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FIRMWARE SYSTEM FOR DIAGNOSTICS OF THE MILL ROLLS

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Abstract

Methodical and technical approaches to solving the problems of monitoring the state of rolls working in a hot rolling mill at one of the largest metallurgical works in Russia – Magnitogorsk' metallurgical complex are considered. The possibility for diagnosing the technical state of a roll during its operation life by means of coercivity measurements is established. To increase the speed and reliability of the testing routine, an automated firmware system of measuring coercivity was developed and introduced and the method of its metrological attestation, suggested.

Keywords: magnetic method, coercive force, control of structure, the mill roll, automated system.

1. Historical background

Cost of maintenance of rolling base at metallurgical plants makes up quite a share of the product cost. To examine the service ability of a roll is possible when using a complex of methods of nondestructive testing. However, such methods of crack detection as, say, ultrasound or eddy-current one, failed to fully control the roll state because these methods are capable of tracing only macrodefects. In addition to the crack detection methods, it is necessary to monitor the state of rolls during their operation life by means of measurements of their characteristics. Some researches[1-2] are available, which show that the coercivity distribution over the roll surface features the degree of nonuniformity of the working layer that arises because of imperfect production technique and accumulation of material defects in the course of operation.

Prior to developing a fixed automated setup for coercivity measurements, a series of meterings were performed in the shop conditions, using a portable device with a plug-in gage whose poles were 20x40 mm in size. The calculated depth of through-magnetizing made up about 20 mm.

Of seven main types of the mill rolls, horizontal roughing and finishing working rolls were taken as the most convenient for diagnostic. The grounds for such choice were as follows:

1. Working rolls are the most common and frequently replaceable tool, which is suitable for collecting statistics. Besides, the operation costs of such rolls are maximal.
2. Horizontal working rolls have rather plain shape and, therefore, are easy to test.

In experiment rolls with different operation life were diagnosed, from the very start of servicing up to their discard (retirement).

Evidently, the most complete information on a roll can be taken, if to plot a grid on the working surface of the roll, and fix the gage data at each node. The size of the involute surface was 2500×2000 mm. The maximal dimension of the gage made up 130 mm. Thus, the maximal number of measurements along the generatrix of a barrel was 15. Readings were virtually taken over the matrix 10×15 for back-up rolls, 10×12, for working roughing rolls and 10×8, for working finishing rolls.

In most cases measurements were performed after setting a roll into a roll-grinding machine where the roll surface was subjected to marking. The gage was sequentially placed at each mark and the coercivity value measured by the device indicator was registered in a test log. After testing one of the generatrix the roll was turned at a specified angle, and the routine was repeated at all marks. Note that the complete cycle of measurements took from 40 min to 1 hour.

The technique of producing a roll can result in a considerable anisotropy of its mechanical properties. Loads onto the working layer of rolls are also anisotropic, therefore, in a number of cases measurements were duplicated with rotating the gage (and, consequently, field direction) by 90°.

To provide comparability of measurements taken at grids of different dimensionality, a two-dimensional spline-interpolation of the experimental data gained was performed. The interpolated coercivity values at the roll surface are given below.

2. Testing of rolls from roughing stands

The coercivity was measured for four types of working rolls that differ in material and producer. The details are as following table:

№	Producer	Material	Number of rolls	Number of replacements		Number of experiments
				min	Max	
1	Producer #1	steel	6	0	23	11
2	Producer #2	steel	14	0	10	49
3	Producer #3	cast iron	4	30	36	15
4	Producer #4	cast iron	2	25	30	21

Figure 1 presents the changes in coercive field on the surface of a working roll of the roughing group. a, b - new roll; c, d - after one replacement; e, f - after 4 replacements.

