INTEGRATED SCHEDULING TECHNOLOGY OF FLEXIBLE MANUFACTURING WORKSHOP BASED ON HOLON MODEL

Yanyun CHEN[1,2] and Pengfei ZHENG[3,*]
[1] Institute of Central China Development, Wuhan University, Wuhan 430072, China
[2] School of Economics and Management, Longyan University, Longyan 364000, China
[3] Shanghai Customs College, Shanghai 201204, China
E-mail: zhengpengfei@shcc.edu.cn

***ABSTRACT**: Along with the continuous application of information model, integrated scheduling of flexible manufacturing workshop is faced with great challenges. Holon model is an intelligent manufacturing system with autonomy and negotiability. On the basis of Holon model, this study establishes a flexible manufacturing workshop system framework based on Holon system architecture to realize the autonomy and negotiability of integrated scheduling technology. The results show that Holon model manufacturing system is an open hierarchical system, and the flexible manufacturing workshop scheduling control system is the basis to ensure robustness and reliability of Holon model. Holon model shows remarkable advantages in average delay and average load range in flexible manufacturing workshop scheduling. This study provides a theoretical basis for realizing dynamic control and intelligent control of the flexible manufacturing workshop system.*

***KEYWORDS**: information model; flexible manufacturing; Holon model; integrated scheduling technology; intelligent control.*

1 INTRODUCTION

Manufacturing industry is the pillar industry of the national economy and the engine of economic growth, directly related to the comprehensive competitiveness of a country (Chinnusamy et al., 2014). As the demand of consumers for products tends to be diversified, personalized and dynamic, the variety and functions of products are constantly increasing, and this multi-variety, medium and small batch and order-based production mode has become the mainstream of production mode, raising higher requirements for the flexibility of the manufacturing workshop (Zhang et al., 2019; Zhou et al., 2017). Integrated scheduling problem of flexible manufacturing workshop mainly involves job scheduling, distribution scheduling and parallel multi-machine scheduling. Scheduling problem is dynamic, random and multi-objective (Allahverdi, 2015; Li et al., 2018; Huang et al., 2018). There will always be some unforeseen phenomena or random disturbance events in the actual flexible manufacturing workshop during the manufacturing process. Once they occur, corresponding environmental change means must be adopted to readjust the scheduling so that the manufacturing workshop can operate continuously and optimally to minimize system performance impact (Wu, 2011).

Compared with traditional manufacturing systems, Holon representing an international intelligent manufacturing system, has autonomy and negotiability and can solve or improve problems, such as adaptability, optimization and reliability of traditional manufacturing systems (He et al., 2008). At present, there are few researches on Holon model manufacturing system at home. It has been found that the characteristics of autonomy and negotiability based on Holon model can respond to the disturbance of the production workshop quickly and generate the dynamic transfer of the logistics bottleneck of the production workshop (Tao et al., 2011; Liu & Lv, 2015). The integrated scheduling technology of flexible manufacturing workshop must be able to adapt to changes and failures of various components, respond to changes in various external variables in a timely manner, and meet multi-objective optimization (Liu et al., 2013). Combined with existing researches, this study, on the basis of Holon model, establishes a flexible manufacturing workshop system framework based on Holon system architecture to realize the autonomy and negotiability of integrated scheduling technology. This study provides a theoretical basis for realizing dynamic control and intelligent control of the flexible manufacturing workshop system.

2 ARCHITECTURE CONSTRUCTION OF HOLON MODEL MANUFACTURING SYSTEM

Integrated scheduling events of manufacturing workshop are various, and different types of factors have different integrated scheduling environments, scheduling strategies, and scheduling methods (Luo & Ma, 2011). Holon model manufacturing system contains an integrated scheduling negotiation mechanism, but an appropriate negotiation mechanism needs to be selected when establishing organizational relationships based on Holon model (Ma & Lu, 2014). Holon model can represent the production capacity in a manufacturing system, which can be abstracted as a facility in actual production. Besides, Holon model represents the process of all products and the relevant knowledge of products, and can realize the exchange between process Holon, resource Holon and product Holon (Zhao & Xu, 2009).

Holon model manufacturing system is an open hierarchical system. Figure 1 is the design of Holon model manufacturing system. Holon model is featured with autonomy, negotiability, dynamic balance, fixed rules and flexible strategy, multiple hierarchy and reconstruction, self-similarity and self-learning ability. The flexible strategy of Holon model enables the system to take corresponding measures quickly and respond to the workshop integrated scheduling in time when an incident occurs (Gu et al., 2017). In addition, Holon model has strong robustness and survivability. The design needs to follow the principle of independence, compatible elements, less or postponed decision-making selection as far as possible, and adoption of non-hierarchical interaction mode, distributed decision-making and open system structure. The design module of Holon model manufacturing system includes negotiation and communication module, logic module, data module, execution monitoring module and physical components.

