STUDY ON THE PROCESS OF AUTOMOBILE PARTS WARM-COLD COMPOUND FORMING

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ABSTRACT: Based on the analysis of the foreign advanced automobile parts production mode, we take warm-cold composite parts - brake piston production line as an example, aiming at the not balanced production line process and logistics chaos problems existing in enterprise, make use of group technology to decompose and recombine the piston machining feature, and combine the lean production to make a new production line layout.

KEY WORDS: automotive parts; brake piston; processing technology; process balance

1 INTRODUCTION

In recent years, with the promotion of globalization and rapid social and economic development of China, customers' customization demand, fast market changing, shortening of product life cycle and so on make high-speed, agility and competition become the biggest challenges for enterprises. How to maintain the vitality and competitiveness of enterprises in the unpredictably changing market environment has become the goal that the enterprises continuously explore and pursue. It has become one of the important means to improve the comprehensive competitiveness of parts production enterprises to improve the ability of rapid response to market changes in the production line, to shorten the production cycle to ensure the delivery time, to reduce the production waste, to reasonably make use of production capacity, and to improve the quality of products.

As the pillar industry of China's national economy, the development of automobile industry will directly affect the development of the national economy. As a supporting industry, automobile parts industry plays an important role in the development of the whole automobile industry. The core of lean production is to eliminate waste, and ultimately achieve the lean goal. Based on the analysis of foreign advanced automobile parts production mode, we take warm-cold composite parts - brake piston production line as an example, aiming at the not balanced production line process and logistics chaos problems existing in enterprise, make use of group technology to decompose and recombine the piston machining feature, and combine the lean production to make a new production line layout.

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2 SUMMARY OF AUTOMOBILE PARTS PRODUCTION MODE

At present, the possible assembly line layout of automobile parts production workshop has the following four schemes:

2.1 Combined /special machine automatic production line TL (Transfer Line)

TL is a distributed automatic production line composed of combined / special machine tools. Each machine, in principle, only performs a process, and only the work-piece "flow" in the whole line, it completes all the processing. The production line equipment is arranged in series, and the work-piece completes a process, it automatically flows to the next process. It is characterized by fewer varieties and more output. TL has the advantages of high production efficiency - process dispersion. Dozens or even hundreds of machine tools are processing at the same time, and single and multi-process are processing at the same time. Each production cycle will produce a part, and its efficiency is much higher than other types of production lines; the disadvantage is huge investment, and all machines cannot work independently. Once a machine fails, production line will stop working. Once the product varies or replaces the varieties, it is necessary to adjust the whole machine tool that the production line is poor in flexibility(Wang, L.& Zhou, Q.,2014).

2.2 Flexible transfer line FTL

In order to meet the diverse needs of users, types of automobiles increase rapidly, and the automobile manufacture industry is transformed from few varieties and large production to multi-variety and middle production system. In consequence, in 1990s, flexible transfer line (FTL) appeared with easy design changes and equipment transformation. Its outstanding characteristic is that it can not only process the parts in the same product range, but also can process variant products, changed products and new products, achieving a balance between high flexibility and low efficiency to some extent (Musharavati, F.& Hamouda,A.M.S.,2015).At present, FTL is one of the most popular production lines in China. This production line has the advantages of high production efficiency, and a considerable flexibility, able to adapt to mass production and variant products production. The disadvantage is that the flexibility is limited, unable to process unforeseen any kind of parts.

2.3 Reconfigurable manufacturing system RMS

At present, the flexible production line is expensive, the investment risk is large, and the contradiction of excess capacity is more and more prominent. People have been trying to solve the increasingly prominent contradiction between diversity and economy, so as to meet the needs of variety and quantity, but also consider the requirements of high flexibility, high efficiency, and low investment and the ability of quick response. The United States proposed a reconfigurable manufacturing RMS. The principle is through the adjustment of the machine tool configuration in the manufacturing system and the addition and deletion of functional modules of the machine tool to rapidly adapt to new products production and production batch changes. The National Research Council of the United States takes the reconfigurable manufacturing as the top key technology of "2020 manufacturing challenges"(Kumar, S. P. L.,2014).At present, the accuracy and reliability and so on key technologies of the RMS machine after reconstruction are still remained to be broken through.

