Logistics analysis and simulation in the intelligent manufacturing workshop

Ping Ni*, Yunxia Wang, and Di Chen
School of Mechanical Engineering, Nanjing Institute of Technology, Nanjing, China

Corresponding author: 3034933478@qq.com

Abstract: This paper aims to study the internal logistics system of manufacturing enterprises, and use the logistics analysis and modeling methods to plan and simulate the layout of the workshop. Firstly, the SLP (Systematic Layout Planning) method is planned for a specific enterprise. Secondly, the Flexsim software and the ExSpect software are used to simulate the logistics of the planned workshop. The Flexsim software is used to know the facility utilization rate, and the cause of the blockage is analyzed. The improvement measure of adding one casting machine and static furnace is proposed to solve the problem of equipment blockage. The modeling and analysis of the workshop is carried out in combination with Petri net, and the total working hours of production and processing are obtained through ExSpect software simulation.

1. Introduction
In the intelligent manufacturing environment, manufacturing companies are pursuing the maximization of the profit of high-quality products, so reducing costs and improving the quality of products are crucial to the survival and development of enterprises. The production cost of the enterprise includes the procurement cost, the management cost, the transportation cost, etc., and the material handling cost accounts for 20%~50% in the enterprise[1]. Related research shows that logistics management and supply chain optimization can greatly reduce transportation costs and supply chain costs. Therefore, the analysis and improvement of enterprise logistics have great practical significance. This paper firstly conducts planning of SLP for a hot rolling shop, then uses Flexsim and ExSpect software to simulate the shop floor logistics in order to analyze and optimize the results.

2. SLP analysis of a hot rolling shop
The workshop processes 210 tons of raw materials per day. The processing losses of the melting furnace, the static furnace, the sawing machine, the milling machine, the hot rolling machine and the
band sawing machine are: 2%, 1.5%, 3%, 9%, 2%, 13%. The losses of the melting furnace and the static furnace are the slag discharge after heating, and the losses of other equipment are to transport the surplus material to the recycling packaging area where the excess material can be collected and then transported to the recycling storage area for reuse[2].

The logistics diagram and non-logistics diagram as shown in Fig.1 and Fig. 2 are obtained through SLP method of facility planning. And the comprehensive diagram and the area graph based on them are gained ,which are shown in Fig.3 and Fig.4.

Fig.1. Logistics diagram

Fig.2 .Non-logistics diagram

Fig.3. Comprehensive diagram

Fig.4. Area graph for workshops

The candidate plan for the factory floor is shown in Fig.5. In the second scheme, the finished product storage area is too close to the hot rolling area whose high temperature can affect the quality of the products; and the transportation route from the band sawing area to the finished product storage area is long; and the finished product storage area is too far from the gate. Finally, the first option is selected as a result of taking into account the above factors.

Fig.5. Candidate plan for layout of workshops

Fig.6. Flexsim simulation model
The Flexsim and ExSpect software are used to simulate the planned workshop, and the unreasonable points in the system are improved based on the results of the simulation.

3. Flexsim simulation
The model shown in Fig.6 is established according to the processing time of each equipment and the relevant information of the route of hot rolling process[3-4].

| Object           | Idle | Processing | Blocking |
|------------------|------|------------|----------|
| melting          | 5.11%| 94.89%     | 0.00%    |
| melting          | 7.02%| 91.36%     | 1.62%    |
| static           | 79.41%| 20.59%     | 0.00%    |
| degassing        | 93.98%| 1.73%      | 4.29%    |
| casting          | 71.78%| 24.77%     | 0.00%    |
| sawing           | 95.10%| 2.63%      | 0.00%    |
| milling          | 81.16%| 17.24%     | 0.00%    |
| heating          | 22.99%| 76.14%     | 0.00%    |
| hot rolling      | 91.47%| 6.20%      | 0.00%    |
| straightening    | 95.87%| 2.03%      | 0.00%    |
| band sawing      | 88.93%| 5.87%      | 0.00%    |

