

## X-ray thickness gauges

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Nowadays it is impossible to separate roentgenometric and roentgenoscopic methods [1] since in the both branches, modern equipment use digital transducing for initial signal processing and for radiometric testing results indication not only digital - but also graphic values (diagrams, graphics etc.) of a measured parameter are utilized, which significantly simplify perception of results. A typical exponent of the roentgenometric method is the X-ray thickness gauging which allows to efficiently measure thickness of a metal rolled stock with the effective material atomic number of  $Z = 12...72$  from micron fractions up to several centimeters in the process without changes in the technological cycle.

The present measuring method is of a contactless type and is environmental friendly as distinguished from the isotope method. As an indirect measurement method, it has certain limitations on the accuracy of measurement results in case of changing the chemical composition of a product under testing and its density. High stability of isotope sources implies the pursuit towards an achievement of such parameters for X-ray equipment. To obtain the necessary accuracy of measurement by X-ray thickness gauges new detectors of ionizing radiation has been created - the heterogeneous multi-camera, with energy sensitivity. This solution makes it possible not only to expand the dynamic range of thickness measurement and correct errors made in the process of measuring the instability of X-rays, but also to avoid the impact of changes in the emission spectrum (anode recrystallization and metal atoms deposition at the x-ray tube window) on accuracy of measurements [2, 3, 4]. Nowadays, the main problem that arises in the process of x-ray thickness gauges design is the need to stabilize the flow of a rigid probe radiation according to the spectrum and as well as to intensity [5, 6]. However, it is important to constrict the spectral distribution of energy flux, since the passage of radiation through an object under testing changes its spectral distribution and, consequently, it is necessary to change correlation coefficients of amendments on a chemical composition of a material. Stabilization of an X-ray flow is a task that is usually solved by using feedback signals of current and voltage at the X-ray tube. Unfortunately, this approach cannot meter changes in the electrostatic field, extending out on the insulating body of an X-ray tube, and temperature changes in the geometry of electrodes. Furthermore, in the course of time, the cathode emission decreases and the anode surface recrystallizes. An exit window of X-ray emission absconds by sediment of anode metal ions on its surface. Sometimes, especially in X-ray thickness gauging, it is very important not to allow changes in the flow intensity, but also in its active energy. In case of a change in a thickness of rolled nonferrous metals and alloys with different values of an effective atomic number, the total mass attenuation coefficient of gamma-quantum absorption depends on the energy. For the purpose of obtaining minimal measurement it is necessary to possess the precise measurement drifts of a flux active energy. In order to solve the matter, a system of specter volatility and probe radiation flux source automatic correction was implemented for the thickness gauges of RIT10 series.

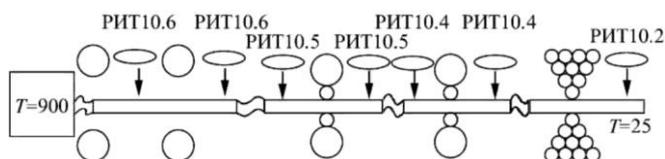


Fig. 1 Scheme of thickness gauges deployment on mills in the technological process of nickel band manufacture.

X-ray thickness gauging allows to measure thickness of a rolled metal stock in the manufacturing process without changes in the technological cycle. The required measurement precision reached to 0,1 ... 0,05%.

X-ray thickness gauges alternated isotope devices from the sphere of industrial production, despite the simplicity and convenience of operation with monoenergetic emission lines. As a rule, in thickness gauges, metal-ceramic X-ray tubes are used with feeding from highly stabilized, constant high-voltage source. Development of detectors and a possibility to implement them in the role of heterogenic cameras with energy resolution, made it possible to create a new and highly effective type of x-ray thickness gauges for thickness gauging of any type of rolled stock made from ferrous and non-ferrous metals and their alloys. The new type of x-ray thickness gauges provide measurement precision higher than 0,1% from a value under measurement. They are manufactured at the enterprises of “Spektr-group” association under the RIT10 trademark.

In developing a technological process of a high-precision rolled stock for nickel coins manufacture, a thickness gauges deployment scheme was utilized in control points of the technological process (fig. 1). The main parameters of these thickness gauges are listed in the table.

### Main characteristics of cold-rolled stock thickness gauges.

Index name	RIT 10.6	RIT 10.5	RIT 10.4	RIT 10.2
Material under testing	Copper Nickel...	Copper Nickel...	Copper Nickel...	Copper Nickel...
Copper range, мм	1...18	0,1...3,5	0Д...4,5	0,02... 1,0
Systematic component of a drift, %	+0,2	+0,05	+0,2	+0,1
Mean-squared deviation of a drift random component, %	0,1	0,1	0,1	0,1
Processing speed, sec.	0,1	0,1	0,1	0,1
Output signal nonlinearity, nominal deviation, %	+0,025	+0,025	+0,025	+0,025

