Simulation and Optimization of Plant Production Takt

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Abstract. In order to solve the problem of planning and optimizing the production takt of a key link in the rocket assembly workshop. The production takt is obtained through the modeling and Simulation analysis of the actual plant based on the Plant Simulation, a professional discrete Simulation software. The factors that affect the production takt are obtained qualitatively and the influences of these factors are quantified, and the configuration of these factors is finally determined through the DOE experiment method to make the production takt reach the practical optimal and the theoretical optimal.

Introduction

As a novel technology, simulation has set off a new upsurge all over the world, which models the object system and analyzes the performance of the system by using the simulation model as an experimental device, and simulation plays an important role in reducing losses, saving costs, shortening development cycle, improving production efficiency and improving product quality, etc. In the industry 4.0 environment, the complexity and intelligence of production system will be greatly improved, and the planning and optimization of complex factories will increasingly need simulation and optimization tools.

The basic idea of simulation is modeling, analysis and optimization. Compare with traditional empirical optimization, algorithm optimization, the computer simulation technology is more intuitive, effective and visual, and the simulation tool Flexsim is used to optimize an assembly line [1]. The simulation technology as a modeling method, can organically combine the relevant elements of the system according to the actual operation logic and truly reflect the behavior of the system. Therefore, the simulation model can be used to study the behavior characteristics of the system [2]. In addition, Em-plant is used to simulate and optimize the material distribution workshop of solar module assembly line, and the proper processing parameters are determined, which can improve the transmission efficiency of the whole logistics system and reduce the cost [3]. Nowadays there are many researchers use simulation tools to solve various problems of various fields.

The rise of simulation software provides the foundation and strong support for the furthest development of simulation technology. Plant Simulation is a discrete Simulation software specialized in the field of intelligent plant simulation, which is an object-oriented simulation tool. And plant Simulation supports layered structure and the modeling process is simple. It with rich statistical analysis tools, built-in genetic algorithm, neural network and other tools can optimize production, also can be 3D simulation; With the SimTalk programming language built in to control the simulation, and a Method object is a specific control program [4]. Plant Simulation is the most advanced simulation software in the field of factory simulation.

The production takt of a key link in a rocket assembly workshop determines the resource planning of other links in the whole plant, but it is difficult to determine the size of production takt based on experience, and we do not know how to optimize the production takt. Therefore, this paper conducts flexible modeling and Simulation of this link in the plant based on Plant Simulation, obtains the

production takt, qualitatively and quantitatively obtains the factors affecting the production takt through bottleneck analysis and experimental analysis, and determines the configuration of these factors to make the production takt get reasonable.

Modeling

The basic idea of modeling is to model according to the production process. Firstly based on the plant layout, each basic object is established and object parameters are set. Then these objects are connected according to the order of the production process to make up the whole plant. Finally, SimTalk programming language is used to control each object according to the actual production logic, making the simulation model run according to the production logic.

The production flows chart and the general process layout of this production link is shown in figure 1. The big arrows and serial numbers represent the process of the workpiece: starting from the warehouse, being transported by pallets, trucks and turnplate, and finally returning to the warehouse after four times of processing. In the process of moving from track of pallet 1 to track of RGV, the workpiece should stay on the turnplate for 2 minutes to prepare for the second processing. It needs to be explained that the track is a single track, each track allows only one truck or pallet, each process allows only one piece of work at a time processing.
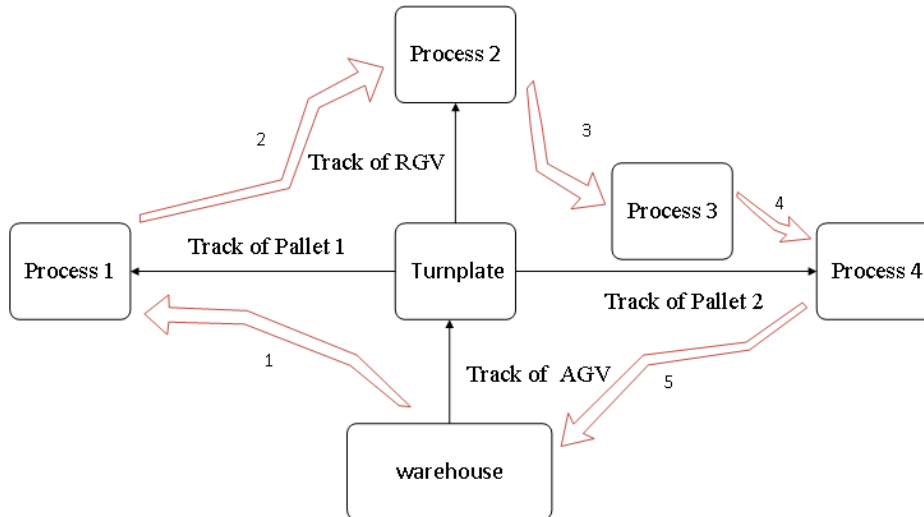

Figure 1. Process flow chart

It means that when there is workpiece on the latter track and station, the workpiece on the former track cannot be transported to the next track through the turnplate, and the workpiece can only enter the next track when the next track and station are all free. This logic is programmatically controlled by the Simtalk language.

