SUMMARY OF CHINA—MADE X—RAY THICKNESS GAUGES FOR STEEL INDUSTRIES

Le Maosheng (乐茂生) and Hua Zongzheng (花宗正)

(Shanghai Electrical Apparatus Research Institute, Shanghai 200063, China)

(Received June 1992)

ABSTRACT

There are two kinds of China- made X- ray thickness gaugemeters i.e. dual beam- dual detector system and single beam- single detector system- SM series, the latter is used dominantly in Chinese steel industries. The performance comparison between domestic and foreign instruments as well as its developments and applications is presented in this paper.

Keywords: X- ray thickness gaugemeters Uses Performance Performance testing Steels Industrial plants Working conditions

1 INTRODUCTION

It is well known that when a beam of X- rays passes through a steel plate of thickness H_x, its intensity I will be attenuated according to Eq.1:

$$I = I_0 \exp(-\mu H) \tag{1}$$

In most thickness gauges, the device output is the difference of measured thickness value H_x and thickness setting value H_s, i.e. thickness deviation $\triangle H$. The deviation can be calculated according to Eq.2:

$$\triangle H = H_x - H_s = -(2/\mu) \cdot [(I_x - I_s)/(I_x + I_s)] \tag{2}$$

where I_x is detected beam intensity corresponding to H_x, I_s corresponding to H_s, μ is the linear coefficient of absorption of the measured steel plate.

The research and development of Chinese X- ray thickness gaugemeter started in the middle of the 1960's, somewhat later than forerunners in the world. Some prototypes and samples of the gaugemeter were worked out and installed on different mills, and field testings were carried out in order to check their suitabilit for field use. After certain improvement, a small amount of instruments were manufactured and delivered.

From the technical point of view, there are two different lines in developing domestic X- ray thickness gaugemeters.

2 DUAL BEAM—DUAL DETECTOR SYSTEM

This line followed the trend that was the dominating one in the world before 1975. These gaugemeters feature two beams of X-rays and two detectors as shown in Fig.1. In these instruments, signals were generated, processed and transferred in analog mode.

1-X-ray generator; 2-Detector for measuring beam; 3-Measured signal preamplifier; 4-Standard steel plates for setting; 5-Detector for reference beam; 6-Reference signal preamplifier; 7-Measuring beam; 8-Reference beam; 9-Unit for calculation, processing and contral; 10-Thickness deviation meter; 11-Thickness setting switches; 12-Setting switches for composition and temperature compensation; 13-Steel plate to be measured; 14-Power supply of X-ray tube

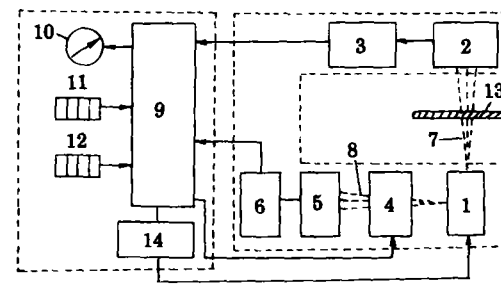

Fig.1 Schematic diagram of X—ray thickness gauge with dual beam—dual detector structure

3 DEVELOPMENT OF SINGLE BEAM—SINGLE DETECTOR SYSTEM—SM SERIES

3.1 Operation principle and instrument features

In operation principle there is an important difference between the SM instruments and other X-ray thickness gauges, i.e., in SM instruments, pulse frequency of detected X-ray particles is used as measuring parameter in stead of some electrical quantity proportional to the detected X-ray intensity. In other words, it uses Eq. (3—5) instead of Eq. (1,2):

$$F = F_0 \exp(-\mu H) \tag{3}$$

$$dH = -(1/\mu) \cdot dF/F \tag{4}$$

$$\triangle H \approx -(1/\mu) \cdot (\triangle F/F) \approx -(1/\mu) \cdot (F_x - F_s)/F_s \tag{5}$$

where F_o is initial pulse frequency of detected X-ray particles corresponding to $H=0$, F corresponding to the measured thickness, F_s corresponding to setting thickness H_s, F_x corresponding to measured thickness H_x.

