Radiation Strip Thickness Measurement Systems
During the past years we have increased our sales of radiometric Vollmer strip thickness measurement systems, i.e. X-ray or isotope gauges, dramatically. Now, these non-contact gauges have gained an important position in our product range, which previously was primarily electronic contact gauges.

**Non-Contact Measurement Range**

**Between 10 microns and 30 mm**

The main advantages of radiation gauges are the non-contact measurement of the passing strip and their resistance against external influence. Radiation gauges are useful not only for measuring strip with especially sensitive surface but also for any standard cold rolling application. Other applications are measurements on hot strip and plate slabs.

As radiometric gauge heads are well off the strip surface during the entire measurement, they are only rarely damaged after a strip break. Vollmer gauges of the Gamma series measure strip even at very high rolling speed - foils of 10 microns as well as strip of 30 mm thickness.

Radiation gauges send ionizing radiation perpendicular through the strip. The passing strip absorbs a portion of the radiation on its way from the source below the strip to the detector above the strip. The thickness measurement is based on the reduction of radiation by the passing strip.

Radiation gauges send ionizing radiation perpendicular through the strip. The passing strip absorbs a portion of the radiation on its way from the source below the strip to the detector above the strip. The thickness measurement is based on the reduction of radiation by the passing strip.

Gauges of the Gamma X type use a high voltage X-ray tube to produce the radiation. Gamma A type gauges have a radioactive isotope in a capsulated container to generate the measurement radiation. Our detectors are specially designed high performance scintillators.

Both system types (isotope or X-ray gauges) use basically the same radiation because \(\gamma\)-radiation and X-rays are identical in their characteristics except for the location where they are generated. X-rays are generated in the electron shell of an atom while \(\gamma\)-radiation is generated in the atomic nucleus (protons, neutrons). Both kinds of radiation are energy-rich light quanta. For comparison:

Energy of visible light: \(2\) eV to \(3\) eV
Energy of \(\gamma\)-rays or X-rays: \(10\) keV to \(x\) MeV

The radiation is reduced by the absorption coefficient \(\mu\) as it passes through the measurement object (absorber). The intensity of the transmitted radiation is inversely proportional to the thickness and the density of the absorber material. The reduction of radiation intensity is evaluated based on a calibration curve which is stored in the measurement processor for each of the various strip materials to be measured.

**Radiation Intensity ..**

The intensity of the measurement signal changes depending on the strip thickness following this physical relation (valid for mono-energetic radiation only):

\[ I = I_0 \cdot e^{-\mu d} \]

- \(I\): intensity with absorber (strip)
- \(I_0\): intensity without absorber
- \(\mu\): absorption coefficient
- \(d\): absorber thickness
Isotope or X-ray Gauge?

The following parameters need to be considered to find the gauge type which best suits an individual application:

- strip material (e.g.: Al, Fe or Cu)
- strip thickness range
- thickness tolerances
- size of measurement spot for cross profile measurement
- strip speed

A comparison between the different characteristics of both gauge types makes obvious which gauge is the best choice for each application (see blue box on the next page).

The Measurement Frame

The gauges have a C-shaped measurement frame and usually the source is installed in the lower measurement arm and the detector in the upper arm. Because the Vollmer detectors, regardless of their high performance, are quite small, our gauges do not need much space.

The measurement frame is mounted on a slidebase and can be traversed hydraulically or motor driven to any selected measurement position on the strip. For service, each frame has an own on-the-spot-control panel.

.. and Statistical Noise

Following the law of physics, the decay of atomic nuclei in an isotope as well as the photons (radiation quantums) generated in the detector, are subject to minor natural variations. This causes slight deflections of the detector signal around the mean value. Such deflections are called the statistical noise $\sigma$. The noise depends on the number of detected particles according to the following relation:

$$\sigma = \sqrt{N} \quad \text{and} \quad \sigma_{\text{proz}} = \frac{\sigma}{N} \cdot 100$$

$\sigma$: statistical noise
$\sigma_{\text{proz}}$: noise in percent
$N$: number of detected particles (photons)

It is obvious that the relative noise decreases when the number of detected photons increases. This means, the best possible results are produced when as many photons as possible reach the detector and can be measured there. The number of particles however, which reach the detector, is dependant mainly on the following parameters:

- Source power: $N \sim A$  
  ($A = \text{isotope activity}$)
- Tube power: $N \sim I_{\text{ro}}$  
  ($I_{\text{ro}} = \text{tube current}$)
- Time constant: $N \sim t$  
  ($t = \text{measurement time}$)
- Distance to source: $N \sim 1/a^2$  
  ($a = \text{distance to source}$)
- Detector area: $N \sim A^2$  
  ($A = \text{active detection area}$)

Engineering of powerful gauges however, is restricted in such a way that the intensity of radiation may be selected only so high that the required radiation protection shielding does not become too large.
The long arms of the measurement frame allow the measurement of strip thickness at any desired position across the strip even on very wide strip. As an option, the measurement frame can be traversed across the strip at a constant speed during the rolling. This option is used for additional measurement of the cross profile strip thickness.

