Optimizing task reassignments in the design of reconfigurable manufacturing lines

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1 Context

The concept of reconfigurable manufacturing systems (RMS) is considered as the most suitable solution, which is able to cope with the current changeable and dynamic market situation. This concept was introduced by Koren et al [3] in 1999, and is characterized by the ability of a manufacturing system to change and reorient its components easily, quickly and cost effectively. RMS are designed to manufacture a wide variety of products within the same family. This is possible by using the so-called reconfigurable machine tools (RMT), which are mainly composed of physical modules that can be rapidly moved and removed from one machine to another. These characteristics give more advantageous to RMS comparing with the well-known dedicated manufacturing lines and flexible manufacturing systems.

However, the RMS concept remains relatively recent and, as a consequence, new approaches and tools have to be developed in order to design and operate them efficiently. This tends to be a very challenging issue, since both the reconfigurable and multi-product aspects need to be taken into consideration. This usually leads to study highly combinatorial optimization problems (see recent literature reviews [1, 2]).

Within this context, we are interested in the design of multi-product reconfigurable manufacturing lines. We consider in this paper that such lines are composed of a linearly-ordered set of workstations. Each workstation sequentially performs a given set of production tasks. The number of tasks per workstation is limited, and the sum of the processing time of the tasks allocated to the workstation represents its load. This latter cannot exceed the so-called cycle time, which reflects the production rate of the line.

In such a line, a given number of products has to be manufactured. Since the products belong to the same family, we consider that they are associated with exactly the same set of tasks to be executed, which are subject to precedence constraints, usually expressed by a directed acyclic graph. However, the latter and the processing time of the tasks may differ from one product to another.

In order to manufacture a product, a corresponding admissible *line configuration* is needed. This latter refers to an assignment of the corresponding set of tasks to a given set of workstations while satisfying all the mentioned above constraints. In the case, where several products are manufactured, an admissible line configuration is necessary for each of them. Moreover, this design has to be done such that switching from one configuration to another is provided as efficient as possible by the reassignment of tasks between existing workstations.

2 Studied problems

The context described in the previous section arises two relevant optimization problems noted here as Q and R. In both problems, a precedence graph of each product, a cycle time as well as a set of workstations are given.

For the problem Q, we suppose that the order of products arriving is cyclic, already known and expressed as follows $P[n] := P_1 \to P_2 \to \cdots \to P_n \to P_1$, where n is the number of products, P_i is the i-th product and an arrow represents a reassignment of tasks. Given $P[n]$, the goal of Q is to design an admissible configuration for each of n products such that the total number of reassigned tasks when switching from one configuration to another is minimized.

Unlike Q, we suppose in R that the order $P[n]$ is not given. In this case, R aims at designing an admissible configuration for each of n products such that the number of reassigned tasks between any two configurations is minimized.

Mixed-integer linear programming (MILP) models are formulated for both problems Q and R, where in Q the objective function is the sum on the number of task reassignments when switching between the different configurations according to the order of products arriving $P[n]$. Whereas the objective of R is formulated as a min-max function on the number of task reassignments between any two different admissible configurations.

Both MILP formulations are tested for $n \in \{2, 3\}$ on two categories of instances with 20 and 50 tasks using CPLEX 12.9. A detailed analysis of the obtained results as well as a comparison between the problems will be presented at the conference. The preliminary results have already shown that the developed MILP models are efficient when solving the first category of instances for both cases of two and three products.

References

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