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# A heuristic to schedule flexible job-shop in a glass factory

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**Abstract**

We describe the design and implementation of a scheduling system in a glass factory. The factory produces a large variety of manufactured glass objects in a complex process ranging from melting the glass in the furnaces and blowing it automatically or manually to decorating, assembling and packing it. The structure basically corresponds to a flexible job-shop scheduling problem with some special characteristics. On the one hand, dealing with hot liquid glass imposes no-wait constraints on some operations. On the other hand, skilled workers performing some manual tasks are modelled as special machines. The system produces approximate solutions in very short computing times, trying to minimize a non-regular criterion defined by the user and based on due dates. It can be used to establish delivery dates for new customer orders, taking into account current machine workloads, or to schedule a set of orders, trying to meet given customer due dates.


*Keywords:* Scheduling; Job shop; Production; Heuristics; Operation synchronization; Overlapping

## 1. Introduction

This paper describes the design and implementation of a scheduling system in a glass factory. The factory produces a large range of manufactured glass objects, more than 3000 different types of pieces, and works under a make-to-order policy. Whenever a new customer order arrives, the information system checks if the required products are in stock and, if is the case, the order is served from existing stock. Otherwise, the system basically creates two kinds of production orders for the shop. Some production orders correspond to finished goods, ready to be sent out to customers, and involve operations such as decorating, assembling, packing and palletization. Other production orders correspond to semi-elaborated products which involve operations in the furnaces, blowing, cooling and bulk packing. Lot sizing considerations determine the number of pieces of each intermediate product in these orders, the number of which is typically much larger than the quantity required by a customer. For instance, if

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an order demands 500 wine glasses of a given model, a production order would consist of decorating and packing these 500 glasses, and a previous production order would consist of blowing 10,000 glasses, 500 of which would proceed to the original order and the remaining 9500 would be stored. So this scheme introduces precedence relationships between production orders.

The operations to be performed on the pieces can, and in fact should, overlap. If an order consists of decorating and packing 500 glasses, we do not have to wait until all the glasses have been decorated to start packing them. Sometimes this overlapping is automatic, that is, as soon as the first piece has been processed on one machine it goes directly to the next machine. On other occasions the overlapping is limited by structural constraints, such as the dimensions of the box to be packed or the capacity of the container used to move the pieces from one machine to the next. Overlapping can even happen between operations of different orders, linked by precedence constraints.

Some orders have an operation in which raw materials (basically recycled glass) are melted in one furnace to produce liquid glass and then another operation on a blowing machine in which the glass is shaped while still hot. These operations must be processed in a special type of no-wait mode, in which every time a glass bit comes from the furnace, it is immediately shaped in the blowing machine. Therefore, rather than talking of no-wait mode, a term usually applied to operations, we talk of *synchronizing* these operations, piece by piece. This synchronization is not restricted to a pair of operations, but extended to other operations in the same production order or in some of its successors. In fact, after being shaped, the pieces are placed on a conveyor belt where, while they cool down, they are transported at a constant speed to the packing area. Once there, the pieces must be packed before they arrive at the end of the belt. Hence, the packing operation must also be synchronized with the blowing operation with a fixed delay specified by the length of the belt and its speed.

The factory has different types of machines. Apart from machines that can be considered standard in terms of scheduling theory, there are several machines specific to this type of factory. The furnaces in which the glass is melted can serve several blowing machines simultaneously. In this sense, they are multi-task machines, working on several production orders at the same time. Packing is done manually by a team of workers. The number of packers varies throughout the day and they process several packing operations at a time, attending to the pieces coming from the different belts. Some of the blowing operations are carried out by automatic blowing machines and some others by teams of highly skilled workers. In the latter case, the operations can usually be performed by several different teams and the production manager gives each of these teams a priority in processing the operation according to the type of operation. Some machine flexibility is therefore introduced because the team to do these operations has to be assigned by the scheduling system.

Some machines are continuously available, but others are not. When an operation is assigned to a machine working only a daily shift and its processing time exceeds the shift length, the process stops when the shift ends and starts again at the beginning of the following shift. However, other interruptions, such as pre-emption, are not allowed. Other types of unavailability also have to be considered. On the one hand, each machine can have its own calendar, with non-working days, holidays or maintenance breaks. On the other hand, when scheduling a set of new orders the manager can decide not to modify the existing production plan and so the new orders must be scheduled in a way that respects the previous machine workload.

The company intends to use the scheduling system in two ways. The user can input a set of orders and ask the system to schedule them as soon as possible in order to propose a delivery date to the client. Another possibility is to set a due date for each order and ask the system to satisfy as much as possible as many of those due dates. In both situations, apart from the primary objective there are some secondary objectives to consider, such as minimizing the work in progress and using, whenever possible, machines with high priorities to process the operations.