Multi-Item Multi-Periods Capacitated Lot-Sizing Problem with Parallel Resources, Setups times and costs and Energy consumption: A case study

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1 Introduction

The industrial sector requires a careful study on the energetic aspect considering the current conditions, on one hand the use of non-renewable energies and on the other hand the harmful impact of the use of fossil energies. In addition, the energy cost is getting increasingly high during the time evolution. In this context, many companies are looking to jointly optimize the product costs and the energy consumption of the production systems. This new tendency becomes a challenge for the industrial sector particularly for the companies with high rate of use and incites several researchers to invest in this field. Renna and Materi [1] conducted a literature review on energy efficiency and sustainability in manufacturing systems. Bettoni and Zanoni [2] studied the relationship between the production rate of machines and their energy consumption in die-casting processes. Liang et al. [3] considered processing technology selection with energy aspects in production planning and scheduling problem. Masmoudi et al. [4] presented single item capacitated lot-sizing in flow shop with energy consideration where each period of the planning horizon is characterized by demand, length, electricity cost and maximal peak power. This work was extended by the same authors to consider the multi-stage problems in [5], and in [6] they considered the multi-item problem. Sanati et al. [7] considered the unrelated parallel machine energy-efficient scheduling problem with sequence dependent setup times and different energy consumption tariffs. In the present work, we address the Muti-items Capacitated lot-sizing problem with parallel non-identical machines considering energy consumption in thermoplastic tubes extrusion industry. The objective is to establish a production plan that optimize, simultaneously two objectives, the total production costs and the total costs of the energy consumed by the whole system. A real case is used as a numerical support for this study.

2 Problem description

In this work we study a production system composed of m production lines considered as machines organized in parallel and processing with different rates to produce a large variety of products (n types of products) in order to satisfy customer demands within a finite production planning horizon of p periods. The manufacturing process is continuous 24h/24h and 7d/7d requiring 3 shifts permanently. The machines used in this system are non-identical and have different speeds and different powers. Each machine can produce certain product types but one product at time, and each machine has a launch power that enables it to turn on and a processing power that can be used to process products. The products that can be produced in the same machine have different execution speeds and, by consequence, different production times. When a machine is turned on, it remains in this state (even if it is not processing) until annual shutdown for high level preventive maintenance operations, this choice is made considering the technical problems that can occur when reactivating the machines after being turned off for a duration. When the machines are not processing, there is an energy consumed in the idle state but it is less important than the launch energy. Besides, when the items are setup, there is an energy consumed that is the same for all products but it is proper to each machine.

3 Modeling and solving approach

To solve this problem, we have established a first mathematical model of production planning whose objective function F_1 includes all production costs PC_{imp}, machines launch costs LC_m, storage costs HC_i and set-up costs SC_i to be minimized. In this model, we considered all the parameters as well as the constraints of the system: parallel machines, products to be manufactured, time and cost of machine launches, time and cost of product's setup, time and cost of product's manufacturing, production capacity constraints and stock balance constraints. A second mathematical model that minimizes the consumed energy costs F_2 was developed, it considers machines launch energy ECL_{mp}, processing energy ECP_{mp}, products setup energy ECS_{mp} and idle state energy ECI_{mp}. The two models have been tested on the Cplex solver. The multi-objective problem that takes into consideration production costs and energy consumption costs was solved on the Cplex solver using the LP metric method which is a multi-criteria decision-making method that transforms the studied bi-objective problem into a single-objective optimization problem P.

$$P = Min\ w1\frac{F_1 - F_{1\ optimal1}}{F_{1optimal}} + w2\frac{F_2 - F_{2\ optimal1}}{F_{2\ optimal}}$$

And $w1$ and $w2$ are the corresponding weights where $0 \leq wn \leq 1$ and $\sum wn = 1$.

And:

$$F_1 = \sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{p=1}^{P} PC_{imp}\, q_{imp} K_{im} + \sum_{m=1}^{M}\sum_{p=1}^{P} LC_m\, lc_{mp} + \sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{p=1}^{P} SC_i\, x_{imp} + \sum_{i=1}^{I}\sum_{p=1}^{P} HC_i\, s_{ip}$$

$$F_2 = \sum_{m=1}^{M}\sum_{p=1}^{P} ECL_{mp} + \sum_{m=1}^{M}\sum_{p=1}^{P} ECP_{mp} + \sum_{m=1}^{M}\sum_{p=1}^{P} ECS_{mp} + \sum_{m=1}^{M}\sum_{p=1}^{P} ECI_{mp}$$

4 References

[1] Renna, P.; Materi, S. A Literature Review of Energy Efficiency and Sustainability in Manufacturing Systems. Appl. Sci. 2021, 11, 7366. https://doi.org/ 10.3390/app11167366

[2] Bettoni L., Zanoni S. (2012) Energy Implications of Production Planning Decisions. In: Frick J., Laugen B.T. (eds) Advances in Production Management Systems. Value Networks: Innovation, Technologies, and Management. APMS 2011. IFIP Advances in Information and Communication Technology, vol 384. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-33980-6_2

[3] Liang, J., Wang, Y., Zhang, Z.-H., & Sun, Y. (2019). Energy efficient production planning and scheduling problem with processing technology selection. Computers & Industrial Engineering. doi: 10.1016/j.cie.2019.04.042

[4] Masmoudi, O.; Yalaoui, A.; Ouazene, Y.; Chehade, H. Lot-sizing in flow-shop with energy consideration for sustainable manufacturing systems. IFAC Pap. (2015), 28, 727–732.

[5] Masmoudi, O.; Yalaoui, A.; Ouazene, Y.; Chehade, H. Lot-sizing in a multi-stage flow line production system with energy consideration. Int. J. Prod. Res. (2017), 55, 1640–1663.

[6] Masmoudi, O., Yalaoui, A., Ouazene, Y., & Chehade, H. (2016). Multi-item capacitated lot-sizing problem in a flow-shop system with energy consideration. IFAC-PapersOnLine, 49(12), 301–306. doi: 10.1016/j.ifacol.2016.07.621

[7] Sanati H., Ghasem Moslehi G., Reisi-Nafchi M. Unrelated parallel machine energy-efficient scheduling considering sequence-dependent setup times and time-of-use electricity tariffs, EURO J. Comput. Optim. (2022), 100052, doi: https://doi.org/10.1016/j.ejco.2022.100052.