Advances in Social Science, Education and Humanities Research, volume 329
4th International Conference on Contemporary Education, Social Sciences and Humanities (ICCESSH 2019)

Research on Production Line Balance Problem Based on Genetic Algorithm

Qingyu Qi
School of Economics and Management
Beijing Jiaotong University
Beijing, China

***Abstract*—As the basis of manufacturing enterprises, the production line balance problem is still one of the main problems faced by small and medium-sized manufacturing enterprises. In this paper, the production line balance model of two-population genetic algorithm is established by Matlab, and the effect of the model is verified by the Jackson production line problem, which shows the validity of the model. Take the sewing production line of a toy factory as an example, analyze the current situation of the production line, and calculate that the production line balance rate of the production line is only 37.27%, and the production line of the "one line flow" with a production line balance rate of 85% or more is not reached. The production line was balanced and optimized by the established production line balance model. By comparing the results, the production line balance scheme with the number of stations was determined. The production line balance rate of the program was 94%, reaching the "first line flow". The production status solves the balance problem of the sewing production line. At the same time, it also shows that the production line balance model established in this paper can effectively solve the problem of production line balance, help small and medium-sized manufacturing enterprises to reduce production costs, improve production efficiency, and improve the economic efficiency and market competitiveness of enterprises.**

Keywords*—matlab; two-population genetic algorithm; production line balance model; sewing production line

I. INTRODUCTION

As one of the pillar industries of the country, the manufacturing industry is the main body of the national economy. It has always been an industry that the state attaches great importance to and vigorously develops. In order to improve the production level and manufacturing technology of the manufacturing industry, China has put forward the strategy of "Made in China 2025", planning aims to achieve China's strategic goal of becoming a manufacturing power. The level of manufacturing determines the development of the country's economy and strength, which is related to the well-being of the country and the people, and therefore has important implications for the relevant research in manufacturing. The balance and optimization of production lines is one of the hotspots of manufacturing research. As we all know, the production line is the basis of manufacturing enterprises. The production line determines the level of production capacity and the quantity of inventory, which determines the production cost and economic benefits of the enterprise.

The production efficiency of the production line is affected by the process with the longest production time, ie the bottleneck process. If the problem of the bottleneck process cannot be solved, there will be a backlog of work-in-progress in the process before the bottleneck process, resulting in an increase in inventory cost and a decrease in production efficiency. The purpose of production line balance and optimization is to solve the problem of bottleneck process, balance the operation time between processes, reduce or even completely solve the problem of overstocking in the process, improve production efficiency and reduce production cost.

In this paper, the production line balance model of the two-population genetic algorithm is established by Matlab. The validity of the model is verified by the Jackson production line problem. Taking the sewing production line of a toy factory as a case for balance optimization, the toy factory mainly produces a doll named "Dass Magic". The main production link of this doll is the sewing production line. In actual production, the production line appears. The problem of overstocking and low production efficiency is due to the serious imbalance in the production line, and the bottleneck process restricts the operation of the entire production line. The sewing line production line was optimized and optimized by the established production line balance model, and an effective balance result was obtained, which solved the problems existing in the sewing production line of the factory. At the same time, it is proved that the production line balance model can effectively solve such production line problems.

II. RELATED BASIC RESEARCH

The problem of production line balance is still the focus of small and medium-sized manufacturing enterprises, which affects the production efficiency and production cost of enterprises, and is one of the important factors that determine the economic efficiency and development of enterprises. Therefore, scholars have conducted extensive research on this issue and proposed different solutions.