The model generates a status report which is displayed in Table 1 mainly showing the status of processors. To be simple, processing actions are used to represent corresponding devices. According to the above table, the utilization rates of the two melting furnaces and the heating furnace are high, but there is a blockage phenomenon that the degassing box and a melting furnace are blocked in the system. The reason for the blockage of the box may be: It takes 3 minutes to process, but the time of the casting machine which is the downstream equipment is up to 45 minutes, which means the difference between their processing time is too large. In addition, the temporary storage area is not suitable in the middle (the liquid flows directly to the casting machine) The two points cause the stoppage of the degassing box. Therefore, a casting machine is added. The reason for the melting furnace blockage is that there are two melting furnaces in the system, but only one downstream equipment. Furthermore, the temporary storage area is not suitable in the middle. The two aspects contribute to the melting furnace to be clogged. So a static furnace is joined. The improved simulation model is shown in Fig.7. The status report of the improved model is shown in Table 2.

![Fig.7. Improved model](image-url)
Table 2. Improved status report

| Object     | Idle   | Processing | Blocking |
|------------|--------|------------|----------|
| melting 1  | 5.24%  | 94.76%     | 0.00%    |
| melting 2  | 7.17%  | 92.83%     | 0.00%    |
| static 1   | 89.34% | 10.66%     | 0.00%    |
| degassing  | 98.21% | 1.79%      | 0.00%    |
| casting 1  | 85.13% | 12.74%     | 0.00%    |
| sawing     | 94.46% | 2.62%      | 0.00%    |
| milling    | 83.05% | 14.39%     | 0.00%    |
| heating    | 33.36% | 65.91%     | 0.00%    |
| hot rolling| 93.55% | 5.34%      | 0.00%    |
| straightening| 95.84% | 2.09%      | 0.00%    |
| band sawing| 89.37% | 5.99%      | 0.00%    |
| static 2   | 89.55% | 10.45%     | 0.00%    |
| casting 2  | 84.80% | 12.96%     | 0.00%    |

It can be seen from Table 2 that the clogging rate in the degassing box and the melting furnace is zero after adding one casting machine and one static furnace in the system. Moreover, the melting furnace and the heating furnace still have high utilization rate. The entire system which is out of blockage is running smoothly.

4. ExSpect simulation

ExSpect is based on the theory about Petri net. Petri net is a method which uses boxes and circles to describe events and their causes and effects. Petri nets define the possible states, events, and relationships between them of discrete event systems[5].

4.1 Analysis and Modeling

The basic steps of modeling include: establishing a hierarchical model, establishing an object model, establishing a table of object relationship, establishing a table of event occurrence, and establishing a dynamic model of the system[6].

4.1.1 Establish a hierarchical object model

The logistics system is divided into three parts: the cache system, the transportation system, and the production and processing system. Each system is composed of different devices, as shown in Fig.8.~Fig.10.
Fig.9. Transportation system

In Fig.8, P indicates the status of the system, such as P1 indicating that the raw material warehouse has an idle position, P2 indicating that the raw material warehouse is full, and P3 indicating that the raw material warehouse is in stock but not full. Other storage areas are similar. In Fig.9, P31 indicates that the forklift is idle. P32 indicates that the forklift is busy. P33 indicates that the conveyor belt has a vacancy and P34 indicates that the conveyor belt has no vacancy. P35 indicates that the pipeline is empty and P36 indicates that the pipeline is full. In Fig.10, P37 indicates that the melting furnace is idle and P38 indicates that the melting furnace is busy. Other equipment states are similar.

4.1.2 Establish a table of object relationship

It can be seen from the above model that the logistics system involves 23 objects from L21 to L43. The relationship between objects is described by event T, which is shown in Fig.11.

Fig.10. Production processing system

4.1.3 Establish a table of event occurrence

Each of the 33 events has its preconditions and post conditions, as shown in Table 3.

Table 3. Event occurrence table

| Eve | He | Post |
|-----|----|------|
| T1  | P31P3 | P32P1 |
| T2  | P31P1 | P32P29orP3 |
| T3  | P31P3 | P32P28 |
| T4  | P37  | P38 |
| T5  | P35  | P36 |
| T6  | P39  | P40 |
| T7  | P35  | P36 |

Fig.11. Object relationship
4.1.4 Establish a dynamic model of the logistics system

A logistics system model is shown in Fig.12. The circle represents the library, and the rectangle represents the transition.