2.4 Market responsive self-contained manufacturing systems

Japan MAZAK company has developed a market response independent manufacturing system, the essence of which is "a single suite production" - a machine tool "independently" completes all the processing of parts (Xiao, H.B.,2015).MSM production line has general module to deal with a variety of different parts, and to organize the process procedure according to the procedure concentration principle. The equipment adopts parallel arrangement. When the production quantity is increased, it only needs to increase the machine tool, and the failure of a machine tool does not affect the operation of the whole production line. Therefore, the MSM production line has the equipment and the production line "double flexibility". RMS and MSM used in the automobile parts production reality is too early, but it is the future direction of automobile manufacturing.

3 DESIGN OF PROCESS SPECIFICATION FOR BRAKE PISTON

3.1 Production line procedure balance theory and its implementation

The balance between the production line procedure is the necessary condition of organizing the continuous pipeline. Because in the actual production, the time quota of each working procedure in the pipeline is unbalanced in most cases. Therefore, the procedure with the longest processing time becomes the bottleneck affecting the whole pipeline, which reduces the pipeline production efficiency. The bottleneck procedure is the weak link of restricting the entire production line productivity. Bottleneck work every minute contributes directly to the output of production line. The loss of an hour in the bottleneck process makes the whole production system lose one hour. Thus, the bottleneck process is the focus of the entire production line management control (Chen, W.,2014).

The following work should be done well to implement the process balance:

1. Draw the procedure time diagram

The procedure time is the time that workers use to complete the operation of each process. Drawing the procedure time diagram is a qualitative analysis of whether the production line is balanced or not from intuitive angle. If the procedure time curve fluctuates greatly, it indicates that the difference of each procedure time is large, and the unbalanced state of the production line is more serious, needed to be adjusted.

2. Calculate the production line balance efficiency and production line imbalance loss rate

(1) Determine the production line balancing efficiency. Production line balancing efficiency is the ratio of the processing time to the actual used processing time. Generally, production line balance efficiency is used as index to evaluate the efficiency of a production line. When the balance efficiency of production line is less than 75%, it means that the working efficiency of the production line is low, needed to be optimized. Its formula is shown as (1):

$$E_{f1} = \frac{\sum ti}{t_m \times n} \times 100\% \quad (1)$$

In (1), E_{f1}——the production line balance efficiency;

$\sum ti$ —the actual operating time of the i procedure;

t_m —bottleneck procedure time

n—station (working place) number

(2) Determine the imbalance loss rate of production line

The production line imbalance loss, that is, the loss of manpower in the production caused by the time difference of each process. The calculated ratio is the production line imbalance loss. The greater the production line imbalance loss rate, the greater the loss of working hours. The calculation formula is as shown in (2):

$$E_{f2} = \frac{t_m \times n - \sum ti}{t_m \times n} \quad (2)$$

In (2), E_{f2} —production line imbalance loss rate

3. Reduce the bottleneck process

There are several ways to deal with the bottleneck process:

(1) Control the production of non-bottleneck processes, and arrange the production of non-bottleneck processes according to the requirements of the bottleneck process, so as to reduce the backlog of re-manufactured products;

(2) Set up the station of bottleneck procedure, and improve the output of the bottleneck process, so as to achieve the balance;

(3) Decompose the bottleneck process, and achieve balance through restructuring the process.

4. Draw the assembly line process time balance efficiency diagram

After drawing the implementation of the bottleneck elimination of the production line time, re-evaluate the production line balancing efficiency and combined with the yield, obtain the decision-making basis.

