Advanced Zinc Coating Control in Galvanizing Lines

Hot dip galvanizing lines (HDGLs) are an industrial process where cost savings in terms of increased production, more stringent tolerances on final product quality, and reduced raw materials utilization are especially needed. One aim of an HDGL is to apply a uniform protective zinc coating to the surface of steel coils, which are then used, for instance, in the construction industry for making rustproof parts.

After being dipped in a molten zinc bath, metal strips are blown on with special air knives (devices that produce bladelike jets of compressed air) to remove excess zinc. As zinc prices continue to soar, closed-loop control is needed to keep the coating mass to a constant, minimum value.

Controlling this process presents many challenges, as it is nonlinear and multivariable in nature and some key variables cannot be measured directly. In addition, coating thickness is conventionally measured after a considerable delay, when the strip has cooled down.

The solution proposed by Danieli Automation solves this problem with a multivariable controller built around an adaptive model of the process, leading to more stringent tolerances and reduced zinc utilization.

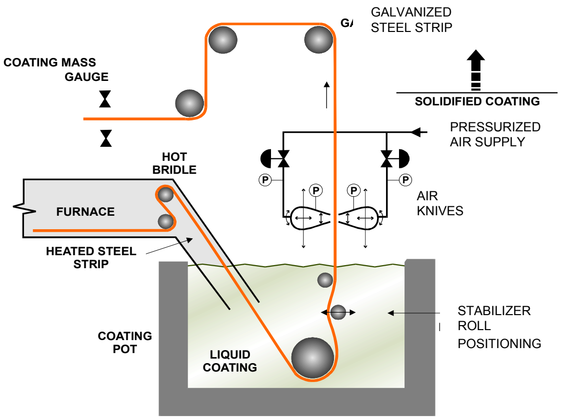
Inventions and Innovations

- Innovative use of a multivariable feedback controller for coating mass in hot dip galvanizing lines
- Online identification of crucial, unmeasured inputs to the nonlinear model of the air knives that is part of the controller

Galvanized steel coils ready to be shipped

Enabling Technologies

- Key to coating control using air knives is the availability of reliable estimations of variables whose measurements are delayed or are not available.
- The final thickness of the coating is conventionally measured about 100 m downstream, so a Smith predictor is built on top of a model of the air knife process.
- The distance between the air knives and the strip surface cannot be measured and must be estimated.
- The model of the air knife process is online and recursively tuned.



Schematic view of an HDGL coating section with air knife actuators and a coating mass sensor

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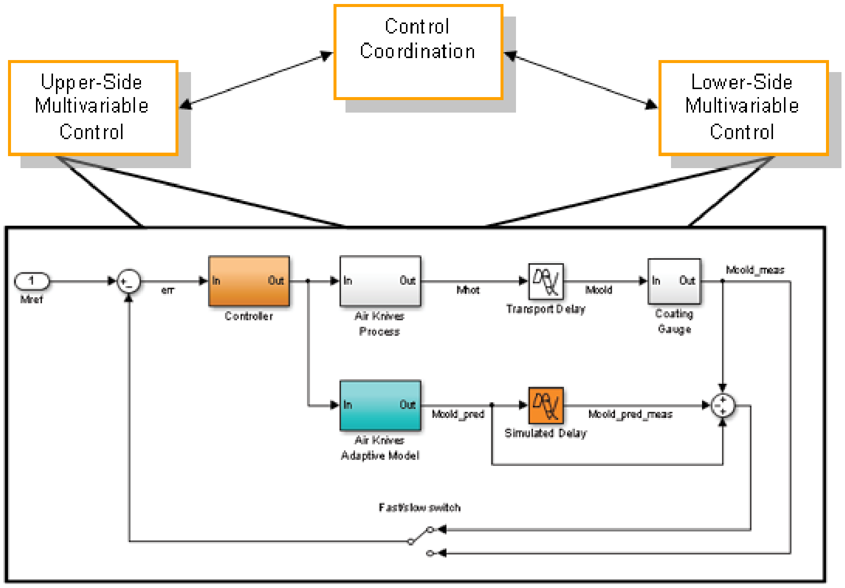


The coating control architecture. The air knife model is subject to online fine-tuning. The orange blocks are implemented in the regulatory control level, the cyan block in the supervisory control level. Only one side of the strip is represented here for simplicity.

Control Architecture

- A multivariable Smith predictor is implemented for each strip side with a controller, an air knife adaptive model, and a simulated delay implemented in the regulatory control level.
- Another synchronizer controller is in charge of coordinating the two multivariable controllers corresponding to each strip side.
- An adaptive, nonlinear model of the air knives is recursively tuned online by the supervisory control level.
- To control the cold coating mass M_{ref}, the multivariable controller acts separately on the air knives' pressure and on their distance from the strip (which is not conventionally measured).

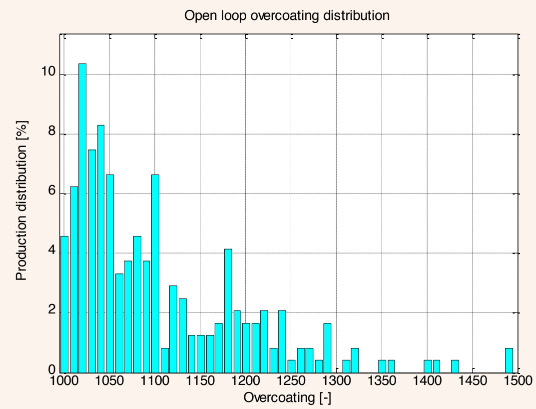
Realized Benefits

- The Advanced Coating Control architecture is regularly commissioned on Danieli mills.
- Use of the section control leads to a dampening of coating mass fluctuations and a
  - 9% increase in average material processing speed
  - 15% reduction in coating weight (about 1.3 kg of zinc per ton of material)
  - 0.45–1.5% reduction in costs
- Considering a plant producing 350 kTon per year and a zinc price of 1700 €/kg, this leads to savings of 760 k€ per year.

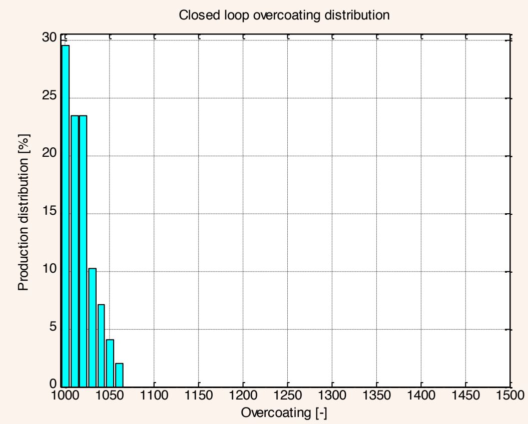
Conclusion

The advanced thickness control solution described here leads to

- Reduction in overcoating, which translates to reduced production costs
- No need for extra hardware
- Robustness to uncertainties in air knife actuators



Typical distribution of coils overcoating (target = 1000, meaning no excess coating is present) when no closed-loop coating control is applied



Distribution of coil overcoating when closed-loop coating control is present. As can be seen, most of the coils are very close to the desired target (1000).

For more information, visit http://www.dca.it/Libraries/Papers/Danieli_Automation_Advanced_Multivariable_Control_scheme.sflb.ashx.