Physics-based models with local parameterization for the jet wiping process in an industrial hot-dip galvanizing line

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In hot-dip galvanizing lines, pressurized gas expelled from gas-wiping dies is used to control the zinc coating weight m on both sides of a steel strip by wiping off excess zinc carried upward by the strip as it leaves a pot of molten zinc. The process is outlined in Figure 1. The coating weight is only measured 70 m to 100 m downstream of the dies using radiometric gauges. Due to the resulting large transport delay, the most common control strategy is a two-degree-of-freedom controller with feedforward compensation for process variables determined by other plant sections and some time-delay compensation in the feedback loop [1]. Pulse-and-wait control is most commonly employed as the time-delay compensator, but Smith predictors have also been used [1].

The performance of feedforward controllers and Smith predictors relies heavily on model accuracy. This explains why many published controllers include an online adaptation of the model [1, 2, 3] to compensate for model-plant mismatch resulting from unknown disturbances or changes in the operating conditions. However, many plants operate under a wide range of operating conditions (strip velocities, zinc temperatures, . . .) with multiple product types, coating weights, and coating materials. Because a large transport delay slows down the model adaptation, frequent set-point or product changes imply that long strip sections are processed before the model has adapted to the new conditions. Thus, improving the modeling of the jet-wiping process is crucial to achieving more accurate coating weight control and, ultimately, reduced zinc consumption.

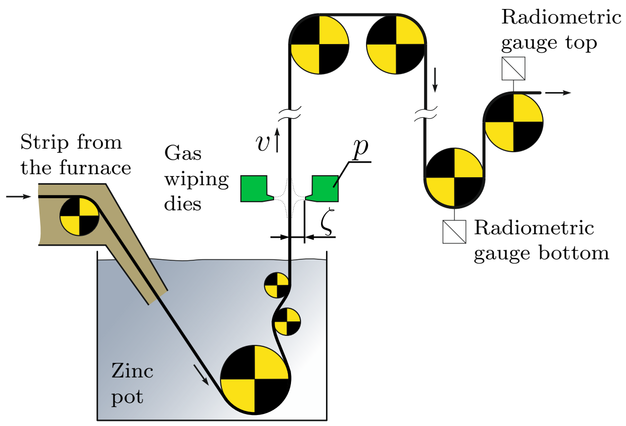

Figure 1: Jet wiping in the hot-dip galvanizing line.

The coating weight is most commonly modeled using the power law

$$m = kv^{\alpha}\zeta^{\beta}p^{\gamma}, \tag{1}$$

with the strip velocity v, the distance between the gas-wiping dies and the strip ζ, and the pressure p in the gas-wiping die as inputs [1]. The parameters k, α, β, and γ are fitted to plant data. This work shows how (1) is derived from a physics-based model [4]. Moreover, it demonstrates that, when fitted to plant data, the power law model (1) has a similar prediction accuracy as the more complex physics-based model. Analyzing the prediction error of the power law model reveals that it is hard to find parameter values valid in the whole input space. Hence, a more flexible model structure is needed.

The hierarchical local model tree (HILOMOT) [5] is suggested as a suitable model structure for this purpose. This approach systematically partitions the input space into regions, each with a locally trained linear model. Sigmoidal activation functions ensure smooth switching between neighboring models when evaluating the model tree. The current work suggests and investigates incorporating the power law model (1) into the HILOMOT structure using a logarithmic transformation. This way, the strengths of physics-based and data-driven modeling can be combined. The different modeling approaches are benchmarked in simulation and based on industrial data. The data-driven models show improved accuracy over the power law. The conditions under which the suggested combination of the HILOMOT model structure and the power law model outperforms the standard HILOMOT are also discussed. Specifically, the effects of unknown disturbances in the case of closed-loop identification are investigated.

References

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