New Profile And Flatness Calculator Optimises Hot Rolling at ArcelorMittal

Mathweis Engineering GmbH, allpccloud GmbH, and pa-innovations GmbH have long collaborated on the development of advanced rolling models and Level 2 automation systems. As part of the ongoing modernisation of ArcelorMittal Eisenhüttenstadt's hot strip mill, the Profile and Flatness Calculator (PFC) has been upgraded, integrated into the existing automation infrastructure, and successfully commissioned. The enhanced PFC employs FEM-based, real-time process models to simulate stand deformation and plastic-elastic strip behaviour within the roll gap. This significantly improves the precision of profile and flatness control, particularly in managing cross-flow effects during hot rolling.

AUTHORS: Jonas Kämper (Mathweis Engineering GmbH), Dr Markus Finck (Allpccloud GmbH), Dietrich Mathweis (Mathweis Engineering GmbH), Roland Feichtinger, Florian Steinecker (both pa-innovations GmbH), Dr Nils Naumann, Uwe Koschack, Eric Kohl (ArcelorMittal Eisenhüttenstadt); info@mathweis-engineering.de, markus.finck@allpccloud.de, florian.Steinecker@pa-innovations.com

The five-stand configuration at ArcelorMittal Eisenhüttenstadt presents greater challenges in profile control compared to seven-stand mills, due to tighter constraints on cross-flow and profile shaping. The PFC was replaced during live operation and migrated to a Linux-based platform. Alongside infrastructure upgrades, process optimisation was essential to meet rising customer expectations and the increasing share of demanding steel grades, such as silicon alloys.

Introduction

Level 2 systems with physics-based models are vital to meet the demands of the ongoing trend towards thinner final gauges and more complex steel grades. The PFC calculates optimal settings for flatness actuators – primarily work roll bending and shifting – based on force and work requirements in the pitch plan model and the current mill status (Figure 1).

Earlier models accounted for elastic roll bending, thermal effects, and wear.

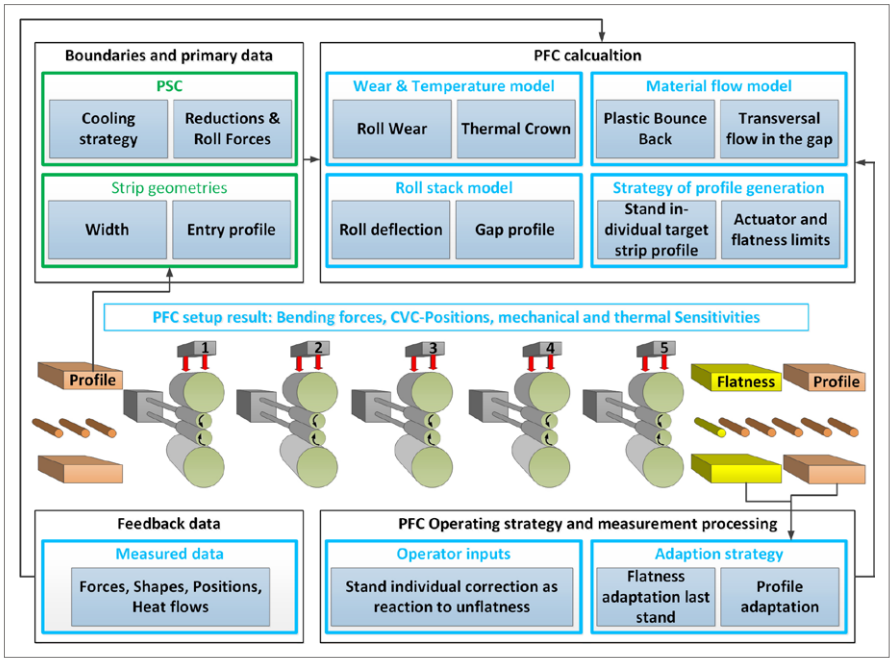

Figure 1: Schematic structure of the Level 2 system and the PFC

However, accurate modelling of profile formation due to material flow is also critical. The PFC incorporates a 3D FEM-based model that includes the 'plastic bounce back' (PBB) effect, which describes the discrepancy between the roll gap profile and the strip exit profile, caused by multiple process variables.

FEM-Based Insights into Strip Deformation

The PFC's FEM core simulates the elastic deformation of all five stands, adjusting actuator settings accordingly. It also integrates thermal and wear variables via a dedicated TCW (thermal crown and wear) model (Figure 2).

To better calculate plastic deformation in the roll gap, a 3D FEM model was developed using an Arbitrary Lagrange-Eulerian (ALE) approach. This allows a fixed computational grid, improving accuracy and performance – especially when run on modern GPUs.

