Industrial Measurement Instruments that Use Radioisotopes

Asao Monno

1. Introduction

Industrial measurement instruments that use radioisotopes (RI) are instruments that harness radioactive rays to measure such parameters as thickness, level, density, moisture and the like. The advantage of such measuring instruments is that they are non-contact, non-destructive and enable online, real-time high-speed measurements. Because the physical properties of RI make these instruments less susceptible to thermal, electrical and vibratory noise sources, these measuring instruments are widely used in such applications as, for example, the mill control in a steel plant, or in production lines at chemical plants and in the plastic and paper industries.

In addition to their use for product inspection purposes, these instruments also are used to production process control systems and have become established as special sensors essential to each production process.

One such example is a hot steel plate thickness gauge that operates automatically under supervision from a process computer and transmits hot state thickness values, with a 50 ms response time, as output for the real time control of a mill, while simultaneously outputting and storing the thickness of the finished product, or in other words the cold state thickness value.

Fuji Electric offers a wide lineup of these instruments, including a gamma ray thickness gauge for use in steel plants, a beta ray thickness gauge for use with plastic and paper, various level gauges, moisture gauges, and the like.

This paper describes a thickness gauge to be housed inside a plate mill, a thickness gauge for hot seamless tubes, and Hitachi-compatible radioisotope-applied measurement instruments.

2. Gamma Ray Thickness Gauge Housed Inside a Hot Plate Mill

In the past, thickness gauges for hot plate mills could be installed only at a distance of at least 10 m from either the front or back of the hot plate mill.

The internally-housed gamma ray thickness gauge measures by irradiating gamma rays from inside the mill housing, or more specifically, from the small gap between the rolls of the conveyor at a distance of 2 m from the center of the mill. Conducive to the early application of mill control, this gauge can be used at the stage when the plate is still a slab of a considerable thickness. Furthermore, use of this gauge enhances mill efficiency since there is no need to convey plates a distance of at least 10 m behind the mill in order to acquire mill control information.

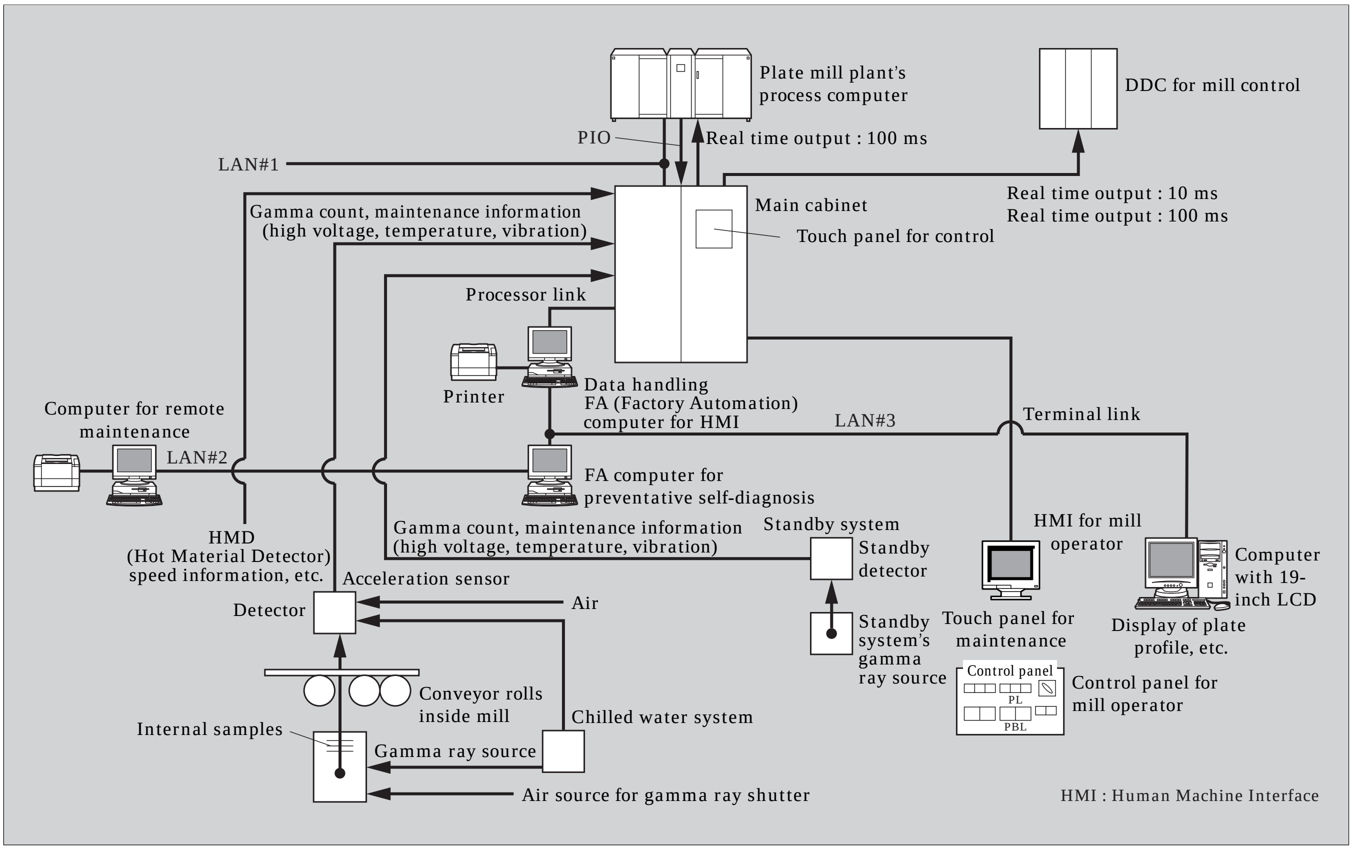
In order to realize such a thickness gauge, in addition to good environmental immunity performance capable of withstanding the harsh environment inside a mill, namely, heat, mechanical shocks, copious amounts of water, adhesion of iron scraps or iron oxides, falling pieces of iron and the like, because the installation site does not allow maintenance to be performed offline, high reliability that differs qualitatively from the reliability of conventional thickness gauges, remote maintenance capability, or the like must also be provided.

