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Development of an assessment method for pickup formation on furnace rolls

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ABSTRACT

Introduction. During the recrystallization annealing of cold-rolled electrical and automotive steels, the formation of pickups on the surface of furnace rolls presents a significant issue, as they lead to surface damage of the steel strip in the form of indentations. **The focus of the present study** is the evaluation of this defect. **Methods.** To this end, a laboratory-based methodology was developed to assess the tendency of furnace rolls to form pickups. The method replicates the contact interaction between the furnace roll and the steel strip under real annealing conditions, taking into account the applied contact pressure, a temperature range of 700–900 °C, the (H_2–N_2) furnace atmosphere, and a humidity level arising from the presence of oxygen adsorbed on the steel strip. To validate the method's reliability, a comparative analysis was conducted between pickups formed on the roll surface after industrial operation and those generated under laboratory conditions in the contact zone between steel samples made of roll and strip materials. The analysis employed optical microscopy, X-ray diffraction, and scanning electron microscopy. **Results and discussion.** The study confirmed that the developed methodology produces pickups on the specimen surfaces with morphology, chemical composition, and phase structure closely resembling those observed on the furnace rolls. A comparative assessment of the pickup formation rate between a typical furnace roll material (*EI 283* steel) and a *NiCrAlY* coating applied by plasma spraying revealed that the pickup formation rate for the *EI 283* steel was an order of magnitude higher. The validated methodology can thus be used to evaluate the effectiveness of strategies aimed at mitigating pickup formation on furnace rolls under long-term high-temperature contact conditions.

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Introduction

To achieve the required operational properties in steel strip for electrical (transformer) steel [1, 2] and automotive steel [3, 4] with a thickness of 0.3–1.0 mm, recrystallization annealing is performed after cold rolling. This process is conducted in furnaces at 700–900 °C under reducing atmospheres. A significant operational issue is the formation of pickups on the surface of the furnace rolls that transport the strip. Subsequent contact between the steel strip and these rolls damages its surface layer, resulting in dents or the transfer of pickup material onto the strip surface as indentations. For electrical steel, this also degrades magnetic properties by disrupting the deformation (*Goss*) texture [1].

The appearance of pickup defects on furnace rolls and corresponding indentations on the processed strip is illustrated in Fig. 1. Pickups on rolls transporting automotive sheet (Fig. 1, *a* [5]) and electrical steel (Fig. 1, *b*, author's data) show minor visual differences, attributable to the distinct chemical compositions of the metals and variations in transport loading conditions. Contact between a roll with pickups and the strip leads to dent and indentation formation on the strip surface (Fig. 1, *c* [1]), a consequence of material transfer from the pickups. Micro-X-ray spectral analysis confirms that the chemical composition of indentations on the strip matches that of the pickups on the rolls [1].

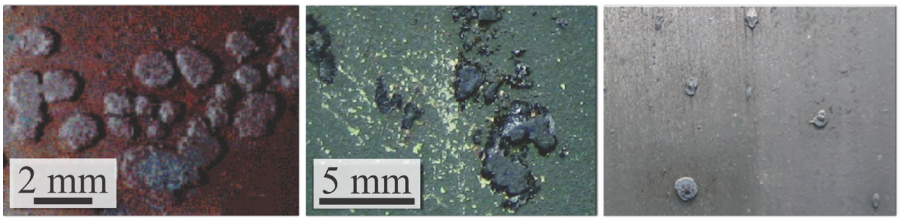


Fig. 1. Defects resulting from recrystallization annealing (see explanations in the text)

The formation mechanism of pickups on furnace rolls in contact with the strip is as follows. Upon heating to ~500 °C in a nitrogen-hydrogen atmosphere, the surface of a silicon steel strip oxidizes due to the higher oxygen affinity of silicon, iron, and other alloying elements compared to hydrogen. This process forms a thin oxide film containing iron, silicon, and aluminum oxides. The composition of the oxide film varies with depth: the layer adjacent to the metal is rich in silicon and manganese oxides, while upper layers contain increasing amounts of iron oxides [6].

As temperature rises, the reducing power of hydrogen and (diffusing) carbon increases. Above ~650 °C, simultaneous reduction of iron oxides occurs – directly from the oxide film by hydrogen and beneath it by carbon diffusing to the metal-oxide interface. This weakens the adhesion between the oxide film and the annealed strip surface.

Silicon plays a key role in oxide film spalling. The formed fayalite (Fe_2SiO_4) creates a eutectic with wüstite ($Fe_{1-X}O$) that melts at only 1,177 °C. Manganese oxides form solid solutions with the main scale components (wüstite, fayalite). Aluminum promotes the formation of a ternary eutectic ($FeAl_2O_4 - Fe_2SiO_4 - Fe_{1-X}O$) with an even lower melting point (1,148 °C). Chromium oxides may also be present in the spalled scale, with silicon and chromium not forming mixed compounds but existing in close proximity [2].

Following spalling, individual microparticles of reduced iron are pressed into the roll surface. This process intensifies, leading to the growth of pickup particles that can reach 2–3 mm in height. The typical chemical composition of pickups is 94.8–95.3 wt.% *Fe*, 2.0–3.2 wt.% *Si*, 0.3–0.4 wt.% *Mn*, and 0–0.3 wt.% *Al*. Their structure is featureless, resembling reduced iron with residues of ferrous oxide [1].

