Simulation design and optimization of production line of a cross axis machining based on Plant Simulation

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Abstract. In order to study the operation process and results of an actual intelligent production line, Plant Simulation was used to simulate the production line of a cross shaft. First of all, the basic layout is modeled, 3D model is used, and the actual machine model is imported or designed to make the effect more realistic. This study analyzed the production process, created orders according to customer requirements, used Simtalk language to complete the simulation logic of the model, and displayed the simulation data in the form of charts after the operation, so as to make the results more intuitive. Finally, the results are analyzed and optimized.

1. Introduction
In the face of the reform and upgrading of the global manufacturing industry, China has also put forward corresponding upgrading strategies [1], and industrial upgrading is centered on intelligence and network [2]. For factory production, intelligent control becomes the future trend, and the concept of intelligent factory [3] emerges at the right moment. In the implementation of intelligent factory, production simulation has become an important part. This paper studies the production line of a cross shaft. According to the functional requirements of the production line, a simulation model of the production line was established to obtain a large number of production data [4]. Production simulation technology can build three-dimensional model, make the production process more intuitive, better understand the actual operation of the production line, provide data for production decision, and help researchers to make decisions and improve.

Plant Simulation, Witness and FlexSim are widely used in factory Simulation of discrete events [5]. Plant Simulation, as a powerful discrete system Simulation software, is commonly used in production and logistics systems. It has been widely used in the optimization and Simulation of discrete event systems. Plant Simulation is used to simulate the production line of a cross-shaft machining analyzed in this paper [6]. The whole production line contains many kinds of equipment, such as robots, CNC machine tools, AGV trolley and warehouse. Using this factory simulation software, the whole production line can be intuitively and accurately restored, supporting the establishment of three-dimensional model, global data statistics, and analysis and decision on the obtained data.
2. The basic layout and production flow of a cross shaft manufacturing line

2.1. Basic layout analysis
According to the situation of a cross shaft production line, the production line has a processing equipment to process the parts, there are also a number of robots and assembly machines to carry and assemble the parts. The above situation can be divided into production and processing area, assembly area and logistics area according to their functions. The key equipment mainly includes: 1 CNC machine tool and 2 distribution robots in the production and processing area, 2 robots and 2 assembly machines in the assembly area, raw material and finished product warehouse in the logistics area and 1 AGV. In addition, there are also the TRACK run by AGV trolley, semi-finished product transportation track, semi-finished product cache area and finished product cache area, etc. According to this idea, the basic layout is implemented and the actual production line is restored through simulation modeling.

2.2. Production process analysis
The production line of a cross shaft is specially designed for the production of fixed products. This production line is divided into three kinds of parts and two kinds of bottom plates of different colors. It can be set according to customers’ orders, assemble different parts and bottom plates, and complete the corresponding number of products according to the order number. After the order is made, the material warehouse distributes the raw materials, among which the parts and the bottom plate are distributed separately. Then it is transported by AGV trolley to the corresponding station and arrives at the production and processing area, where the raw materials are processed by CNC machine tools. After that, the robot will be distributed to the assembly area for assembly, and the finished products will be obtained. After quality inspection, the qualified products will be transported to the finished products cache area and sent back to the finished products warehouse by AGV trolley, and the unqualified products will be collected in the defective products recovery area.

2.2.1. Production and processing zone flow.
The first robot in the production and processing area will transfer the raw material parts to THE CNC machine for processing, wait for the completion of processing, and transfer the semi-finished products to the semi-finished products cache area. A second robot then places the semi-finished product on a different transport track, depending on the type of part, from which it is transported to the assembly area.

2.2.2. Assembly area flow.
The first robot in the assembly area takes different types of parts from the transport track and places them on different assembly machines, depending on the order. The bottom plate was also captured and placed on different assembly machines by the first robot according to different colors. After the operation of the two assembly machines, the second robot will put the finished products, after quality inspection, respectively in the finished product cache area and the defective products recovery area.

2.2.3. Flow of logistics Area.
The Logistics is divided into storage area for raw materials and finished products, track side cache area and AGV trolley running area.

The raw material storage area stores the corresponding parts and floor plates according to the order requirements, and the finished product storage area is used to preserve the genuine products after processing and assembly. Parts and base plate are shipped out two at a time.

There are three cache libraries in the track side cache area, one is the part cache library in the production process area, and two are the bottom plate cache library and the finished product cache library in the assembly area.

The AGV trolley runs through the raw material and finished product storage area, production processing area and assembly area. The main task of the AGV trolley is to receive the raw materials,
transport the parts and floor plates to the production processing area and assembly area respectively, and then transport the finished products back to the finished products storage area. Follow this loop until the order is completed and the operation is suspended.

3. Design of simulation model for production line of a cross shaft

3.1. Model requirement analysis
According to the actual situation of a certain cross shaft production line, the type and quantity of the processed parts are processed according to the customer order, and the simulation model is designed and produced according to the customer order first. Then according to the previous basic layout and production process design, four robots, CNC machine tools, AGV trolley layout and operation of the data statistics. Statistical data can be presented in the form of charts to make the results more stereoscopic and intuitive. Add bottleneck analyzer to analyze the global machine and input/output to find the problem. Design the 3D shape of the machine according to the desired effect.

