Improvement and Simulation of Rear Axle Assembly Line Based on Plant Simulation Platform

Hong-Ying SHAN\textsuperscript{a}, Guang-Fu LU\textsuperscript{b,*} and Yi WANG\textsuperscript{c}

\textsuperscript{a}Ji Lin University, School of Mechanical Science and Engineering, Changchun, China
\textsuperscript{b}1977916962@qq.com, \textsuperscript{c}1548553693@qq.com, \textsuperscript{c}489560299@qq.com

*Corresponding author

Keywords: Assembly Line, System Simulation, Heuristic Balance.

Abstract. In this paper, the rear axle assembly J Company A products to improve the object, simulation, assembly line balancing theory and heuristic search method for balancing the rear axle assembly improvement analysis. First, the reality of the assembly line, assembly line collection of information, and the status quo was Plant Simulation. Then, the application assembly line balancing theory and heuristic methods to improve and assembly lines for simulation. By comparing the simulation results before and after the improvement from the original amount of the rear axle assembly line worker 17 people down to 15 people, the equilibrium rate rose from 69.75% to 79.85%, the balance delay rate dropped to 20.15 percent from 30.25, assembly efficiency is improved.

Introduction

With the expansion of the scale of business development, sales continue to rise, the market will show a blowout outbreak will sometimes appear unpredictable fall. For such a changing market, if companies blindly invest and build factories, increase production lines, the purchase of equipment to a certain extent, can increase productivity, but doing so will greatly increase the burden on enterprises. And because of the lack of reasonable expectations of the market, once the market demand down, the blow to the enterprise is fatal. Therefore, manufacturers should conduct a comprehensive analysis of the production line to identify the key factors restricting production capacity and improve for it to improve the balance of production lines within the enterprise, so that companies cannot increase investment in the case of expansion of production capacity, but also to ensure The enterprise's resources are maximized utilization, reducing the machine idle.

Assembly line balancing is the technical means to average the entire production process, adjust the operating load, and make the operating time as close as possible. The purpose of the method is to eliminate the loss of efficiency and overproduction. The assembly line balancing problem can be presented as: The assembly process consists of a number of work elements in which there is a logical order of assembly among some of the work elements. Under the condition of certain cycle time and satisfying the assembly order between some work elements and some other objective conditions, a certain number of processes are calculated and the work elements are distributed to each process with considering that the output time of each product is equal to the cycle time and the difference of time between the processes is small. Almost in all industries, the assembly line balancing is used to do improvement.

Simulation is another method for production line improvement. There are too many software for production line such as Plant Simulation, Flexsim, witness, AutoMod, etc. All of the software use the object-oriented method to set up the simulation model, plan the system design of the model, collect the system data and optimize model. The model uses dynamic display of two-dimensional or three-dimensional visualization, so that decision makers can analyze all aspects of the production line and find out the problems more easily. This article uses Plant Simulation as the simulation platform of the automobile production line. The software is developed by Israel Tecnomatix company, written in C++ and can be applied to multi-domain simulation software platform. Graphical capabilities,
modeling and data analysis module are integrated in the software. And the structure and operation of the system are used to meet the object-oriented Claim. Plant Simulation is used in a wide range of plants and production lines. It can be used to model, simulate and optimize the production systems.

The heuristic balancing method has been proved to be a feasible and effective method to solve the assembly line balance problem in a wide range of practical applications. And the heuristic method can consist of meta-heuristic method and heuristic method. For meta-heuristic method, there are too many methods used in solving this problems. Such as: Genetic Algorithm (2010)[1], Hybrid Genetic Algorithm (2011)[2], Ant Colony Algorithm (2011)[3], Hybrid PSO Algorithm (2013)[4], Modified Genetic Algorithm (2014)[5], Differential Evolution (2016)[6]. And for heuristic method, Martino and Pastor (2010)[7] proposed heuristic procedures in solving assembly line balancing problem with setups. A heuristic methodology is proposed by Fazlollahtabar et al. (2011)[8] for solving assembly line balancing problem. A heuristic approach is proposed by Avikal et al. (2013)[9] for U-shaped assembly line balancing. And Kellegöz (2016)[10] proposed heuristic method for solving problems with multi-manned stations.

Next, the rear axle assembly line will be analyzed and simulated in part two. In part three, the assembly line is optimized by a heuristic method. And the last part is the conclusion, the improvement has been proved to be effective.