Although continuous annealing lines operate at elevated temperatures, moisture is present on the strip surface. Potential sources include water condensation on the metal before furnace entry or from the furnace atmosphere gases (**H_2, N_2**) when their temperature falls below the **dew point**. Condensation forms droplets or oxide films. For a given hydrogen content, the partial pressure of water vapor in the atmosphere is determined in accordance with equation [7]:

$$\lg P_{H_2O} = 9.8T_{DP} / (273.8 + T_{DP}) - 2.22,$$

where P_{H_2O} is the partial pressure of water vapor; T_{DP} is the dew point temperature.

In turn, the thermodynamic stability of the oxides forming the pickups is a function of the partial pressure of oxygen in the furnace atmosphere. The oxidation potential $\left(P_{H_2O} / P_{H_2}\right)$ **of** the furnace atmosphere is one of the main technological parameters of recrystallization annealing.

The typical dew point in an industrially employed annealing atmosphere is –30 °C (380 ppm H_2O, corresponding to P_{O_2} = 3.16·10^{-22} atm). According to the *Richardson-Ellingham-Jeffes* diagram [8], decreasing the dew point to –58 °C (≈14 ppm H_2O, $\boldsymbol{P_{O_2}}$ ≈ 7.6·10^{-25} atm) leads to a reduction in the driving force for oxidation. Although the annealing conditions are reducing for iron, selective oxidation of alloying elements with high oxygen affinity (*Si*, *Mn*, etc.) may nevertheless occur, depending on the oxidizing potential of the atmosphere. Studies of various classes of steels have shown that an increase in the water vapor content of the incoming gas, i.e., an increase in the oxidizing potential of the annealing furnace atmosphere, leads to an increase in the thickness of the oxide film on the metal surface and a change in its structure [3, 9–12]. Thus, variations in atmospheric humidity alter the rate of pickup growth owing to changes in the oxidizing potential of the working atmosphere. In the furnace atmosphere, the concentrations of H_2O and H_2 are monitored using standard furnace instruments, such as a thermohygrometer, which measures the temperature and dew point [13].

In addition to chemical processes, mechanical stresses also influence the formation of pickups on the furnace roll and the corresponding indentations on the steel strip. The pressure exerted by the strip on the roll is low and is determined by the mass of the strip between two consecutive rolls in the vertical section of the annealing unit. An estimation indicates that for a strip with a thickness of 0.7 mm and a width of 1,000 mm, and a vertical distance between the axes of consecutive rolls of 8,000 mm, its mass suspended between the rolls will be approximately 40 kg. Under these parameters, the maximum pressure in the contact zone between the smooth surface of the roll (with a diameter of 600 mm) and the strip will be 0.5 MPa; however, at point contacts over the pickups, the pressure increases by an order of magnitude or more. Furthermore, the mismatch in linear velocities between the strip and the roll surface accelerates pickup growth [14]. However, in the production process, the velocity mismatch can be controlled and maintained at a level of ~0.3%, under which conditions pickups on the roll form after several months of continuous operation. This led to the conclusion that the role of chemical reactions between elements is significantly greater than the role of the mismatch in linear velocities between the roll and the strip [10].

Various methods are used to reduce the tendency for pickup formation: changing the chemical composition of the steel strip and the furnace roll [15], applying protective coatings [5, 14, 16], or installing intermediate components, e.g., carbon sleeves [13, 17]. Determining the effectiveness of these methods requires the development of a method for assessing the resistance of metallic surfaces to pickup formation.

The most reliable assessment, based on full-scale roll tests, is characterized by excessive duration and substantial cost, since the time between maintenance cycles of the annealing furnace spans 4–9 months [1].

To reduce the duration of testing, a method for assessing resistance to pickup formation was proposed, in which a sandwich assembly, consisting of two metal plates with a steel strip placed between them, is heated in a laboratory furnace at 800–950 °C under a nitrogen-hydrogen atmosphere with a typical composition of 97% N_2 + 3% H_2. Following this exposure, pickups form on the surface of the steel strip via the mechanism described above. The material of the metal plate serves as an analog for the annealing furnace roll, while the steel strip simulates the processed sheet. After holding the assembly in the laboratory furnace for up to 200 hours, the resistance of the plates to pickup formation is evaluated based on the number (density) of pickups per unit area [6]. Although this method enables the formation of pickups, it does not account for the humidity of the furnace atmosphere, and does not allow for the evaluation of humidity variations, which reduces the reliability of the results.

The purpose of this work was to develop a methodology for evaluating the propensity of metallic surfaces to form pickups during contact under elevated temperature conditions in an H_2-N_2 atmosphere with controlled humidity.

Methods

To assess the resistance of furnace rolls to the typical operational defect of pickup formation, a methodology was developed involving the heating of a sandwich assembly under simultaneous exposure to pressure (***P***), temperature (***T***), controlled environmental humidity (***Hum***), and a gas atmosphere (H_2–N_2). The assembly, designated "Plate 1 – Strip 2 – Plate 1" (Fig. 2), consists of two plates of ***EI 283* steel** (according to *GOST 5632–2014*), which is the standard material for furnace rolls, and a central strip of ***Fe*–3% *Si* electrical steel** (*GOST 21427.1–83*), simulating the processed strip. The chemical compositions of these steels are provided in Table 1.

