Magnetic Diagnosis of Metallurgical Equipment Resource Considering a Roll as an Example

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Abstract. The magnetic method of steel mechanical properties and microstructure has been applied in the territory of the former USSR since early 70s. The main principles of this testing are described in the standard GOST 30415-96 "The steel. The NDT of mechanical properties and microstructure of steel articles by magnetic technique". The method is widely applied so it is completely presented in special literature.

The present work describes the method application in iron and steel industry, particularly in a roll state testing.

The following tasks are fulfilled by means of testing of structural stressed state of a roll barrel surface layers:

1. Accomplishment of incoming control of a roll structural stressed state before its service life starting. Incoming control makes it possible to reveal a roll residual stress caused by a supplier's methodical violations.
2. Diagnosis of abnormal areas in a roll barrel working layer which appeared due to the roll damage in the run of operation.
3. Determination of the optimal depth of re-grinding which guarantees removal of layers with intolerable level of accumulated residual stress.

Calculation of residual resource of each roll that allows to define optimal amount of roll inventory.

Diagnostics of preparation and installation defects of rolls in the rolling mill stands.

Optimal stress redistribution in multi-stand mills.

Magnetic monitoring makes it possible to reduce roll consumption per a tonne of rolled products, to increase a roll service life and to improve geometric characteristics of rolled products.

Keywords: Steel

1. Advantages of ferromagnetic item state estimation with application of magnetic method

Many-sided and long approbation of magnetic structure control for testing stress deformed state of metal permits to speak about the new approach in the technical diagnostics, the base of which is reliable revealing of operation defects start or elaborate the degree of nearness to this stage, i.e. residual resource control of metal items, as it is. We have inspected a great number and considerable variety of metal structures of different designation i.e. all types of load-lifting cranes and elevators, pressure vessels, oil and gas pipelines, rail lengths of continuous welded railway tracks, crane-runaway girders and columns, shop ceiling girders, gas industrial high-pressure tanks, APS reactor shells and their pipeline strapping units, power equipment of local heating plants and electric power stations (turbo-generators, boilers and steam pipelines).

The present work deals with magnetic monitoring of ferromagnetic items in iron and steel industry, a roll being an example. Physical basis of this work is usage of known interconnections between structural and stressed states of ferromagnetic items and magnetic structural sensitive characteristics. Reject limits during mean-time-between-failures (MTTR) are calculated within coercive force values. In the present work the coercive force is accepted as complex index of an item state. Magnetic monitoring of rolls makes it possible to obtain information concerning the roll quality while delivered and operation condition influence on their wear resistance, unattainable by other means. Application of magnetic monitoring allows to reduce roll consumption per a tonne of rolling product, to anticipate roll damage in the run of rolling, to choose a roll initial profiling which guarantees meeting the requirements of a strip geometry, optimize the process of production and reconditioning of rolls.

Moreover, this method does not require a long-months special training of personnel. A roll grinding machine operator can become familiar with the work procedure and roll state estimation after two weeks of training at his workplace. The method is easy to formalize so the process of testing estimation results yields to automation.

2. Methods of measuring of a roll working layer state

Circular segments of 150-200 mm width are marked on a roll, as well as lines along its generator for carrying out magnetic measurements. The distance between the lines along the generator line is also 150-200 mm. A sensor is installed in the centre of the square having been formed with circular sector and barrel generator line marking (see Fig.1). For providing monitoring we always start a series of measurements at the same dot, for example, at the spline on the roll neck from the drive side.

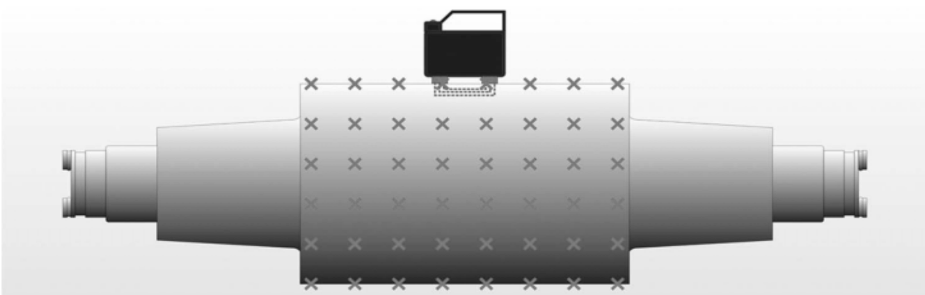


Fig. 1. A roll marking for working layer magnetic chart

We use a coercive force meter with a double-pole sensor and 20-25 mm magnetization depth for a roll magnetic characteristics measurement to take a magnetic chart which is a matrix of digital data in the initial state where series correspond to the barrel generator line measurements and columns correspond to the circular segment measurements. The results of the measurements are processed with help of special software to plot a graphical display of a magnetic chart. In our work the coercive force corresponds to different colours of the spectrum from blue for low values of coercive force to red for high values.