Details of the performance of the detector have been reported previously, and therefore, the description below will focus on apparatus performance, sys-

Table 1 Main specifications of the internally-housed gamma ray thickness gauge

Radiation source	^{137}Cs 1.11 TBq
Detector	Plastic scintillator detector
Detector amp	Pulse amp method (digital count method)
Detector stabilizing method	Spectra stabilization by near-ultraviolet rays
Max. impact acceleration	735 m/s^2 (75 G)
Impact reduction ratio	1/10 or less
Thermal resistance	Continuous operation possible inside a hot plate mill
Measurement range	Approx. 2 to 150 mm
Statistical noise	Ex: 33 µm at 20 mm with 90 % reliability, 0.2 s response
Drift	5 µm / 8 h
Instrument response	10 ms

Fig.1 System configuration of the internally-housed gamma ray thickness gauge



tem configuration and maintainability.

Main specifications of the internally-housed gamma ray thickness gauge are listed in Table 1, and the configuration of a system currently being constructed is shown in Fig. 1. A 100 ms real time signal is output for mill control, and a fast 10 ms response signal is output to enable more detailed ascertainment of the plate profile. Thickness data is presented to the mill operator via a digital display and a plate profile image is displayed in real time at each pass of the rolling procedure, providing support for instantaneous decision-making.

Remote maintenance, implemented while the gauge is online, uses internal samples to perform automatic multi-point calibration, which includes the zero point (see Published Japanese Patent No. H04-43207). This remote automated calibration, combined with the good stability of the detector, eliminates the need for onsite maintenance of the instrument calibration.

Furthermore, as independent processor is additionally provided to implement a preventative self-diagnosis function which stores in a database various types of maintenance data for the detection and standby systems, as well as real time measurements of vibration, impact, acceleration and the like, and supplies data for the purpose of diagnosing and analyzing failure and to prevent trouble.

Table 2 Main specifications of the tube wall thickness gauge for hot seamless tube mills

Radiation source	^{137}Cs 1.11 TBq, length 223 mm
Detector	Plastic scintillator detector with 350 mm measurement width
Detector amp	Pulse amp method (digital count method)
Detector stabilizing method	Spectra stabilization by near-ultraviolet rays
Measurement range	Outer diameter : 25 to 180 mm Wall thickness : 2 to 45 mm
Measurement accuracy	Within 0.2 % of the wall thickness
Drift	0.2 µm / 12 h at 81 mm (outer diameter) and 9.21 mm (wall thickness)
Instrument response	8 ms