Simulation results show how entry profiles influence load distribution and roll deflection. For example, a strip with a 0.1 mm entry crown (strip width:

Sources: Mathweis Engineering GmbH

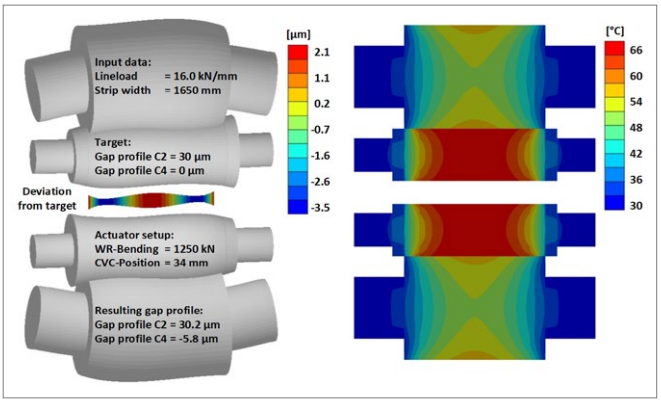

Figure 2: Calculation of deformation and temperature distribution in a roll set

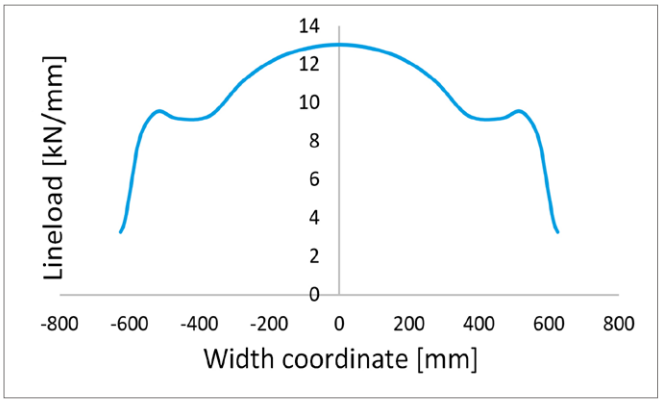

Figure 3: Line load distribution across the strip width in the roll gap

1,650 mm, initial thickness: 25 mm, final thickness: 12 mm, yield strength: 100 N/mm², profile elevation at entry: 0.1 mm, friction coefficient: 0.25) produces a peak load at the centre and reduced loads at the edges (Figure 3). This uneven distribution increases roll deflection which must be compensated through roll bending or crowning.

Figure 4 illustrates how the strip centre elevation changes between entry and exit, and how this relates to the roll gap profile. In the example shown, the entry profile starts at 0.1 mm and is reduced to approximately 0.05 mm. Unlike the PFC model, the 3D simulation assumes the work rolls are rigid and perfectly cylindrical, resulting in a roll gap profile with zero elevation. The assumption that the strip exit profile matches the roll gap profile is, therefore, incorrect. Even with flat entry and roll gap profiles, a centre crown can emerge due to material flow. This must be accounted for — e.g. by increasing roll bending — to meet profile tolerances.

The variation in stress across the strip width explains this behaviour. At the edges, material flows freely in the transverse direction, while the centre flows mostly longitudinally. This leads to tensile stress at the edges and compressive stress at the centre, causing localised thickening in the middle and thinning at the edges (Figure 5). These effects are partially self-compensating but must be modelled accurately.

A heuristic model was developed and integrated into the automation system to predict line load distribution and PBB effects. This required extensive simulation and iterative tuning during plant operation.

Implementation in Plant Operations

The PFC's physics-based approach enhances both real-time control and post-process analysis. Profile adjustments are distributed across stands to minimise cross-flow while respecting flatness constraints and