The key initial process parameters are shown in table 1.

Table 1. Table of initial process parameters

Parameters Name	Value	Parameters Name	Value
Warehouse release time	2min	Speed of AGV	0.2m/s
Track length of AGV	16m	Speed of pallet	0.14m/s
Track length of pallet 1	4.85m	Process time of P1	14min
Speed of RGV	0.13m/s	Track length of RGV	8m
Process time of P2	3min	Track length of pallet 2	5.5m
Process time of P3	3min	Process time of P4	1min

The production takt of this link is defined as the time interval from the time when the previous workpiece leaves station 4 to the time when the next workpiece leaves station 4. Due to the limitations or needs of other links in the plant, the production takt of this link is required to be less than 14 minutes.

The purpose of simulation is to determine the production takt under the initial parameters, analyze the factors affecting the production takt, and optimize the production takt through the configuration of these factors, so get the takt within a reasonable range. After certain simplify, the simulation model is modeled according to the basic modeling idea, as shown in figure 2.

The production takt was 17 minutes and 15 seconds at the end of the simulation, so the production takt time under the initial parameters was not qualified.
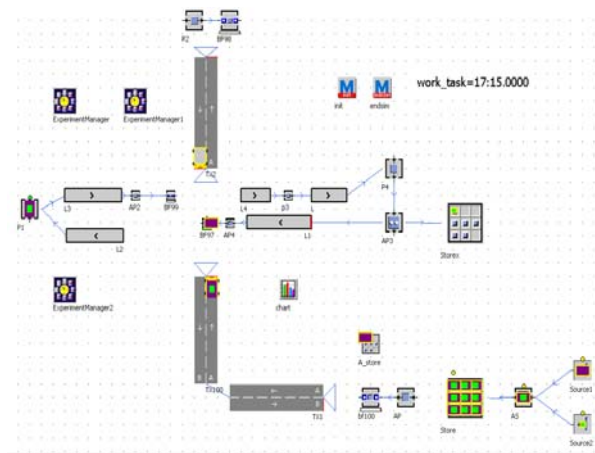

Figure 2. Simulation model

Analysis and Optimization

Plant Simulation has built-in bottleneck analyzer, which can automatically analyze the resource utilization of each process after the completion of the simulation model run. The resource statistics of the four process obtained after running are shown in figure 3. As can be seen from figure 3, process 2, 3 and 4 are waiting for most of the time. The reason is that the processing time of process 1 is too long, resulting in too long time for the workpiece to stay at this station. As a result, subsequent process is waiting for the completion of process 1. And the production takt is the time interval from the time when the previous workpiece leaves station 4 to the time when the next workpiece leaves station 4, and when the current workpiece leaves station 4, the next workpiece will stay at the station 1 because process 1 has too long processed time. Therefore, the decisive factor affecting the production takt of this link is the processing time of process 1.
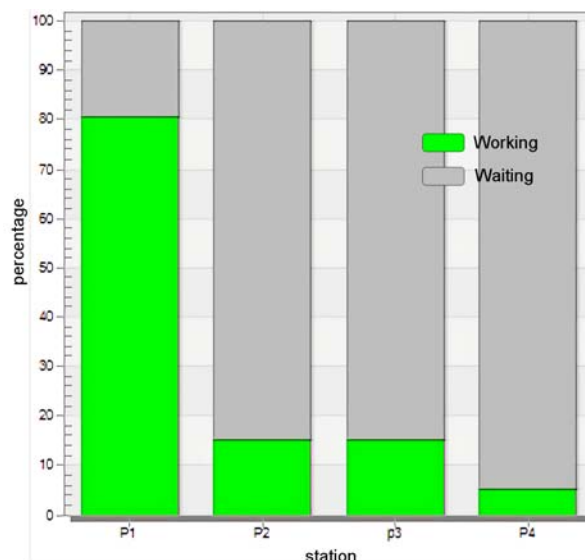

Figure 3. Resources statistics

In addition to qualitative analysis, we can also quantitatively analyze the influence degree of these four factors on production takt. We refer to the factor design experimental, which is essentially changing single or multiple factors simultaneously to see how this change affects the production takt, and determine the impact of this factor on the production takt. According to the actual situation, the range of processing time of process 1 is 8 minutes to 15 minutes, process 2 is 2 minutes to 4 minutes, process 3 is 2 minutes to 4 minutes, and process 4 is 40 seconds to 1 minutes and 20 seconds(The range is determined by the complexity of the actual process and the proficiency of the workers). The experimental results of factor analysis are shown in table 2. According to the table 2, within the actual processing time range, processing time of process 1 is the only factor affecting the production takt.

