Non-contact plate thickness and profile measurement

The new Radiometrie RM 306 ES simultaneous hot plate thickness and profile gauge is based on the established technology of detectors with a plastic scintillator, but yielding twice the accuracy of conventional gauges that use ionisation chambers.

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For nearly three decades, Thermo Electron Corporation has developed and installed a variety of hot plate thickness and profile gauges with special measurement features that permit a high degree of versatility. This detector technology has been well established at many plate mill and plate shearing line installations and the article describes a non-contact gauge for simultaneous thickness profile measurement of hot steel plate. The gauge measures the thickness profile at both plate edges, the centreline thickness, wedge and crown, plate speed and length, as well as plate temperature profile. Additionally, a plate width gauge can be seamlessly integrated into the system.

Measurements
The primary measurement provided by the Radiometrie RM 306 ES is a fast, accurate centreline thickness; however, it also provides a simultaneous thickness profile measurement of the edge of about 1,200mm on each side (see Figure 1). Also, with a geometrical resolution in the cross direction of 40mm, rolling defects such as laps and ridges can be identified. This allows the operator to adjust a spray nozzle or change a roll to prevent further occurrences on following plates.

The system also provides edge and temperature profiles over the complete plate length.

Cross-profile thickness measurement values are processed every 10ms and recorded every 50 to 500ms. The profile measurement values are displayed in cross and length direction and temperature cross-profile is measured typically with a line scan pyrometer about 25 times per second. Wedge, crown and edge profile are displayed every 50ms. The fast, low-noise, thickness measurement for automatic gauge control (AGC) in the centre of the plate is processed and recorded every 10ms. Measurement values are sent via Ethernet and/or Profibus interface to the mill computer for profile control and supervision by operators. The measuring range of the gauge is typically 5–120mm, but it can be extended up to 180mm. The radiometric noise (2-sigma) is between +/- 0.03 and +/- 0.1% of nominal thickness, depending on integration time and thickness.

Due to the coefficient of thermal expansion, the plate length, width and thickness change from rolling (typical temperature 600–1,200°C) on cooling to room temperature (20°C). In order to display the dimensions as they would be at room temperature, the gauge incorporates a temperature expansion (dilation) correction feature. To calculate the correct thickness profile, the measured temperature at each measurement position is corrected. The material-specific identification values or dilation curves can be sent by the mill host.

Figure 1 Simultaneous plate thickness and profile measurement
The C-frame is manufactured from stainless steel protected by a water-cooled heat shield mounted on the lower C-frame arm (see Figure 2). To protect the internal components from excessive heat, cooling air is blown between the upper arm heat shields and the C-frame. The entire C-frame is kept under positive pressure to prevent dust and humidity from entering. For centreline measurement, a set of scintillation detectors is mounted in the centre of the upper C-frame arm. The compact detector package can be built-up from as many as four detectors to provide redundancy and minimise mill down time. The corresponding source and source container are located in the centre of the lower arm and the output from this high-speed centreline measurement channel is used for plate mill AGC systems.

For edge measurement, two sources in their source containers are installed in the upper arm, with their corresponding detector arrays in the lower arm. The detector arrays and the source containers are mounted to carriages that are driven by stepper motors for controlled movement and position feedback. There is no mechanical connection between the detector arrays and source carriages; the alignment between both is carried out by the position control algorithm, which continuously verifies position and controls sensor alignment. Each of the two detector arrays typically includes 28 rectangular scintillation detectors (or more or less, depending on mill requirements). The individual detectors are adjusted in their geometrical orientation to meet the specific measurement requirements. Due to the arrangement of sources and detector arrays, each array is only illuminated by one source and interference or cross talk between the individual detectors is avoided by shielding and beam collimating. Due to the number of detectors, the Radiometrie RM 306 ES thickness profile gauge inherently contains a high level of redundancy.