![Logistics system model](image)

**Fig.12. Logistics system model**

4.2 ExSpect simulation

The logistics model is divided into two parts: the main system and the subsystem, as shown in Fig.13 and Fig. 14. The main system which generates input and records the throughput time of the system describes the general flow of production. The subsystem describes the detailed process. The subsystem is adjusted according to the model established in Fig.13 and the actual operation process of ExSpect software. Materials in the sawing machine pass by the storage cache and then are conveyed to the milling machine area. However, the similarity is that the processes of the sawing machine to the storage cache and the storage cache to the milling machine are related to transportation time to a large extent. The process from the sawing machine to the milling machine is directly indicated by T11 in ExSpect to simplify the model, and the corresponding transportation time is set. The process of transporting waste to the recycling packaging area is not involved since it has little effect on the overall operation of the system.

In Fig.14, the events are:
- T1: Transportation from the raw material warehouse to the melting furnace;
- T2: Melting;
- T3: Transportation from the melting furnace to the static furnace;
- T4: Standing;
- T5: Transportation from the static furnace to the degassing box;
- T6: Degassing;
- T7: Transportation from the degassing box to the casting machine;
- T8: Casting;
- T9: Transportation from the casting machine to the sawing machine;
- T10: Sawing;
- T11: Transportation from the sawing machine to the milling machine;
- T12: Milling;
- T13: Transportation from the milling machine to the heating furnace;
- T14:
Fig.13. Main system

Simulate the established model and the relevant output data is obtained, as it is shown in Fig.15.

Fig.14. Subsystem

Simulate the established model and the relevant output data is obtained, as it is shown in Fig.15.

| subrun | xmethods | xaverage | covariance |
|--------|-----------|-----------|-------------|
| 1      | 0         | 0.00      | 0.00        |
| 2      | 1         | 823.13704665548763 | 0.00 |
| 3      | 1         | 809.4081366855585 | 0.00 |
| 4      | 2         | 814.60686417296417 | 16.39039798378770 |
| 5      | 1         | 814.3486240354953 | 0.00 |
| 6      | 2         | 814.25972592097845 | 5.4969227412753740 |
| 7      | 1         | 815.11574542330814 | 0.00 |
| 8      | 2         | 819.68993233141210 | 10.85103993524154 |
| 9      | 1         | 818.72383283690307 | 0.00 |
| 10     | 2         | 818.80904861494028 | 2.2184145429941086 |

Fig.15. Output

It can be seen from Fig.15 that the time of running the model once is between 809 min and 820 min, which means that the length of time required for a complete production process is also within this interval.

5. Conclusion

This paper uses the SLP method for a specific factory to determine the layout of each production workshop, and then uses Flexsim and ExSpect software to simulate the system from different aspects.
The blockage of the system is found through Flexsim, then the causes are analyzed. Finally, corresponding measures are taken to improve the system processing efficiency. At the same time, the total working hours of production and processing are clear by ExSpect. This paper is significant in decreasing the production cost and improving the competitiveness of enterprises.

6. References

[1] Dwijayanti K, Duwal S Z M, Jamasri and Aoyama H 2010 International MultiConference of Engineers and Computer Scientists (China: HongKong) 3 pp1640-5

[2] Li Y H, Wu Z Y and Lu C G 2014 Journal of Southeast University (Philosophy and Social Sciences Edition) 16 102-8

[3] Fang D and Liang C Z 2017 Journal of Shijiazhuang Railway Vocational and Technical College 16 70-5

[4] Gao J 2017 Modern Trade Industry 32 197-8

[5] Jiang Z B 2004 Petri net and its application in modeling and control of manufacturing system (Beijing: Mechanical Industry Press)

[6] Xu L 2007 Logistics Analysis and Simulation Research in Factory Facilities Planning (Jilin: Jilin University)

Acknowledgements

This research is sponsored by Ministry of Education, Humanities and Social Sciences Project of China (No.16YJCZH108). Major projects of the School level Innovation Fund (CKJA201509). Science and Technology Innovation Projects of School Level(TB201916015).