

Improvement of the Hot Dip Galvanizing Process by a 'Hot' Coating Weight Measuring and Control System

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Introduction

A 'hot' coating weight measuring system provides a precise, fast and non-contact coating weight length profile measurement of metal coatings (Zn, Zn/Al, Zn/Ni, Al, Sn, Pb/Sn) applied to steel strips. The measuring system is installed at the 'hot' end of the hot dip galvanizing line, approximately 2 m above the 450 °C (723 K) zinc pot.

This location for gauge installation significantly improves coating weight autocontrol performance due to the short dead time between the air knife and the coating weight measurement. Raw coating material is saved and mill utilization optimized. In addition, off-

center displacement of the strip between the air knives and/or change in roughness of the strip's surface are recognized immediately. Safety margins on the coating weight target values normally applied can be tightened, virtually eliminating under/overcoated strip. In manual control mode, each adjustment of the coating device (air knife distance, height and angle, pot and correction roll) can be checked by the operator within a few seconds.

Measuring Principle

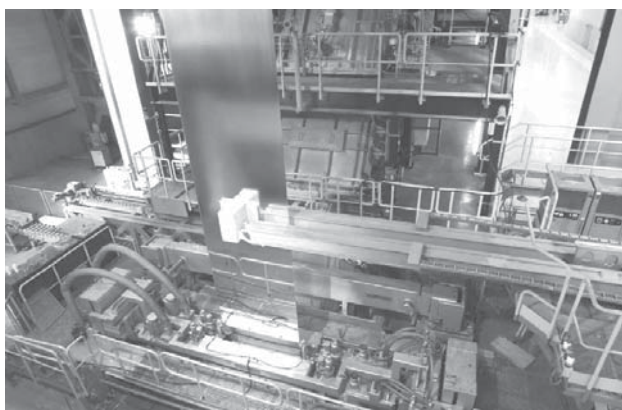
The coating weight of pure metal coatings on steel is generally measured by excitation of the characteristic X-ray fluorescence radiation caused by the photoelectric effect. This well known state-of-the-art method is also used as the basis for various other types of measurement, such as evaluating the intensity of several material fluorescence radiation energies.

Each element has characteristic

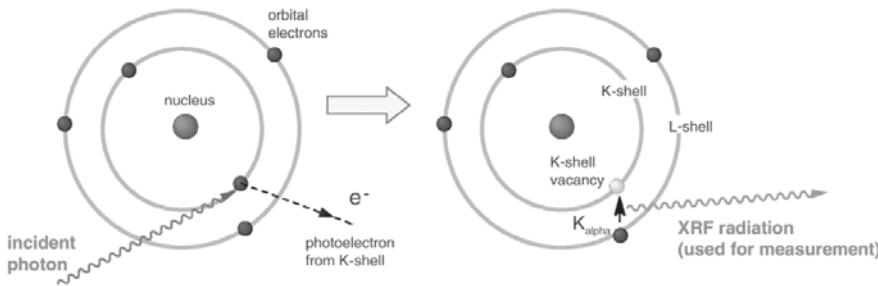
fluorescence energies (K-alpha and L-alpha), and associated absorption-edges (K_{ab}, L_{ab}) at slightly higher energies. In practice, only the K series are normally used in coating weight gauges. The primary radiation beam must have some component energies which are higher than the K_{ab} absorption-edge energy of the element required to fluoresce at its corresponding K-alpha energy.

For measurement of thin metallic coatings applied to steel strips, the following X-Ray Fluorescence (XRF) principle is used:

The coated steel strip is exposed to a primary beam of photon radiation. This photon radiation can be gamma rays or X-rays, having sufficiently high energy to stimulate excitation and emission (fluorescence) of X-rays. The excitation of iron atoms in a steel strip leads to emission of fluorescence radiation with an energy of 6.4 keV (1 kilo electronvolt = $1.6 \cdot 10^{-16}$ J). If the steel strip is coated by another material, the 'iron fluorescence' radiation is attenuated while passing through the coating. If the coating weight increases, less radiation emitted by the steel will pass through the coating. It is also possible to use the fluorescence



'Hot' gauges installed directly above the zinc pot and air knife machinery



Generation of XRF radiation by photoelectric effect

radiation of the coating material to calculate a coating weight measurement. In both cases, ionization chambers measure the intensity of the fluorescence radiation.

