Layout optimization of workshop equipment based on WITNESS

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Abstract. According to the production order, the engine parts workshop of a company mainly produces four parts: valve hydraulic tappet, camshaft, camshaft gear and bearing cover. With the increasing demand of production, the production capacity brought by the original workshop equipment layout gradually cannot meet the increasing demand. In this paper, based on the WITNESS simulation software, we are preparing to collect the data of engine parts and components production workshop in order to get the data information of each element by simulation, and reasoning the unreasonable parts where the busy rate is too high and put forward several improvement methods. Through WITNESS software simulation, respectively, we can analyse whether there will have improvement and conclude the optimal improvement project. As the busy rate of lathe group and milling machine group of the original workshop layout is more than 80%, while the statistics are less than 60% by using the optimal plan to improve the existing layout, reaching a reasonable busy rate. It can be concluded that it is feasible to solve the problem of high work step busy rate and improve the overall production efficiency of the workshop through reasonable equipment layout optimization.

1. Introduction

Engine parts enterprise is a special small and medium-sized manufacturing enterprise, which has the characteristics of multi product, small and medium batch production [1]. The success of a manufacturing enterprise depends to a large extent on its manufacturing system. With the increasing requirements of customer product quality and delivery time, the production of engine parts must have the flexibility of continuous improvement of system operation with low cost and high efficiency. Therefore, it has become the most fundamental prerequisite for the development of engine parts enterprises on how to improve the production system, improve the production efficiency, increase the production capacity and overcome the production problems for the flexible production situation [2]. Workshop layout is a design activity in which the specified equipment is reasonably placed in the specified layout space under the premise of satisfying the necessary constraints, so as to achieve a certain optimal index [3]. Workshop is the hub connecting all work links and the basic work unit, its equipment layout will directly affect the efficiency of the production system. Therefore, the layout of the workshop needs scientific analysis and optimization, so that the production system could improve to achieve the optimal.
2. Problem analysis

The engine parts production workshop of a company mainly produces valve hydraulic tappets, camshafts, camshaft gears, and bearing caps. Each part has a different process. The specific process is determined according to the production order. The schematic diagram of workshop layout is shown in figure 1.

![Schematic diagram of workshop layout.](image)

As can be seen from figure 1, each processing equipment is distributed in the corresponding processing interval, and the processing steps of the four products are respectively processed in each interval. Due to the workshop arrangement use fixed number of year is too long, in the face of growing demand workshop capacity is only 50% ~ 60% at the same time, some lathe group in the process of production equipment has been in processing condition, compared with some other lathes group equipment wait for long time, cause about two-fifths of the workshop equipment is in a state of low utilization rate or idle for a long time\(^{[4]}\), belongs to the typical equipment layout is unreasonable phenomenon.

3. Simulation modelling

3.1. basic information of the four products

The engine parts production workshop has lathes, milling machines, drilling machines, grinders and other product processing equipment. During the production process of each product, some of the equipment corresponding to the machine tool group are used. Each machine tool group forms a whole. In order to facilitate the operation, the numerical representation of each process is simplified as shown in table 1, the names of the four processes are simplified as shown in table 2.

| process | turning | drilling | milling | grinding | welding |
|---------|---------|----------|---------|----------|---------|
| On behalf of the digital | 1 | 2 | 3 | 4 | 5 |

| process | polishing | polishing | inspection | electroplating |
|---------|-----------|-----------|------------|---------------|
| On behalf of the digital | 6 | 7 | 8 | 9 |

Table 2. Simplified table of process name.

| Instructions              | Valve hydraulic tappet machine set | Camshaft gear machine set | Camshaft gear machine set | Bearing cover machine set |
|---------------------------|-----------------------------------|---------------------------|---------------------------|---------------------------|
| Processing process        | A                                  | B                         | C                         | D                         |
Table 3 shows the process routes for producing four different products and the average processing time of the steps in each process route.

Table 3. Summary table of processing route and processing time of each product.

| The product type | Routing               | Average service time in successive processes /MIN |
|------------------|-----------------------|---------------------------------------------------|
| Valve hydraulic tapper | 1,2,3,4,5,6,7,8,9     | 15,7,12,20,14,17,11,2,8                           |
| Camshaft gear    | 1,2,3,4,6,7,8,9       | 12,6,11,18,14,7,2,8                               |
| The camshaft     | 1,3,4,6,7,8,9         | 11,11,15,12,8,2,6                                 |
| Bearing cover    | 1,3,4,6,7,8,9         | 10,11,15,13,7,2,7                                 |

In the actual operation process, due to the uncertainty of the production site and the complexity of the production process, the actual model can only represent the most important part of the real system, so in the process of setting the simulation model and parameters, it will be simplified and assumed appropriately [5]. After setting the main entity elements of the simulation model, the schematic diagram of the workshop simulation model is obtained, as shown in figure 2.

Figure 2. Schematic diagram of workshop simulation model.

4. Simulation results

Under the premise of various simulation settings, run the simulation model, the simulation clock in the model defaults to 1 indicating that the time unit defaults to 1 minute, and run the 2000 simulation time unit for the system model [6], and get the simulation results of four parts production lines (the vertical coordinate represents the Busy rate), as shown in figure 3.