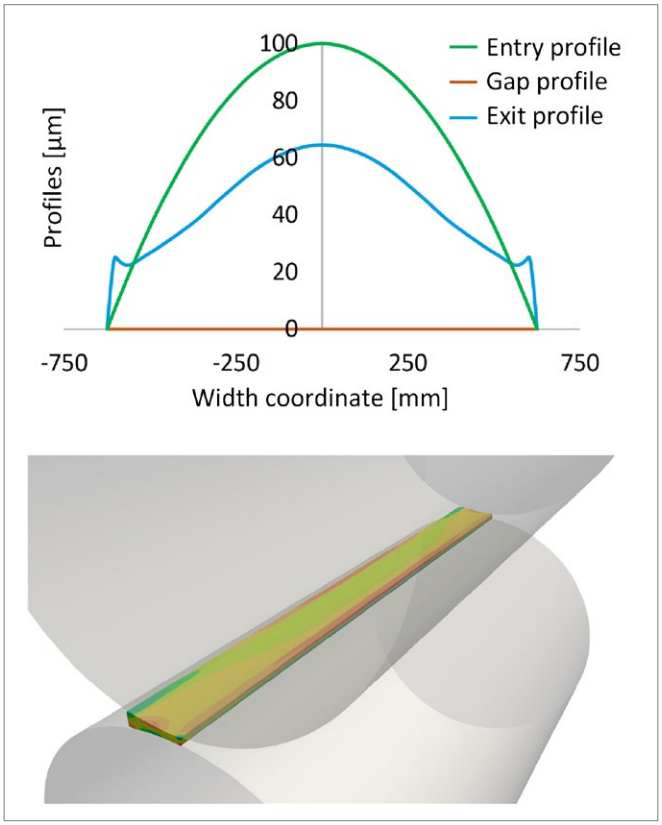

Figure 4: Strip profile change in the roll gap (strip entry/exit)

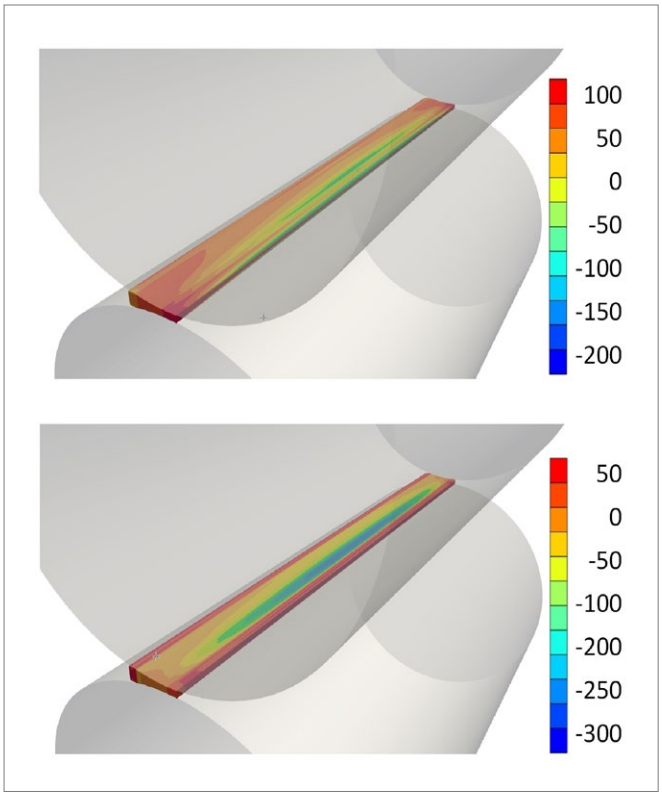

Figure 5: Stress distribution [N/mm²] in the strip (top: vertical stresses, bottom: longitudinal stresses)

actuator limits. Each setup is calculated iteratively to determine the optimal profile distribution and actuator setpoints.

In online operation, profile corrections are shared across stands based on their capacity to influence shape, while flatness corrections are isolated to individual stands. This improves control precision and simplifies operator intervention (Figure 6).

Operational transparency is essential, given the high throughput of hot strip mills (Figure 7). The PFC logs all setup data and mill conditions, enabling detailed review via the HMI. A quick morning check of the previous day's production allows operators to assess average profile quality and investigate any anomalies.

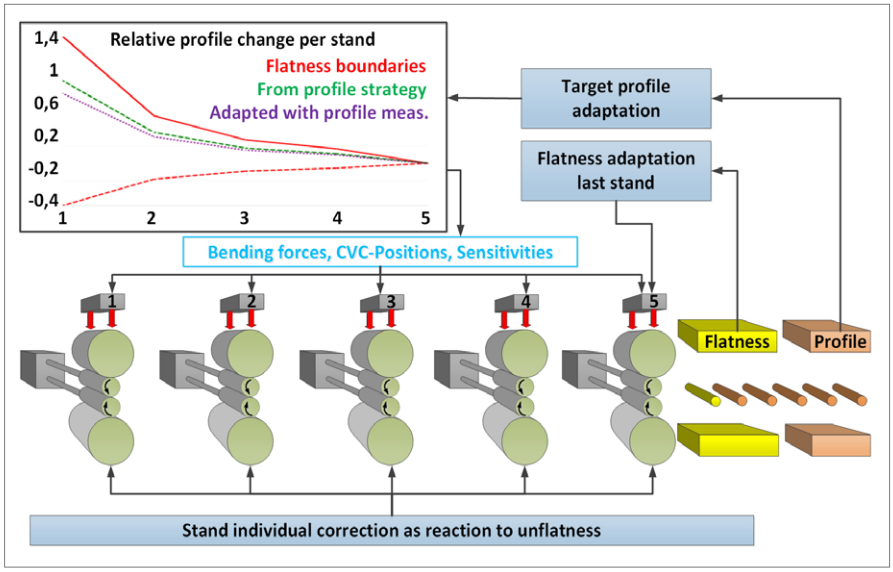

Figure 6: Sketch of operating concept

Summary and Outlook

The new PFC delivers a physics-based model that enables substantial process optimisation, fully exploiting the technological limits of profile generation and flatness control to enhance both product quality and throughput. This is achieved through FEM-based modelling of material flow and a modern, practice-oriented operating concept. Transparency and customer focus are central to its design. The PFC is suitable for both new installations and tailored retrofits. It can be deployed independently or as part of a Level 2 system on various platforms, including Windows and Linux.