The 'Hot' measuring heads are installed in detector housings, which contain additional sensors for measuring the distance from strip to measuring head, and the temperature. Detector housing and measuring head are water-cooled for use up to 100 °C (373 K) ambient temperature. Additionally the detector windows are cooled by air jets.

Distance Sensor

The distance between the measuring head and the strip (typically 25 mm) is continuously measured to follow the strip movement by a distance control loop with tracking mechanism. The influence of high frequency distance variations due to strip flutter is compensated by software.

Temperature Sensor

A temperature sensor measures the air gap temperature between the measuring head and the strip to compensate for changes in the temperature of the air gap. Another temperature sensor inside the measuring head checks the internal

temperature to generate an alarm if over-temperature occurs and to automatically retract the measuring head from the strip.

Measuring Mechanism for 'Hot' Measuring heads

The measuring heads are mounted on detector arms that can be driven independently to the measuring or standardization position.

In the standardization position, coated samples can be measured and a capability check can be made. The detector arms can be installed on a moveable base, for driving to the

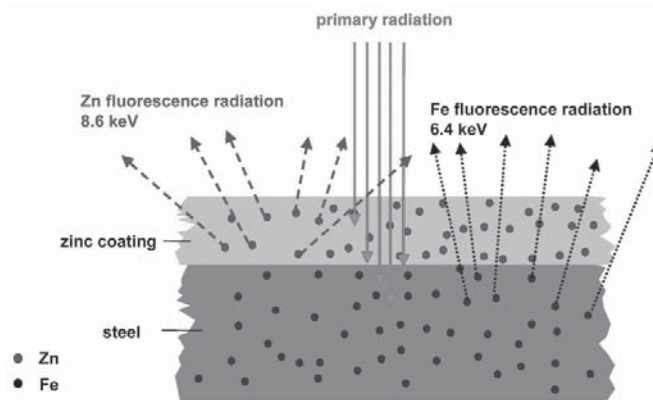
detector support and drive mechanism, junction boxes and cooling unit on this platform are completely assembled. This drastically reduces the installation time, which is always important for galvanizing line modernization projects. In special cases the measuring heads are mounted directly on the air knife.

Electronics and operation

The processing electronics consists mainly of a processor unit, analogue and digital I/O, high-resolution A/D converter and the Ethernet hub. The Ethernet is used for connecting to the coating weight autocontrol system, the operator station and the electronics of the 'cold' measuring system for cascaded control mode. Operators issue commands and monitor coating measurements through logical, easy-to-navigate screens on a PC-based operator station.

Improvement of manual operation of the coating device

At line start up, e.g. after coating device changes (air knife, bath rolls, etc.) the hot gauges provides an immediate check of the new set-up. The operator can directly see the effects of his adjustments as changes in the measured coating weight of the top and bottom side. In manual mode, each effect of fine-tuning of the coating device (air knife distance, height and angle, pot and correction roll) can be seen within a few seconds. The effects are shown on large digital displays nearby the 'hot' gauges.



Zinc coating gauge, emission of fluorescence radiation

measuring position and to the maintenance position beyond the strip zone. For the whole measuring mechanism, a maintenance and installation platform is available. The

Improvement of coating weight autocontrol by 'HOT' gauges

Typically, a coating weight autocontrol system is based on the coating weight measurement with scanning cross profile gauges at the 'cold' end of the hot dip galvanizing line.

The position of the 'cold' end measuring system is about 120 m behind the actuator (air knife). At a line speed of e.g. 100 m/min (330 ft/min) the dead time is about 72 seconds. During this time, no feedback control actions can be carried out.

