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Research on the Balance of Assembly Line in an Automobile Manufacture Enterprise

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Abstract Production line balance is one of the important means of manufacturing resource planning and restructuring. For automobile manufacturers, studying the balance of production lines is an indispensable link to improve benefits, which can reduce production costs and maximize benefits. This research analyzed the current situation of the automobile chassis assembly line, and the genetic algorithm is used to solve the problem. Matlab was used to program the genetic algorithm, and the time and sequence constraints of each station were input into the simulation algorithm to analyze and evaluate the optimization results. The results show that the genetic algorithm can well solve the balance problem of the production line, and has satisfactory results in improving the balance rate of the production line, reorganizing and optimizing the allocation of resources, and improving the core competitiveness of enterprises.

Keywords: *automobile chassis assembly line, production line balance, genetic algorithm*

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1. Introduction

The automobile industry is one of the major industries in manufacturing. [1,2] With the improvement of people's income level and the rapid development of science and technology, people's demand for cars continues to grow. As a widely used production mode in the automobile industry, the improvement of assembly line balance is of great significance to the improvement of production efficiency. Maintaining the balance of the assembly line can not only improve the production efficiency but also optimize the allocation of resources and enhance the competitiveness of enterprises

The limited working tasks in the assembly line all have an operation processing time and a set of priorities. The fundamental assembly line balancing problem is how to assign a set of tasks to an ordered set of workstations, such that the precedence relationships are satisfied and some measure of performance is optimized. [3]

Generally, there are three methods for balance optimization of the assembly line: mathematical model method, heuristic method, and IE method. [4] The mathematical model method abstracts complex problems into mathematical models. However, for large-scale assembly lines, there would be a large amount of computation. IE method is combined with practice to improve efficiency through reasonable changes, but data needs to be measured and may be affected by subjective factors.

The research work has been carried overtime on different approaches like genetic algorithm, particle swarm optimization and other approaches to solve the assembly line balancing and sequencing problems. [5] Hu, Hu [6] proposed a dual-objective optimization model, and simulated annealing is applied to solve the assembly line balancing problem. By considering the constraints of assembly line Takt and daily access time, Zheng, Wang [7] proposed a multi-objective optimization mode, which was solved by genetic algorithm based on a sequenced coding scheme. Belassiria, Mazouzi [8] used a hybrid genetic algorithm to solve assembly line balancing problem type E. The model provided a more realistic situation of assembly line balancing problem with station restriction and zoning constraints. The above researches showed that genetic algorithm is an appropriate solution to the assembly line balance problem.

This research aims to analyze the assembly line status of an automobile manufacturing enterprise and optimize it by genetic algorithm. Thus, production efficiency can be improved [9] to meet people's needs. At the same time, the competitiveness of enterprises could be improved.

2. Problem Description

2.1. Assumption

The assembly of automobile products is one of the most crucial processes in the manufacturing process of

automobile products. In the actual production process, the following conditions often need to be observed:

(1) The amount of work to be done in a workstation is consistent with the total number of basic task units assigned to that workstation.

(2) The time of the task elements arranged at each station shall not exceed the assembly line's cycle time.

(3) To ensure the completeness of the assembly process, all units should only be assigned to each assembly station.

2.2. Evaluation Index

Line balance is generally measured by line balance rate (LBR) and line balance loss rate (Bd). LBR is an index to measure the working load and production efficiency of each station. [10] The higher the LBR, the higher the balance degree of the production line. Generally, if the LBR reaches above 85%, the production line is efficient. Meanwhile, line balance loss rate refers to the percentage of time wasted on the line due to unbalanced workload. [4] The evaluation criteria of the line balance loss rate is shown in Table 1.

Table 1. Evaluation of balance loss rate

Bd/%	Evaluation effect
<10	Excellent
10-20	Good
>20	Poor

The formula is expressed as follows:

$$\text{LBR} = \frac{\sum_{i=1}^{n} T_i}{CT \times n}$$

$$B_d = \frac{\sum_{j=1}^{n} T_j}{CT \times n}$$

T_i: the standard working time of each process;
T_j: the standard working time lost in each process;
CT: the cycling time;
n: the number of operators.

2.3. Priority Sequence Diagram of Automobile Chassis Assembly Line

In this research, each process of automobile chassis assembly has forward constraints, and its sequence is shown in the Figure 1.

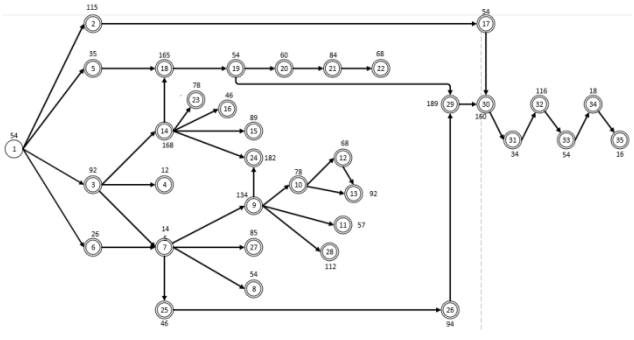

Figure 1. Priority sequence diagram of automobile chassis assembly line

The assembly line's original CT = 257 seconds and the number of stations Z = 18. The above two evaluation indexes are calculated:

$$\text{LBR} = \frac{\sum T_i}{CT \times n} = \frac{2934}{257 \times 18} = 0.63424$$

$$B_d = \frac{\sum_{j=1}^{n} T_j}{CT \times n} = 0.37200.$$

3. Model setup

3.1. Codec Method

Using a random key encoding and decoding method, for an assembly line balance problem with n processes, the genetic algorithm uses an array of length n to represent a solution to the problem, and the value range of each dimension code is [0, 1]. The decoding process is divided into n steps, specifically: the first step is to make the smallest value in the current encoding to be 1; the second step is to make the second smallest value in the current encoding to be 2; ..., and so on, and finally in the nth, the largest value in the current encoding is n, and a set of arrays in the range [0, 1] can be converted into a 1 ~ n array, which constitutes a solution to the original problem.