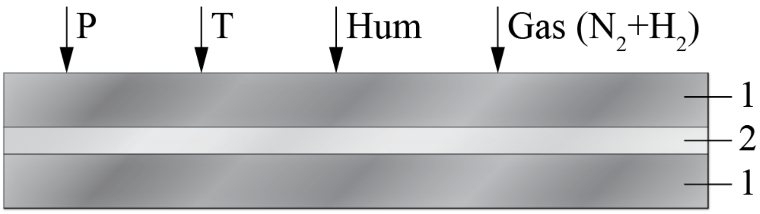


Fig. 2. Scheme of the method for assessing the resistance of furnace rolls to pickup formation (see explanations in the text)

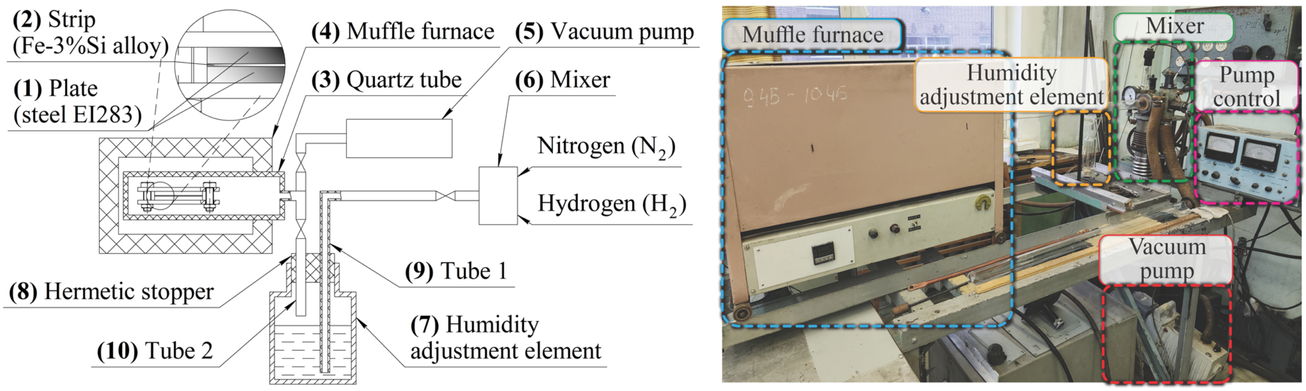
Table 1

Standard chemical composition of steels *EI283* and *Fe-3 Si*, wt.%

Element	Steel *EI283*	Steel *Fe-3 Si*
C	0.003–0.04	0.003–0.04
P	< 0.03	< 0.03
S	< 0.03	≤ 0.03
Si	2.9–3.5	2.9–3.5
Cr	22–25	≤ 0.3
Ni	17–20	≤ 0.3
Mn	< 2	–
Al	–	0.004–0.03
Cu	–	0.01–0.6
N	–	0.001–0.013
Ti	–	≤ 0.006
Fe	Bal.	Bal.

Fig. 3, *a* presents a schematic of the laboratory setup for pickup formation. The sandwich assembly comprises two metal plates (**1**) with dimensions of 50 × 20 × 4 mm and a steel strip (**2**) of 50 × 20 × 0.7 mm placed between them. This assembly is mounted inside a quartz tube (**3**), the working part of which is inserted into a *SUOL-0.4.4/12-M2-U4.2* muffle furnace (*AB* "*Umega*", Lithuania) capable of maintaining a set temperature of 850 ± 1 °C (with a maximum capability of 1,250 °C). The quartz tube is connected to a vacuum pump (**5**) for initial air evacuation and to a gas mixer (**6**) for supplying a gas mixture from cylinders with a composition of (95–97% N_2 + 3–5% H_2) by volume. A humidity adjustment unit (**7**) regulates the moisture content of the incoming gas. This is achieved by diverting the gas flow through tubes (**9**) and (**10**), which are integrated into a flask containing distilled water sealed with a hermetic stopper (8). The gas mixture is bubbled through the water via tube (**9**) and exits via tube (**10**) before re-entering the main gas line to the quartz tube. The gas flow is controlled by valves. The water vapor content in the gas mixture is measured at the inlet of tube (**10**) using a hygrometer and is correlated with the dew point of the surrounding atmosphere. This correlation allows the water vapor content inside the quartz tube (**3**) to be equated to the humidity of the ambient atmosphere. By controlling the ambient temperature, the humidity level inside the quartz tube can be adjusted. This capability enables the assessment of the impact of humidity on the oxidation rate of the strip surface, which serves as an analogue for the annealed sheet under actual humidity conditions in the high-temperature zone of an industrial annealing furnace.

