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DCT Workshop Production Process Evaluation Based on Analytic Hierarchy Process

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Abstract: This article through to a Dual Clutch Automatic Transmission (DCT), the existing workshop production situation analysis, find out the bottleneck and conflict of the existing workshop process. The production process by using analytic hierarchy process production process evaluation index and index weight and carrying out optimization analysis based on the existing resources. Finally, it will conclude that the optimized scheme for DCT plant process system of the production process have the effect of improvement and can be applied to different scale of production later.

Key words: DCT workshop, production process, analytic hierarchy process, evaluation index

INTRODUCTION

In recent years, with the prosperity of the world economy, the car's development speed is amazing. Among them, as change running speed of the machine such as car or traction device, usually mounted on the between engine drive shaft and driven shaft transmission play a decisive role. Implementation process rationality of production of the workshop is always one of the goals of the people (Kulkarni *et al*., 2007; Zhang *et al*., 2005).

According to workshop production scheduling problem, as early as in 1954, Johnson had studied on two machine scheduling problem. A lot of experts and scholars at home and abroad had studied the analytic hierarchy process. Gan *et al*. (2009) introduced the generated and the management pattern of analytic hierarchy process and it is the basis of the analytic hierarchy process. Azadeh *et al*. (2009). integrated the analytic hierarchy process and value engineering and provided a production system of the hybrid scheduling scheme. Wang *et al*. (2008) and Zhang *et al*. (2008) build DCT workshop production process simulation model used to evaluate its existing production processes and different optimization program. The solution time of Mathematical model and the optimal is increased exponentially with the size of the problem is difficult to establish accurate constraints by Panwalkar and Iskander (1977). Warfield (1999) solve the enterprise systems, in particular the uncertainty of the underground enterprise systems, reliability, running entropy, the complexity of applied research.

PROBLEM DESCRIPTION

DCT workshop manufacturing system is a Flexible Manufacturing System (FMS), a flexible manufacturing system will be automatic and flexible organically unifies, it absorbs the workshop high efficiency of production line and flexible of task to meet the requirements of high efficiency and low cost. It can effectively improve the production efficiency and change the production in a relatively short period of time to adapt to market changes in a timely manner. Shanghai Automobile Factory DCT workshop in the FMS are linked by an automated material transfer system of an automated manufacturing (assembly) unit using the general hierarchical control computer system and can optionally be provided in a pre-determined series member of manufacture or assembly of the product. DCT processing production workshop layout diagram as Fig. 1.

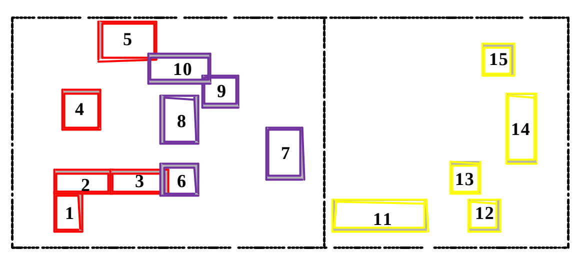

Fig. 1: DCT processing production workshop layout diagram

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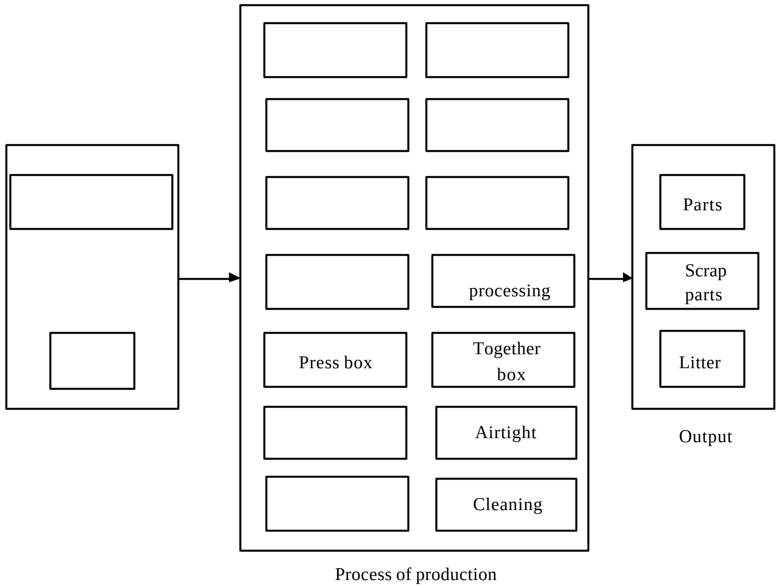