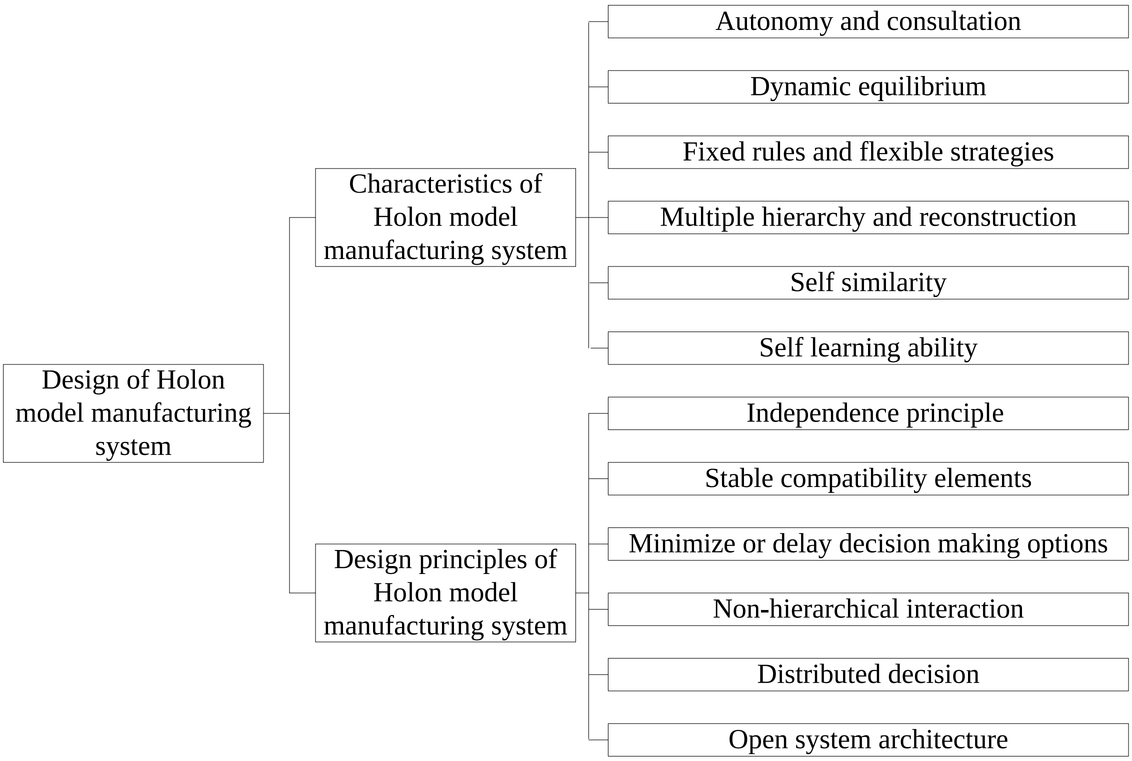


Fig. 1 Design of Holon model manufacturing system

3 DESIGN OF INTEGRATED SCHEDULING SYSTEM OF FLEXIBLE MANUFACTURING WORKSHOP

3.1 Production scheduling problem model in flexible manufacturing workshop

The integrated scheduling system of flexible manufacturing workshop mainly involves workshop production and production scheduling problem. A large-scale mixed flow production workshop needs to process multiple products simultaneously on multiple lines under constraints of production resources and product process. The optimal production performance is achieved by integrated scheduling production and production scheduling. The scheduling problem of flexible workshop is influenced by the quantity of products, the quantity of processing equipment and the processing procedure of products. Through reasonable arrangement, the equipment does not operate without load, so as to ensure the maximum lap joint efficiency. Figure 2 shows the location of the workshop production scheduling function. The scheduling function module is started by means of the main production plan, the bill of material and the inventory control, and the production scheduling and re-scheduling are realized through the real-time data collection of the manufacturing workshop. According to the discrete characteristic of workshop manufacturing, the optimal solution can be decoded by using the difference interface operation strategy to determine the processing sequence of the product. In addition, the optimal processing procedure for the scheduling problem of workshop production can be selected according to the minimization of the maximum completion time. Figure 3 is a production flow chart of integrated scheduling of a flexible manufacturing workshop. Before production scheduling, product processing orders are generated according to product production center or customer demand, and then production scheduling is determined according to processing procedure of the product. Finally, the workshop products are processed according to the production schedule.

