X-RAY THICKNESS GAGES OF THE RIT10 FAMILY FOR THICKNESS MEASUREMENT AT LINE PRODUCTION OF ROLLED METAL

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Abstract

When inspecting the thickness of rolled metal with the use of thickness gauges we cannot obtain the true value of thickness. That means the measurement gives us only an approximate value. This is explained by both precision consideration in principle of the thickness gauge and the nature of the inspected material. The accuracy of thickness gauge is a characteristic that shows the degree of approximation of test indication to the true value of thickness. It correlates with physical phenomena that the device is based on, its schematic circuit and the tolerance of individual units of the gauge.

The key disadvantage of the X-ray technique in thickness measurement is difficult interpretation of readings, namely the conversion of radiation attenuation in material into its thickness. According to the current Russian standard, the variation in metal density and its chemistry is not taking into consideration when measuring. To compensate this and to eliminate its influence on the measurement accuracy, we offered a new scheme for the X-ray thickness gauge design (patents 22152601, 2215259, …). In the whole we have patented more than 20 designs of the RIT10 X-ray thickness gauges that have allowed us to improve the accuracy in comparison with the design with conventional arrangement of the emitter and detector of X-ray radiation. It resulted in the increase of product yield. For analytical research we used the base scheme of gauge arrangement in test points of technological process. We theoretically analyzed the influence of metal chemistry variation on gauge interference with the use of samples of cross and longitudinal crown in rolled metal from all stages of metal processing and the data on rolled metal chemistry.

Today it is impossible to draw a line between the X-ray method and the radioscopy method [1], since both employ new equipment that uses digital conversion for primary signal processing. To represent radiometric control data, such equipment uses not only the numerical but also graphic values of a measured parameter (charts, graphs etc.) which drastically facilitates data perception. The X-ray method is primarily represented by X-ray thickness gaging that allows thickness of rolled metal with the effective atomic number of material Z = 12….72 to be effectively measured accurate within micron fractions to a few centimeters, such measurement performed in process without interfering with the technology cycle.

Key words: X-ray method, thickness measurements, emitter, detector, ionizing chamber

1. X-ray thickness gages comes to replace isotopic instruments

This measuring method is convenient (it is noncontact and pollution-free as distinct from the isotopic technique), but being an indirect method of measurement, it has certain measuring accuracy limitations in case of varying chemical composition and density of a tested object. High stability of isotopic sources makes such parameters necessary for X-ray gages. To obtain the desired measuring accuracy of X-ray thickness gages, new ionization detectors were designed representing multilayer heterogeneous energy-sensitive chambers. This solution helps not only obtain an extended dynamic thickness measuring range and adjust the measuring error caused by instable X-ray radiation, but also avoid the influence of radiation spectrum variations (anode recrystallization and metal atoms settling on the X-ray tube window) on measuring accuracy [2,3,4]. The main problem that X-ray thickness gage designers are facing today is the need to ensure stiff stability of the probe radiation flux both in terms of the spectrum and intensity [5]. It is important to narrow the spectral distribution of flux energy, since as radiation passes through a tested object its spectral distribution changes, which makes it necessary to change the correlation factors of corrections for material chemical composition. X-ray radiation flux stabilization is a task normally handled by receiving current/voltage feedback signals on the X-ray tube anode. Such an approach, however, cannot allow for changes in the electrostatic field spreading over the X-ray tube insulating case and for electrode geometry temperature variations. Furthermore, the cathode emission drops eventually and the anode surface recrystallizes. The X-ray radiation window is covered with settling anode metal ions. For some applications (especially X-ray thickness gaging) it is critically important to maintain stability both of flux intensity and active energy. In case of thickness variations in nonferrous rolled stock and alloys with different values of the effective atomic number, the full mass coefficient of gamma absorption attenuation depends on energy, and it is important to know the exact value of the active flux energy to minimize measuring errors. This task was tackled by incorporating an automatic correction system for spectrum instability and probe radiation source flux into the RIT10 thickness gage. X-ray thickness gaging enables effective in-process measurement of metal rolled stock thickness, without interfering with the technology cycle. The X-ray thickness gaging accuracy required by metallurgists has risen to 0.1….0.05%.

