Research on the circulation type of products between processes under the mode of intelligent manufacturing

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Abstract. This paper begins by examining the significance of production scheduling in manufacturing operations and highlights its pivotal role in governing the flow of products. In the context of batch production enterprises engaged in processing and assembly, where parts exhibit a diverse range, and process routes, manufacturing techniques, and technological equipment vary significantly, the manner in which products flow between different stages presents a multitude of options. These distinctive flow patterns, in turn, pose specific requirements for scheduling algorithms. Consequently, a thorough investigation into the interoperation modes of product flow between manufacturing processes becomes imperative. Primarily, three predominant modes of material movement between sequential steps are identified: sequential movement, parallel movement, and integrated movement. This article provides a comprehensive analysis of these modes, offering insights into their respective advantages, disadvantages, and suitable application scenarios.

Keywords: Process; Transfer of products and materials; Production scheduling

1 Introduction

In recent years, the emergence of intelligent manufacturing has brought about profound changes to the traditional production landscape, presenting new opportunities and challenges. Mechanical processing enterprises have put forward requirements for the fine management of various production resources. They need to maintain and manage the basic attribute information of these resources through information systems. This information is then applied to the planning and scheduling of demand orders to maximize production capacity under limited resources. This leads to more refined production task management and higher economic benefits [1,2]. However, when production plans encounter unexpected situations that require adjustments, the lack of effective means to assess the impact of these changes on the current production plan often leads to frequent adjustments in the production process, resulting in a suboptimal production management state characterized by imbalances at both ends [3,4].

A. Rauf et al. (eds.), *Proceedings of the 3rd International Conference on Management Science and Software Engineering (ICMSSE 2023)*, Atlantis Highlights in Engineering 20,
https://doi.org/10.2991/978-94-6463-262-0_63

Under the realistic conditions of "multiple varieties, small batches, and high quality", while the enterprise will face a large number of emergency plans at the front end, the back end of the enterprise will involve the alternate use of many processing equipment and testing equipment will become difficult [5-6]. Moreover, when multiple plans need to utilize shared equipment resources, the workshop scheduler can only qualitatively analyze the bottleneck resources to communicate and coordinate resource conflicts and organize production based on priority. However, they cannot determine the impact of these resource conflicts on the plans or provide clear order delivery dates.

This paper focuses on the analysis of common product flow scenarios between production processes in the manufacturing workshop.

2 Related works

In batch production enterprises involved in processing and assembly, where parts exhibit a diverse range and process routes, manufacturing methods, and technological equipment vary significantly, there exist multiple ways in which products can flow between different stages. Generally, there are three main modes of material movement between process steps: sequential movement, parallel movement, and integrated movement.

Let's consider a hypothetical customer order for a product with a batch size of 4 units that needs to go through 4 process steps. The individual processing times for each process step are as follows: t1 = 10 minutes, t2 = 5 minutes, t3 = 15 minutes, t4 = 10 minutes. We will not consider the transportation time and setup time between process steps. Below, we will calculate the production cycle for this batch of products under different modes of material movement.

2.1 Sequential Movement Mode

Sequential movement refers to a batch of parts being completely processed in the preceding process step before being "transferred as a whole" to the subsequent process step for further processing, as shown in the following Figure 1:

$$T_1 = n\sum_{i=1}^{m} t_i \tag{1}$$

For the above case, substitute the data into formula (1) to get:

$$T_1 = n\sum_{i=1}^{m} t_i = 4 * (10 + 5 + 15 + 10)\,\mathrm{min} = 160min \tag{2}$$

In the sequential movement mode, since the parts are moved in batches between process steps, the organization of work is relatively straightforward. The parts are processed and transported in a centralized manner, which reduces equipment setup time and transportation workload. During the processing, the equipment in each process step operates continuously, resulting in high equipment efficiency. However, most products experience waiting times for processing and transportation, which leads to longer production cycles, slower capital turnover, and poorer economic benefits. This mode is typically suitable for situations with small batch sizes, short processing times for individual process steps, and longer distances between process steps or workstations.

2.2 Parallel movement method

The parallel movement mode refers to a production mode in which a batch of work in progress is transferred to the next process immediately after processing a part in the previous process, without waiting for the entire batch to be processed before moving to the next process. A batch of parts can be processed in parallel in different processes at the same time, so it is called parallel movement (or flow movement), as shown in Figure 2 below.