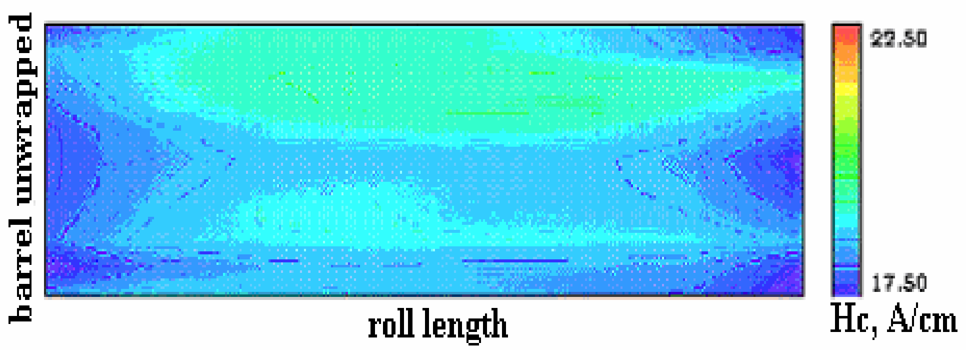
The analysis of the obtained in such a way magnetic chart allows to solve several groups of diagnostic problems.

2. Technical problems solution of which has been proved practically

1. Incoming control of structural stressed state of a roll is carried out before starting its operation. The following data is used for analysis: the average value of coercive force according to the magnetograph, dispersion of coercive force meanings and general view of the magnetograph. Incoming control provides initial data for a roll monitoring in the run of operation, makes it possible to reveal structural inhomogeneity (spotness) in a roll, caused by a supplier's process violations, as well as define whether there is any residual stress in a roll before putting it into operation.

   EXAMPLE: Fig. 2 a) and b) presents a couple of new iron rolls, produced by different suppliers. The initial strength characteristics of the lower roll are less and the barrel edges have not been subjected to thermal treatment that caused cracking along the barrel edges in the process of operation. It is evident that the incoming control revealed the "A" supplier's advantages. The "B" supplier should be recommended to correct the process or his service would be rejected.

a)



b)

Fig.2. Magnetic chart of iron working rolls produced by different suppliers

2. Abnormal areas in the working layer of a roll barrel caused by the roll damage in the run of operation are tested, as shown in Fig.3.

   EXAMPLE: A roll of a cold rolling mill after a damage with a strip (a cut) is presented here. The damage may lead to further roll peeling on the damaged section.

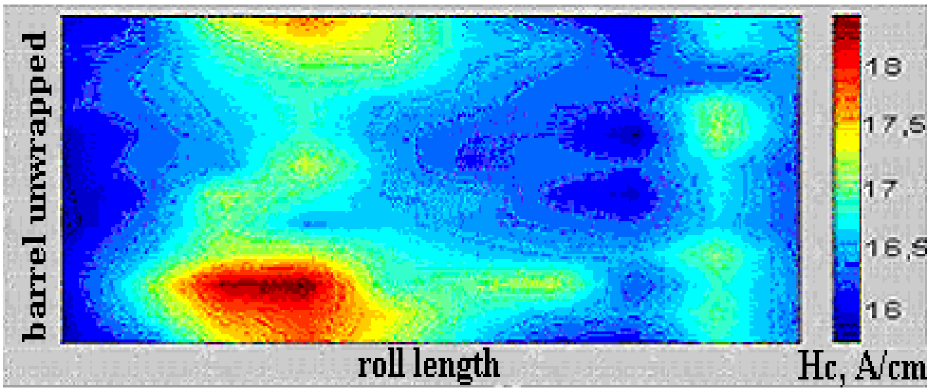


Fig.3. The damage trace in the working layer of the roll barrel.

3. Optimal depth of re-grinding which guarantees removal of layers with intolerable level of accumulated residual stress will be tracked, as shown in Fig.4.

   EXAMPLE: There are some traces left after the last operating period when the backing-up roll was wrapped along the diagonal line with a torn strip.