Therefore, effects like off-center displacement of the strip between the air knives or change in roughness of the strip's surface will be recognized too late.

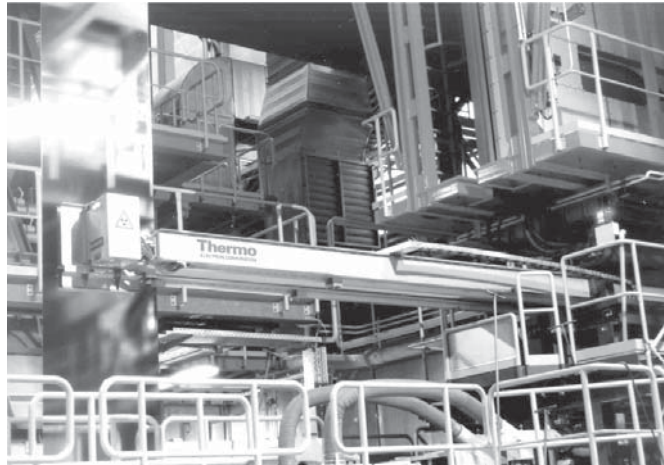
A closed loop autocontrol using the 'hot' coating weight measurement system overcomes these disadvantages. For comparison, the position of the 'hot' end measuring system is only 2 m behind the actuator, with a dead time of only about 1 second. Due to the very short response time of feedback control, the autocontrol ensures rapid recovery to any line problems while minimizing waste.

If the measuring equipment consists of both a 'cold' gauge and a 'hot' gauge, the autocontrol can run in cascaded mode. In this case, the 'cold' gauge provide the reference input value for the coating weight setpoints of the 'hot' gauge.

Autocontrol

The coating weight autocontrol system mainly consists of the Advanced Presetting System (APS) and the Adaptive Autocontrol (AAC).

The Advanced Presetting (APS) serves as a presetting system for



'Hot' coating weight gauges

the pressure control to assure a short transition time during product change and to minimize over- or undercoated strip during and immediately after product change. The Adaptive Autocontrol (AAC) provides data for the closed loop coating weight autocontrol by air or nitrogen pressure control of the air knife.

Advanced Presetting System (APS)

For advanced presetting, expert system software is used for the remaining dead time (transport lag, typically 1 second—and air knife pressure response time, typically 5 seconds). At a product change, presetting feed-forward data to the air knife machine are provided. The software calculates the necessary air or nitrogen pressure-set point based on the actual line conditions.

The expert system software is an integral component of the coating weight autocontrol system. It provides an extensive product data base as follows:

During the production process, the

expert system automatically determines product data sets with 'good production results' (i.e. with the smallest coating variations). These data sets are stored in the expert system's database. Over time the database is filled with sets of these 'good' product data.

If new set points are preset for the next coil, an algorithm selects 'good' data sets with the same or similar production conditions. Before a product change, the expert system is called up automatically (typically initiated by the welding

seam contact) or manually by the operator. It provides the presetting data to the air knife machine before the Adaptive Autocontrol (AAC) takes over the air or nitrogen pressure control.

Adaptive Autocontrol (AAC)

The Adaptive Autocontrol (AAC) continuously controls coating variations that result from the influence of external variables that cannot be measured (e.g. surface condition of the strip, etc.) or from the remaining prediction uncertainties of the presetting after product change. As with APS, the output of the AAC algorithm is the necessary air or nitrogen pressure-setpoint for the current line conditions.

Measurable process line variables are considered and their influences to the coating are predicted by feed forward control. For example, changes of strip speed and/or air knife to strip distance are immediately considered and their influence to the coating is compensated by a corresponding immediate pressure adjustment.

Additionally the AAC includes the following functions:

Independent Top and Bottom Side Coating Control (ICC)

While considering the process parameters such as strip speed, distance air knife to strip and the target coating, the Adaptive Autocontrol (AAC) continuously calculates the necessary air- or nitrogen-knife pressure (separately for top side and bottom side) for output to the controller of the air knife machinery. The coating weights of both the top and bottom side are controlled independently.