3.2. Specific design of the model
The simulation model is designed according to the function of each area, so the design needs to be correct and complete, so that each link can be connected.

3.2.1. Customer order model design.
The production process is performed according to the orders specified by the customer [7]. The order generation is set up via the DataTable in Plant Simulation. This model is divided into two orders, one is the order of part generation, the table has four columns, respectively is the source of part, the quantity of part generation, the name of part (A1, A2, A3), the details of part (corresponding base plate color, the destination). One is the order generation of the bottom plate, and this is the order generation of the corresponding parts. The order also has four columns, namely the source of the bottom plate, the number of the bottom plate generation, the name of the bottom plate (black, pink), and the details of the bottom plate (arriving at the destination).

3.2.2. Logistics area model design.
The first is the distribution of raw materials, which is carried out by Source according to the customer's specific orders. The parts generated by the orders are of Type Mu and the bottom plate is of type Container, which is convenient for assembly.

The finished product storage area is stored by the Store, and the track edge cache area is stored by three buffers, which Store parts, bottom plate and finished products respectively. Then, AGV trolley is transported according to the requirements of the production line. The logic of AGV trolley transportation is programmed by Method using Simtalk language. Trigger points are set on the transport track to enable AGV trolley to complete logic with different functions through different trigger points.

3.2.3. Design of production and processing zone.
The cache area of parts is picked up by the first robot PickAndPlace to the CNC machine for processing. After completion, semi-finished products are picked up to the cache area of semi-finished products. By setting the Angle and time of the robot, it can grasp and place the parts normally.

After setting the Angle and time, input the code to the robot according to the requirements of the production process. Add Method to the target under controls. The code for Target is shown in Figure 1.
Figure 1. Target code

According to different semi-finished products, the second robot is placed on different conveyor belts and transmitted to the assembly area. This robot needs to call methods at the exit, which is distinguished according to the type of parts.

3.2.4. Assembly area design.
The first robot in the assembly area picks up semi-finished products on different conveyor belts and places them on the corresponding assembly machine, and also grabs the bottom plate in the bottom plate cache area beside the track and places it on the assembly machine according to different colors. Then the machine is assembled for assembly. The method at the exit of the robot is similar to that of the second robot in the production and processing area.

3.2.5. Simulation model data statistics.
Plant Simulation provides a Chart for the entire production line to visually see the statistical results, which can be shown in the form of a 3D or 2D bar Chart or line Chart. Data on the intelligent production line included the efficiency of four robots and CNC machines.

3.3. 3D model appearance design
The Plant Simulation system gives the default appearance of each machine by default. However, depending on the reality, the Plant Simulation system can be modified to make it closer to the desired effect. You can do this either by changing the system's default machine look or by importing the machine shape you want directly. Another approach is to design your own, and you can make the machine more realistic by importing pictures of the machine, as shown in Figure 2.

Figure 2. Design the appearance of the machine

4. Simulation operation and result analysis of a cross shaft production line

4.1. Simulation Operation
The machining time of CNC machine and the running speed of AGV trolley were set up after the simulation model of a cross shaft machining production line was set up. Open the simulation runner and start running, as shown in Figure 3.
4.2. Analysis of simulation results

After the simulation model is run, open the Chart to see the corresponding statistical data, as shown in Figure 4. The proportion of AGV running by small car is shown in Figure 5.

![Resource Statistics Chart](image)

Figure 4. Statistical diagram of simulation results

![Proportion of AGV operation](image)

Figure 5. Proportion of AGV operation

4.3. Problems

According to the above analysis results, it can be found that there are problems in the simulation operation of a cross-shaft manufacturing production line:

1. The processing time of CNC machine is the bottleneck of this intelligent production line, which is longer than that of the robot behind.
2. The utilization rate of the first robot and the second robot in the processing and production area is almost the same.
3. The first robot in the assembly area is less efficient, while the second robot is less efficient.
4. AGV car movement time accounts for 80%, and empty time accounts for 20%.

4.4. Optimization methods

For the above problems, the following optimization methods can be proposed:

1. Since the processing time of CNC machine is relatively fixed and the improvement space is relatively small, the handling speed of parts can be improved by two robots in the processing area, so that they can carry objects to the next area as soon as possible.
2. The robot in the assembly area has a low utilization rate. One reason is that the arriving speed of the parts after processing is not fast enough, so we can consider preparing the processed parts in advance and placing the belt area. Another reason is that the speed of robots in the assembly area has not kept up with the pace of robots in the processing and production areas, which can make the pace of robots in the assembly area consistent with that of robots in the processing and production areas and increase the utilization rate.

3. As for the AGV car, it can be seen that its utilization rate has not reached 100% yet, so we can choose to reduce its speed appropriately and keep the efficiency unchanged while improving the utilization rate.

5. Conclusion
Plant Simulation was carried out for a cross-axis machining production line, and customer orders, machining production area and assembly area were designed, so that the AGV car could complete tasks on the track according to requirements. Finally, the operation results are obtained, and the statistical data can be seen more intuitively in the form of 3D chart. Through the analysis of the result data, the bottleneck of this production line is found out and the optimization method is put forward. This simulation model is of great help to the actual production line, which can simulate the actual operation results to make further improvement, solve the problems encountered in the production line, convenient and labor-saving.

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