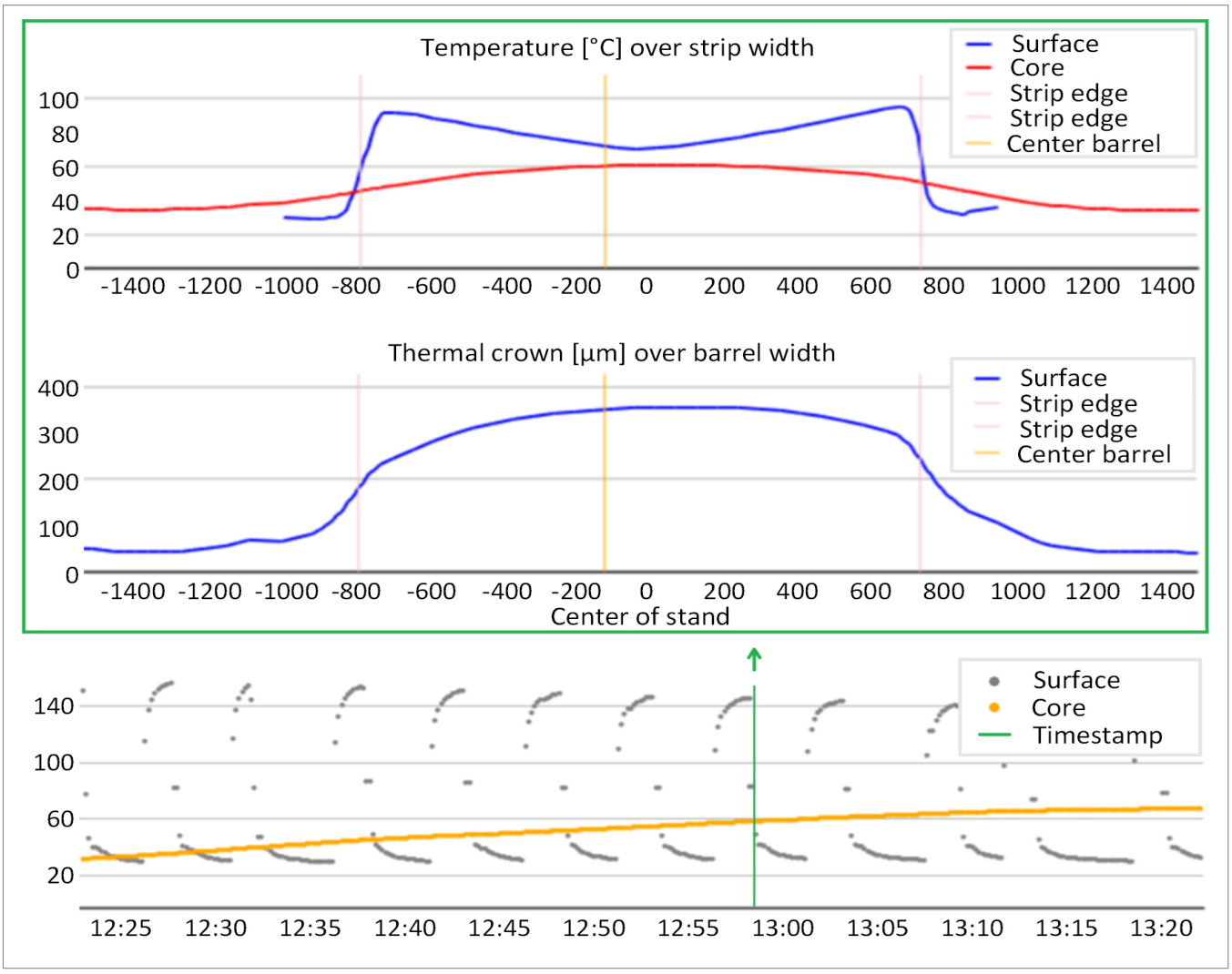

Figure 7: Transparent process using the example of locally detailed temperature calculation (top) at a selected point in time (bottom)

Sources: Mathweis Engineering GmbH