X-ray thickness gages have ousted isotopic instruments from the industrial production area, despite the latter's usability and convenience of their monoenergetic radiation lines. As a rule, X-ray thickness gages feature ceramic-metal X-ray tubes powered by highly stabilized DC voltage sources. Improvement of detectors and their possible use as heterogeneous chambers with energy resolution, enabled creation of new high-efficiency X-ray thickness gages to measure thickness of any types of ferrous/nonferrous rolled stock and alloys with a measuring accuracy exceeding 0.1% of the measured value. These gages (RIT10) are manufactured by SPECTRE-GROUP Association.

2. Industrial Testing

In order to create a high-precision rolling process for production of nickel coins, a thickness gage layout was used in which gages were located at process checkpoints (Fig.1).

Fig.1. Layout of Thickness Gages for the Nickel Band Rolling Process

Use of thickness gages to monitor longitudinal and lateral gage interferences at the hot band thickness measuring stage prior to roll-mill treatment allowed the product yield (high-precision band for production of nickel coins) to be substantially increased in comparison with the traditional thickness gage layout by negating the rejection of finished band coil edges. The actual arrangement of thickness gages in metallurgical shops and their appearance are shown in Fig.2.

Fig.2. RIT10 X-ray Thickness Gages in the Rolling Shop

2.1 Measuring Stability and Accuracy

The strip processing algorithm varies depending on the method of sales of rolled products. Fig.3 shows the profiles of the first and final strip passes in the roll mill. Judging by the illustration, it is safe to say that the metal (rolled section) is sold by running meters, not by weight as was the case before. It becomes obvious if you pay attention to how carefully the rolled metal thickness is brought away to the negative area, practically to the dimension limit as specified by the relevant state standard (GOST). Application of this technique helps save metal and shows the process accuracy margin in production [6]. Experimental studies show that the degree of influence of instability of the probe radiation source voltage and current on nonferrous rolled metal thickness measurements performed with an X-ray thickness gage, with heterogeneous chambers used as detectors, decreased by more than 10 times and became indiscernible against the background of quantum fluctuations in the detectors. When power is on, the controlling computer (via DACs) will be gradually increasing the X-ray tube anode voltage until the specified value of active flux energy is obtained. Following this, an anode current value is set by the level 0.97 from the maximum value of the second section of the reference chamber. This allows the thickness gage operation to be started with fixed flux/effective energy values, without having to wait (for up to 30 minutes) for complete stabilization of processes in an X-ray generator prior to calibration and measurement after the equipment has been off for a long time.

Fig.3. Examples of Input and Output Gage Interferences of Rolled Stock along the Coil (RIT10.5)

2.2 Operating Conditions

- Corrosion environment (acids and alkalies)
- Vibrations and impact loads
- High temperature and humidity
- High EMI levels (100 kV DC motors controlled by pulse-length modulation)
- Temperature differentials at equipment shutdowns for New Year holidays and roll mill preventive maintenance (from -25 to +35°C inside the shops)
- Required continuous 3-shift work for indefinite time.

Equipment use in such conditions requires not just fast equipment reconditioning (which in any event entails suspension of the entire production process), but preventive maintenance involving replacement of system components, the parameters of which are approaching critical values.

3. New Approaches to Servicing Thickness Gages at Primary Metals Establishments

The main problem today is company management having yet to become psychologically prepared to accept remote equipment maintenance. At present, it is no problem whatsoever to receive a fixed network IP address for a gage at the place of operation, which provides direct access to the gage bypassing intermediaries represented by company personnel. The situation was quite different a few years ago. We have gained certain experience in remote maintenance and diagnostics over five years of using our gages in rolling production. A good example is diagnostics of RIT10.5 thickness gages employed by the Quatro roll mill at Kirov Nonferrous Machining Plant in Kirov, Russia. Fig.4 shows the results of remote thickness gage testing performed after Sunday roll mill maintenance, involving no plant personnel (shop staff). The known calibration values and tolerance limits for measured signal dispersion allow a situation to be diagnosed in 99% of faults or failures and exact remedial directions to be given to personnel before such faults or failures begin affecting product quality.

Fig.4. Year's Experience of Thickness Gage Use in Rolling Production.