Fig. 2: DCT workshop process model

In this study, we study the auto transmission of DCT manufacturing workshop as a new workshop, the production of a variety of categories of transmission, mainly including teeth combined with tooth area in thermal bonding area of the production areas, shaft, machine shell, machine heat production area a total of ten sections, each section includes many location involved in production and processing process, the final raw material at the completion of the area of processing and assembly process can be generated after transmission. In the DCT workshop equipment with a lot of different types, different countries and the production of products is also a variety of categories; and the main production is DCT 360 transmission. Mainly of three parts including shaft, gear, shell processing and assembling.

The workshop mainly produces three parts, enter the inner shaft, a speed driven gear assembly, main shell. These parts of the manufacturing process is actually a process of resource input and output, is composed of a series of mechanical manufacturing process, the process is a process chain, each a specific process diagram has its similar input and output.

Based on the above analysis, the establishment of DCT parts production workshop manufacturing process model as shown in Fig. 2, including input, output, production process of three parts.

EVALUATION METHODS AND PROCESSES

Complex system assessment using the analytic hierarchy process can be simplified, analysis and it has a clear concept and the system analyst can be systematic, mathematical and modeling. Quantitative data analysis need not much but it requires the problem contains specific and clear factors and their relationships; Suitable for multiple criteria, multiple objective decision analysis of the complicated problem, is widely used in regional economic development scheme comparison, scientific and technological achievements appraisal, resource planning and analysis as well as the enterprise personnel quality evaluation. So this article use analytic hierarchy process to evaluate DCT workshop production process, in the hope of the correct analysis and evaluation of DCT workshop which have the effect of improvement.

By adopting the method of AHP to evaluate production process, specific evaluation process is as follows:

- Field investigation, collecting related information in the DCT production workshop including workshop layout, production cost, production conditions, product quality, etc
- Analysis of relevant information, find out all the influence factors of production, all the indicators classified analysis, into a few broad categories, to facilitate this article production technology rationality evaluation index selection
- The above indexes finishing through expert consultation method, In this study, the AHP method used in the index. Because these indicators are qualitative or quantitative indicators, is not can be directly calculated using analytic hierarchy process, so need to quantitative indicators to calculate

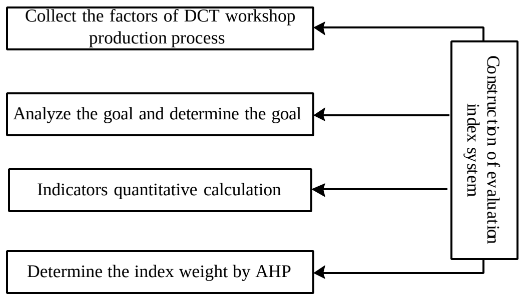

Fig. 3: Evaluation flow chart of production process

- According to the expert scoring method and observation method to determine the degree of importance of selected indicators and then according to the index calculation method to determine the weight in AHP method. Eventually, Shanghai auto transmission DCT workshop production technology index evaluation system is established

Specific evaluation process is shown in Fig. 3.

EVALUATION SYSTEM CONSTRUCTION

Selection of evaluation indexes: DCT workshop as a flexible manufacturing system, involves more indexes system of evaluation and therefore it is necessary for all kinds of index classification processing, form a distinct, multi-level comprehensive evaluation index system, to evaluate the process.

Index Settings should follow the principles: (1) The level number and the index number of structure is reasonable; (2) The evaluation index of clearly defined, there is no definition for duplicate index; (3) As far as possible is given priority to with quantitative indicators, standardization of qualitative indicators; (4) Considering the positive and negative benefits evaluation index at the same time, all-round evaluation objects.

On this basis, based on the simplified process of expert consulting method construct indexes as shown in Fig. 4.

Through consulting a large number of literature, according to the build of DCT in the production process flow chart of evaluation index system of building steps, will affect the workshop production process index is divided into four categories and then choose highlight reflect the four sorts of evaluation indexes and these have rationality and systemic index, so as to ensure the process of characterization described the correctness of evaluation result. Preliminary indicators as shown in Table 1.

