Coordination of production and transport in additive manufacturing

Supervisor: Khaled Hadj-Hamou, Full Professor, khaled.hadj-hamou@insa-lyon.fr

University / Institution: Lab. DISP - INSA Lyon

Co-supervision: Marina Vinot, Associate professor, marina.vinot@insa-lyon.fr

University / Institution: Lab. DISP - INSA Lyon

Key words: Additive manufacturing – Scheduling – Planning – Transportation – Optimization – Operations Research

I. Context and motivation

In this research project, the aim is to develop methods and tools to help manufacturers with the digital transition (called 4.0) of production activities. Concretely, it is about exploring physical and digital technologies and integrating them into production and transport activities. On the other hand, to integrate the challenges of Industry 4.0 into the practices and tools for optimizing industrial activities. We will be particularly interested in additive manufacturing technologies. Additive manufacturing - or 3D printing - is evolving and is currently in its first phase of industrialization. Applications are multiplying and some are starting to have a real impact on the supply chain.

The implications of the arrival of additive manufacturing are major. Time savings in the prototyping of parts, tailor-made and customization, reduction in inventory, additive manufacturing is revolutionizing the industrial production method (Pour et al, 2016). Several manufacturers are already familiar with the technology and it is time to think about structuring a dedicated production system. Thus production planning, raw material supply systems, inventory management, the calculation of needs but also scheduling to manufacture new types of products must be rethought. Logistics is another crucial step in the organization of these systems, it has a considerable impact on costs and determines customer satisfaction. This step, often the slowest and most inefficient in the supply chain, must also be adapted and optimized for the new issues of additive manufacturing. The challenge is therefore not easy to meet because it requires careful planning and complex coordination between production and transport (Lacomme et al., 2019).

Unlike traditional centralized means of production, additive manufacturing makes it possible to decentralize manufacturing production and thus promote last mile logistics. In addition, this new type of production allows the generation of production waste to be minimized and the use of packaging to be reduced, so it is part of an environmental approach.

II. Problem addressed and scientific objectives

Given the customer's order book, the size of the parts to be manufactured, the availability of machines and the work in progress, the challenge is to determine when and where the customer will receive his order while optimizing production and transport costs.

The objective is therefore to offer:

- an assignment of parts to be manufactured to machines spread over several sites to minimize the distances and times of delivery of parts to customers. This assignment problem is very difficult to solve in the algorithmic sense for large instances, especially in industrial situations.
- a grouping of parts into production batches and nesting parts to optimize production space during a machine cycle. This last problem (3D bin-packing) is all the more difficult if the shape of the parts is arbitrary.
- a scheduling of production batches on the various machines.
- a synchronization of production and transport for the final distribution of parts to customers.

The originality and the scientific lock therefore concern the simultaneous consideration of the problem of production and transport of parts in additive manufacturing machines, the estimation of manufacturing times, the scheduling of launches and distribution. The objective is to optimize the overall production time / cost (including logistics) and generate statistics on the gains in terms of customer satisfaction.

This thesis project concerns the development of new modeling tools and algorithms for joint optimization of production and transport in the presence of additive manufacturing technologies. The state of the art in additive manufacturing is substantial and is structured around three main axes, source materials, processes and functionalities. A first exploratory work shows, to our knowledge, that the research work that addresses the planning of production in additive manufacturing is very recent (Li et al, 2017) (Chergui et al, 2018) (Aloui and Hadj-Hamou, 2021). Exploring this line of research with transport issues would open up a fourth axis structuring the state of the art on additive manufacturing.

It is an important subject, situated at the crossroad of computer science, applied mathematics and engineering and bearing real technological, industrial and economic potential. The introduction of operational research for the joint optimization of production and transport in the presence of additive manufacturing resources also raises difficult theoretical problems (allocation, 3D bin-packing, scheduling, transport) to which is added an real-life application.

III. Positioning of the subject in relation to the DISP laboratory

This project is in line with the scientific strategy of the DISP laboratory, in particular in the "Operation management for goods and services production systems" axis, taking into account the challenges linked to the impact of new technologies such as additive manufacturing, in the context of the industry of the future. This axis aims to respond to issues from several areas (transport, manufacturing, production planning, scheduling, placement, etc.), thanks to optimization tools from operations research and data science.

Transport and logistics issues are therefore an integral part of the laboratory's research with many works in different fields (industry, health, etc.). In this project, the case of additive manufacturing generates new scientific considerations with, for example, the location of production close to customers to meet personalized needs without building up stocks. Therefore, promoting last mile

logistics and urban distribution is a major issue in the organization of additive manufacturing. Logistics and transport must be optimized in these new industries with distribution networks to be rethought. Scientific barriers around last mile logistics must be lifted through new distribution / transport models that are more efficient for our society. To answer these questions, operational research and decision support tools should be used and adapted to new sectors and new issues, such as additive manufacturing as part of this thesis topic. In addition, the main challenge of this subject is to jointly optimize production and transport because, in these complex systems, their interdependence is often very strong.

References:

- M. A. Pour, M. Zanardini, A. Bacchetti, and S. Zanoni, Additive Manufacturing Impacts on Productions and Logistics Systems, *IFAC-PapersOnLine*, 49(12):1679-1684, 2016.
- P. Lacomme, A. Moukrim, A. Quilliot, and M. Vinot, Integration of routing into a resource-constrained project scheduling problem. EURO Journal of Computational Optimisation 7, 421–464, 2019.
- Y. Zhang, R. K. Gupta, and A. Bernard, Two-dimensional placement optimization for multi-parts production in additive manufacturing, Robotics and Computer-Integrated Manufacturing, 38:102-117, 2016.
- Q. Li, I. Kucukkoc, and D. Z. Zhang, Production planning in additive manufacturing and 3D printing, Computers & Operations Research, 83:157-172, 2017.
- A. Chergui, K. Hadj-Hamou, and F. Vignat, Production scheduling and nesting in additive manufacturing, Computers & Industrial Engineering, 126:292-301, 2018.
- A. Aloui, K. Hadj-Hamou, A heuristic approach for a scheduling problem in additive manufacturing under technological constraints, Computers & Industrial Engineering, 154, 2021.