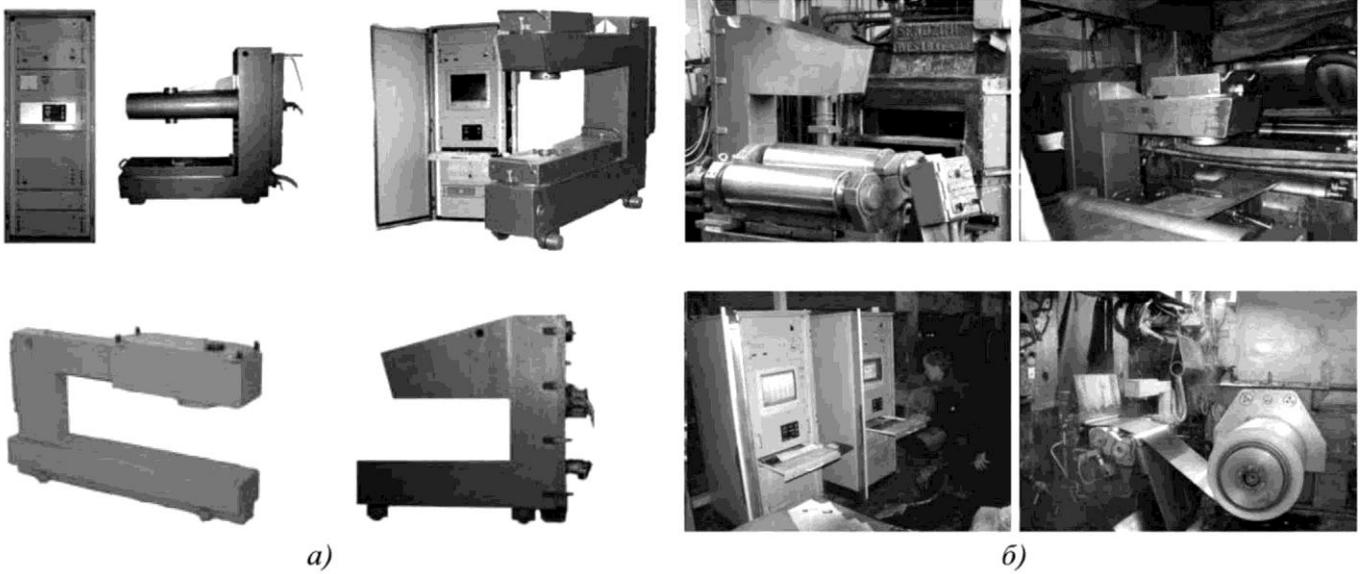


Fig. 2 RIT10 series X-ray thickness gauges at the rolled stock manufacture

Application of thickness gauges at the stage of a hot tape thickness measurement before processing at the mill for testing longitudinal and transverse variations in a band thickness has allowed to significantly increase yield of nondefective products (high-precision band for manufacture of nickel coins) in comparison with a common thickness gauges deployment scheme. It was achieved by nullifying the scrapping of rollers' edges. At the figure 2, the deployment of thickness gauges in metallurgical workshops (b) and their external appearance (a) are shown.

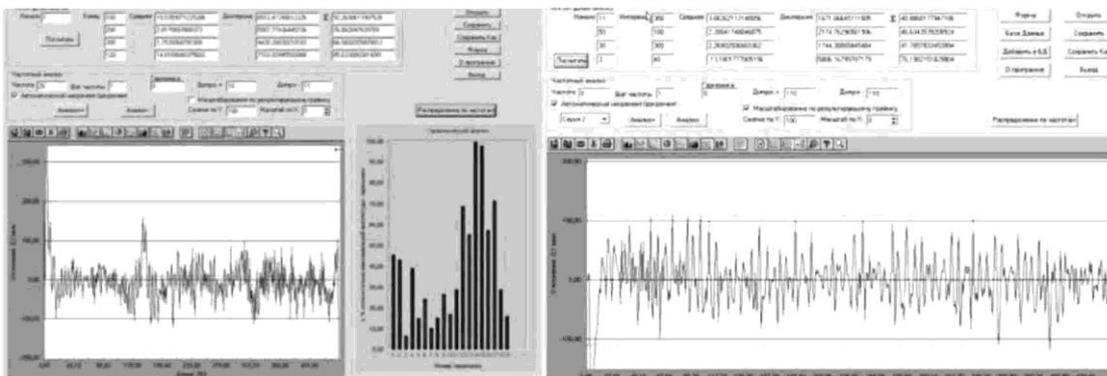
**Measurements stability and precision**

Band processing algorithm changes depending on sales means of rolled stock. Profiles of the first and the last runs of the band in a rolling mill is shown at the figure 3. Looking at these diagrams it is possible to take note that the metal sales (section shearing rolling stock) goes in accordance with adjustable meters but not with weight as it was before.. It is observed on how the thickness of a rolling stock is drawn in the minus area i.e. literally into the limit bond regulated by Government Standards. Utilization of such method allows saving lots of metal and shows the technological precision reserve in production [7].

