the ratio of feed rates of electrodes with the smallest and largest carbon equivalent value, which determines the properties of the deposited metal.

2. The application of the technology of surfacing horizontal slabbing rolls by the working layer of variable chemical composition and properties leads not only to eliminating an uneven wear, but also to increase in the operation of rolls per 1 mm of wear of the working layer.

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