From Figure 2, it can be seen that the longest processing path of a part is composed of the total working hours of the process with the longest single-piece working hours and the single-piece working hours of other processes (red arrow part), so the calculation formula for the processing cycle of the parallel movement method is as follows:

$$T_2 = \sum_{i=1,\ i\neq i_{max}}^{m} t_i + nt_{max} = \sum_{i=1}^{m} t_i + (n-1)t_{max} \tag{3}$$

For the above case, substitute the data into formula (3) to get:

$$T_2 = \sum_{i=1}^{m} t_i + (n-1)t_{max} = (10+5+15+10)\ \text{min} + (4-1) = 85min \tag{4}$$

In the parallel movement mode, since the waiting between processes is reduced to a minimum, its processing cycle is the shortest, the WIP reserve between processes is also greatly reduced, and the occupation of working capital is also reduced. However, when the processing time of the front and back processes is not equal, if the time of the latter process is less than the time of the previous process, the equipment and workers will stop after the processing of each part in the latter process, and the stop time is relatively short. Difficult to make full use of; if the processing time of the previous process is less than the time of the subsequent process, there will be a phenomenon of parts waiting for processing. And it will increase the cost of handling and replacement due to frequent handling and switching. It is usually applicable to the situation where the unit time of each process is basically equal and the distance between processes (work places) is relatively short.

2.3 Comprehensive mobile mode

The comprehensive movement method is a method that combines the sequential movement method and the parallel movement method, that is, a batch of parts or products, which not only maintains the parallelism of each process, but also maintains the continuous operation movement method. When the entire batch of parts has not yet completed the processing of the previous process, some of the completed parts are transferred to the next process for processing. The lead time for transferring parts to the subsequent process shall be subject to maintaining the continuous processing of the batch of parts in the subsequent process, as shown in Figure 3 below.

In the comprehensive movement mode, due to the different sequence of long and short processes, there are two different arrangements:

The processing cycle of the comprehensive movement method can be obtained by subtracting the time of each overlapping part (shown by the red arrow in the figure) from the processing cycle of the sequential movement method. When the processing time of the previous process (before t) is less than the processing time of the subsequent process (after t), the overlapping part of the processing time of the batch of parts in the two processes is (n-1) t ago; the processing time of the current process When the time is greater than the processing time of the subsequent process, the overlapping part of the processing time of the batch of parts on the two processes is (n-1)t later; when the processing time of the previous and subsequent processes is equal, the processing time of the batch of parts on the two processes is The overlapping part is (n-1) t before or (n-1) t after. In each of the above cases, before t and after t are short man-hour processes, so they can be collectively represented by (n-1)t short.

$$T_3 = n\sum_{i=1}^{m} t_i - (n-1)\sum_{i=1}^{m-1} t_s \tag{5}$$

For the above case, substituting the data into the formula gives:

$$T_3 = n\sum_{i=1}^{m} t_i - (n-1)\sum_{i=1}^{m-1} t_s = 4 * 40\text{ min} - 30 * 20\text{ min} = 100min \tag{6}$$

The production cycle of parts is shorter under the comprehensive moving mode, which eliminates the downtime of the equipment to a certain extent, concentrates the downtime of the equipment, and is convenient for other work. However, this method of organization and management is more complicated, and is generally applicable to object-specific organization forms.

The CNC installation equipment used in this study is a vertical CNC machining center, as shown in Figure 4, vertical CNC machining is a commonly used CNC machining equipment in workshops. The type is lifting and lowering movement, horizontal and vertical movement of the workbench.