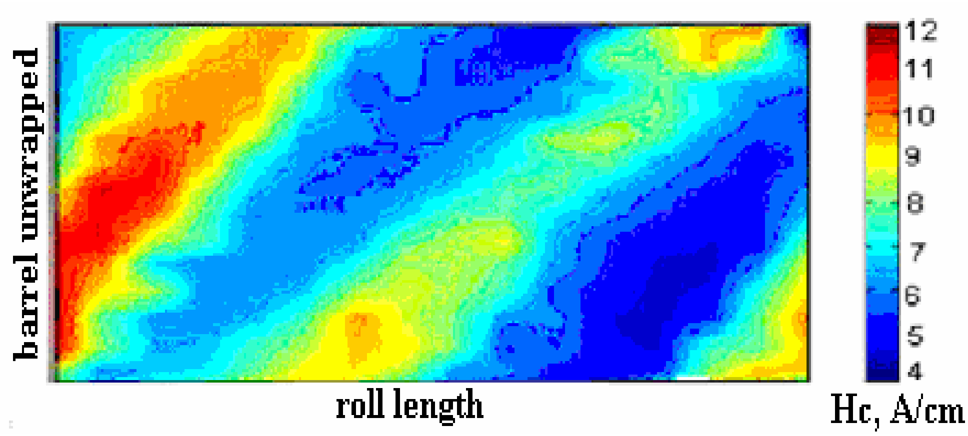


Fig.4. A backup roll prepared for expanding into place with some traces of a non usual damage [3]

4. Residual resource of each roll is calculated which allows to determine the optimal amount of roll inventory and the schedule of their delivery. The increased value of coercive force corresponds to increased values of accumulated fatigue stress.

   EXAMPLE: A change in coercive force is in dependence with the volume of rolled product. The alignment chart is obtained as a result of observation of a cold rolling mill backup rolls.

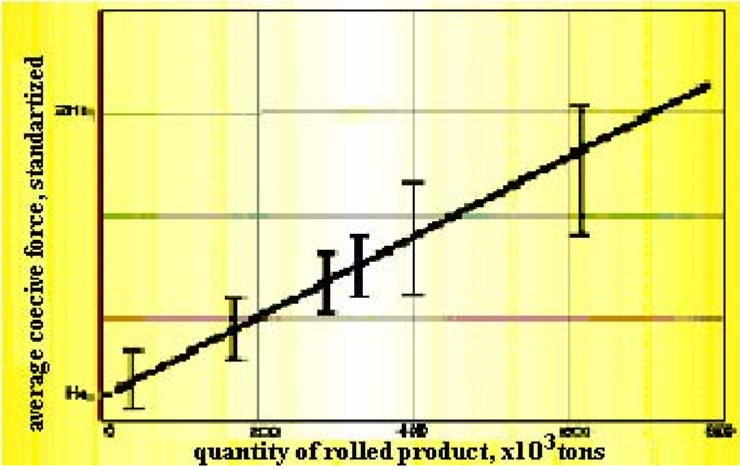


Fig.5. Alignment chart for calculation of residual resource of a cold rolling mill backup rolls [3]

5. Shortages of rolls and attached equipment preparation are determined. A roll wrongly prepared on a roll grinding machine or wrongly installed in a stand keeps up residual stress, distribution of which indicates wrong preparation.

   EXAMPLE: The upper backup roll of the 10th finishing stand of a hot rolling mill was working with run-out because of out-of-roundness caused by a roll preparation faults on a roll grinding machine (Fig.6). One half of the roll barrel is overloaded, the other is light loaded. The lower backup roll in this operating period was being loaded and unloaded to compensate the run-out of the upper roll.

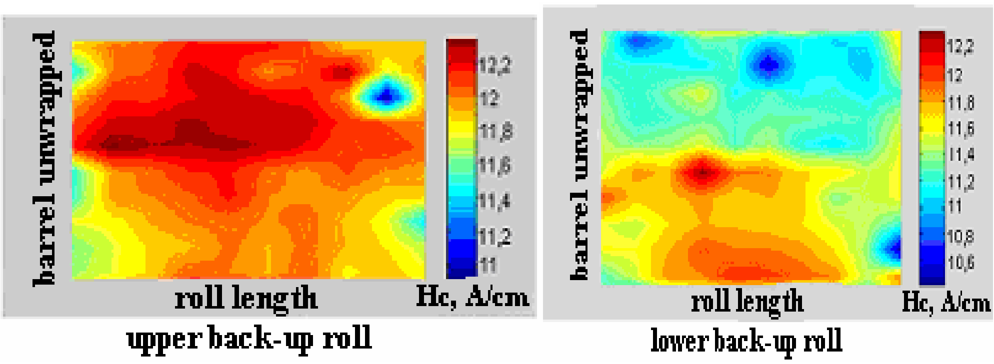


Fig. 6. Inhomogeneous distribution of stress in a couple of backup rolls, caused by out-of-roundness of one of them [3]

6. Process faults in roll repairing are becoming evident.

   EXAMPLE: After re-cutting and re-quenching of a roll the scheme of thermal treatment has led to conic distribution of working layer strength properties. The thermal treatment needs correcting and the repairer's rolls need incoming control.