The implemented setup for evaluating pickup formation (Fig. 3, *b*) includes the following key components: the muffle furnace with the inserted quartz tube containing the samples; the gas mixer for supplying the gas mixture from cylinders; the vacuum pump for evacuating air from the working zone prior to gas supply, equipped with a control unit and a pressure gauge; and the humidity adjustment unit. The duration of the continuous laboratory tests was set at 96 hours, which is approximately 40 times shorter than the typical duration required for full-scale industrial trials.



a *b*

Fig. 3. Installation for assessing the pickup formation:

a – diagram; *b* – view (see explanations in the text)

During the laboratory experiments, a series of pickups were generated and subsequently compared with pickups retrieved from a furnace roll after full-scale industrial operation. The microstructure and elemental distribution on the investigated surfaces were analyzed using scanning electron microscopy (*SEM*). A *Carl Zeiss EVO 40* microscope (Germany) operating at an accelerating voltage of 20 kV with a tungsten cathode and a *TESCAN VEGA II XMU* microscope (Czech Republic) equipped with an *INCA ENERGY 450* energy-dispersive X-ray spectroscopy (*EDS*) system (*Oxford Instruments*, UK) were employed. X-ray diffraction (*XRD*) analysis was performed using a *Shimadzu XRD 7000 Maxima* diffractometer (Japan) with a graphite monochromator and *CuKα* radiation. Diffraction patterns were recorded in the angular range of 2θ = 10–80° with a step size of $\Delta\theta$ = 0.02° and an accumulation time of 2 seconds per step. Full-profile analysis was conducted using the International Centre for Diffraction Data (*ICDD*) *PDF-4* database.

Results and Discussion

Pickups formed on the furnace roll

Fig. 4, *a* shows the surface of the furnace roll with formed pickups after six months of continuous operation. Fig. 5 and Table 2 present scanning electron microscopy (*SEM*) images of an individual pickup and the chemical composition from the investigated areas ***A*** and ***B*** (Figs. 4, *b*-*d*) in the form of spectra. The pickups shown in Fig. 4, *b* have average dimensions of 11×4 mm.

The chemical composition of the pickup surface (Table 2) includes the metals *Cr*, *Al*, *Fe*, *Mn*, *Ni*, and *Si*, which diffuse from both the strip and the roll. The high oxygen content (20–25 wt.% O) indicates the presence of oxides.

X-ray phase analysis was conducted on the sample depicted in Fig. 4, *b*. The determination error is 2%, which is attributable to the error in measuring the intensity of superimposed diffraction lines. The data are presented in Fig. 5 and Table 3.

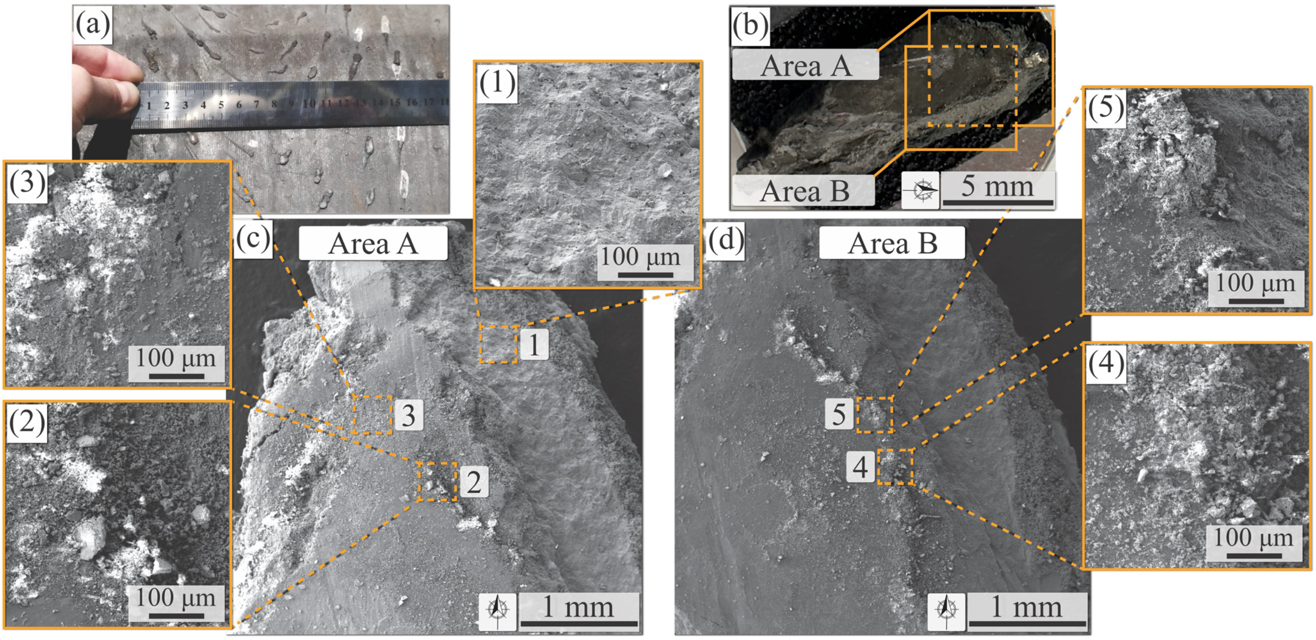


Fig. 4. Photographs of pickups on the surface of the furnace roll (*a*) and a single pickup (*b*) with details of its areas (*c*, *d*); *SEM* images of areas "***A***" (1–3) and "***B***" (4–5)

Table 2

Chemical composition of the pickup surface, sections 1–5 in Fig. 4, *c-d*, wt.%

Spectrum	*O* (δ < 1.24 %)	*Al*	*Cr*	*Ni*	*Fe*	*Mn*	*Si*
1	22.66	0.27	–	–	74.61	2.23	0.24
2	20.62	1.46	1.4	–	71.84	1.79	2.89
3	24.73	1.8	2.44	0.17	64.47	2.54	3.84
4	21.07	1.68	1.46	0.17	70.5	2.42	2.71
5	22.36	1.44	1.03	0.14	70.19	2.01	2.82

* The accuracy of micro-elemental analysis with this instrument is ±5% of the measured value. To ensure the total elemental content sums to 100%, values are presented with higher precision, which is due to the algorithms embedded in the instrument's software.