Figure 3. Processing process busy rate diagram.
From figures 3, it can be seen that in the production process of the four parts, there are several serious problems. The turning rate of the first step of each process is 100%, and the other steps must wait for the turning to be completed before continuing. This exposes the insufficient production capacity of turning, which will affect the production efficiency to a great extent. The second is the milling machine group, the busy rate of the machine is also very high, reaching 90% or even higher, such a high busy rate will inevitably lead to a series of efficiency problems. Therefore, in the process of analysing the equipment layout of the workshop, the two machine groups of turning and milling should be taken into account. only by solving these two problems can we improve the production efficiency and solve the production capacity problem to a great extent. To provide the company with the maximum revenue.

5. Layout optimization

The purpose of this paper is to optimize the equipment layout of the whole production workshop by analyzing the busy rate of each production line and improving it. As mentioned above, the busy rate of turning and milling machines is very high, indicating that the processing capacity is not enough to meet its production load, which will inevitably constrain the production efficiency. Therefore, the improvement of the whole workshop production system focuses on the optimization of the two machine sets, and the proposed three optimization methods are as follows.

Method 1: Due to the high busy rate of the turning machine group, first add a turning device to the turning machine group and retry the trial operation to observe whether the busy rate of the turning machine group and other lathe groups has decreased to a reasonable range. In order to ensure whether the change is caused by changing the turning machine group, the number of machine groups in other processes needs to be kept as it is.

Method 2: Due to the high busy rate of the milling machine group, first add a milling device to the milling machine group and retry the trial operation to see if the busy rate of the milling machine group and other lathe groups has decreased to a reasonable range. In order to ensure whether the change is caused by changing the milling machine group, the number of machine groups in other processes needs to be kept as it is.

Method 3: A turning device is added to the turning machine group, a milling device is added to the milling machine group, and the number of other process machine groups remains unchanged. Since the busy rate of other work steps in the workshop meets the normal standard, and the three methods will not have much influence on other work steps, it is only necessary to judge whether the method is feasible according to whether the busy rate of turning and milling two work steps is reduced to a reasonable range (lower than 60%) after adopting three different methods.

The equipment layout model after the modification of the method 1 is simulated, and the busy rate of the two steps of turning and milling is compared with the original busy rate, as shown in figure 4. (the vertical coordinate represents the busy rate, 1-1,3-1 represents the busy rate of turning and milling after method 1 is adopted).

According to figure 4, after adding a device to the turning machine group, the busy rate is reduced to the normal range. The busy rate of the milling machine group is still particularly high, which basically coincides with the original busy rate. Each machine tool group in the entire workshop is a part of the whole, and should not pursue the optimization of a single basic unit, and ignore its overall effect. Although this method balances the busy rate of turning, overall, the method 1 is still not desirable.

The equipment layout model after the modification of the method 2 is simulated, and the busy rate of the two steps of turning and milling is compared with the original busy rate, as shown in figure 4. (the vertical coordinate represents the busy rate, 1-2,3-2 represents the busy rate of turning and milling after method 2 is adopted).

According to figure 4, under the condition that other conditions remain unchanged, adding a device to the milling machine group can effectively reduce the busy rate of milling steps, but the busy rate of turning steps is still the highest, and the remaining machine groups are still low utilization and more idle. Therefore, after comprehensive consideration, the method 2 is not desirable as an improvement plan.
The equipment layout model after the modification of the method 3 is simulated, and the busy rate of the two steps of turning and milling is compared with the original busy rate, as shown in figure 4. (the vertical coordinate represents the busy rate, 1-3,3-3 represents the busy rate of turning and milling after method 3 is adopted).

According to the results obtained in figure 4, under the premise of keeping other conditions unchanged, after adding a turning device to the turning machine group and a milling device to the milling machine group, the busy rate of turning and milling steps in the four processes decreased obviously. This shows that after optimizing the layout of the workshop equipment, the busy rate of each process is maintained in a relatively normal range, and there will not be a high busy rate of one or several steps, which will cause the remaining machine tool groups to wait too long and have low utilization. This method can better improve the production efficiency of the workshop, so method 3 is the best optimization solution, which can be used to optimize and transform the actual equipment layout system.

![Figure 4. Busy rate diagram for two operating procedures.](image)

6. Conclusions
Due to the long layout of equipment in the engine parts production workshop, the production efficiency of the original workshop equipment layout cannot meet the increasing production demand. The layout of the equipment used in the processing of the four main parts needs to be optimized. Taking the busy rate of various processing process production lines as a reference, by establishing a WITNESS model and inputting the collected data into WITNESS software, the production capacity of the existing equipment layout can be analyzed, and the unreasonable equipment layout can be obtained. On this basis, different improvement methods are proposed for the equipment layout with high busy rate, and the optimal solution is obtained by analyzing and comparing the data obtained by WITNESS software simulation. Therefore, in the actual production process, the problems existing in the workshop production process can be obtained and optimized through the modelling and simulation software of the process, so as to achieve the purpose of reducing various wastes, improving production efficiency and maximizing production efficiency.

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