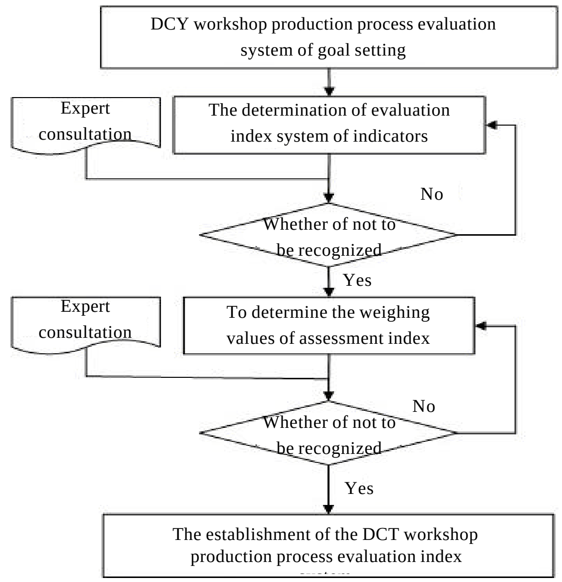

Fig. 4: DCT workshop production process flow chart of the construction of evaluation index system

Index quantitative calculation: Man-hour quota is refers to under certain conditions, set the production of a product or a complete procedure must consume work practice. Machining process belongs to discrete, so the man-hour quota is the content of research: workers in discrete time consumption in the process of production, through the statistical summary to get spare parts, product or equipment, etc. Formulation of the fixed working hours is an important part of the design process.

Due to production time T information mainly from the company's data directly, so there is no need to consider the calculation method.

The workshop production situation D is comprehensive determined by the average number of products, workshop resource utilization and workshop logistics strength. Because these are unknown condition and need certain calculation method for calculation.

Workshop on average in the number of products: In products, already in production but not yet manufacturing refers to the finished product. Workshop of WIP number reflects the balance of production workshop and bottleneck rate, the product the greater the number, then bottlenecks in the manufacturing system, the more the more production imbalance:

$$p = \frac{\sum p_i}{T_p}$$

Table 1: Effect index of workshop production process

The production cost C	Production time T	Production time D	Quality of the product Q	Production time D
Workers' wages energy cost	The processing time Preparation time Auxiliary time	Average number of products Resource utilization The logistics situation	Product percent of pass	Workers' wages energy cost

Among them, the Pi-machine or buffer parts number in the production time, Tp-total production time.

Resource utilization: Workshop resources include equipment, cars and auxiliary tools such as knives, quantity, fixture; resource utilization reflects the rationality of the process, the higher utilization ratio, the lower capacity waste:

$$R = \frac{\sum (C_{si} \times \eta)}{C_t}$$

Unit price among them, the Csi-resources, η-single piece production time resource utilization, Ct-resources price.

Workshop logistics intensity: Workshop logistics intensity is the sum of all the paths on the car running mileage, total mileage reflected the workshop logistics load:

$$L = \sum V_i t_i$$

Among them, the Vi-car running speed, ti-car total time for cargo operation and no-load running.

Product quality is by the qualification rate of products to determine the Q:

$$Q = \frac{N_s}{N}$$

Type of Ns-workshop production of qualified emitting, total number of N-workshop production of the product.

Determination of index weight: Complete an evaluation index system is the key step is to determine weights of evaluation index system of indicators. Using the analytic hierarchy process evaluation process, generally according to the following steps:

Step 1: **Pass class hierarchy model is set up:** At the highest level is the target layer, middle layer is the criterion layer, the bottom is the solution layer or measures

Step 2: **Constructed the hierarchy all judgment matrix:** Judgment matrix representation for level units (elements), the level is related to its relative importance between units

Step 3: **Hierarchical single order and consistency check:** Level single sorting is to all the elements of this layer for a layer, discharge appraisal order which is the largest eigenvector calculated judgment matrix, is the most commonly used method and volume method and the root method

Step 4: **Level total sorts and consistency inspection:** Single sort of calculation results, further integrated out of a higher level of quality, is the level of total sorts of tasks

Step 5: Normalized processing of matrix

Step 6: Calculate weight combination, according to maximum membership degree principle, determine the optimal solution

According to the principle of AHP method in the calculation, the establishment of DCT manufacturing workshop production process evaluation flow chart shown in Fig. 5.