Table 2. Results table of factor analysis

Processing Time	Process 1	Process 2	Process 3	Process 4
Process 1	$H1 = 7.0$	$W1,2 = 0.0$	$W1,3 = 0.0$	$W1,4 = 0.0$
Process 2		$H2 = -0.0$	$W2,3 = 0.0$	$W2,4 = 0.0$
Process 3			$H3 = -0.0$	$W3,4 = 0.0$
Process 4				$H4 = 0.0$

Therefore, how to determine the processing time of process 1 to meet the requirements of the plant has become the key point of optimization analysis, meanwhile how to reduce the processing time of process 1 will also become the focus of process optimization.

The production takt is independent of the processing time of process1, 2 and 3. Therefore, this paper continues to study the specific relationship between processing time of process 1 and production takt through DOE (Design of Experiment) experiment method with the processing time of process 2, 3 and 4 unchanged. DOE experiment is essentially to change the input with a certain step length within a certain input range and get the output under the corresponding input, then get the best configuration from the experimental results. The processing time of process 1 was changed within the range of 1min to 15min with the step length of 5 seconds, and the corresponding production takt was recorded. Processing time increases with the experimental process. Experimental results are shown in figure 4.
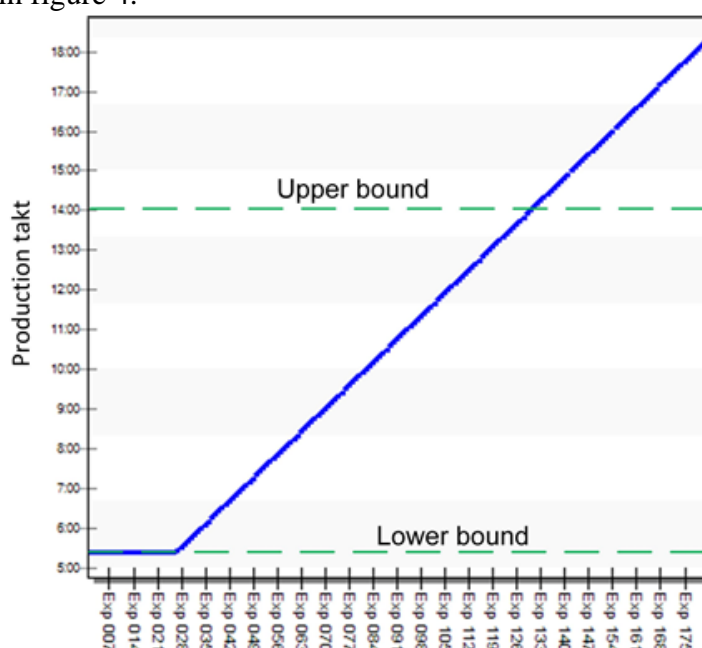

Figure 4. The relation graph of production takt and processing time of process 1

According to figure 4, within the whole range, the production takt is proportional to processing time of process 1. However, there is a lower bound on the production takt. According to the detailed result, the processing time of this experiment is 2 minutes and 9 seconds, and the corresponding production takt is 5 minutes and 24 seconds(It should be noted that this production takt is only optimal in theory, because in fact, processing time of process 1 cannot be reduced to that, which is restricted by practical conditions). The purpose of simulation is to reduce the production takt to less than 14 minutes, according to the detailed results of DOE, the production takt is 13 minutes and 55 seconds when the processing time of process 1 is 10 minutes and 40 seconds, which is the upper bound meeting the requirements. In other words, the processing time of process 1 must be reduced to 10 minutes and 40 seconds to meet the requirements of the whole factory.

In order to express the relationship between them more conveniently and intuitively, the data obtained from the simulation experiment are fitted into a piecewise function to facilitate the guidance of actual production. The piecewise fitting function obtained is:

$$y = \begin{cases} 324 & 60\text{s} \le x < 129s \\ x + 195 & 129s \le x \end{cases} \tag{1}$$

Where x is processing time of process 1, y is production takt, the units are seconds. And the upper and lower bound parameters obtained by the DOE are shown in table 3:

Table 3. Upper and lower bounds of production takt

Processing Time of Process 1	Production Takt
2 minutes and 9 seconds	5 minutes and 24 seconds
10 minutes and 40 seconds	13 minutes and 55 seconds

Conclusion

In order to solve the analyzing and optimizing problem of the production takt of the key link in the rocket assembly workshop, this paper conducts the modeling and simulation optimization of the actual plant based on the professional discrete simulation software Plant Simulation. The factors affecting the production takt are analyzed and the degree of these factors affecting are quantified. Finally, the configuration of these factors was determined through DOE experiment method to keep the production takt within a reasonable range. A specific problem that was difficult to be determined by the plant's experience was solved, illustrated that the advantages of simulation technology and software in solving problems of discrete-events.

Acknowledgment

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