3. Tube Wall Thickness Gauge for Hot Seamless Tube Mills

Seamless tubes are high-strength steel tubes suitable for use under severe conditions such as oil well drilling. The tube wall thickness gauge for hot seamless tube mills is designed for mill lines, and especially for mill control in a stretch-reducing mill (that reduces tube diameter and stretches tube wall thickness). This gauge is an automated measuring system that outputs wall thickness measurements in

Fig.2 System configuration of the hot seamless tube wall thickness gauge

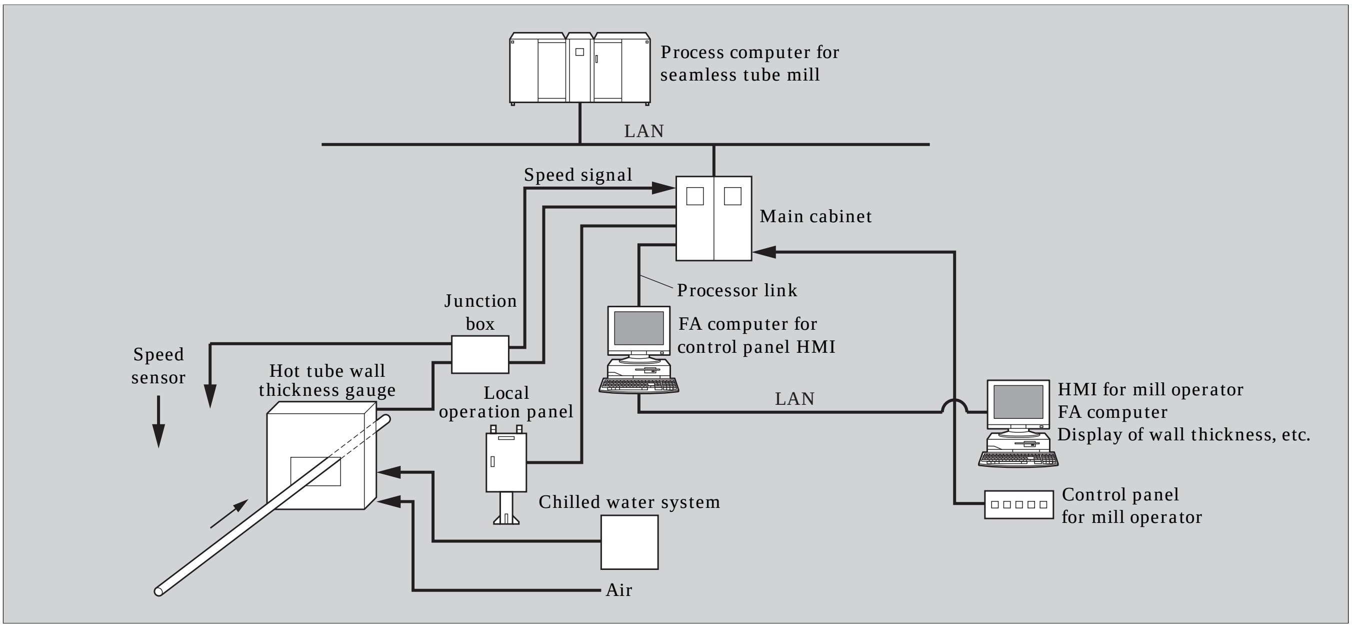


Fig.3 Mechanical part of hot seamless tube wall thickness gauge

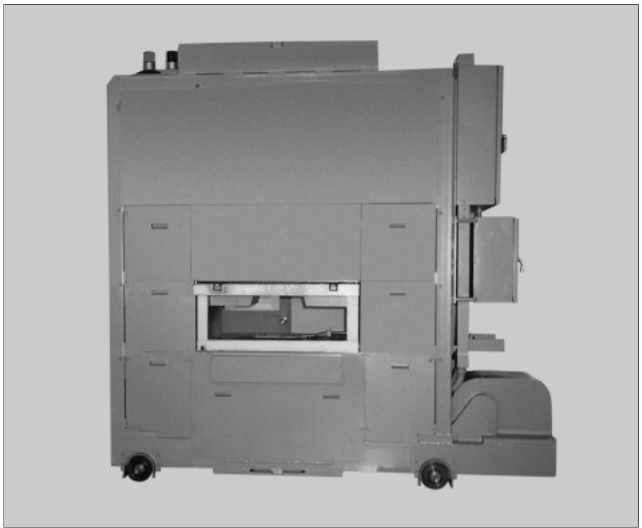
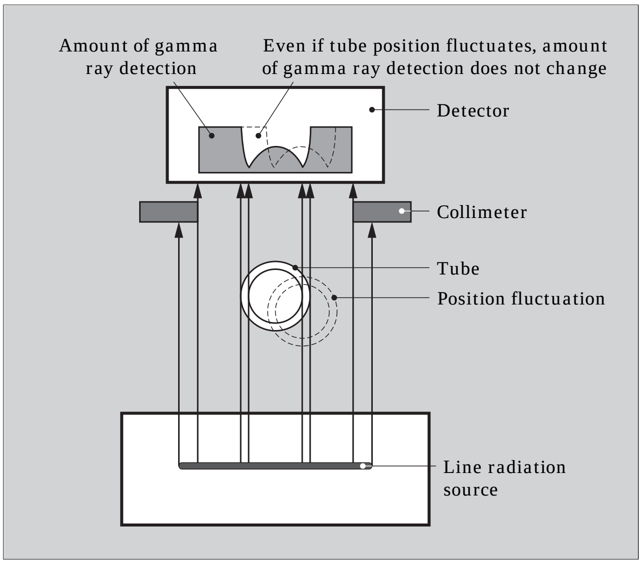


Fig.4 Measurement principle of hot seamless tube wall thickness gauge



real time with a fast 8 ms response speed, while simultaneously determining the top and bottom cut-off locations and storing wall thickness profile information.

As guidance to the mill operator, an image of the wall thickness profile is displayed in real time for each piece. The historical wall thickness profiles of any arbitrary piece in the database can also be displayed upon request.

Table 2 lists the main specifications of the apparatus under construction in FY2004, and Fig. 2 illustrates its configuration. In addition, Fig. 3 shows the appearance of a conventional tube wall thickness gauge, and Fig. 4 illustrates the measurement principle of the hot seamless tube wall thickness gauge. The measurement principle avoids the introduction of measuring error, even in the case where the position of the tube wall fluctuates horizontally or vertically during the course of motion (see Japanese Registered Patent No. 1474136-00).

In order to realize this principle, not only must the gamma ray irradiation field be made uniform, but the detector sensitivity must also be uniform. This challenge was solved by combining an approximately 350 mm-wide plastic scintillator with a special light guide that focuses the scintillation light uniformly and then guides it to a photomultiplier. The electronic circuitry is the same as that of the internally-housed gamma ray thickness gauge, and the near-ultraviolet ray reference method is used as the stabilizing method.