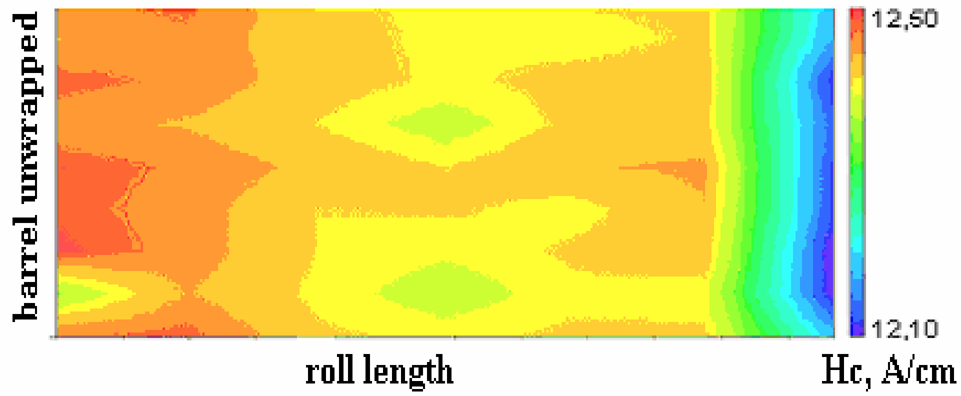


Fig.7. Reconditioned roll [4]

7. Optimal re-distribution of loads in stands of multi-stand mills, optimization of the initial grinding profiling_of rolls. Rolls with surplus grind crowning used to be overloaded along the rolling axis which is clearly seen in the magnetic charts. Rolls with insufficient initial grinding profile are overloaded in the near-edge areas which gives rise of premature roll wear because of cracking in overloaded areas.

   EXAMPLE: Some magnetic charts were taken after the first operating period of backing-up rolls from the same lot, which had showed that "A" roll preserved uniform stress distribution in the working layer of the roll barrel, while "B" roll had already suffered the wrong initial grinding profiling. It is evident that extra grinding profile has led to the roll overload along the rolling axis and has resulted in stress accumulation that might cause roll cracking unless grinding profile is corrected.

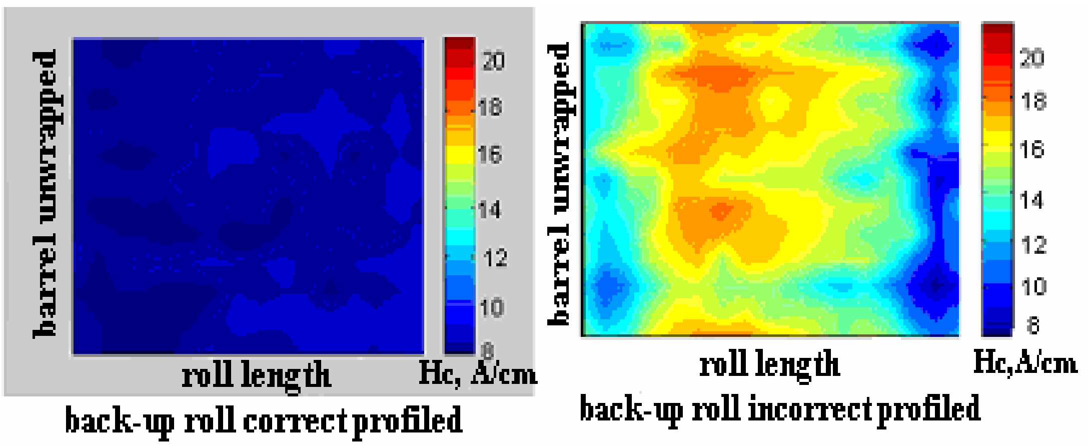


Fig.8 Two similar backup rolls after approximately 40,000 tonnes of cold rolled sheet [8]

Coercive force meter КРМ-Ц-К2М used in this work is applicable for operation with rolls of section mills but to fulfill this task it is necessary to change pole piece shapes.

3. Reference

[1] Fig.2 shows measurements obtained at Mittal Steel Temirtau.
[2] Fig.3 - the same at Magnitogorsk Iron and Steel Complex.
[3] Fig.4, 5, 6 and 8 – backup rolls of “Severstal” cold rolling mill
[4] Fig.7 – Novolipetsk Iron and Steel Complex