Power Peak Minimization in the Balancing of a Simple Assembly Line

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1 Introduction

The advent of Industry 4.0 allows the industrial sector, which is responsible of an estimated 44% of the global total final energy consumption (TFEC) [1] to live up to the enormous expectations of the public opinion concerning its environmental awareness.
In particular, industries are increasingly asked to be energy efficient. This is the motivation of the growing amount of recent research works that deal with energy-related optimization or constraints in production systems. For instance, [2] try to minimize energy consumption along with tardiness in a job-shop ; [3] tackles energy cost minimization in a job-shop system ; [4] proposes an exact approach to minimize makespan and power peak in a job-shop system ; [5] deals with the minimization of energy cost under a maximum overall power peak constraint.
However, few works seem to exist that address energy-related optimization problems at the design stage of a production system. The works of which we are aware of are variants of the well-known Simple Assembly Line Balancing Problem (SALBP) [6], the core problem in the optimization of production system design, and are in most cases Assembly Line Design (ALD) problems, in which both production tasks and equipment to perform them must be assigned to workstations. An example is [7], which defines a bi-objective, two-sided Robotic Assembly Line Balancing (RALB) problem and proposes a simulated annealing-based approach to jointly minimize cycle time and the energy consumption of robots assigned to workstations.

2 SALBP with Power Peak Minimization

The only problem of which we have knowledge that addresses at design stage the optimization of some energy aspect related to production tasks (and not the associated equipment) is the Simple Assembly Line Balancing Problem with Power Peak Minimization (SALB3PM) that we introduced in [8]. The SALB3PM extends the SALBP in that the power consumption associated with production tasks is considered and the overall power peak is minimized so as to smoothen the power consumption profile.
A paced, synchronous production line is considered on which a set of tasks must be processed. Each task j has a constant processing time t_j and a set of direct predecessors which must be completed before j can start. Differently from the SALBP, in the SALB3PM the number m of workstations and the maximum allowed cycle time c are both given, and each task j also features a constant power consumption W_j. The goal becomes to find a feasible assignment of tasks to workstations, and a scheduling of tasks along the cycle, s.t. the overall power peak is minimized. The integration of scheduling aspects, which can usually be treated in a post-optimization step in the case of SALBP, make the SALB3PM harder than the core problem.

3 Valid Inequalities and new Formulations for the SALB3PM

In this work, two new formulations, namely a Mixed-Integer Linear Programming (MILP) disjunctive formulation and an alternative Integer Linear Programming (ILP) time-indexed formulation are proposed for the SALB3PM. Moreover, we propose some valid inequalities to strengthen the time-indexed formulation of [8] based on the transitivity of precedence constraints. The results of computational sessions conducted on the benchmark instances of [8] are presented in order to assess the impact of the proposed valid inequalities and the performance of the new models, so as to allow a comparison among the different formulations.

References

[1] International Energy Agency, *Tracking Clean Energy Progress 2017 : Industry.* `https://www.iea.org/etp/tracking2017/industry/`, 2017.

[2] R.Zhang, R.Chiong, *Solving the energy-efficient job shop scheduling problem : a multi-objective genetic algorithm with enhanced local search for minimizing the total weighted tardiness and total energy consumption.* J. Cleaner Prod., 112(4) :3361–3375, 2016.

[3] M.Selmair, T.Claus, F.Herrmann, A.Bley, M.Trost, *Job Shop Scheduling With Flexible Energy Prices.* European Conf. on Modelling and Simulation, Regensburg, Germany, 2016.

[4] S.Kemmoe, D.Lamy, N.Tchernev, *Job-shop like manufacturing system with variable power threshold and operations with power requirements.* Int. J. Prod. Res., 55(20) :6011–6032, 2017.

[5] O.Masmoudi, X.Delorme, P.Gianessi, *Job-shop scheduling problem with energy consideration.* Int. J. Prod. Econ., 216 :12–22, 2019.

[6] İ.Baybars, *A Survey of Exact Algorithms for the Simple Assembly Line Balancing Problem.* Manage. Sci., 32(8) :909–932, 1986.

[7] M.Dai, D.Tang, A.Giret, M.A.Salido, W.D.Li, *Energy-efficient scheduling for a flexible flow shop using an improved genetic-simulated annealing algorithm.* Rob. Comput. Integr. Manuf., 29 :418–429, 2013.

[8] P.Gianessi, X.Delorme, O.Masmoudi, *Simple Assembly Line Balancing Problem with Power Peak Minimization.* Advances in Production Management Systems, 239–247, 2019.