Isotope Gauges: Gamma A

These gauges use as radiation source the isotope Americium 241 (chemical Symbol: $^{241}$Am) in various activity classes (source power) from 37 GBq to 185 GBq (1 Ci to 5 Ci). Americium emits photons with an energy of 59.6 keV. These photons do not activate other substances, i.e. material that is exposed to such radiation does not become radioactive itself.

The radiation source is encapsulated in a removable, completely shielded source container which fulfils all requirements for protection against radiation. The service personnel or members of the fire brigade can remove the container without any extra radiation protection.

The container consists of:

- a massive stainless steel housing with integrated tungsten shielding.
- a tungsten capsule for the radiation source. This capsule can be removed from the container by service personnel who have been trained for this.
- a radiation shutter which covers the source when the gauge is not measuring. The shutter is opened and closed by a bidirectional pneumatic pressure cylinder with an extended piston rod. Following the fail-safe principle, two independent springs pull the shutter over the source if the pneumatics do not actively hold it open. Two proximity switches put out a signal to the gauge control when the radiation shutter is in the 'closed' position.

X-ray Gauges: Gamma X

The X-ray tube in its container is installed in a carriage which runs on rails in the lower measurement arm. The carriage can be pulled off the measurement frame for service or for quick replacement.

The tube container consists of:

- a tungsten shutter to stop the emission of X-rays
- a number of filters for the adjustment of the optimal radiation spectrum
- a reference filter for the automatic correction of the calibration curves

The X-ray energy is set to an appropriate level according to the kind of material and to the strip thickness which are mainly processed on the mill. Due to optimal selection of the radiation filters set there is usually a single energy setting sufficient to cover the entire thickness range.

If the mill processes strip of two very different thickness ranges, individual energy levels are set for each range.

Tube carriage with quick change module: Very short downtimes are realized for tube replacement.
at constant performance, which means it stays always in thermal balance, there is no need to wait for any adjustment time after switching voltage levels.

In order to ensure a very long tube life, we use always 'oversized' tubes which are capable of a much higher performance than actually required. In addition, all Vollmer X-ray gauges are equipped with metal-ceramic tubes which last much longer than glass tubes.

<table>
<thead>
<tr>
<th>Strip thickness ranges</th>
<th>Isotope Gauges</th>
<th>X-ray Gauges</th>
</tr>
</thead>
<tbody>
<tr>
<td>for Al alloys</td>
<td>3 ... 50 mm</td>
<td>0,1 ... 150 mm</td>
</tr>
<tr>
<td>for Fe alloys</td>
<td>0,2 ... 7,5 mm</td>
<td>0,01 ... 25 mm</td>
</tr>
<tr>
<td>for Cu alloys</td>
<td>0,1 ... 4,0 mm</td>
<td>0,01 ... 20 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement spot diameter</th>
<th>3 ... 20 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time constants</td>
<td>30 ... 100 ms</td>
</tr>
<tr>
<td>Height of measurement gap</td>
<td>60 ... 200 mm</td>
</tr>
<tr>
<td>Strip speed</td>
<td>... 600 m/min</td>
</tr>
<tr>
<td>Radiation energy</td>
<td>59,6 keV</td>
</tr>
<tr>
<td>Radiation spectrum</td>
<td>several discrete lines</td>
</tr>
<tr>
<td>Warm-up time</td>
<td>none</td>
</tr>
<tr>
<td>Switching time</td>
<td>no switching</td>
</tr>
<tr>
<td>Service intervals</td>
<td>none</td>
</tr>
<tr>
<td>Radiation protection</td>
<td>shielding in source container</td>
</tr>
<tr>
<td>Life</td>
<td>half-life of Am241: 433 years</td>
</tr>
<tr>
<td>Advantages</td>
<td>sturdy, maintenance free</td>
</tr>
</tbody>
</table>

advantages: sturdy, maintenance free, highest reliability
The Scintillation Detector VIS 2000

Scintillation detectors are reliable components that have been in use for decades in many kinds of radiometric gauges. Their function principle is based on the property of some substances, such as ZnS, NaJ, some plastics and other carbon compounds like anthracene, to emit light when being exposed to ionizing radiation.