3.2. Evaluation Function

$$\text{f}\left(x_i\right) = Z\left(x_i\right) + pf \cdot Volidation(x_i).$$

In this function, $Z(x_i)$ represents the number of positions corresponding to the solution x_i; pf represents the penalty coefficient and the degree of violation of the processing sequence constraint. The purpose of the algorithm is to solve min (f (x_i)).

3.3. Initialization

The i^{th} solution in the current population is written as $x_i = (x_{i1}, x_{i2}, \ldots, x_{id}, \ldots, x_D)$, and the initialization formula is: $x_{id} = x_d^{lb} + rand(0,1) \cdot \left(x_d^{ub} - x_d^{lb}\right)$, i=1,2,…,n; d=1,2,…,D (D=57). $[x_d^{lb}, x_d^{ub}]$ represents the value range of the d^{th} dimension decision variable, and the range is [0, 1], and rand (0, 1) represents a random number on [0, 1].

3.4. Roulette Wheel Selection Probability

The genetic algorithm uses the roulette rules to perform the selection operation. For n chromosomes in the current population, the probability that the i^{th} chromosome will be selected is:

$$P_i = \frac{1/f(x_i)}{\sum_{j=1}^{N} 1/f(x_j)}$$

f (x): the evaluation function, which means the value of the solution x_i on the evaluation function (i.e. fitness).

3.5. Cross Operation

The genetic algorithm uses linear crossing. For two chromosomes xi and xj (i = j), linear crossing is achieved as follows:

$$x_{id} = \lambda \cdot x_{id} + (1-\lambda) \cdot x_{jd}, d = 1,2,\ldots,D$$

λ: a random number in the interval [0,1].

3.6. Mutation Operation

The Gaussian mutation of the genetic algorithm is conducted. For a chromosome x_i, the individual mutation is:

$$x'_{id} = \leftarrow G\left(x_{id}, 1/n\right), d = 1,2,\ldots,D$$

n: the encoding length.

4. Result and Discussion

Matlab was used to program the genetic algorithm, and the time and sequence constraints of each station were input into the simulation algorithm and the optimization results were obtained, which were shown in Table 2, Table 3, and Figure 2.

Table 2. Algorithm iteration chart

Iteration	Best cost	
490	14	**
491	14	**
492	14	**
493	14	**
494	14	**
495	14	**
496	14	**
497	14	**
498	14	**
499	14	**
500	14	**

Table 3. Optimized workstation distribution

Total number of stations: 14		
workstation	time	process
1	3.7500	0,1,6,7
2	2.8167	5,9
3	3.4500	2,3
4	3.7000	17,14
5	3.5167	18,25
6	3.4167	19,26,11
7	3.9000	27,20,15
8	3.1500	29
9	3.4333	30,16
10	3.8333	10,21,22
11	3.6333	12,31,32
12	3.8667	28,33,4,8
13	3.6000	34,35,24
14	2.8333	23,13,36
Production line balance rate:0.87321		

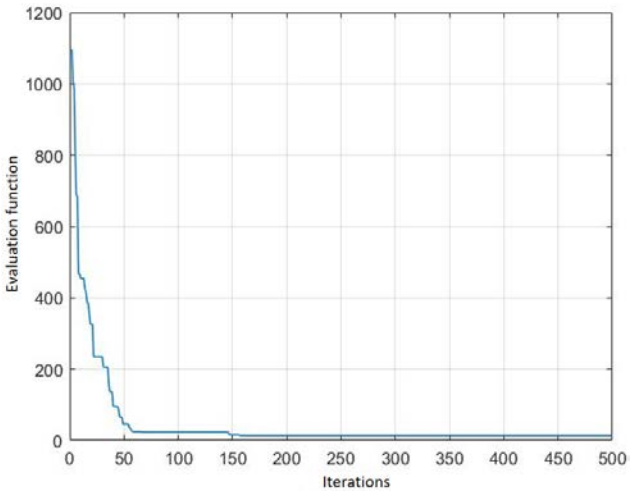

Figure 2. Algorithm convergence diagram

After optimization, the LBR=0.87321, and the Bd=0.12679. The results showed that the improvement effect of the line balance rate is significant, and the time waste caused by an unbalanced workload is greatly reduced.

5. Conclusion

This research analyzed and studied the automobile chassis assembly line of an automobile manufacturing enterprise, and found that the time difference between workstations was large, and the number of stations was large, which would lead to too much chaos in the production site and increased the production cost. By calculation, the LBR is 63.4%, in need of improvement. hence, the genetic algorithm was used to optimize the assembly line, and the LBR reached 87.3%, which achieved a good effect.

The model in this research studies the line balance problem of a single variety, and the production mode is fixed. However, nowadays, there are many flexible production enterprises or the multi-variety assembly line, mixed assembly line. Therefore, in order to promote the model, it is necessary not only to improve the universality of the model but also to improve its ability to solve the problems of data type transformation and production mode differences. Specific research needs to be further discussed.

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