Analysis and Simulation of Rear Axle Assembly Line

The rear axle assembly line of J Company is a multi-product mixed flow production line. For the multi-product mixed production line, product A is chosen for study as the product is the largest number of assembly products. The action of each station is very complex, so the action is divided into work elements and numbered by serial number. In order to make the actual data more accurately, the error bound method is used to calculate the observation times of each work element. And then stopwatch is used to measure the work time of each workstation. Finally, the abnormal data is been removed by using triple error method and the work time of A product is shown in Table 1.

| Work station | work elements contained | Number of workers |
|--------------|-------------------------|-----------------|
| 1            | 1                       | 1               |
| 2            | 2                       | 0               |
| 3            | 3, 4, 10                | 1               |
| 4            | 5, 6, 7, 8, 9           | 1               |
| 5            | 11, 12                  | 1               |
| 6            | 13, 14, 15              | 2               |
| 7            | 16, 17, 18              | 2               |
| 8            | 19, 20, 21, 22          | 2               |
| 9            | 23, 24, 25, 26          | 2               |
| 10           | 27, 28, 29              | 2               |
| 11           | 30, 33, 34              | 1               |
| 12           | 31, 32                  | 1               |
| 13           | 35                      | 1               |

Through the company’s rear axle assembly process on-site research and technical personnel exchanges, drawing the following figure 1 shows the priority of the assembly elements of work order.
Based on the eM-Plant simulation software platform, the assembly process flow of the rear axle assembly flow is simulated and modeled. As shown in Figure 2, the simulation model of the rear axle assembly line is established. There are 13 processing units, one buffer. And the workstations are connected by a main line. The black line between objects indicates that the process cells are connected. And then, run the simulation model, the workstation time ratio and the idle rate are shown in Table 2. In addition, the balance rate of product A is 69.75%, the balance delay rate is 30.25%, the total operating time is 1070 seconds, the number of work stations is 13 and the number of the operators is 17 persons.

Table 2. Work Element Allocation Table.

| Work station | Work time ratio | Idle time ratio |
|--------------|-----------------|-----------------|
| 1            | 28.82%          | 71.18%          |
| 2            | 33.91%          | 66.09%          |
| 3            | 89.83%          | 10.16%          |
| 4            | 72.88%          | 27.11%          |
| 5            | 78.81%          | 21.18%          |
| 6            | 52.54%          | 47.45%          |
| 7            | 96.60%          | 3.39%           |
| 8            | 64.40%          | 35.57%          |
| 9            | 86.43%          | 13.55%          |
| 10           | 73.72%          | 26.26%          |
| 11           | 79.65%          | 20.33%          |
| 12           | 99.98%          | 0.01%           |
| 13           | 59.31%          | 40.69%          |
According to the time efficiency table of each station of product A, it can be seen that the loading of the workstation of the assembly line is non-balance. From the assembly line and other indicators of the production line, the assembly line has large space to improve.

**Assembly Line Simulation Optimization Based on Heuristic Method**

In order to improve more reasonable, through sorting the historical data, the average output of product A is 187 for one shift and the work time of the production line is 7 hours per shift. So the cycle time is 134 seconds. Considering the total operating time, the theoretical minimum number of workstation is eight. In order to re-divide the working elements of the assembly line, a heuristic balance method is used to search for possible combinations of work elements in the assembly operation, and the feasible solutions can be obtained by calculating the combination of the cycle time and the theoretical minimum working area. There are three principles in the application of heuristic methods: the types of job elements in the workstations should be the same; the job elements in which the leading job elements have been assigned are assigned preferentially; and the job elements with longer time are assigned firstly.

Combine the above principles, the heuristic steps can be developed as follow. Initializing: starting from the first job element on the assembly flow chart.

- Step 1: Judging the job element and the last allocated job element whether they are homogeneous elements, if they are, perform step 2, otherwise, entering the next workstation;
- Step 2: Determine whether the element meets the principle one, if not, select its leading element and conduct Step 2 to this element;
- Step 3: Determine whether there are other elements in line meet with the principle one, if there are, using principle two, compare the two elements and select the element with longer operation time, if not, select this element. And then, put the selected element to the operation of the current workstation and the time of the element is accumulated in the working time of the current workstation;
- Step 4: Comparing the cycle time with the working time of the current workstation if the cycle time is bigger than the operation time of the current work station then conduct step one to next work element; if the work time is greater than the cycle time, then stop the procedure and conduct step one to next work element; When the work elements have been assigned to the certain station, the heuristic ended and the output is shown.