Some scholars use heuristic algorithms or precise algorithms to plan and design the production line. Shi Wei et al. studied and analyzed the single heating production line, and used the position weighting method to balance the optimization of the single heating production line. After the optimization of the production line, the number of stations was reduced by 5, and the production balance rate was increased by 33.40%, which improved the utilization rate of the workshop [1]. Fathi, Masood et al. proposed a hybrid integer programming (MIP) model to reduce the number of stations for linear and U-shaped production lines, and used a car manufacturing company to validate the model. The results show that the model can provide the best solution [2] . Some scholars use industrial engineering theory to balance the optimization of the production line. He Manhui et al. analyzed and researched the PC assembly line of Company B, and used the model method in the standard action time standard method to find out the movements that did not meet the standard, and used the 5W2H method to find Reasons were made and improved by the principle of action economy. After the improvement, the production balance rate increased from 33.6% to 66.5% [3]; Sun Zhiqiang et al. used the value stream current map to analyze and analyze the S20 products of Company A, using ECRS pull production. The method improves the process and layout, draws the future value stream map, and brings more benefits to the enterprise [4]. Some scholars use simulation to solve such problems. Yan Yuanyuan et al. applied discrete-system simulation methods to study the automobile connecting rod production line, and analyzed the bottleneck process, production line balance rate and production line efficiency of the production line, using Anylogic software. The production line model was built and simulated, and the optimal production line sorting scheme was obtained [5]. Some scholars use artificial intelligence algorithms to solve such problems. Pan Zhihao et al. studied and analyzed the pulsation production line of aircraft assembly, and designed a hybrid optimization algorithm combining non-dominated sorting genetic algorithm, cuckoo search algorithm and dynamic search algorithm to balance. Optimization, and finally through the benchmark problem test, the algorithm can effectively improve the production line [6]; genetic algorithm is the most used algorithm to solve the production line balance problem, Chen Xingyu analyzes a company's coupler production line, and uses the two-population genetic algorithm to carry out the production line. Balance optimization, after optimization, the production line balance rate increased from 58% to 96%, the company's production efficiency has been greatly improved [7]; Triki, Hager et al. studied the second type of production line balance problem, through multiple objective functions The new version of the hybrid multi-objective genetic algorithm balances the production line and determines the minimum production tempo of the fixed workstation. The experimental results show that the method has a good ability to solve the problem [8].

This paper absorbs the previous experience of production line balance optimization, and uses the two-population genetic algorithm to balance and optimize the sewing production line. The production line balance problem of this study belongs to the second type of production line balance problem, that is, the number of workstations is given, and the minimum production beat is obtained. Maximum line balance rate issue.

III. Research on Production Line Balance Based on Genetic Algorithm

There are many working elements in the production line, and the problem is more complicated. The traditional industrial engineering theory solves the problem of balance of production line, which is very cumbersome. It is very quick and convenient to solve the problem by using genetic algorithm. The genetic algorithm used in this paper is a two-population genetic algorithm. The two-population genetic algorithm is characterized by two sub-populations. These two sub-populations evolve independently and communicate on the correct nodes according to the rules. The advantages of the dual-population algorithm are very obvious. The sub-populations ensure that the characteristics of their respective populations are preserved in separate evolution. In the process of mutual communication between sub-populations, the search scope is expanded, the diversity of the population is enhanced, and the feasibility is ensured. The fast convergence of the solution avoids falling into the local optimal dilemma.

A. *Construction of Production Line Balance Model Based on Genetic Algorithm*

The construction of the production line balance model mainly includes three parts: determining the job element priority relationship matrix, assigning the job elements in the workstation, and determining the job elements in the workstation.

1) Determining the job element priority relationship matrix

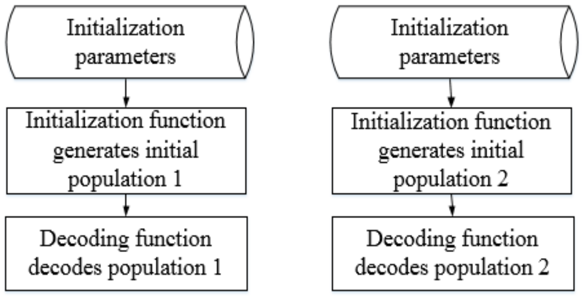

Fig. 1. Determine job element steps.

The first step in establishing the production line balance model is to initialize the parameters, determine the priority relationship matrix of the job elements according to the process priority map, call the "initialization function", and initialize the operation with the priority relationship matrix as the input quantity, wherein each job element corresponds to the initial population. Genes on each chromosome, resulting in an initial population 1 and an initial population 2.

After generating the initial population, the next step is to call the "decoding function" to assign the job element to the workstation that has given the determined value. The distribution principle of this paper is that the sum of the working elements of each workstation is smaller than the production beat CT. Since this paper studies the second type of production line balance problem, the production beat CT is unknown, so the first need to do is to determine an estimated beat CT1. The estimated beat used in this paper is the time of the bottleneck process, and the time of each operation element is increased. The amount is heuristically calculated until the time of the job element of all workstations is less than the estimated beat CT1.

2) Assigning job elements in the workstation

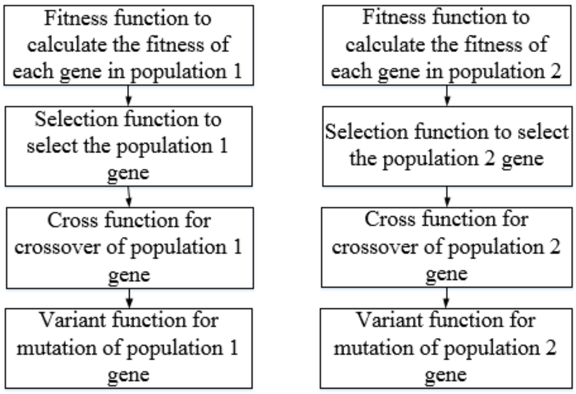

Fig. 2. Assign job element steps.