In short, through the adjustment of the bottleneck process, we can improve the equipment of the various processes and the load of personnel, so the product flows more smoothly in the pipeline, and the labor productivity can be greatly improved.

3.2 Analysis of brake piston machining process

The process time of piston basic machining features mainly include basic time, test time and cutters adjustment time, auxiliary time and so on. Through the relationship between the machining allowance and processing parameters, the times are calculated, as shown in (3):

$$t = t_m + t_e + t_t + t_\alpha + t_r$$

In (3), t_m —basic time, namely the time for directly changing the size, shape, performance, and relative position relationship of production object.

t_e —test time, namely the test time for the feature online or offline.

t_t ——cutters adjustment time. The time for changing or stoning cutters each time, according to the frequency of changing and stoning cutters, are distributed evenly to each work-piece, then the time sum for single piece changing cutters and stoning cutters can be obtained.

t_α —auxiliary time, namely the time consumed for completing various auxiliary actions to work in with the basic process, such as the feeding and retracting time.

t_t —the processing adjustment time brought about by work-piece material and so on factors.

The production process of piston is shown in table 1, and the working procedure time is shown in figure 1. According to table 2, the working procedure time, the bottleneck process is the fifth process, 34 seconds, and then the actual beat of the production line is 34 seconds.

The balance efficiency of the production line is calculated according to (1):

$$E_{f1} = \frac{\sum ti}{t_m \times n} \times 100\% = 49.8\%$$

Calculate the production line imbalance loss rate based on (2):

$$E_{f2} = \frac{t_m \times n - \sum ti}{t_m \times n} = 50.2\%$$

The calculation results show that, due to the imbalance of the working time, the production line imbalance loss rate is serious losing. According to the working procedure chart of figure 1, it can be seen that the maximum difference of working time is 26 seconds, and the working time deviation is up to 76.4%. In order to achieve production goals, it is necessary to backlog a large number products before the bottleneck process, at the same time, to increase the bottleneck shifts, to digest the backlog products. Because each process between the beat has bigger difference, the size deviation between the two processes beats and the production conditions in the last process directly affect the number of products. The backlog products will inevitably lead to a series of systematic wastes.

Table 1. Brake piston production process flow

Process	Processing content	Processing time (s)	Processing time using rate (%)
1	Rough car port	14	41.2
2	Rough car bottom	15	44.1
3	Outside diameter of rough mill I	8	23.5
4	Drilling and milling inner hole	17	50.0
5	Inside form of rough car	34	100
6	Fine car bottom	16	47.1
7	Rough car groove	13	38.2
8	Fine car groove	15	44.1
9	Drilling hole	18	52.9
10	Inside form of fine car	28	82.3
11	Outside diameter of rough mill II	10	29.4
12	Fine mill	15	44.1