Based on above mentioned principle, SM instrument have following fundamental features: single X-ray beam and single detector; using pulse frequency as setting parameter and few sample plates for calibration instead of complex setting system; signals being generated, processed and transferred in fully digitized mode, hence low deviation resulted; Rard-wired logic circuits being used for signal processing.

In the 1970's, several models for both cold and hot rolling mills were developed, manufactured and operated successfully on different mills. In the late 1980's, SM 400

series of microprocessor-based X-ray thickness gauges were developed. Besides fundamental features mentioned above, SM400 instruments have following additional features: major parts of original hard-wired logics being replaced by a microprocessor; using adaptive digital noise filtering technique to improve S/N ratio efficiently; automatic calibration; operation monitoring, fault alarm and automatic diagnosis; precise calculation of thickness deviation and processing of other data; optional function of typing out of the measured data.

3.2 Problems ought to be solved in application

3.2.1 Protection against severe environment and demands of satisfactory supply of electric power, cooling water and compressed air

In the rolling mills many detrimental factors might exist, such as: high environmental temperature and its rapid variation; dust, iron oxide scale, water drops on the surface of measured strip, vapors; high humidity.

In order to protect the C-frame and its associated subassemblies, following measures have been adopted: water jacket of C-frame sensor with cooling water system; water-seal or gas tight structure being adopted for subassemblies mounted on the C-frame; dry nitrogen with low positive pressure being supplied, if necessary; Iron-oxide scale, water film and other obstacles on the X-ray window being blown away by compressed air; cooling water, compressed air, clean electric power and earthing system ought to be supplied properly.

A mechanical shelter is necessary to assure safe operation of the C-frame sensor on the rolling line, because breaking or misguiding of the steel strip may often impact the C-frame and cause the instrument malfunctioning or to be damaged. But the configuration and location of installation should be carefully selected in order to avoid detrimental effects on normal operation and/or treatment of accidents during rolling process.

3.2.2 Strengthening rules and regulations for maintenance

It is necessary to set up two maintenance teams: on duty team and repairing team. The former is in charge of daily preliminary maintenance, inspection and recording of the operational state of the instruments, especially during relief. The latter is in charge of the diagnosis and elimination of troubles, working out and executing of weekly and monthly inspection schemes, mainly for preventive maintenance.

3.3 A comparison between Chinese and foreign developmental status

In the early 1970's, most companies in the world adopted the traditional system structure of dual beams-dual detectors with analogue calculation and display. In the later 1970's some systems of single beam-single detector were developed gradually. The measured analogue signal from detector was amplified by a logarithmic amplifier and transformed into a digital signal by an A/D converter. Then, the thickness deviation was calculated by the microprocessor and transformed back into analogue

signals, for displaying and recording. We called such structural form as "Analog-Digital-Analog" form (A-D-A form). We have noticed that Toshiba Co. and Daystrom Co. have all adopted this form. From above description it was understood that an all digital form was adopted for the SM type thickness gauge.

In the field of improvement of pulse time resolving capability of the X-ray detector, application of digital filters and software development of the microprocessor *etc.*, hard work have been done in order to improve the functions and specifications of the instrument, as well as to reduce the dose of X-ray radiation. Safety, ease of application and low price are the main features of these instruments. All these meet the demands of continuous improvement of product quality and raising of productive efficiency. Main technical specifications of typical products of various countries are listed in Table 1.