There are two main objectives for solving the balance problem of the second type of production line. One is that the production cycle CT is the smallest, the production line balance rate P is the largest, and the other goal is that the smoothness index SI is the smallest. Therefore, in the production line balancing scheme of the production beat CT, it is also necessary to find the optimal balance scheme with the smallest smoothness index SI.

In this paper, the evolutionary characteristics of genetic algorithm is used to find the optimal scheme. The only basis for the evolution of genetic algorithm is the fitness function Fit. This function can distinguish the advantages and disadvantages of the individual population generated by the genetic algorithm, and select the individuals with high fitness according to the evolution rule of "the survival of the fittest". The fitness function Fit consists of three parts, namely Fit1, Fit2, and Flag, and the relationship between them and their respective calculation formulas are as follows:

$$\text{Fit} = \text{Fit1} + \text{Fit2} + \text{Flag}$$

$$\text{Fit1} = \frac{\text{Total time}}{\text{Maximum assembly time of station} \times \text{Working number}}$$

$$\text{Fit2} = \frac{1}{\text{Variance of processing time of each station} + 0.01}$$

Flag is to evaluate whether a certain process is fixed at the designated station. If a certain process has a designated station, then Flag=3. If there are two processes with designated stations, then Flag=6, and so on.

After the "fitness function" is called to calculate the fitness of each body, the "selection function" is called according to the determined fitness, and the selection operation is performed on the genes in the population 1 and the population 2, that is, the operation elements, using the rotation selection method. The selection formula is as follows, where the fitness is F(P), the probability of selection is S(P), and the population is Pop_size:

$$S(P) = \frac{F(P)}{\sum_{q=1}^{Pop\_size} F(P)}$$

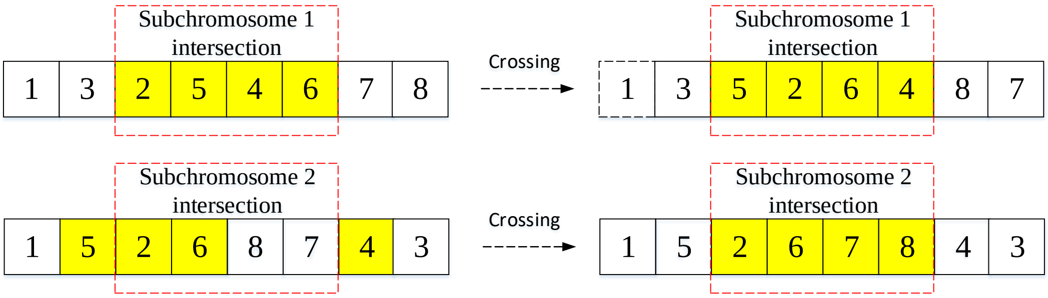

Fig. 3. Cross operation.

Call the "cross function" to cross-select the selected gene, call the function to generate a random integer, determine the intersection position, find the gene at the intersection of the sub-chromosome 1 in the sub-chromosome 2, and then adjust the chromosome according to the gene order in the sub-chromosome 2. 1 The order of the intersection positions, in the same way, chromosome 2 also performs the process, thereby completing the crossover operation.

Calling the "variogram" to mutate the chromosome that completes the crossover operation, calling the function to generate a random integer, preserving the gene before the random integer, and the genes after the random integer are arranged according to the priority matrix until all the job elements are assigned.

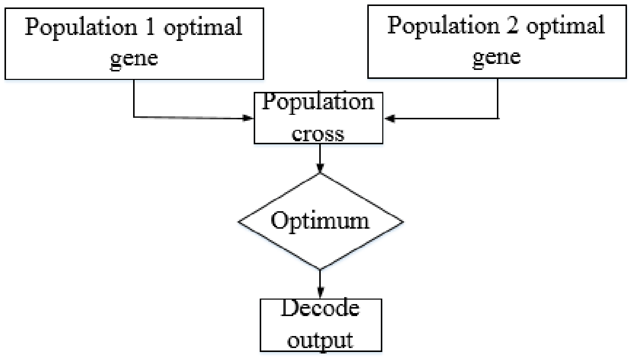

Fig. 4. Determining the job elements in the workstation.

After calling the "initialization function", "decoding function", "fitness function", "selection function", "cross function" and variogram, generate the optimal genes of population 1 and population 2, and perform population 1 and population 2 The crossover operation of the middle gene, the cross result is judged whether it is optimal, and if it is optimal, the output is decoded, otherwise the above work is continued.