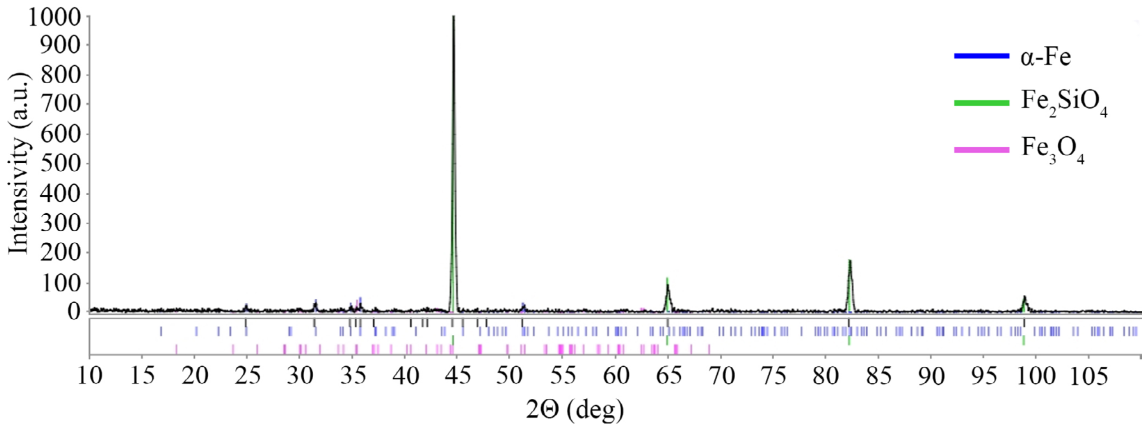


Fig. 5. X-ray diffraction patterns of the pickup removed from the roll

Table 3

Phase composition of the pickup removed from the roll, at.%

Phase	*PDF-4*	aт. % / at. %
α-*Fe* (iron)	01-080-3816	89
Fe_2SiO_4 (fayalite)	01-079-1208	5
Fe_3O_4 (magnetite)	01-084-9337	4

The higher iron content and lower content of the other elements, as determined by X-ray diffraction analysis compared to chemical analysis, may be attributable to the partial dissolution of these elements in iron, whereas the positions of the iron peaks in the diffraction pattern remain unchanged.

Laboratory formed pickups

Surface analysis

Visual inspection of the samples (Figs. 6, *a-b*) revealed that the pickups on the plate and the indentations on the strip have an appearance comparable to the formations on the actual furnace roll and transformer steel strip shown in Fig. 1. Dark areas corresponding to the color of the metal are observed along the edges of the plate, where the least pressing force was applied, and lighter areas are observed around the pickups and indentations.

The microstructure of the formed pickup surface in areas ***A*** and ***B*** is presented in Figs. 6, *c-d*. The corresponding chemical composition of these areas, as determined by *SEM* analysis, is given in Table 4. These areas were detailed in the figure as "area ***A***" (regions 1–2 in Fig. 6, *c*) and "area ***B***" (regions 3–10 in Fig. 6, *e*), as well as region 11 at the boundary between the pickup and the area without pickups, and region 12, where no pickups were visually observed (Fig. 6, *d*).

The oxygen and metal contents in the surface layer of the pickup on the plate (Table 4) are similar to the values obtained for the pickup surfaces on the roll according to the author's data (Table 2). The observed variation in iron content (in the range of 2.47–97.46 wt.% *Fe*) may be associated with the extraction of the