Experimental researches has shown that the incidence of power and current instability on measurement results of nonferrous metals rolling stock by means of a x-ray thickness gauge with application of heterogenic cameras [8] in the role of detectors decreased more than 10 times and became invisible against the background of quantum fluctuations in detectors. At PC power-on through the DACs, it slowly raises the voltage on the X-ray tube to the specified value of the effective energy flux. Then the value of the anode current level 0.97 of the maximum value signal of the second section the reference camera is being set, which allows to start thickness gauge operation with fixed values of the intensity and the effective energy stream without waiting for complete stabilization processes in the X-ray emitter. This does not require long waiting (up to 30 minutes) for stabilization of radiation source parameters before calibration and measurements after a prolonged shutdown of equipment (Fig. 4).

**Operation conditions:**

- Aggressive environment (acids and caustics);
- Vibrations and impact loads;



Puc. 3. Examples of inbound and outbound gauge interference along the roll.

Fig. 4. Process of stabilizing emission source parameters (a) and normalizing thickness value to the value of probe radiation source instability (b)

- High temperature and moisture;
- High level of electromagnetic disturbances (1001 kW dc motors operated with implementation of a pulse | length modulation);
- Temperature gradient at the equipment I continuous offline i.e. holidays and maintenance of rolling mills (from -25 up to +35 °C within premises of a workshop);
- Non-interruptible, three-shift operation. Equipment operation in such conditions needs not only the online restoration which, either way, leads to a downtime of the whole production

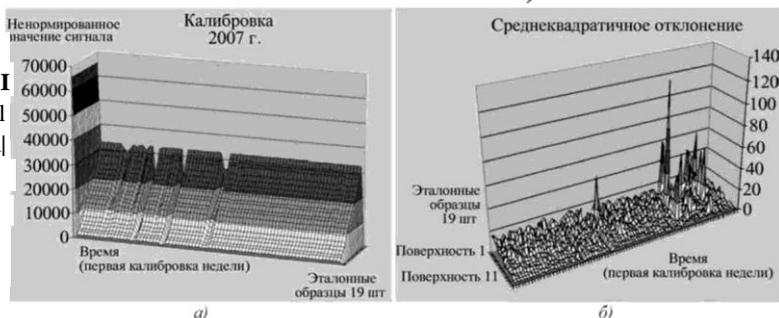
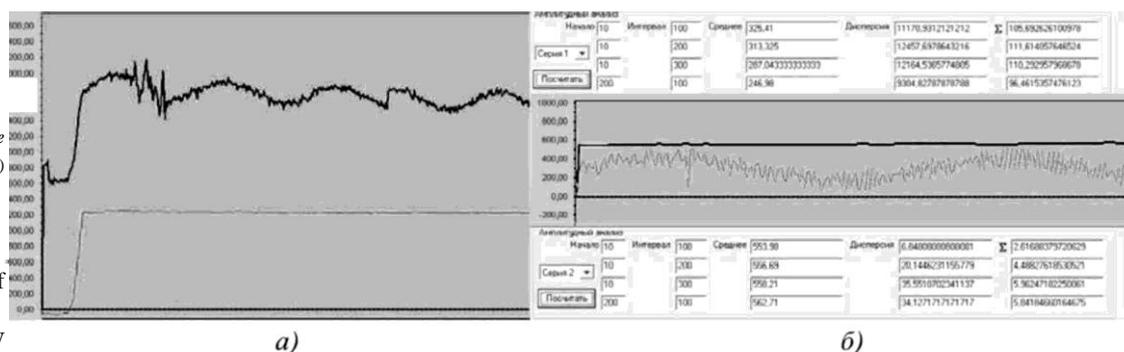


Fig. 5. Thickness gauges production operation experience throughout a year:

a - results of calibration by master samples; b - common deviations in measurement results parameters of the latter reaching to the

process, but also requires maintenance with system elements replacement factored in, with critical. [9].

### New approaches to equipment gauges maintenance at metallurgical enterprises.

The main issue is to overcome the psychological barrier of management of an enterprise to get an ability for remote equipment maintenance. Nowadays, it is not a problem to receive a fixed IP-address in a network for a device in situ, which allows to organize addressing to a device, bypassing thirdsmen in the person of plant personnel. As far back as several years ago the situation was completely different. In a number of years of "Spektr-group" devices operation in rolling stock production, a certain experience of remote diagnosis and maintenance was gained. As an example, diagnosis of RIT10.5 thickness gauges operating at the "Quatro" mill of KZOCM (Kirov) plant can be given. At the figure 5, results of thickness gauges testing received remotely and without plant personnel interference, performed after Sunday mills maintenance. Antecedently, the known values of operation calibrations and limit allowances for dispersions of a measured signal make it possible to diagnose a situation and give precise instructions to personnel on fails elimination before its impact on quality of manufactured products in 99% of failures and malfunctions.

### Conclusion

Utilization of this operation procedure for equipment maintenance by developers themselves allows to shorten equipment downtime. According to the data by plant operations and records departments in 2007, the average downtime of x-ray thickness gauges has reduced to 13hrs. a year per one device.

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