Utilizing two of these detectors, this apparatus

Fig.5 Hitachi-compatible radioisotope-applied measurement instrument

(a) Detector for gamma ray level gauge

(b) Radiation source container (shielding container)

realizes high count values and reduces statistical error with a fast 8 ms response speed.

4. Hitachi, Ltd.-Compatible Measurement Instruments

Fuji Electric manufactures and sells equipment that is fully compatible with Hitachi, Ltd.'s radioisotope-applied measurement instruments.

Not only is such measurement equipment interchangeable on the system level, but compatibility is also guaranteed on the component level for such basic components as the radiation source container, detector, electronic circuitry, cables, accessories and the like, making it easy to implement partial equipment upgrades.

In particular, the source capsules, parts, drawings and manufacturing processes of Fuji Electric's and Hitachi's radiation source containers are completely identical. This is beneficial to the user for ensuring compliance with the applicable laws and regulations.

Since the start of marketing activities under the terms of cooperation between Hitachi and Fuji Electric, these instruments have already been delivered to several tens of customers, and in all cases, the equipment is operating stably.

Figure 5 shows an example of a compatible instrument.

5. Conclusion

The internally-housed gamma ray thickness gauge achieves better durability in terms of impact resistance and thermal resistance than Fuji Electric's previous thickness gauges, and also realizes stable maintenance-free operation, high-speed response, and a database function. In the future, Fuji Electric intends to apply these technologies to its entire line of thickness gauges and to provide systems with even higher levels of reliability.

Because the hot seamless tube wall thickness gauge handles tube diameters of approximately 180 mm, it is intended for rather large-scale systems. In the future, Fuji Electric plans to develop lower cost equipment for smaller tube diameters or systems having simpler configurations.

Level gauges and density gauges are available both as Fuji Electric models and as Hitachi-compatible models. Future product development will promote the advantages of each.