According to the production process of the flow chart of evaluation, firstly establish the index importance comparison table is shown in Table 2.

Using the judgment matrix calculates the weight of each factor on the target layer and specific steps are as follows 1-4:

Step 1: Each to A column vector normalization and get:

$$w_{ij} = a_{ij} / \sum_{i=1}^{n} a_{ij}$$

Step 2: Summation of the normalized matrix w_{ij} line and get:

$$w_i = \sum_{j=1}^{n} w_{ij}$$

Step 3: To sum of matrix w_i then normalized and get:

$$W_i = w_i / \sum_{i=1}^{n} w_i$$

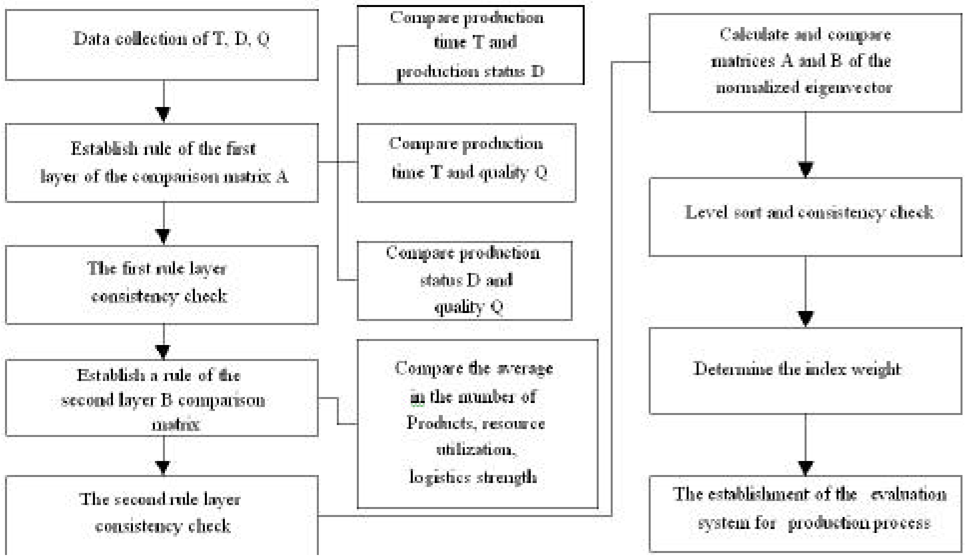

Fig. 5: Flow chart of process evaluation based on AHP

Table 2: Each index importance comparison table

	Production time	Production status	Production quality
Production time	1	1/5	1/3
Production status	5	1	3
Production quality	3	1/3	1

Table 3: First rule layer index weight list

Production time	0.106
Production condition	0.633
Quality	0.261

Table 4: Second criterion layer importance comparison table

	Number	Rate	Intensity
Average in-progress	1	2	3
Resource utilization	1/2	1	2
Logistics intensity	1/3	1/2	1

Table 5: Second rule layer index weight table

Average in-progress	0.539
Resource utilization	0.297
Logistics intensity	0.164

Table 6: Total order weight at the second level factors

Average in-progress	0.341
Resource utilization	0.188
Logistics intensity	0.104

Step 4: According to the formula:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{W_i}$$

Calculate the approximate value of the largest eigenvalue

Use Consistency check method of AHP method to calculate CI_A:

$$CI_A = \frac{\lambda_{max A} - n}{n-1}$$

According to the above calculation, the first rule layer weights of three indexes such as shown in Table 3. Determined by expert consultation method of comparison, the importance of the rule of the second layer is shown in Table 4.

According to the rule of the first layer weight calculation method to get the second criterion of index weight are shown in Table 5.

Second rule layer about general objective weighting is the rule of the second layer on the state of the rule of the first layer of production level single sorting weight and the first rule about target layer production the weight of the single sort of product.

Get the second level of various factors and the total sequencing weight are shown in Table 6.

Rule of the first and second layer after level single sort of consistency inspection, judgment matrix A and B are already has A relatively satisfactory consistency. When comprehensive inspection, due to the rule of the second layer of the average number P, R, resource utilization logistics intensity L are only associated with rule of the first layer of production conditions, who are not affiliated with the other three criteria, therefore, the proportion of total ordering consistency rule of the second layer is still within the acceptable range. To this, the DCT workshop production process evaluation system set up is complete.