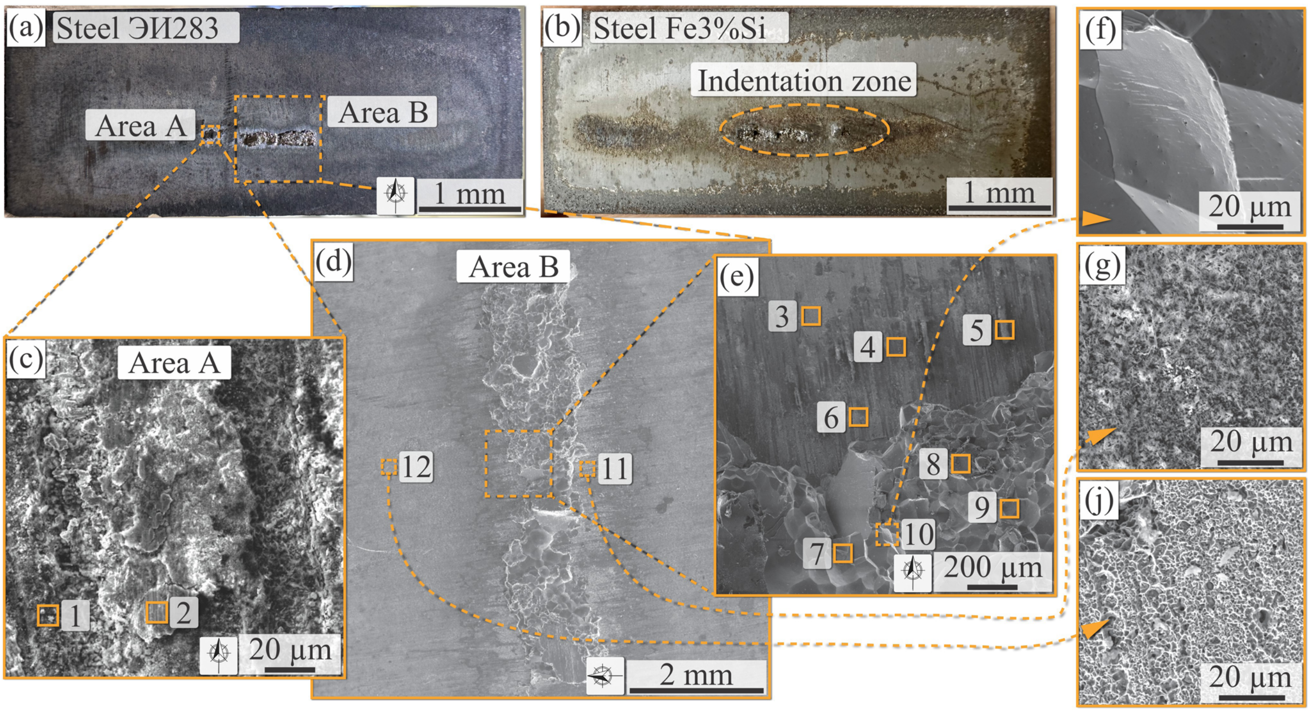


Fig. 6. View of plates with pickups (*a*) and strips of transformer steel (*b*) after testing according to the developed method, 96 hours; images of the surface of the pickups in areas "***A***" (*c*) and "***B***" (*d-j*)

Table 4

Chemical composition of the plate surface areas according to Fig. 6, *a*, wt.%

Spectrum	*O*	*Al*	*Cr*	*Ni*	*Fe*	*Mn*	*Si*
1	3.25	–	4.26	–	87.78	0.96	3.76
2	24.74	0.24	31.3	1.39	25.01	10.72	6.61
3	25.99	0.12	47.69	0.89	6.73	18.27	0.31
4	19.23	0.48	27.95	3.44	30.26	16.22	2.43
5	30.32	0.46	21.89	–	2.47	35.3	9.55
6	5.52	1.51	2.85	1.44	82.66	0.47	5.55
7	7.83	–	–	–	89.2	0.55	2.43
8	2.01	–	–	–	94.22	0.4	3.38
9	1.01	–	–	–	97.46	0.44	1.1
10	0.74	0.08	0.06	0.05	95.37	0.43	3.26
11	23.38	–	43.49	0.69	6.29	25.32	0.83
12	2.67	1.69	3.45	1.5	86.36	1.2	3.14

internal material volume from the strip due to intense diffusional adhesion. The high oxygen content (up to 30.32 wt.% *O*) in the chemical composition of the pickup (Table 4) indicates the presence of metal oxides on its surface, primarily *Fe* (82–98 wt.% in spectra 1, 6–10, and 12). The presence of aluminum (up to 1.69 wt.% *Al*), nickel (up to 3.44 wt.% *Ni*), manganese (up to 35.3 wt.% *Mn*), and silicon (0.31–9.55 wt.% *Si*) indicates the presence of oxides of these elements. The elevated *Mn* concentration can be explained by its high affinity for oxygen and the transfer of corresponding atoms from the furnace roll material to its surface in the contact zone with transformer steel. During the annealing process of high-strength manganese steels, the presence of *Mn* oxides in the pickups is more pronounced than in the electrical steel examined in this study [6, 13]. In all other respects, the data from other researchers on the chemical composition of pickups on rolls during annealing are similar.

Laboratory-formed pickups

Cross-section analysis

For the pickup in area ***B*** (Fig. 6, *a*), a cross-sectional analysis was performed, the general view of which is presented in Fig. 7, *a*. *SEM* and elemental mapping were conducted for characteristic sections of the "pickup–plate metal" interface boundary: in the middle of the pickup (Figs. 7, *b-c*) and at its edge (Figs. 7, *d-f*). The chemical composition of the cross-section of the pickup on the plate, as determined after spectrum processing, is given in Table 5 for sections located within the pickup (**1**), at the interface boundary (**2**, **3**), and in the near-surface layer of the plate (**4**).

As evident from Table 5, the oxygen content is several orders of magnitude higher than its solubility limit in iron [18]; thus, it is present in the form of oxides. Meanwhile, in the cross-section, the oxygen content is 20–100 times lower than on the surface (Table 4), which is qualitatively corroborated by the elemental mapping of characteristic sections of the pickup (Fig. 7).

The obtained data are consistent with the results of chemical analysis (Table 2) and X-ray phase analysis (Fig. 5) of the pickup surface removed from the roll, as well as with data from other studies on the elemental content within the volume of pickups during recrystallization annealing of steel [1–3, 9, 13]. This attests to the reliability of the laboratory method developed for assessing pickup formation on the surface of furnace rolls.