4. Conclusion

The above approach to organizing maintenance of equipment directly by its designers helps reduce the downtime. According to the data of factory operation and accounting departments, in 2007, the average annual downtime of X-ray thickness gages reduced to 13 hours per gage.

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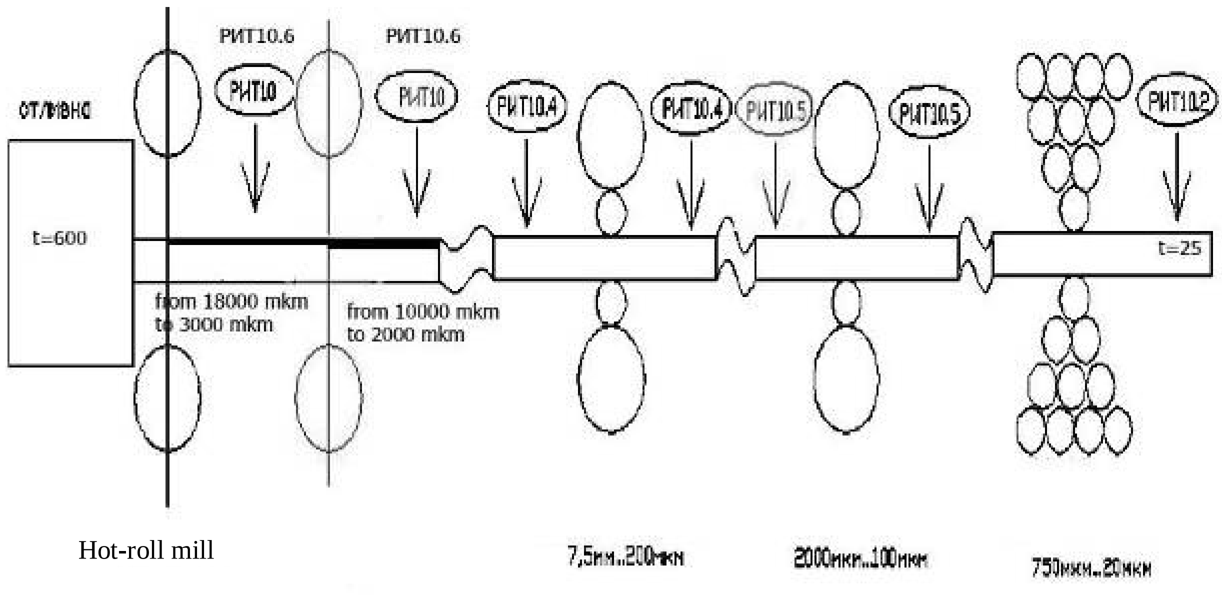