B. Model Evaluation Index

There are two evaluation indicators for the balance optimization of the production line, namely the production line balance rate P and the balance index SI.

$$P = \frac{\sum_{i=1}^{m} st_i}{m \times \max(st_i)} \times 100\%$$

Where st_i is the time of each station, m is the number of workstations, $\max(st_i)$ is the most used station time, that is, the bottleneck station time. The greater the balance rate of the production line, the closer the bottleneck station time is to the average time of each station, and the better the balance of the production line.

$$SI = \sqrt{\sum_{i=1}^{m} (ct - st_i)^2}$$

Where ct is the production beat, st_i is the time of each station. The smaller the smoothing index, the smaller the difference between the production beat and the time of each station, and the better the balance of the production line.

C. Model Effect Verification

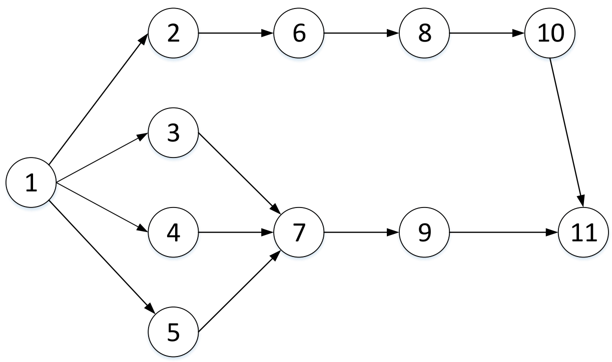

Fig. 5. Jackson process priority map.

In this paper, the efficiency of the classic Jackson line balance problem verification algorithm is used. Jackson uses the enumeration method to optimize the balance of the production line. Jackson's process priority sequence is shown in Figure 2-2. The time of each process is Time=[6 2 5 7 1 2 3 6 5 5 4].

According to the process time and optimization relationship matrix of Jackson production line, the production line is balanced and optimized by the dual-population genetic algorithm. The optimized workstations and process sequence are shown in Fig. 7. The station enumeration method, the line balance rate and balance index, and the various station time, line balance ratio, and smoothness index using the improved genetic algorithm are shown in “Table I”.

TABLE I. JACKSON BALANCE PLAN DATA

Station (time) / Method	1	2	3	4	5	P	SI
Jackson Enumeration	10	7	10	10	9	92%	3.16
Model	9	8	10	10	9	90%	2.50

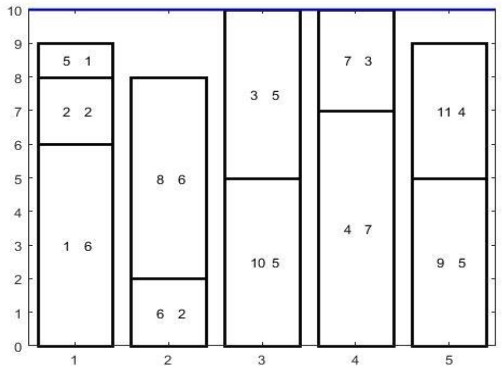

Fig. 6. Jackson line balancing program.

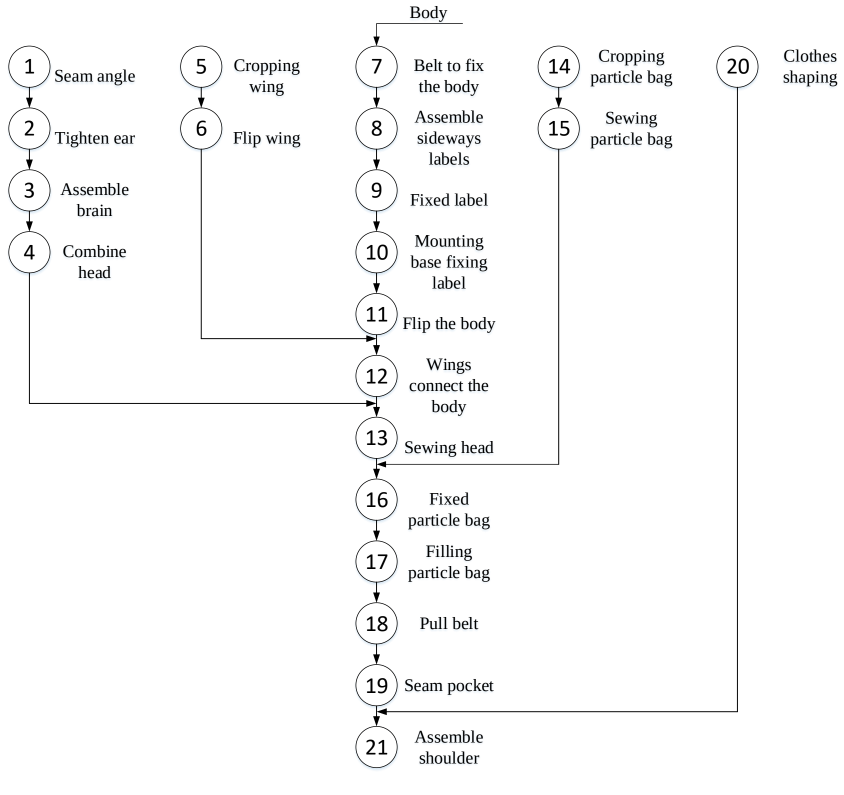

Fig. 7. Sewing production line process flow chart.