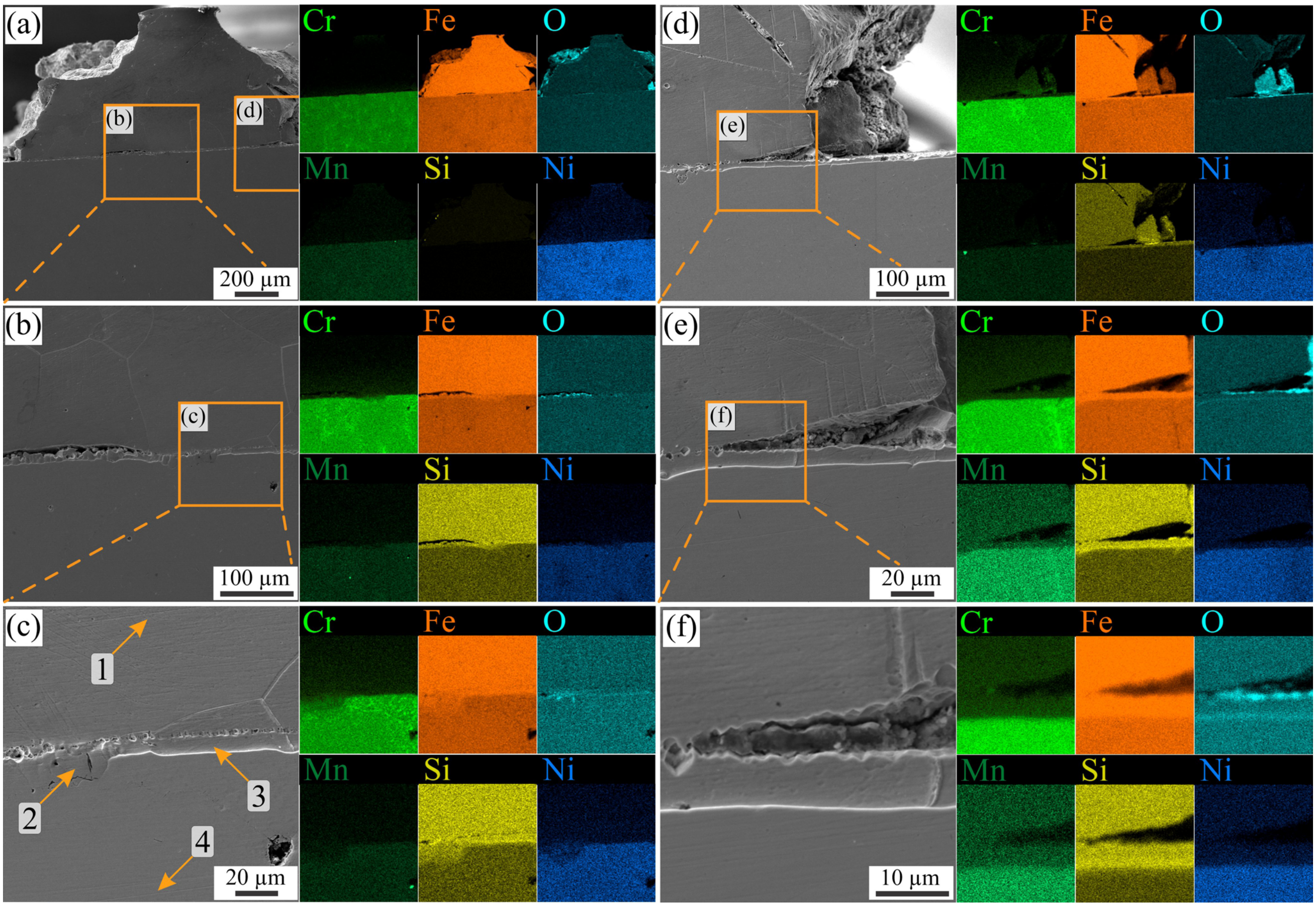


Fig. 7. SEM images and elemental mapping (*EDM*) of the cross-section of the *EI283* steel plate with the pickup

Table 5

Chemical composition of the cross-sectional areas of the pickups on the plate, shown in Fig. 7, wt.%

Spectrum	O	Cr	Ni	Fe	Mn	Si
1	0.22	1.75	0.98	94.06	–	3.2
2	–	9.26	5.57	81.92	1.01	2.23
3	0.04	3.72	1.53	90.98	0.64	3.13
4	0.21	16.77	9.53	71.49	1.51	0.7

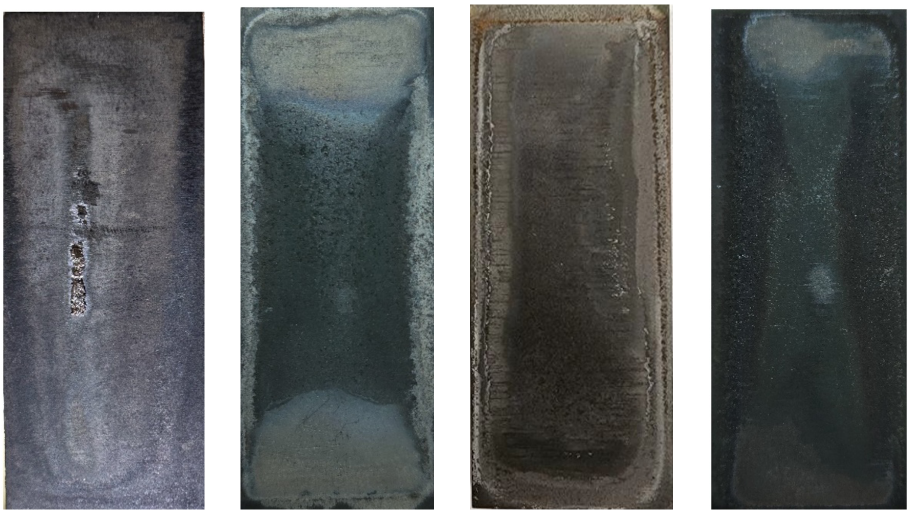
Laboratory test of NiCrAlY-based coating on plates

