Modelling and optimization of slab workshops

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1 Introduction and context

In steel production, slab workshops are essential to maintain a smooth flow between the steel-making workshop, where slabs are cast, and the hot rolling mill, where they are transformed into coils. Before rolling, slabs must be treated to be conform with expected characteristics. These treatments mainly involve "Full-face" and "U-shape" operations, depending on the type of defect.

At the ArcelorMittal Fos-sur-Mer site, these operations take place in two dedicated workshops: a scarfing hall, where defects are removed with torches, and a grinding hall, where mechanical corrections are applied. Coordinating these operations is critical, as delays or inefficiencies quickly propagate upstream and downstream.

In this work, we develop an optimization model to support the planning and scheduling of slab-cleaning operations while respecting industrial constraints specific to the Fos-sur-Mer workshops.

2 Problem description

Each slab arriving in the workshop requires a specific processing tasks: "Full-face", "U-shape", or both. Tasks must be performed on scarfing posts (Flam) or grinding posts (Meul), with compatibility rules: some tasks require grinding, others must avoid it, and some can be performed on either type of posts. This generates several material flows and multiple stock categories.

A key decision involves determining the daily allocation of open posts, i.e., deciding how many scarfing and grinding stations should be operational each day. This decision directly influences throughput capacity and inventory levels. Currently, these allocations are based on simple rules using partial stock metrics, failling to account for real arrival dynamics, the cumulative impact across multiple days, or the ability to evaluate alternative scenarios.

To address this challenge, we introduce a detailed slab-level optimization model. Each slab is modeled separately with its processing requirements and workstation compatibility. The model includes workstation capacities, inventory thresholds, and the daily schedule of arrivals. Reasoning over multiple days allows anticipating bottlenecks, testing staffing strategies, and generating robust daily plans.

The resulting optimization problem is a variant of the *Job Shop Scheduling* problem, first formalized by *G. L. Thompson* in 1960 [1]. Our problem extends on the classical Job Shop Scheduling problem introducing additional complexities, such as capacity calculations in *tonne-equivalent* (TEQ) and flexible task assignments, which make it significantly more challenging than the classical problem.

3 Methodology

We formulate our problem as a mixed-integer linear program (MILP) where decisions concern (i) the daily opening of scarfing and grinding posts, and (ii) the assignment of each slab to a workstation. The model enforces compatibility rules, capacity limits, inventory thresholds, and slab arrival schedules. It is used as a scenario-analysis tool for testing staffing or process alternatives and evaluating their impact on stocks and throughput. For instance, the grinding capacity constraint ensures a slab can only be processed if enough capacity is available:

$$\sum_{i \in I} s^M_{j,m,i} \cdot p_i \cdot ct^M_{t(i)} \begin{cases} \leq teq^M \cdot x^M_{j,m} & \forall j \in J, m \in M \\ \geq 0.8 \cdot teq^M \cdot x^M_{j,m} & \text{with } t(i) \text{ the work associated to } i \end{cases}$$

where $s^M_{j,m,i} = 1$ if slab i is processed on grinding machine m on day j, $x^M_{j,m}$ is the number of posts open on m, teq^M is the total capacity of the post in tons, and the summation represents the total load in tons required by the assigned slabs.
We simplify the capacity constraint by aggregating it at the daily level while handling granular assignments at the workstation level during a later post-processing phase, which significantly reduces the computational effort to solve the problem.

4 Numerical results

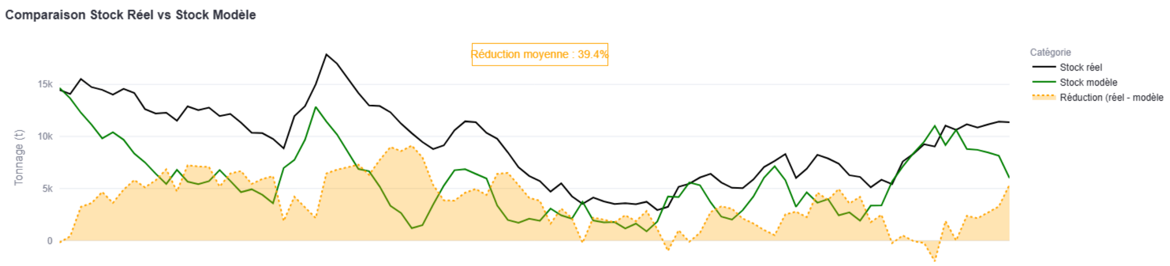

FIG. 1: Inventory reduction with MILP Model

The approach was tested on real data from Fos-sur-Mer for different production scenarios. The optimized workstation allocation strategy reduces inventory while balance the workload between scarfing and grinding operations. Compared to the current rule-based approach, it limits inventory peaks, prevents grinding overloads, and anticipates bottlenecks. In addition, the model serves as a tool for evaluating alternative operational configurations and projecting end-of-year inventories. Computation times remain compatible with daily planning and scenario studies. As shown in FIG. 1, the model significantly reduces average inventory levels compared to the current approach.

5 Conclusion

The slab-level optimization model is both an operational decision-support tool and a scenario-analysis framework. Through its integration of operational constraints and multi-day dynamics, it outperfoms rule-based approach and supports strategic decisions such as annual inventory forecasting. Future work includes an approximation-based model implementation and the integration of actual inventory holding costs.

References

[1] G. L. Thompson. Recent developments in the job-shop scheduling problem. *Naval Research Logistics Quarterly*, 7(4):585–589, 1960.