The initial coercivity distribution in the form of randomly located spots, which is likely to be caused by a methodical specificity of the roll production, is changed by a structure of spots extended along the barrel generatrix. Since the reasons for the changes in the magnetic properties of the working rolls are mainly of thermal origin, one can suggest that the inhomogeneity of magnetic properties is conditioned by a local inhomogeneity of heat exchange between the roll and metal. The degree of this inhomogeneity is low since the coercivity distribution is even narrower than the initial one. Such a pattern of the coercivity distribution over the roll surface is characteristic of trouble-free operating rolls up to their discard.

Note as an example that for roughing rolls of producer 2 there is observed an increase in the coercivity of working surface after first 5 replacements, and then its value becomes stabilized up to the roll discard (approximately after 24 replacements). Such behavior of the coercivity indicates that the mechanism of changes in the properties of the working surface during the operation period is of thermal nature. Actually, if the changes are stopped after 5 grinding procedures, this means that the depth of changes makes up 5 thicknesses of the layer removed. For roughing rolls it amounts to several millimeters, which corresponds to a calculated depth of heating the roll material in the zone of its contact with metal.

Note that the current technique of roll preparation provides stability of the working surface characteristics during the whole operation life. After experiments, a method was worked out that makes it possible to optimally lower the thickness of material removed from the surface of defect-free rolls after producer #2**.** This should lead to prolongation of the operation life of such rolls.

3. Testing of rolls from finishing stands

The data for finishing rolls were mainly gained at rolls after producers #1 and #2. The details are as following table:

№	Producer	Number of rolls	Number of replacements		Number of experiments
			Min	max	
1	Producer #1	11	0	139	55
2	Producer #2	6	9	64	38
3	Producer #3	2	0	65	10
4	Producer #4	2	9	73	12