One approach to reducing the propensity for pickup formation involves the application of thermal spray coatings to the surface of furnace rolls. In particular, *MCrAlY*-type coatings (*M – Co*, *Ni*) are promising, as they enable the formation of protective oxide scales based on Al_2O_3 and Cr_2O_3 at elevated temperatures. The formation mechanism of these scales is detailed in monographs [19, 20]. Such coatings have demonstrated high durability in gaseous environments such as *Ar*-20% O_2 and *Ar*-4% H_2–2% H_2O. They are employed to extend the service life of gas turbine blades [21], as well as technological rolls in metallurgy [5, 22], and components of tribological pairs operating under boundary lubrication or dry friction conditions, with elevated loads and temperature fluctuations (in engine building, metallurgical equipment, aviation, and space technology) [23].

In accordance with the methodology described above, the propensity for pickup formation was evaluated on plates made of *AISI 310S* steel (analog of *EI 283* steel), onto which coatings were applied via plasma spraying using powders of (*NiCrAlY* (70–20–9–0.38) + n·Y_2O_3), where n = 0, 5, and 10 wt.% [24].

Visual inspection after testing revealed differences in the surface condition of the plates (Figure 8). The surfaces of the coated plates exhibited no traces of adhesion with the strip material, in contrast to the uncoated *AISI 310S* steel plate.

Further investigation of the contact zones included determination of microhardness, roughness parameters, and topography, as well as energy-dispersive X-ray spectroscopy (*EDS*) on the surface and on characteristic cross-sections before and after testing.

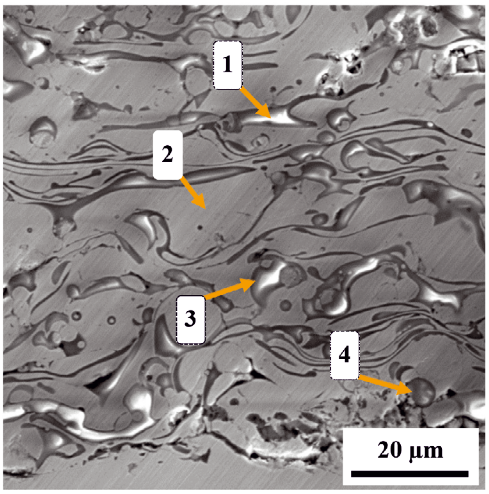


a *b* *c* *d*

Fig. 8. A view of plates with *NiCrAlY* coating after testing:

a – without coating, *b*-*d* – with coating ($NiCrAlY + n{\cdot}Y_2O_3$), *n* = 0, 5, 10 wt. % for *b*, *c*, *d*, respectively

It has been demonstrated, in particular, that spinels of the (*Al*, *Cr*, *Y*)*Ox* type formed in the cross-sections of *NiCrAlY* + (5–10 wt.% Y_2O_3) coatings after spraying, with the Y fraction increasing from approximately 18 to 45 wt.% as the Y_2O_3 content in the initial powder increased (Fig. 9). Post-test examination revealed an insufficient quantity of Fe and Si in the contact zone to enable adhesion of the electrical steel strip to the coating. Furthermore, the addition of Y_2O_3 was found to exert opposing effects. On one hand, increasing its content leads to enhanced hardness, which is beneficial for improving the coating's wear resistance. Additionally, during wear, the oxides within the layer will impede adhesion. On the other hand, the addition of Y_2O_3 facilitates Si diffusion from both the strip and the substrate sides, thereby increasing the propensity for pickup formation. To determine which of these processes will exert the predominant influence on the coating's performance, full-scale industrial testing is required.



Microchemical analysis of coating cross-section areas 1–4

	1	2	3	4
O	33.84	–	15.13	27.08
Al	35.45	9.90	9.45	27.55
Cr	3.43	18.72	19.63	13.38
Ni	3.71	71.38	55.79	18.93
Y	23.56	–	–	13.07

Fig. 9. Microstructure of a cross-section of a sprayed coating ($NiCrAlY$ + 5 % Y_2O_3) with microanalysis regions

Conclusion

The experiments demonstrated that the developed methodology, which entails the forced application of pressure on the contact surface of steel samples during prolonged heating at 850 °C for 96 hours in an atmosphere of (95–97% N_2 + 3–5% H_2) with controlled humidity, results in the formation of pickups on the plate surfaces. These pickups exhibit a morphology (shape and chemical composition) analogous to that observed during the operation of furnace rolls in continuous annealing lines. Optical microscopy, X-ray diffraction, and scanning electron microscopy revealed that the chemical and phase compositions of the pickups under laboratory and full-scale conditions were comparable. The study results confirm the reliability of assessing pickup formation on the surface of furnace rolls using the developed laboratory method.

The application of the developed method is illustrated through the assessment of the comparative propensity for pickup formation on *AISI 310S* steel and on plasma-sprayed coatings based on *NiCrAlY* with additions of up to 10 wt.% Y_2O_3. The results indicate that laboratory testing enables the selection of a coating material with the required properties to enhance resistance to pickup formation on metallic surfaces.

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Conflicts of Interest

The authors declare no conflict of interest.