# Sequencing operations in a manufacture system

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# 1 Introduction

Aim of this presentation is to introduce a general approach for the *blocking* and *no-wait* scheduling problem.

In the manufacture context the blocking constraint arises when there are limited buffer machines. Whereas the no-wait constraint allows to model consecutive jobs on the same machine.

# 2 The Alternative Graph

The *alternative graph* is described by a triple $G = (N, F, A)$. There is a set of nodes $N = \{0, 1, \ldots, n\}$, a set of directed arcs $F$ and a set of pairs of directed arcs $A$. Arcs in the set $F$ are fixed. Arcs in the set $A$ are *alternative*. If $((i, j), (h, k)) \in A$, we say that $(i, j)$ and $(h, k)$ are paired and that $(i, j)$ is the alternative of $(h, k)$. In our model the arc length can be either positive, null or negative. A selection $S$ is a set of arcs obtained from $A$ by choosing at most one arc from each pair. The selection is *complete* if exactly one arc from each pair is chosen. Given a selection $S$ let $G(S)$ indicates the graph $(N, D \cup S)$. A selection $S$ is consistent if the graph $G(S)$ has no positive length cycles. Given a consistent selection $S$, we call extension of $S$ a complete consistent selection $S'$ such that $S \subseteq S'$, if it exists. The *makespan* of a consistent selection $S$ is defined as the length of a longest path from node 0 to node $n$ in $G(S)$.

# 3 Steelmaking Manufacture

The steel production process is well known to have extremely strict requirements of material continuity and flow time. Figure 1 shows the layout of the production line for a stainless steel line located in central Italy.

In particular, the processing of stainless steel consists of a sequence of high temperature operations starting with the loading of scrap iron in an Electric Arc Furnace (EAF). The time to melt the scrap iron is substantially independent of the batch type. The liquid steel is poured into ladles that a crane transports to a subsequent machine, called Argon Oxygen Decarburization unit (AOD), where nickel, chromium and other elements are added to the steel in order to meet the chemical quality requirements. After the AOD the ladles are transported to a Ladle Furnace (LF) which can host at most

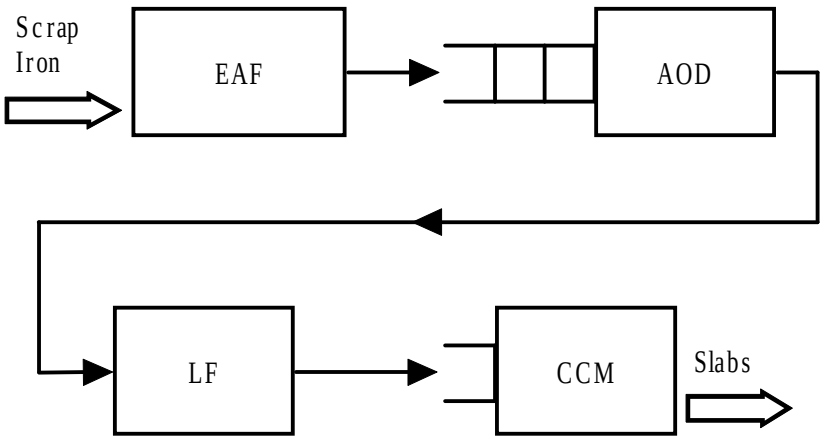


Figure 1: Layout of the stainless steel production line

two ladles. Even if some operations are executed in the LF, in practice it acts as a buffer to maintain the ladles at the proper temperature before the last operation, to be executed in the Continuous Caster Machine (CCM). Here the liquid steel is casted and cooled to form slabs. The CCM needs to be tooled with a particular tool, called flying tundish, which must be changed when switching from a lot to another.

# 4 Conclusions

To test the algorithm some random test instances are solved using some heuristic algorithms. The test instances have a variable size and a production mix similar to the real production mix. In most of the cases the best heuristic finds the optimal solution, and in the real world instance improve the original solution of 2%. Moreover the robustness of the proposed solutions is comparable with the original solutions.

Further research should implement an integrated system for constrained real time scheduling problems and develop local search algorithms for the alternative graph.