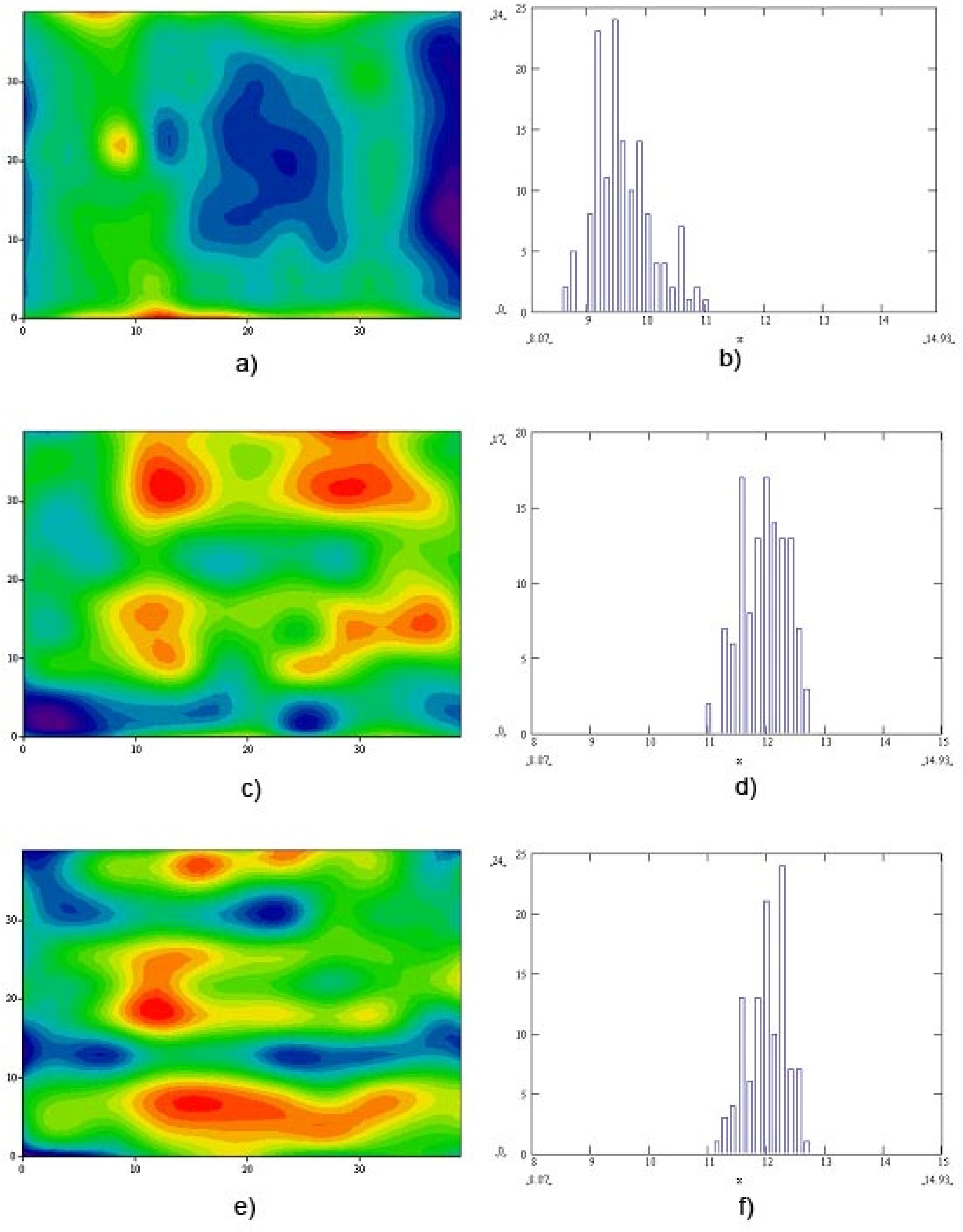

Figure 1. Spline interpolation of coercivity and coercivity distribution function
a,b – new roll; c,d, - one replacement; e,f, - four replacements

In Figure 2, data on the coercivity distribution over the roll surface after different producers are shown.

The most essential inhomogeneity is characteristic of rolls after producer #2; somewhat less, after producer #3. The distribution of inhomogeneities (strictly along the axis) indicates that the reason should be sought in the production technology. Taking into account that all the rolls were investigated at a half period of operation life, the inhomogeneity of working layer of the rolls after producer #2 can be estimated extremely low.