It can be seen from "Table I" that the balance ratio P of the genetic algorithm and the Jackson enumeration method are balanced after the production line is balanced, but the smoothness index of the production line balanced by the genetic algorithm is smaller than the Jackson enumeration method, so the effect of the algorithm is more Ok, it is possible to balance the production line.

IV. PRODUCTION LINE BALANCE RESULTS AND ANALYSIS

A. Production Line Status Analysis

The process flow chart of the sewing factory sewing production line is shown in "Fig. 8". The number of each process and the corresponding operation name can be seen from the figure. For example, the operation name of the process 1 is "seam face angle", that is, the sewing doll The face is made to fit the size required by the design. The two steps are connected by arrows, the direction of the arrow is the working direction of the process, the processes 1 and 2, the process 1 is the previous process of the process 2, and the operation of the process 2 can be performed only after the work operation of the process 1 is completed. Since steps 1, 5, 7, 14, and 20 have no preceding processes, their order of operations is not affected by other processes. There are two or more preceding steps in some processes, and the previous processes in the process 12 are the processes 6 and 11, and the operations of the process 12 can be performed only after the operations of the processes 6 and 11 are completed. The priority between processes is a key factor to consider when balancing the production line. The priority determines the position of the process on the entire production line. The priority of the process when using the genetic algorithm to balance the production line is taken as the input of the priority matrix.

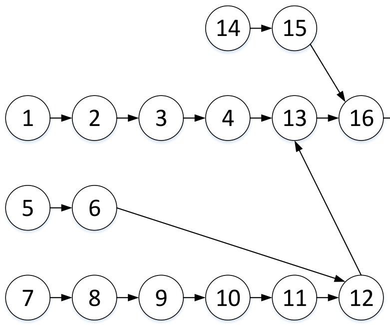

Fig. 8. Process priority map.

In order to more intuitively see the priority of each process, the process priority map is often used, as shown in Fig. 9. In the process priority map, only the number of the process and the previous or subsequent process of the process connected by the arrow are used. The process priority map can be used to more easily list the priority relationship matrix of the process.

B. Production Line Balance Result

Before running the genetic algorithm in matlab, set the experimental parameters as follows: the initial population is set to 100, the initial population is set to 100, the number of exchange genes is set to 5, and the initial population 1 crossover probability is set to 0.8. The initial population 2 crossover probability is set to 0.2, the initial population 1 mutation probability is set to 0.2, the initial population 2 mutation probability is set to 0.05, and the reproductive algebra is set to 250.

1) Balance result of station m=4

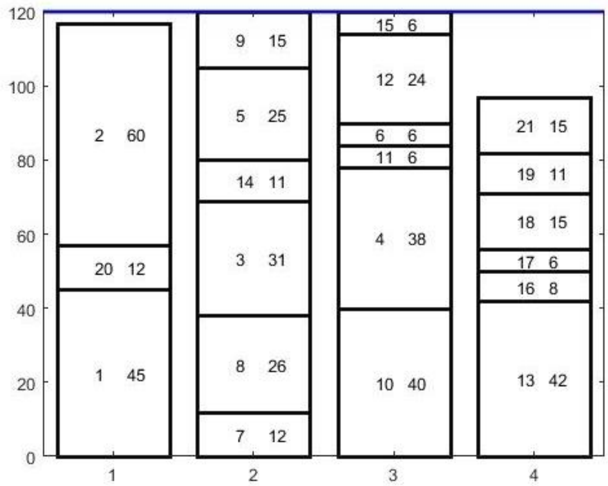

Fig. 9. m=4 balancing program.

