Flexible Job-Shop Scheduling with Batching for Semiconductor Manufacturing

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1 Introduction and Problem Description

Scheduling decisions in the diffusion and cleaning area of a semiconductor manufacturing facility have an important impact on the overall performance of a plant. Consequently, we want to optimize those decisions while taking real-world constraints into account. An important property of machines in this work area is their batching capability: They can perform multiple operations at the same time. We want to take account of this in our algorithm.

We need to schedule a given set of jobs. For each of them, a fixed sequence of operations must be performed. This sequence is called the route of the job. Operations can only be performed on qualified machines and their processing durations depend on the selected machine. A capacity limit constrains the number of jobs that can be processed per batch. Each operation is assigned to a family and only operations of the same family can be combined in the same batch. For each job, we are given a ready date and a due date. Those constraints describe a flexible job-shop scheduling problem with batching. We aim to minimize total weighted tardiness.

For the described problem, we present a simulated annealing algorithm that is based on an extended evaluation of disjunctive graphs. In our proposed approach, batching decisions are taken dynamically during graph traversal.

2 Related Work

The problem considered in this work is a generalization of the classical job-shop scheduling problem which is already NP-hard. An extension is the flexible job-shop scheduling problem where for each operation one of multiple machines that are qualified has to be chosen. A literature review on scheduling problems with batching in semiconductor manufacturing is given in [3]. Only few research was conducted on job-shop scheduling problems with batching.

[2] considers a complex job-shop scheduling problem that includes batching as well as sequence-dependent set-up times. There, a disjunctive graph representation is introduced that represents batches using additional nodes. A study on a generalized job-shop scheduling with batching for semiconductor manufacturing that represents batches in a similar way is presented in [5]. In comparison to existing research, we propose a novel approach to take batching decisions: Instead of adding auxiliary nodes that represent batches, we calculate batches during a traversal of the disjunctive graph.

3 Solution Approach

In a disjunctive graph, nodes represent operations and edges represent dependencies. An edge either corresponds to a dependency induced by the route of a job or to a precedence in the ordering of operations on a machine. We calculate batches during a traversal of the graph which is based on an adapted topological ordering.

An initial solution of the problem is created using an insertion heuristic. We iterate jobs ordered by their ratio between due date and weight and successively insert operations. We then improve the found solution using a simulated annealing algorithm that is based on a neighborhood of moves that reorder and reassign operations. The recalculation of batches is implicitly performed in a graph traversal after each move.

4 Conclusion

We see two main advantages for this approach. Firstly, we avoid additional complexity in the graph. This is advantageous in particular for the inclusion of batching into the approach proposed in [1]. There, a sophisticated definition of routes already increased the complexity of the graph. Secondly, we consider the dynamic recalculation of batches promising to obtain good results since batching decisions are dynamically adapted to the current assignment and ordering decisions.

We have implemented and evaluated our method and present a comparison of our current results using the benchmark instances given by [4]. We plan to include further real-world constraints to obtain a scheduling system that is fully applicable for the every day planning of a semiconductor manufacturing facility.

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