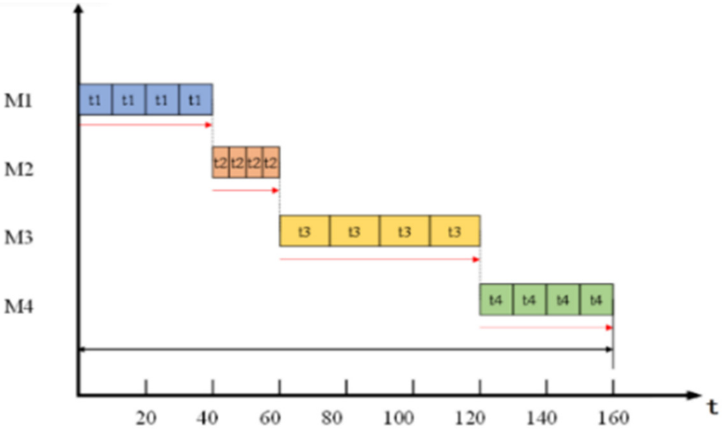

Fig. 1. Sequential Movement Mode

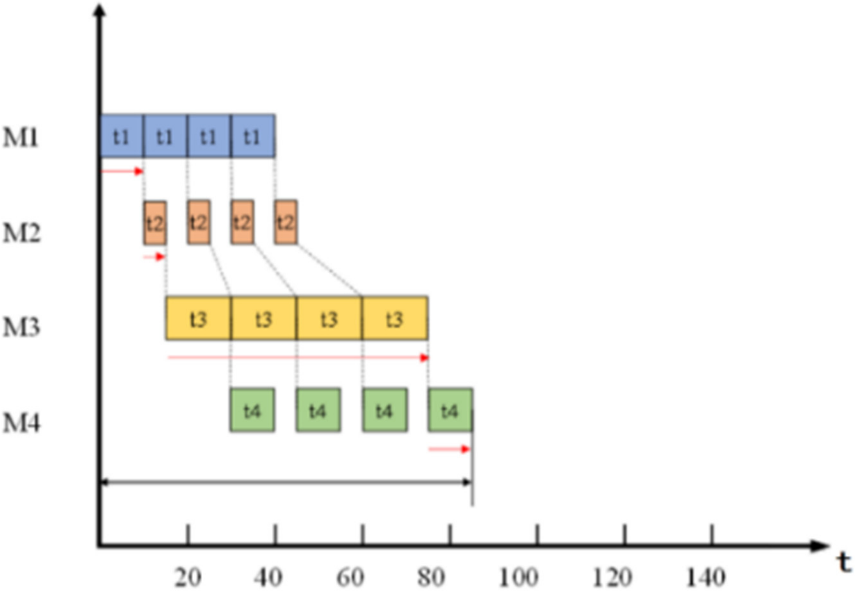

Fig. 2. Parallel movement mode

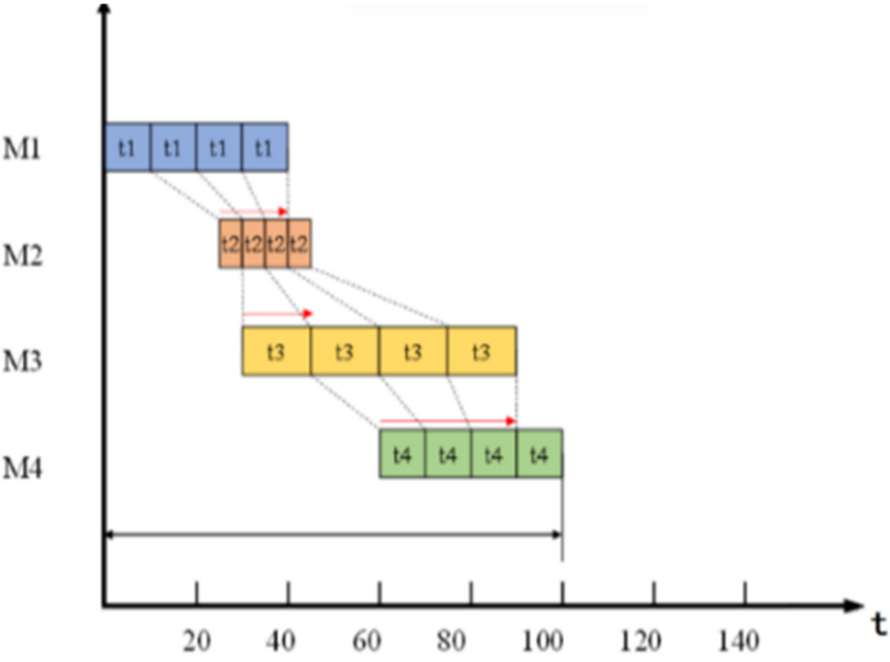

Fig. 3. Comprehensive mobile mode

Fig. 4. CNC matching equipment

2.4 Comparison and selection of three moving modes

The above three moving methods have their own advantages and disadvantages, and their comparisons are shown in the Table 1.

Table 1. Advantages and disadvantages of different transport methods

Compare Items	Sequential Movement	Parallel Movement	Comprehensive Movement
Processing Cycle	Long	Short	Medium
Number of Transports	Less	More	Medium
Equipment Utilization	Good	Poor	Good
Organizational Management	Simple	Medium	Complex

3 Conclusion

In the study of product flow modes between process steps in the context of intelligent manufacturing, different methods have been examined. From the perspective of the processing cycle, parallel movement and comprehensive movement show advantages, while sequential movement offers simplicity in organizational form. The choice of movement method depends on various factors, including the specialization form of the production unit, labor requirements, weight of parts, equipment adjustment labor, production type, and task urgency. These factors guide the selection of the most suitable movement method. It is essential to consider the specific conditions of the enterprise and utilize one or a combination of methods to optimize the production process effectively.

Acknowledgments

This work was supported by Sichuan Machinery Research and Design Institute (Group) Co., Ltd (Number: 2020ZDZX0006) and Qilu University of Technology (Shandong Academy of Sciences) (Number: 241901040101).

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