Fig.1. Arrangement of Thickness Gauges on Roll Mills in Nickel Band Production

Fig.2. RIT10 X-ray Thickness Gages at the Rolling Shop

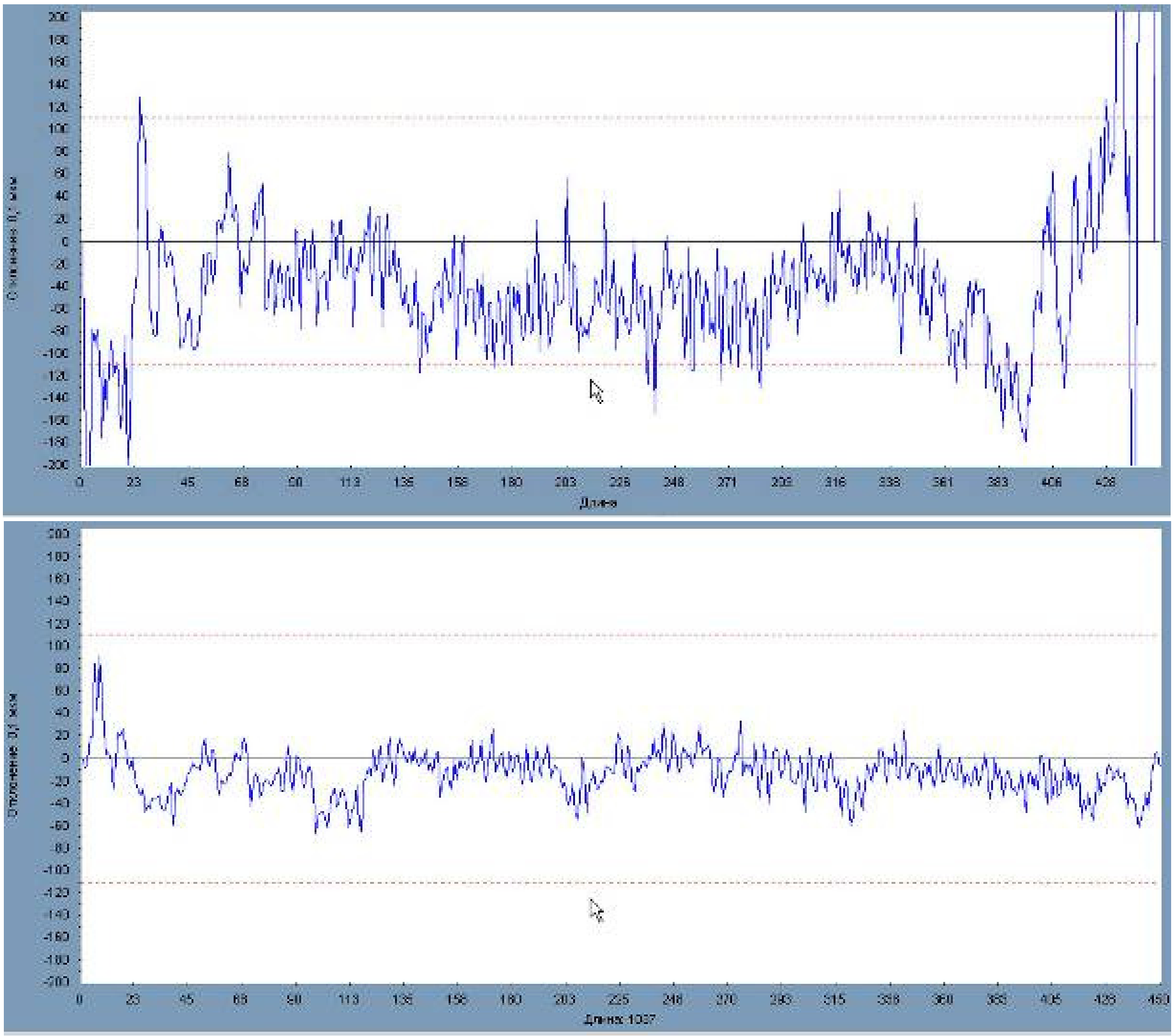
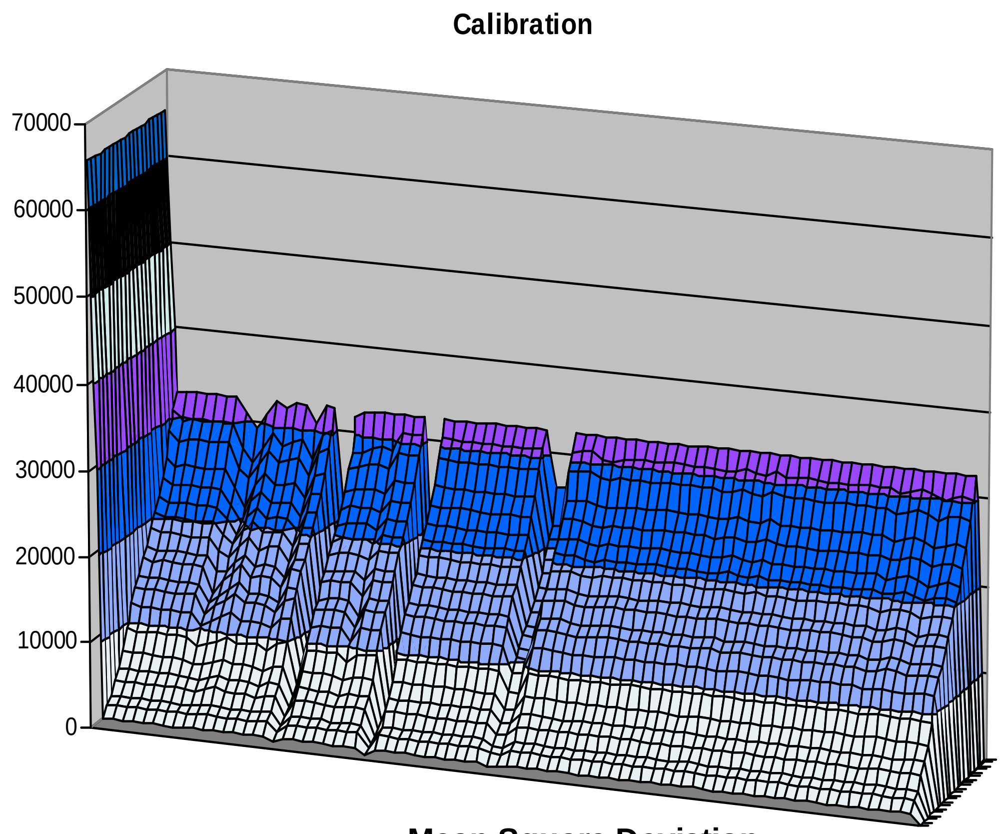
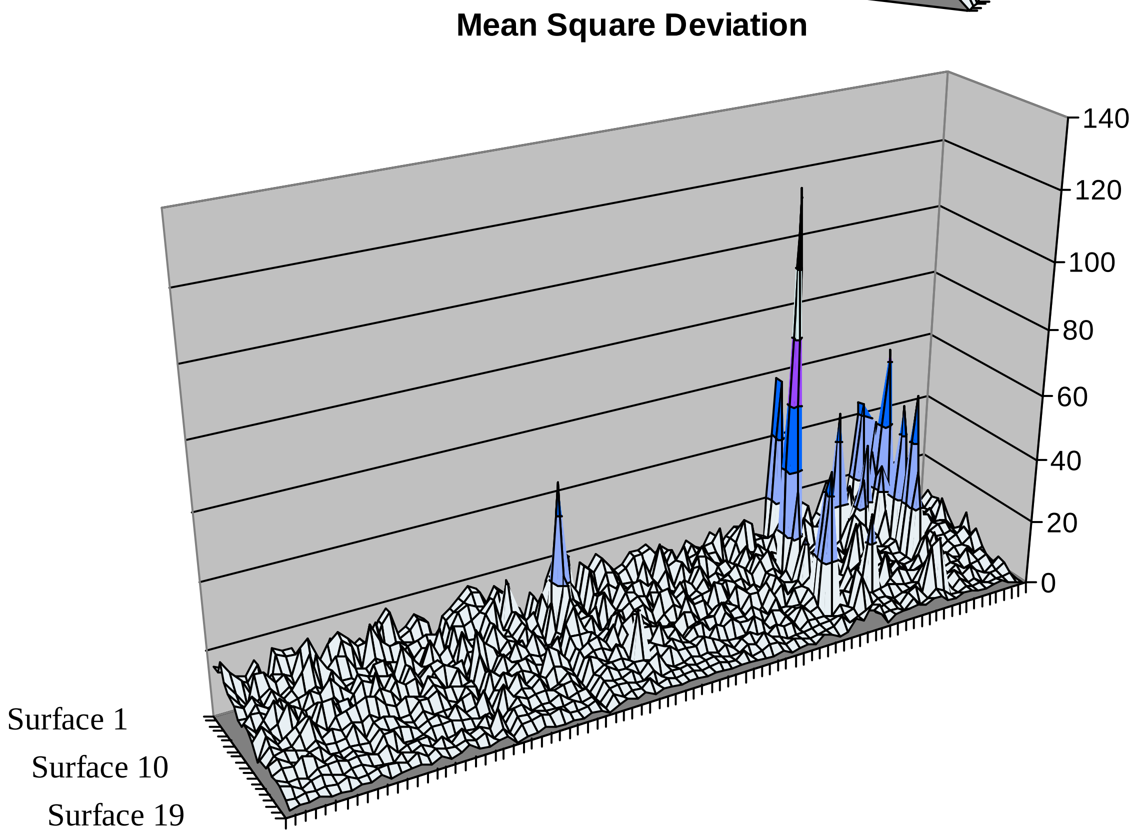


Fig.3. Examples of Input and Output Gage Interference along a Rolled Coil (RIT10.5)





- **results of calibrations by model samples**
- **mean square deviation of measurement results**

Fig.4. Year's Experience of Operating Thickness Gage: