A Three-Step Heuristic for Operational Production Planning in Semiconductor Manufacturing

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1 Introduction

Manufacturing planning problems answer very diverse questions on different scales. To manage manufacturing production at mid-term, production planning seeks to define quantities to release or produce over a time horizon, generally taking into account capacity constraints and customer demands. In this way, the main goal is to give feasible instructions for the operational part taking into account objectives determined at the strategic level. In the semiconductor manufacturing industry these production planning problems are very difficult to treat notably due to the size of instances (hundreds of jobs at the same time, each requiring hundreds of process operations), and the process flow complexity (e.g. re-entrant flows, batching constraints, non-identical machines) \cite{4}. This complexity forces researchers to develop simplified models, e.g. considering capacity only on bottleneck resources \cite{1}, grouping equipment as workcenters \cite{3}, reasoning only on quantities \cite{2}. Our goal is to develop a planning approach which optimize respect of tactical and strategic production objectives, while providing feasible operational objectives by handling the complexity of a semiconductor manufacturing facility (fab), and avoiding important aggregation choices.

2 Problem Definition

The planning horizon is decomposed into periods, which can be days, weeks or months. A set of jobs currently in the fab (usually called Work In Progress), as well as other jobs to be started are considered. Each job has a customer delivery date also called due date. A solution plan has to define, for each operation of each job, the period in which it has to be executed. A number of constraints are considered, the most important ones being capacity constraints.

3 Heuristic based planning approach

We show that the problem we defined is NP-Hard as such we choose to adopt a heuristic approach for our planning tool, which is decomposed into three main modules detailed below.

3.1 Job Projection

This first module requires the input, for every type of product, of the associated theoretical cycle time, which is mainly based on historical data. At the end of this process, the projection module provides theoretical start and end dates for every operation of every job. It consequently
generates an initial solution (not necessary feasible yet), which is a forecast of the operations to be processed in each period.

3.2 Workload Balancing

The second module aims at estimating the workload for each machine in each period, i.e., at distributing the product quantities on non-identical machines. This problem is solved, for each period and for each independent group of machines, using a linear program. At the end of this process, thanks to a detailed machine and product modelling, we get a dynamic machine workload forecast notably taking into account the product-mix. For some machines, workload can be larger than the capacity, i.e., machines can be overloaded and solution is not feasible yet.

3.3 Step Shifting

This third method combines Lot-Sizing based forward smoothing procedure as well as scheduling based shifting policies to ensure that capacity constraints are satisfied, while optimizing production objectives.

Once the capacity constraints are satisfied for all machines in a period, the projection module is launched again for the next period, taking into account the operations postponed by the “Step Shifting” module. The heuristic ends once all periods have been considered.

4 Performance Evaluation and Perspectives

The heuristic is fully implemented in a factory of STMicroelectronics in France. The decision support tool provides production and capacity plans in one minute for large-sized real problems. A mathematical model also was developed and solved using CPLEX, and a comparative study for instances of small sizes shows great performances of the heuristic approach. Given the multitude of objectives considered, several smoothing rules were developed. A comparative study based on thirty real instances is conducted, showing domination of certain rules.

Amongst future studies, extending the Step-Shifting module to consider multiple periods, by developing a backward smoothing seems promising, as it would allow a local search that does not necessarily degrade the solution as it is the case with the front smoothing. However, improvements are probably possible further upstream, from the design of the initial solution. For example, it would be interesting to use a linear model, aggregated but reasoning globally, in order to build better initial solutions leading to better quality final production plans.

Références