TABLE II. BALANCE PLAN DATA TABLE WITH M=4

Workstation number	Workstation time/s	P	SI
1	117	94.58%	23.19
2	120		
3	120		
4	97		

2) Balance result of station m=5

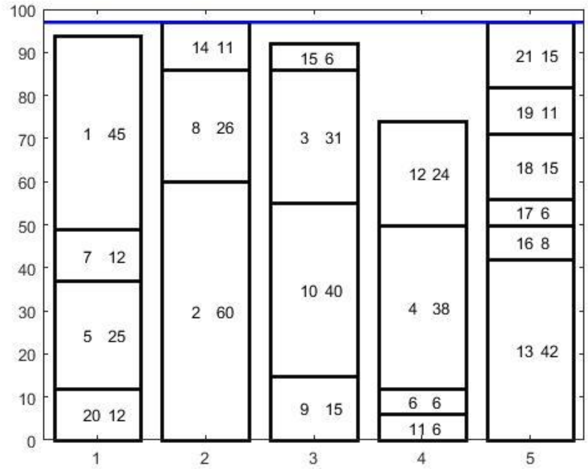

Fig. 10. m=5 banlancing program.

TABLE III. BALANCE PLAN DATA TABLE WITH M=5

Workstation number	Workstation time/s	P	SI
1	94	93.61%	23.73
2	97		
3	92		
4	74		
5	97		

3) Balance result of station m=6

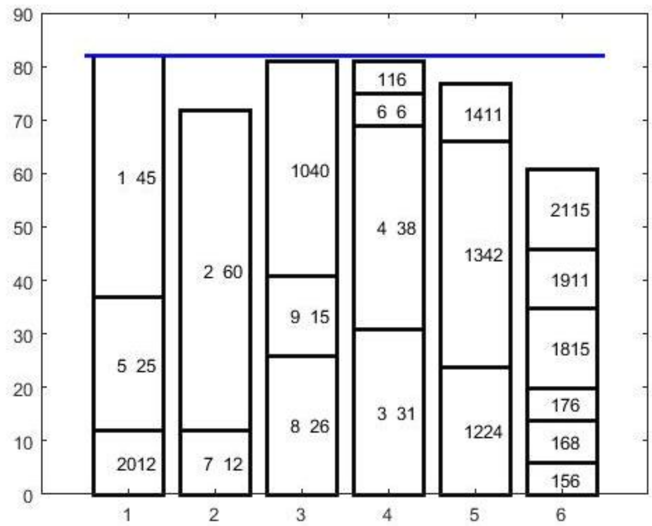

Fig. 11. m=6 banlancing program.

TABLE IV. BALANCE PLAN DATA TABLE WITH M=6

Workstation number	Workstation time/s	P	SI
1	82	92.28%	23.83
2	72		
3	81		
4	81		
5	77		
6	61		

4) Balance result of station m=7

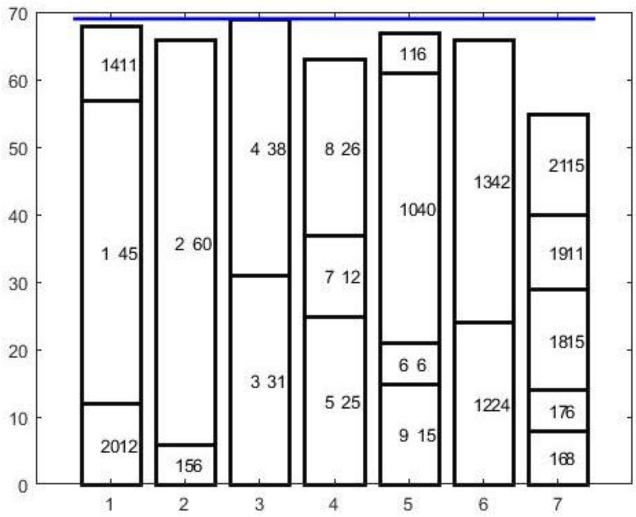

Fig. 12. m=7 banlancing program.

TABLE V. BALANCE PLAN DATA TABLE WITH M=7

Workstation number	Workstation time/s	P	SI
1	68	94.00%	15.97
2	66		
3	69		
4	63		
5	67		
6	66		
7	55		

5) Balance result of station m=8

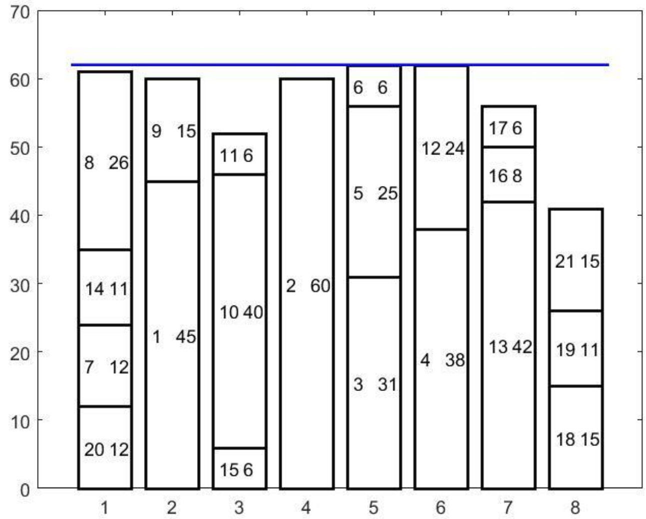

Fig. 13. m=8 banlancing program.