‘Intelligent’ terminals mounted on the detector carriage handle signal pre-processing and the analogue to digital conversion of the detector signals. The data is sent via a fibre optic conductor to the main electronics cabinet for further processing. The fibre optic conductor cabling and cooling water hoses are guided in cable tracks.

Accurate and low noise measurement is provided by caesium -137 sources with typically 1.85TBq activity. Each source is installed in a stainless steel source container shielded by depleted uranium. This provides very compact source containers with high shielding properties. The sources are coupled with a reliable and proven scintillation detector design, yielding twice the accuracy of conventional gauges that use ionisation chambers. Each detector consists of a plastic scintillator, photo multiplier, power supply and preamplifier.
Electronics and system operation

The high performance industrial processing electronics is panel mounted and access to all components is facilitated by the modular construction of the electronics console. The operator has overall control of the gauge through the operator station which is connected to the processing electronics via standard Ethernet hardware. This architecture allows additional operator stations to be connected, simply using standard hardware. The operator station running EPOS application software provides the functions for system control, data input and graphical and numerical measured value display (see Figure 3). The EPOS-operator interface is based on the Microsoft® operating system Windows® 2000/Windows® XP.

The main features of EPOS are:

- Operation via mouse, keyboard, touch screen, or virtual keyboard (soft-keyboard)
- Numerical display of the values shown graphically (profile, trends, and histogram)
- Language manager: Language of the operator interface can be changed during operation
- Level manager: For security purposes, every action/function of the gauge is set to an access level (administrator, maintenance, and user; 1-3)
- Print manager: Selected pages can be printed or saved to a PDF file. The printing can be triggered manually or automatically by selected different mill events. Customer network printers can be used
- Product data memory: For storage and preparation of product data sets

The gauge is equipped with a remote access tool for software maintenance, analysis and diagnostics. The tool is available through a telephone link like ISDN or over the Internet such that all functions which are normally carried out from the gauge operator station can be controlled remotely from the Thermo Electron Corporation factory. This includes:

- Software updating
- Long-term analysis by downloading log files (errors, operator commands, digital/analog inputs, standardisation history, measurement results)
- Analysis of the current gauge status (reading actual standardisation values, reading actual analog voltages and digital signals, display of profiles, trends, histograms)
- Diagnostic functions (host communication, internal data communication)
- Gauge operation (execution of commands, data input)

![Figure 3 Example of screen display](image)

The remote access tool enables fast trouble shooting if problems occur. The attendance of a software engineer at the site is not necessary.

Data archiving system

The data archiving system is connected to the Radiometrie RM 306 ES thickness profile gauge via an Ethernet communication link. The electronics of the data archiving system consists of a standard high performance PC-compatible computer unit. The system stores all archived data in a SQL database, the type and amount of archived data being configurable by the process engineer. The application software for data archiving mainly includes the following functions:

- For each plate and pass measured, a database set is automatically generated using the plate/pass number and/or actual date and time for reference
- Plate documentation is configured to start when the head of the plate enters the gauge measurement beam and ends when the tail of the plate leaves the beam
- For combined length and cross-profile thickness measurement, all available profile data in the configured resolution will be archived. In addition to the measured data, the plate reference number and pre-set data are stored within the same database set
- Standardisation data is stored every day in a separate database set, automatically generated on the basis of the actual date. Within this file, the date and time of the standardisation and the results are stored
Furthermore, all system messages are stored on a daily basis. As with the standardisation log, the first message on a new day automatically starts a new message log file referenced by that date. All subsequent messages for that day are stored in that message log and any abnormal condition that results in a message is stored within this file. For example, over temperatures, wrong data input or commands, or communication errors will be recorded for later analysis.

The archived data is stored in an MS Excel spreadsheet file structure. This allows for further data analysis using many standard SQL query applications.

**Summary**

The Radiometric RM 306 ES provides hot plate mill operators with a complete simultaneous edge profile and all the critical measurements needed to optimise the rolling conditions for every plate. The resulting consistency will improve plate quality, mill set-up time and therefore overall mill efficiency.

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