| Work station | Work element and sequence | Time | workers |
|--------------|---------------------------|------|---------|
| 1            | 1→2→4                    | 84   | 1       |
| 2            | 3→10→5→6                 | 131  | 1       |
| 3            | 7→8→9→11→12              | 132  | 1       |
| 4            | 13→14→15                 | 103  | 2       |
| 5            | 16→17→18→23              | 131  | 2       |
| 6            | 19→20→21→22→24→25        | 131  | 2       |
| 7            | 26→27→28→29              | 117  | 2       |
| 8            | 31→32                    | 118  | 2       |
| 9            | 30→33→34                 | 94   | 1       |
| 10           | 35                       | 70   | 1       |

Next, the work station one will be used for an example for the heuristic method. Work station one: The work time of work element L1 is 34 seconds which is bigger than that of work element L4, so the work element L1 is selected and then the work time of work station one is 34 seconds, smaller than the cycle time. Work element L2 and L1 are belong to the same work element, the work time of work element L2 is 40 seconds which is bigger than that of L4, so the work element L2 is selected and then
The work time of work station one is 74 seconds, smaller than the cycle time. Next, work element L3 and L2 should be separated, so L4 is selected, the work time of work station one is 84 seconds. The work element L3 should be divided into work station two. Until this procedure, the work station one is finished. Refer to this method, work station two to ten can be completed. And Table 3 shows the time and job element combination of each work station after balancing search.

Table 4. The Work Time and Idle Time Ratio after Improved.

| Work station | Work time ratio | Idle time ratio |
|--------------|-----------------|----------------|
| 1            | 62.69%          | 37.31%         |
| 2            | 97.74%          | 2.26%          |
| 3            | 98.46%          | 1.54%          |
| 4            | 76.81%          | 23.19%         |
| 5            | 97.67%          | 2.33%          |
| 6            | 97.65%          | 2.35%          |
| 7            | 87.19%          | 12.81%         |
| 8            | 87.92%          | 12.08%         |
| 9            | 70.02%          | 29.98%         |
| 10           | 52.13%          | 47.87%         |

Conclusion

In this paper, the system simulation technology and assembly line balance theory are combined to solve the problem of the rear axle assembly line of J Company. With the improvement of heuristic balance, the operation elements of the assembly line do not change, the number of operating worker is reduced from 17 to 15, the assembly line balance rate increases from 69.75% to 79.85%, and the balance delay rate drops from 30.25% to 20.15%. And the idle time and work loading of each work station are more balanced.

Acknowledgements

This work was supported by the National Natural Science Foundation of China under Grant 61304216.

References

[1] Yu J, Yin Y. Assembly line balancing based on an adaptive genetic algorithm[J]. The International Journal of Advanced Manufacturing Technology, 2010, 48(1-4): 347-354.
[2] Akpinar S, Bayhan G M. A hybrid genetic algorithm for mixed model assembly line balancing problem with parallel workstations and zoning constraints[J]. Engineering Applications of Artificial Intelligence, 2011, 24(3): 449-457.
[3] Fattahi P, Roshani A, Roshani A. A mathematical model and ant colony algorithm for multi-manned assembly line balancing problem[J]. The International Journal of Advanced Manufacturing Technology, 2011, 53(1-4): 363-378.
[4] Hamta N, Ghomi S M T F, Jolai F, et al. A hybrid PSO algorithm for a multi-objective assembly line balancing problem with flexible operation times, sequence-dependent setup times and learning effect[J]. International Journal of Production Economics, 2013, 141(1): 99-111.
[5] Alavidoost M H, Zarandi M H F, Tarimoradi M, et al. Modified genetic algorithm for simple straight and U-shaped assembly line balancing with fuzzy processing times[J]. Journal of Intelligent Manufacturing, 2014: 1-24.
[6] Zhang H, Zhang H, Yan Q, et al. An integer-coded differential evolution algorithm for simple assembly line balancing problem of type 2[J]. Assembly Automation, 2016, 36(3): 246-261.

[7] Martino L, Pastor R. Heuristic procedures for solving the general assembly line balancing problem with setups[J]. International Journal of Production Research, 2010, 48(6): 1787-1804.

[8] Fazlollahtabar H, Hajmohammadi H, Es’haghzadeh A. A heuristic methodology for assembly line balancing considering stochastic time and validity testing[J]. The International Journal of Advanced Manufacturing Technology, 2011, 52(1-4): 311-320.

[9] Avikal S, Jain R, Mishra P K, et al. A heuristic approach for U-shaped assembly line balancing to improve labor productivity[J]. Computers & Industrial Engineering, 2013, 64(4): 895-901.

[10] Kellegöz T. Assembly line balancing problems with multi-manned stations: a new mathematical formulation and Gantt based heuristic method[J]. Annals of Operations Research, 2016: 1-28.