Because of the non-linear relationship between the zinc coating weight and the air or nitrogen pressure, the effect of the autocontrol depends on the operating conditions. Taking this into consideration, the Adaptive Autocontrol (AAC) continuously adjusts the actual pressure target depending on the process line conditions.

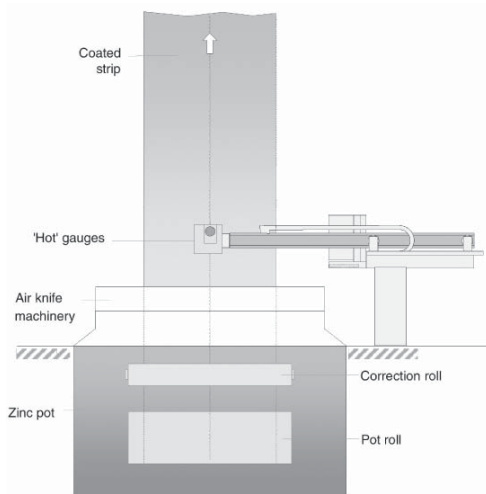
Sum Coating Control (SCC)

With the sum coating control, the arithmetic average of the target pressures the top side and the bottom side is applied to the air knife system. As both sides of the air knife then operate with the same pressure, 'blowing away' of the strip is avoided. This operating mode is highly recommended at low strip tension operation or if problems with the passline control at the air knife level occur.

Automatic Balance Control (ABC)

If the same coating weight is desired on both the top and bottom side (target value top = target value bottom), the automatic balance

control adjusts the air knife distance, so that the coating weights of both sides are the same. Automatic Balance Control requires an air knife with an

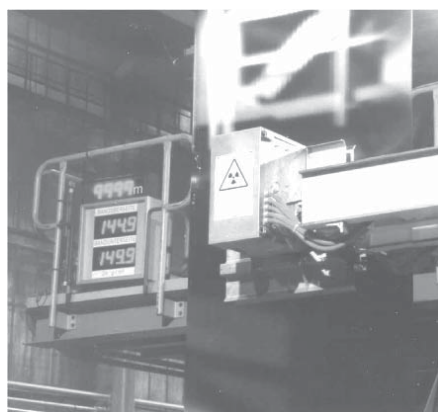


Typical arrangement of 'Hot' gauges

adjustable distance/skewing device.

Target Optimization Control (TOC)

The measurements taken by the scanning 'cold' gauges are used for a dynamic optimization of the coating



Immediate check of the adjustments of the coating device. The actual coating weight of top and bottom side are displayed.

target to keep the zinc consumption as low as possible. By evaluating the statistical distribution of the coating in the machine and cross directions, the

control set point is adjusted, considering the given tolerance limits. Under these conditions, production of the coated product will be as close as possible to the allowed minimum nominal coating weight value. TOC can be switched on/off from the operator screen.

Cross Profile Control (CPC)

The profile control works independent from the air knife pressure control and corrects the coating weight cross profile by adjustment of the air knife distance at the left and right strip edge (skew of the air knife). This feature can only be implemented if the air knife is equipped with an adjustable distance/skewing device.

Air Knife Distance Adjustment (AKD)

The upper and lower pressure limits of the air knife can be pre-set. If the average air knife pressure exceeds these ranges, then the distance of the air knife to the strip can be automatically changed such that the pressure control loop is brought back within the operating range. This feature can only be implemented, if the air knife distance can be adjusted automatically.

Summary

The ability to reliably measure the zinc coating directly above the pot allows for dramatic improvements in hot dipped galvanizing line performance. The feedback time for air knife control is nearly instantaneous. When coupled with intelligent control software in a complete coating weight Autocontrol system, a hot coating weight gauge can reduce overcoating to save raw materials, avoid overcoating and increase overall mill yield. □□□