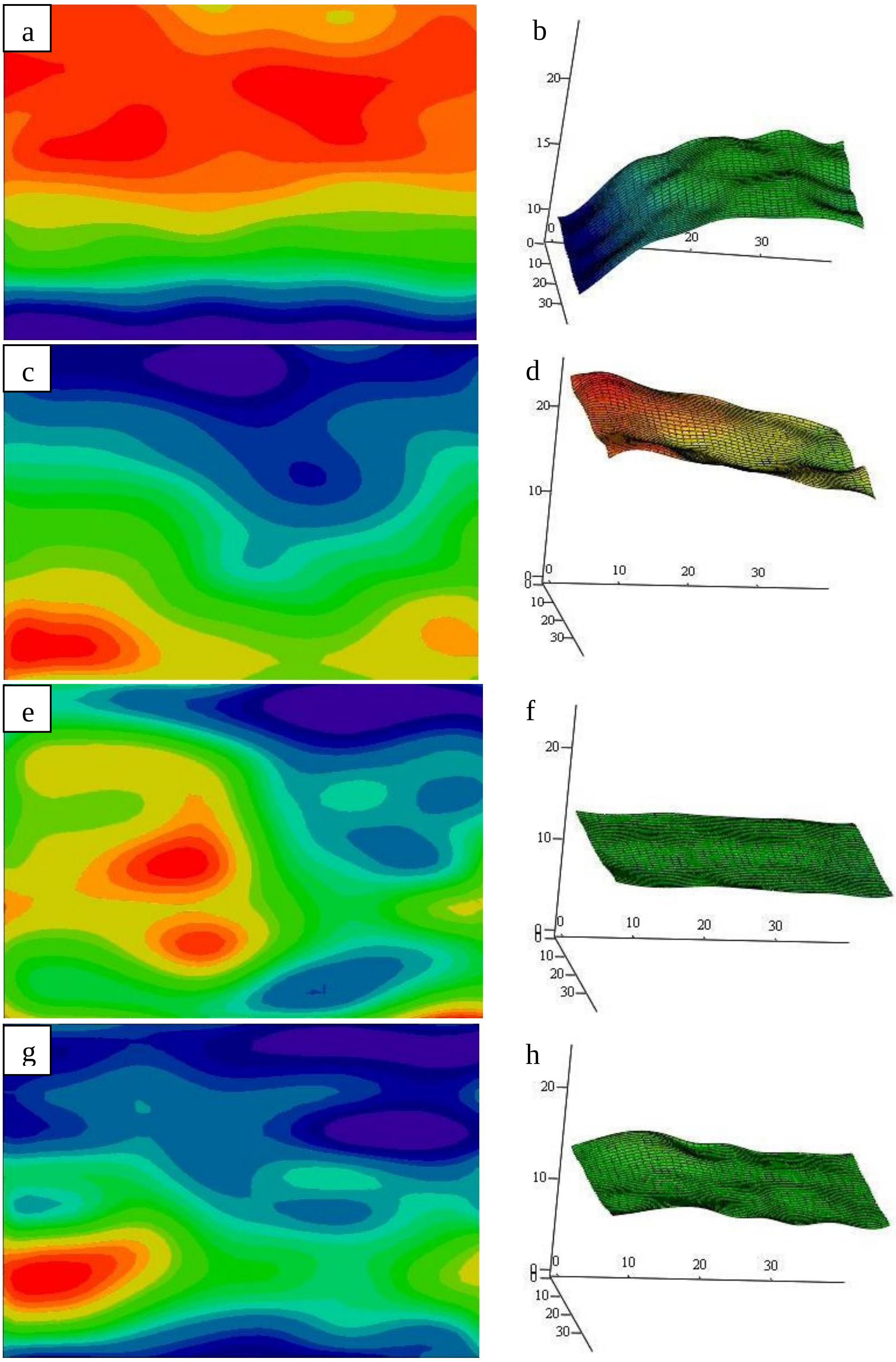

Figure 2. Magnetic inhomogeneity
of working layer for the rolls after different producers
a, b – producer #2; c, d - producer #3; e, f – producer #4; g, h – producer #1

In Figure 3, data on the changes in the average coercivity values in the course of the operation life are given. Note the high data stability over the whole operation life for the rolls after producer #1. Good reproducibility of the data for different rolls evidences a good routine practice and high production standards.

Unlike the rolls after producer #1, the rolls after producer #2 significantly differ from each other. Moreover, two groups of data can be picked out in the plot – if rolls NN 25, 28, and 40 are stable over the whole period of operating, rolls NN39 and 275 show up a sharply descending characteristic. Further analysis of the data demonstrated that just these rolls were characterized by a maximal inhomogeneity of the magnetic properties along the roll axis. Feasibly, such inhomogeneities are related to an instability of the production technology.