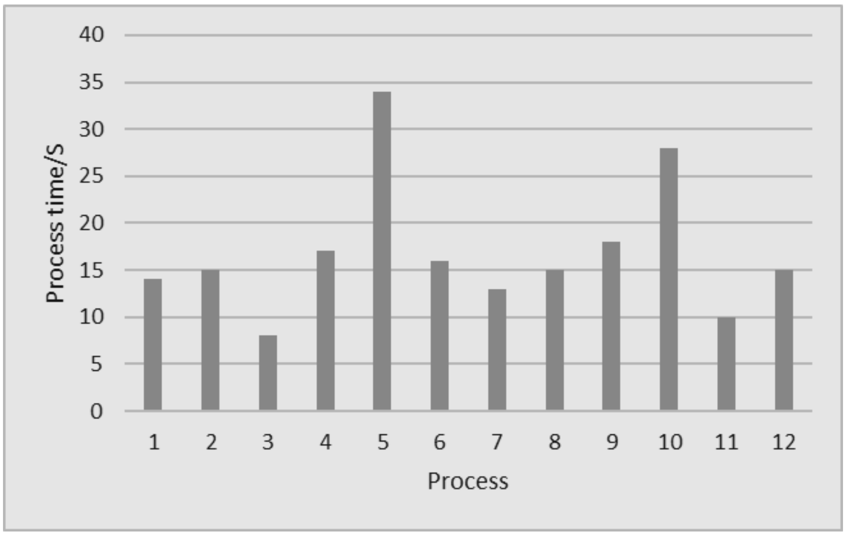

Figure 1. Brake piston original processing time diagram

3.3 Re-organization design of process specification for brake piston

Based on the analysis of the status and causes of the production line balance efficiency, it is necessary to carry out the basic process reorganization and the reorganization design and transformation of the machine tool based on the group technology for the original production line. Piston process re-organization is a multi-objective and multi-constraint work. In this paper, the balancing efficiency of production line is taken as the main objective, and other objectives and principles are taken as the constraints to comprehensively consider. Specific machining features and process analysis are as follows:

(1) From the process time chart in figure 1, it can be seen that, the fifth and tenth processing time are particularly long, respectively rough car inside shape and fine car inside shape process; the third and eleventh processing time are extremely short, respectively outside diameter of rough grinding I and rough grinding diameter II.

(2) The process of rough and fine groove is connected in series, and each piston needs two times of loading and unloading to complete the processing of the groove. Since that the two processes use the same type of numerical control

lathe, in the condition of meeting function, it is possible to achieve the rough and fine processing of groove on each machine after a single folder, so as to reduce the clamping. The bottom of the car and the car groove are based on the mouth as the reference surface, using the same positioning and clamping mode. The numerical control lathe CJK61361 has six-position horizontal electric tool rest, which may realize the automatic cutter change. This has provided the function safeguard for the two processes merge. This can reduce the clamping once again, and increase the cutter change. Then, the working time is shorten to 25 seconds.

(3) The inside shape process of rough car is a bottleneck process, a lathe can be added here, and the parallel structure of the same process is formed by the two lathes. But in this way, the rough car inside shape single piston process time changes to 17 seconds, but also causes the short time of the process here, and too redundant the function of the machine. Due to the same positioning and clamping mode used by mill inner hole and inner shape of rough car, the two processes can be combined, and the machining process can be completed on a lathe. For instance, after the merge, add a cutter change and reduce the loading and unloading, then the processing time changes to 45 seconds (22.5 seconds).

After the above process reorganization, the processing process is shown in table 2, and the working time is shown in figure 2.

Table 2. The processing process after the reorganization

Process	Processing content	Amount	Processing time (s)	Processing time using rate (%)
1	Rough car port	1	14	50.0
2	Rough car bottom	1	15	53.6
3	Outside diameter of rough mill I	1	8	28.6
4	Drilling and milling inner hole	2	45（22.5）	80.4
5	Fine car bottom and groove	1	25	89.3
6	Drilling hole	1	18	64.3
7	Inside form of fine car	1	28	100
8	Outside diameter of rough mill II	1	10	35.7
9	Fine mill	1	15	53.6