CASE STUDY

Initial data: (1) According to DCT workshop manufacturing resources and the present condition of the workshop production and processing system compiled with month workshop shift arrangement, work 8 h per shift, day three shift, monthly statistics only 21 days, required production is 10000 sets, details are shown in Table 7 below.

Main process including packing assembly line, assembly, testing, four most offline, production technology of this four parts total processing time as shown in Table 8: As the unit of time is in seconds (s).

Results analysis: In this study Tecnomatix and KG companies jointly develop eM-Plant9.0 simulation software developed by SIMPLE++ for simulation. Found that in the simulation in packing line and assembly line, the percentages of each location of the blocking state are big and preparing time and processing time percentage is very small. Which means process routes in weekday are a lot of time is in a state of waiting for the assembly into the buffer but the real assembly time is less, so the finish time will be stretched, affect the entire production line assembly time. According to the principle of industrial engineering in the assembly line simulation modeling analysis and balance analysis based on the use of ECRS four big principles and combining with production line economic equilibrium theory, principles and production to improve bottleneck station.

After improvement, the blocking of each station here state the percentage of the smaller and the percent of all processing time state significantly increased, the whole plan of shortening the processing time. WIP is less in the system, logistics intensity is relatively improved. Among them, the production time for 1800 s before optimization, improve the production time after the 1620 s; Factory in average WIP number is 70 before optimization, the optimized plant average WIP number 35; Equipment utilization on average 12% before optimization, the optimized equipment utilization rate is 18% on average, the logistics intensity is 5 km before optimization, the optimized into a 4.5 km; Product qualified rate was 95% before optimization and after optimization the product percent of pass is 90%. According to the above data, establish various indexes before and after optimization data comparison table as shown in Table 9.

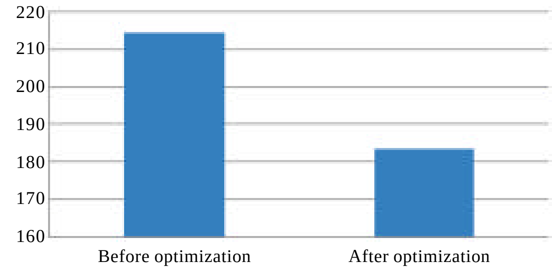

Fig. 6: Before and after optimization system score plot

Table 7: Shift time

Every shift work time	8 h
Shift	3 shift
Statistical cycle	21 day
Total time	504 h
Yield	10000 set

Table 8: Assembly line processing schedule

Processing operations	Processing time
Partial assembly	500
Final assembly	800
Text	350
Off line	200

According to the weight of each index in the evaluation system of the overall calculation, the overall evaluation of computation formula is as follows:

$$\min = Z = 0.106f_1+0.341f_2-0.188f_3+0.104f_4-0.261_f$$

Among them, the objective function Z, said production time function f1, f2 said on average in the number of products, the f3 said equipment utilization, f4 said logistics strength, f5 said the quality of products have to 214.9 before optimization, the optimized to 183.9, according to the overall score, it can be seen after improvement, the workshop, the rationality of the overall improved it also suggests that DCT workshop production process evaluation system established in this paper is reasonable and effective.

Comprehensive scoring system is shown in the Fig. 6.

Production line is able to balance the beats for production directly affects the enterprise's production capacity. So production line balance analysis, solve the bottleneck problem, improve the production capacity is the enterprise focused on the production line. Through the object-oriented simulation modeling technology and production line balancing analysis method to analyze the bottleneck station of DCT assembly workshop, improve and balance, improve scheme after enterprise achieve the goals and objectives.

Table 9: Results compared

	Processing time (sec)	Average in-progress number (%)	Average utilization rate of equipment	Logistics intensity (km)	Rate of qualified products (%)
Before optimization	1800	70	12	5.0	95
After optimization	1620	35	18	4.5	90

CONCLUTION

Through the object-oriented simulation modeling technology and production line balancing analysis method to analyze the bottleneck station of DCT assembly workshop, improve and balance, improve scheme after enterprise achieve the goals and objectives. And can be seen from the comparison data before and after optimization, the established evaluation system is correct, can true reflect DCT plant in the actual production, through the index evaluation, find a way to optimize the workshop. And can be applied to different scale of operations.

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