Table 1

Specifications of some Chinese and foreign X—ray thickness gaugemeters

Type	TOSGAGE 5521 Japan	DAYSTROM 5040 UK	IGCI 500 USA	SM2A China	SM3A China	SM422 China
Measuring range / mm	1—16	1—16	1—25	0.1—5	1—20	1—25
Setting accuracy / % of set thickness	±0.1	±0.1	±0.15	±1.0	±1.0	±0.2
Noise / % of set thickness	±0.12	±0.15	±0.2	±1.0	±0.5	±0.2
Drift per 8 h / % of set thickness	±0.2	±0.2	±0.25	±1.0	±1.0	±0.2
Response / ms	10	30	10—100	50	50	30
Microprocessor	Tosmic 16	Scout NM4/ M	Zilog 80	—	—	M68000
Auto calibration function	Yes	Yes	Yes	No	No	Yes
Self-diagnosis function	Yes	Yes	Yes	No	No	Yes
X-ray parameters	120 kV 1.5 mA	120 kV 1.5 mA	120 kV 2 mA	70 kV 100 μA	120 kV 100 μA	130 kV 100 μA

3.4 The manufactures and applications of X—ray thickness gaugemeters in China

In the adopted domestic X-ray thickness gauge in China, the quantity of SM type thickness gauges is the largest one. We have supplied about 100 sets of products of types SM2, SM3A, SM3B and SM400 since the 1970's. Table 2 is the reference list of Chinese X-ray thickness gaugemeters.

3.5 Economic benefit analysis

The X-ray thickness gaugemeter is a kind of large scale, inreplaceable instrument of high techniques in whole set of steel rolling equipments. In the past, for the sake of quality administration in steel plate production and self-economic benefits, all the principal metallurgical enterprises did not spare at all costs to import foreign thickness gauges.

Economic benefits give expression to the following features: improvement of the object rolling accuracy; speed up the rhythm of rolling process; the distinct and direct display of the thickness gauge may bringing much convenience to the workers and minimizing their labor intensities.

Table 2

Reference list of Chinese X—ray thickness gauges

No.	Users	Types	QTY	Remarks
1	Anshan Iron & Steel Co.	SM2, SM2A	7	Cold rolling
2	Shanghai No.10 Iron & Steel Works	SM2A	7	Cold rolling
3	Shanghai Cold Strip Works	SM2A	2	Cold rolling
4	Wuhan Cold Rolling Plant	SM2A	2	Cold rolling
5	Beijing Special Steel Plant	SM2A	3	Cold rolling
6	Beijing No.3 Cold Strip Works	SM2A	2	Cold rolling
7	Shanghai No.1 Iron & Steel Works	XCR-1	1	Hot rolling
8	Tianjin Medium Plant Works	HX-1	1	Hot rolling , medium plate
9	Jinan Steel Plant	HX-1	2	Hot rolling, medium plate
10	Tianjin Bicycle Factory	HX-2	1	Cold tandem mill
11	Anshan Iron & Steel Co.	SM3A	1	Hot semi-tandem mill
12	Shanghai No.1 Iron & Steel Works	SM3A	1	Hot semi-tandem mill
13	Xi'an Heavy Machine Institute	SM3B	1	Cold reversible mill
14	Maanshan Medium Plate Works	SM422	1	4 Height, medium plate
15	Shanghai No.10 Iron & Steel Works	SM421	1	Hot semi-tandem mill
16	Tielin Aluminium Plant	SM401	1	Al cold rolling
17	Anshan Iron & Steel Co.	SM3A	1	Hot semi-tandem mill

Take Anshan Slab Mill Works as an example. The annual production of 5—15 mm steel plates was 500 thousand tons. A SM3A type thickness gauge have worked successfully for 9 years. The economic lost/day due to breakdown of that thickness gauge is about 10 thousand yuan (RMB). Consequently, the direct annual benefits may be more than 3 million yuan. Furthermore in the Maanshan Medium Plate Works, the annual production of 4—25 mm medium plates was 240000 tons. For the purpose of raising the accuracy of rolling object (0.15 mm in average) and minimizing the measuring time, the direct annual economic benefits of using the thickness gauge may be as high as 1—1.5 million yuan.

3.6 Conclusion

Although in the field of research and manufacture of X-ray thickness gaugemeters China has gained adequate development and experience during the past years, in comparison with the advanced countries, we still have a long way to go.