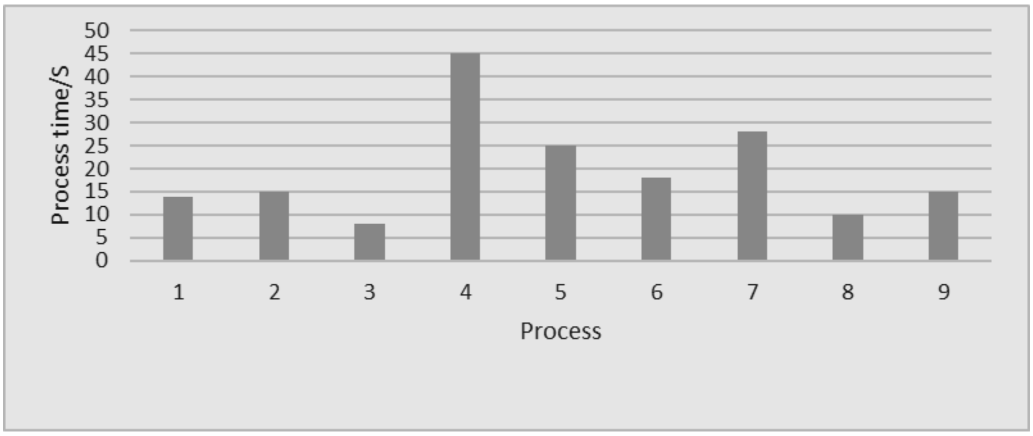

Figure 2. Processing time diagram after the reorganization

After calculation, the efficiency of the production line after re-organization is 61.7%, and there is a big gap from the target of 75%. We can see from table 2 that, the processing time of process 3 and 8 is very short, 8 seconds and 10 seconds respectively, and the machine function redundancy is too large. Therefore, process 2 and process 3, process 8 and process 9 are connected through the automatic feeding devices and reorganized into rough car - rough grinding production unit and rough grinding - fine grinding production unit. The processing processes are shown in table 3, and the processing time is shown in figure 3

Table 3. Working time after recombination

Process	Processing content	Amount	Processing time (s)	Processing time using rate (%)
1	Rough car port	1	14	50.0
2	Outside diameter of rough mill I	2	23	82.1
3	Drilling and milling inner hole	2	45（22.5）	80.4
4	Fine car bottom and groove	1	25	89.3
5	Drilling hole	1	18	64.3
6	Inside form of fine car	1	28	100
7	Outside diameter of rough mill II and fine mill	2	25	89.3

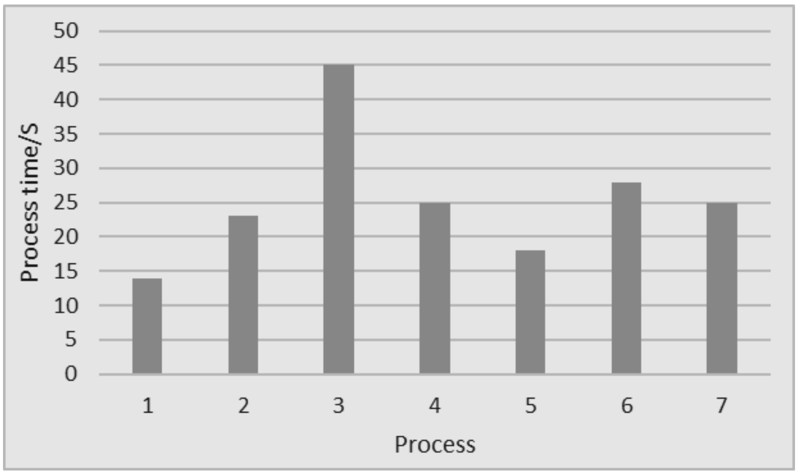

Figure 3. The processing time diagram after the reorganization

After processing characteristics analysis and process reorganization, the original 12 processes and 12 equipment were reduced to the current process 7 processes and 10 equipment, and the production line beat was reduced from the original 34 seconds to 28 seconds. By calculation, the production line balance rate was 79.3%, better than 49.8% before the reorganization, meeting the objective of 75%. After the reorganization, the process not only to sped up the production beat, but also reduced the number of process equipment and improved the load of machine tools and personnel, making production line more balanced.

4 CONCLUSION

This paper introduces the classification of production line layout and the foreign advanced production mode of automobile parts and determines the improved objective in allusion to the current production line layout. Taking piston production line as an example, based on the balance theory of production line process, the beat balance of production line as the objective, the machining characteristics of piston are decomposed and reconstructed. After processing characteristic analysis and process reorganization, the original 12 processes and 12 equipment are reduced to currently 7 processes and 10 equipment, the production line is reduced from the original 34 seconds to 28 seconds, and the production line balance efficiency is increased from 49.8% before the reorganization to 79.3%, effectively improving the piston production efficiency.

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