The scintillator is mounted at the entrance of a photomultiplier tube (PMT), where the tiny flashes of light are converted into measurable electric signals. The flashes of light which were generated in the scintillator by the ionizing particles get into the PMT where they generate the release of electrons. Those electrons become multiplied by acceleration in electrical fields and successive reflection to a number of electrodes, the so-called dynodes. On the dynodes, each single electron generates the emission of several other electrons. This results in a strong amplification ($v = 10^6$) of the current of electrons reaching the anode. Therefore only very few photons on the PMT cathode are necessary to indicate an occurrence at the scintillator.

Scintillation detectors have several advantages against ionisation chamber detectors which are usually installed in radiometric gauges. The measurement is much faster (less than 1 millisecond) because signal transmission happens at the speed of light and in comparison to the ionisation chamber there is no need to wait for ions moving to the electrodes. Because of its solid body a scintillator has a much higher probability to detect a radiation particle than the gas in an ionisation chamber. This difference becomes especially important on high-energy radiation. Scintillators are much smaller than ionisation chambers of the same performance.

The Vollmer scintillation detector VIS 2000 offers the following features:

- extremely constant high speed detector with a response time below 1 millisecond (equivalent to one measurement every 20 mm with a rolling speed of 1200 m/min)
- internal optical stabilization
- temperature compensation
- drift compensation
- very constant measurement results (temperature deviation < 0.02% / °C, long term deviation < 0.02 % within 8 h)
- works especially well on long coils
- measurement system performs automatic zero adjustment every 8 hours

Because of the integrated measurement amplifier, the VIS 2000 detector unit requires only a 24 V power supply and a serial data interface RS 485. The digitized measurement signal is transferred error free to the mill’s control computer and in return, the operation parameters of the detector can be set via this interface. The high digitalization rate (20 bit) allows to use the same measurement range on thick as well as on thin strip, so that there is no switching necessary even in case of considerable strip thickness variations between different coils.

Advantages of the Vollmer detector system VIS 2000:

- error-free signal transfer (RS 485) for best possible noise reduction
- very high measurement speed
- no drift problems
- high detection probability even under high-energy radiation
- small in size
- maintenance-free
- no adjustments required after the very first start-up

Control

The entire electrical installation of the gauges is fitted into one electronic cabinet. Control tasks are divided between a Siemens S7 PLC and a Siemens industrial PC. The PC is connected to the PLC via a DP-interface. This use of a standard bus system also allows the connection for signal transfer to and from an existing mill control system. As we install a standard type PLC, there remain all options open for easy changes or extensions of the measurement system in the future.

Data Acquisition and Evaluation

All measurement data from the gauge are continuously recorded, evaluated, displayed and stored by the computer system. The monitor indicates all relevant strip parameters and mill parameters in digits or graphically. The computer system also monitors the operational status of the entire measurement system and indicates if there are signs of malfunction.

A measurement report for documentation of strip quality can be printed for each coil or set of coils. The thickness measurement program is easily operated via pull-down menus.

Additional features:
- calibration routine for gauge adjustment
- calibration on new alloys, setting of the calibration curves
- error messages (error list, unlimited)
- calibration and status data (storage list, unlimited)
- interface protocol 'Profibus'
- X-ray system monitor and status check
Advantages of Vollmer Radiation Strip Thickness Gauges:

- sturdy mechanics, easy to maintain
- hydraulic traversing as standard feature
- may be combined with a high precision Vollmer contact gauge for alloy adjustment that eliminates errors from coil to coil alloy variation

Isotope Gauges (Gamma A)

- sturdy, compact design
- absolutely maintenance-free
- maximum safety and optimum radiation protection due to removable, fully shielded source container
- very good measurement results despite the relatively low radiation power (in comparison to X-ray gauges) because of intelligent use of the individual parameters of the application
- reduced danger of mechanical damage despite small measurement gap due to rotatable detector mounting
- may be used for enhanced resolution of the strip edges during cross profile thickness measurements (special collimation and special evaluation algorithms)

- automatic calibration curve correction by means of referencesamples. The replacement of gauge components, dirt deposits on the beam window or mechanical changes of the measurement frame do not require the determination of new correction factors.

X-ray Gauges (Gamma X)

- highest measurement accuracy and low noise level even at very small collimation (very small measurement spot)
- small measurement spot produces very high resolution, especially important close to the strip edges for exact cross profile strip thickness measurement
- large measurement gap dimensions possible due to high radiation energy (maximum tube current 45mA)
- several thickness ranges possible for optimal adjustment to the strip material parameters (no waiting time after switching ranges)
- automatic calibration curve correction by means of reference filters. A replacement of gauge components, dirt deposits on the radiation window or mechanical changes of the measurement frame do not require the determination of new correction factors.
- long life due to conservatively sized, metal ceramic X-ray tubes
- easy service on-site due to quick change module