TABLE VI. BALANCE PLAN DATA TABLE WITH M=8

Workstation number	Workstation time/s	P	SI
1	61	91.53%	24.58
2	51		
3	60		
4	62		
5	61		
6	62		
7	56		
8	41		

6) Balance result of station m=9

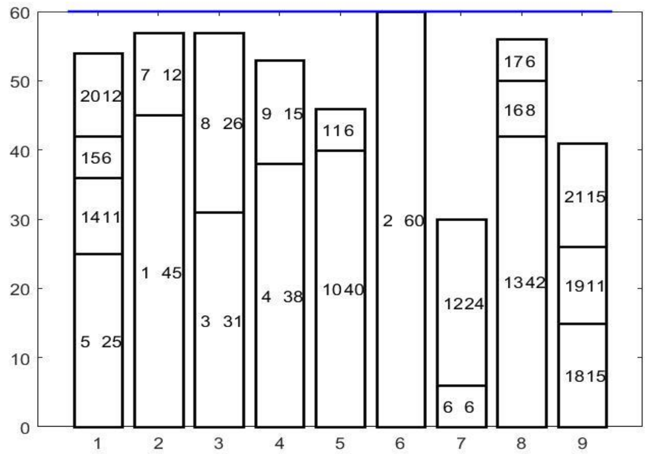

Fig. 14. m=9 banlancing program.

TABLE VII. BALANCE PLAN DATA TABLE WITH M=9

Workstation number	Workstation time/s	P	SI
1	60	91.53%	24.58
2	51		
3	47		
4	60		
5	46		
6	55		
7	38		
8	56		
9	41		

C. Balanced result analysis

Under different working digits, the production line balance rate P and the smoothness index SI of the toy factory sewing production line are shown as “Table VIII”.

TABLE VIII. DIFFERENT M INDICATOR COMPARISON TABLE

m	4	5	6	7	8	9
P	94.58%	93.61%	92.28%	94.00%	91.53%	84.07%
SI	23.19	23.73	23.83	15.97	24.58	36.50

In order to conveniently see the changes of the evaluation indicators of each station, draw the trend graph of the production line balance rate P and the smoothness index SI as a function of the station, as shown in “Fig. 15” and “Fig. 16”.

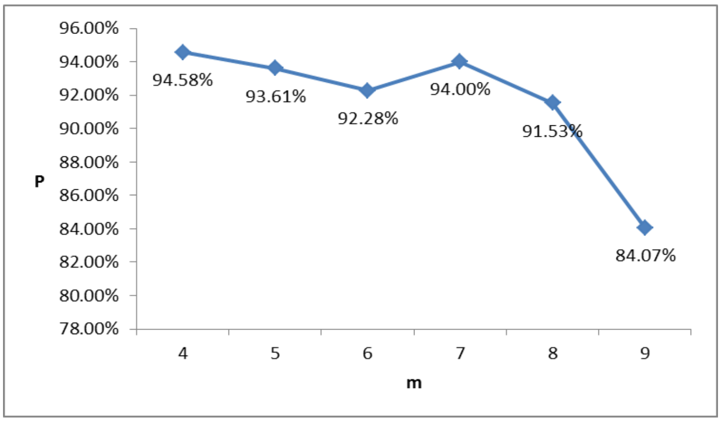

Fig. 15. Production line balance rate P trend graph.

"Fig. 15" shows the change of the production line balance rate P of different working digits m. When the number of stations is 4, the production line balance rate P is the largest. During the process of changing the number of stations from 4 to 6, the production line balance rate P It is in a downward trend. When the number of stations changes to 7, the production line balance rate P has a large rebound. When the number of stations changes to 8 to 9, it can be seen that the production line balance rate P drops significantly, especially the number of stations exceeds at 8 o'clock, the decline was the largest.

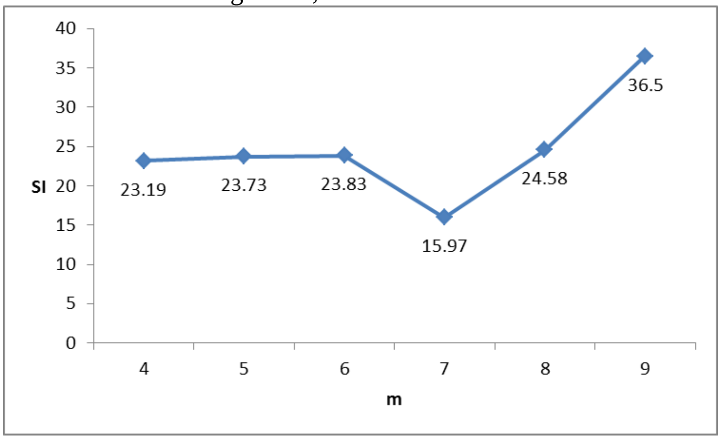

Fig. 16. Smoothing index SI trend graph.