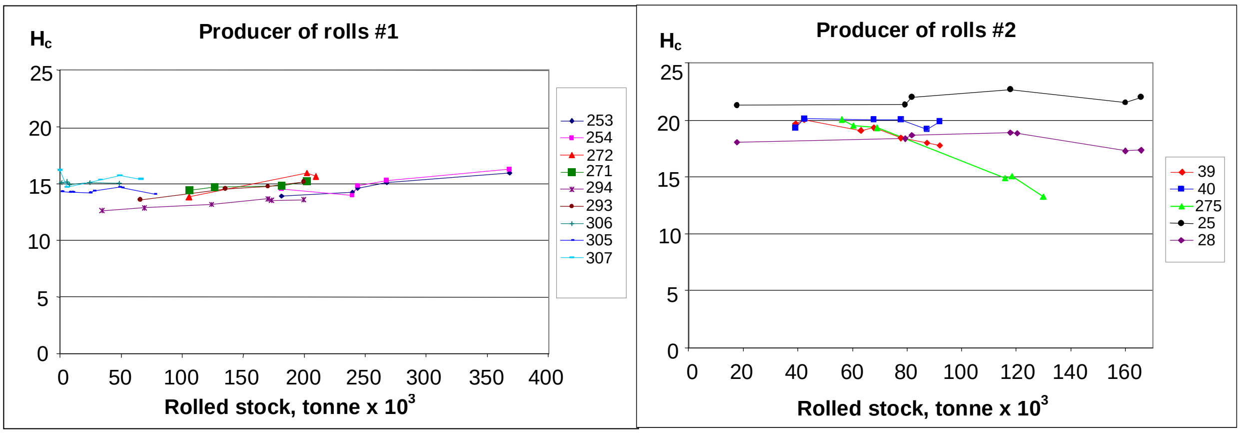

Figure 3. Coercivity changes during the operation life of rolls

4. Firmware system

To nondestructively test the quality of rolls, an automated firmware system was developed, which allows simultaneous measurements of coercivity at a given number of points along the roll generatrix and, using a microprocessor, analysis and storage of the test data. The structure elements of the testing system are presented in Figure 4. The system is a fixed installation attached to the roll-grinder machine. It consists of four main components:

- multichannel device of meterings;
- mechanical part with a drive moving the gages in to the working position;
- operating computer complex (OCC);
- automated personal workstation (APW).

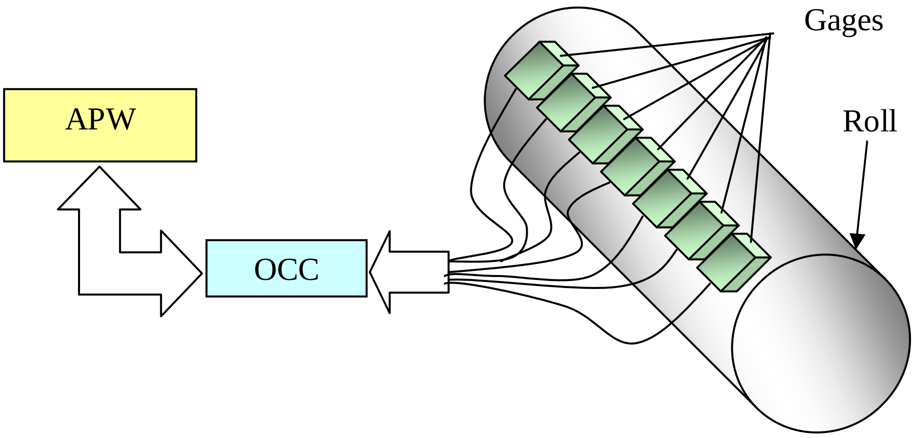

Figure 4. Structure elements of the testing system

The number of gages can vary and depends on, in particular, the length of a roll under test. The system modularity first enhances its reliability, and second, makes it possible, if necessary, to increase the number of measuring channels. Using APW, the supervisor can control the system gages, set the operating regime of the system and visualize the test data.

After setting the operating regimes for the system, a supervisor launches the measurements. Then, the system automatically controls the angle of roll rotation along the axis, placement of gages onto the roll surface, and measurements. After scanning the whole roll surface, the data collected are processed and transferred to the screen at the workstation in the form of the roll surface involute and coercivity distribution.

For metrological certification of the system the method of its verification and the set of standard samples were developed.

5. Conclusion

As our researches have shown coercivity distribution over the roll surface can serve as a criterion of its suitability to further operation. The developed automated system, first, allows one to perform the incoming control of new rolls. Secondly, tracing the changes in the coercivity in the course of operation allows one to predict changes in the service characteristics of rolls and the term prior to their discard.

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