"Fig. 16" shows the change of the smoothing index SI under different working digits m. When the working number is 4 to 6, the smoothing index SI is very close, indicating that the time difference between their workstations and the production tempo is close. When the number of stations is 7, the smoothing index SI drops sharply, indicating that the time difference between each workstation and the production tempo is smaller. When the number of stations is 8 to 9, the smoothing index SI rises sharply, indicating the workstations and production. The time difference of the beats is getting larger and larger, and the balance of the production line is getting worse.

The goal of the second type of production line balance problem studied in this paper is to produce the smallest tempo, that is, the production line balance rate P is the largest and the smoothness index SI is the smallest. According to the final production line balance result, there are two balance schemes that meet the target, namely, the number of stations is 4 and the number of stations is 7, and the balance ratios of the production lines are 94.58% and 94.00%, respectively. It is 23.19 and 15.97. From the point of view of the production line balance rate P, the number of stations is slightly larger than 4 and the number of stations is 7. From the smoothing index SI, the number of stations is far greater than the number of stations is 7. However, considering the actual production method, when the number of stations is 4, there are more work elements in each workstation, and the workstation time is longer, which is not suitable for a single station operation. When the number of stations is 7, the number of assignments of the work elements of each workstation is reasonable, the workstation time is suitable and balanced, and it is suitable for single station operation. Therefore, the optimal solution for the balance of the production line is that the number of workstations is 7.

V. CONCLUSION

In this paper, the production line balance model of the two-population genetic algorithm is established by Matlab, and the sewing production line of a toy factory is balanced and optimized. Firstly, the current situation of the sewing production line of a toy factory is analyzed. It is found that there is a problem of backlog of in-process inventory in the production line, the time difference between each station is large, and the production efficiency is very low. Calculating the balance ratio P of the production line, it is found that the balance ratio P of the production line is only 32.27%, which is quite different from the balance ratio of the production line of more than 85% required by the "one-piece flow" production line. The production line balance model of the established two-population genetic algorithm is used to balance the sewing production line, and the balance plan with the number of stations is 4, 5, 6, 7, 8, and 9. The balance ratio P and smoothing of the production line are obtained according to the evaluation index. The comparison of the index SI and the actual production considerations yields an optimal balance scheme with a number of stations of 7. The production balance rate P of the optimal balance scheme is 94.00%, realizing the "one-piece flow" production mode, and effectively solving the problems existing in the sewing production line of the toy factory. At the same time, it also proves that the production line balance model established in this paper can solve such production line problems and improve the production efficiency, economic efficiency and market competitiveness of enterprises.

REFERENCES

[1] F. Shi, Y. Shen, Y. Han. Research on balance optimization of single heating production line based on position weighting method[J]. Value Engineering, 2017, 36(7): 81-82

[2] Fathi M, MarÃ¬a JesÃºs Ã lvarez, Victoria RodrÃ¬guez. A new heuristic-based bi-objective simulated annealing method for U-shaped assembly line balancing[J]. European Journal of Industrial Engineering, 2016, 10 (2):145.

[3] M. He, K. Zheng. Research on balance improvement of pc assembly production line by MOD method [J]. Modern Manufacturing Engineering, 2017(7)

[4] Z. Sun, K. Xu, Research on Efficiency Improvement of S20 Production Line Based on Value Flow Graph [J]. Precision Manufacturing and Automation, 2017(3)

[5] Y. Yuan, W. Fan, Y. Feng. Modeling and simulation of automobile connecting rod production line[J]. Journal of System Simulation, 2018, 30(09): 135-140+151.

[6] Z. Pan, Y. Guo, S. Cha. Balance problem of aircraft assembly pulsation production line based on hybrid optimization algorithm [J]. Computer Integrated Manufacturing Systems, 2018, 24(10): 64-75.

[7] X. Chen. Research on assembly line balance technology based on improved genetic algorithm [D]. Shanghai Jiaotong University, 2011.

[8] Triki H, Ahmed M , Faouzi M. A multi-objective genetic algorithm for assembly line resource assignment and balancing problem of type 2 (ALRABP-2) [J]. Journal of Intelligent Manufacturing, 2014.