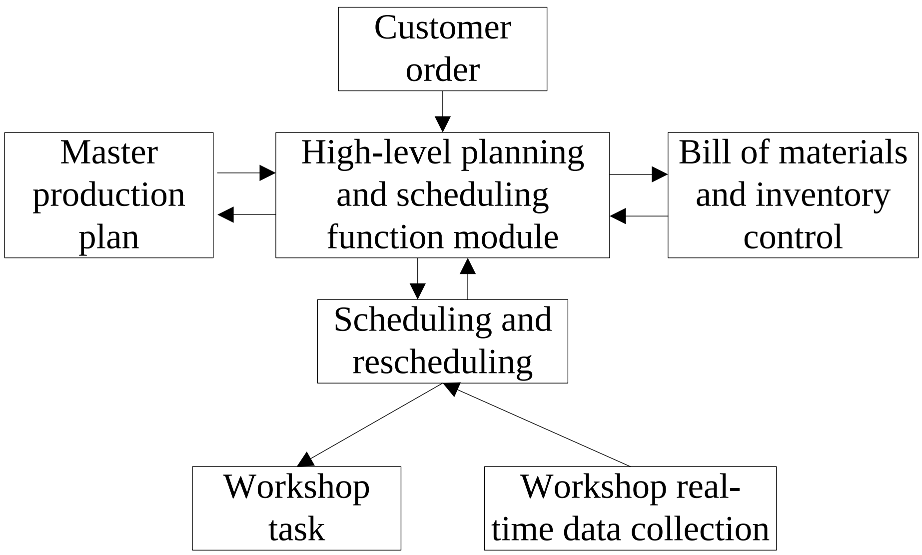


Fig. 2 Function orientation of workshop production scheduling

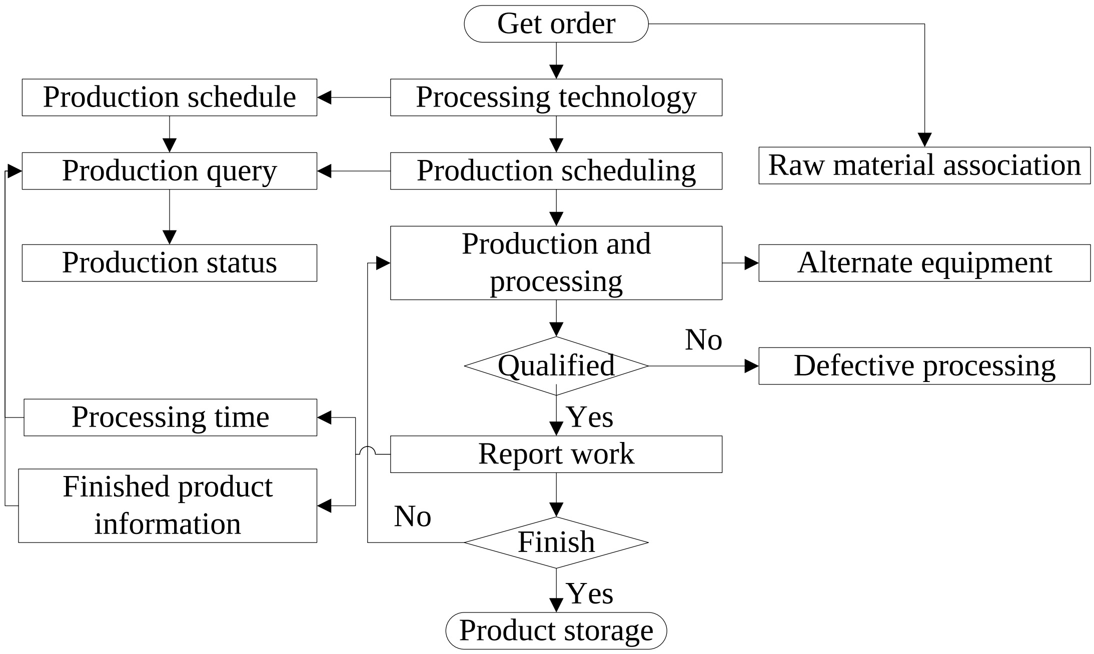


Fig. 3 Integrated scheduling production flow chart of flexible manufacturing workshop

3.2 Structural model of flexible manufacturing workshop scheduling control system

The whole flexible manufacturing workshop can be divided into different resources or functions, including workshops, units, resources, products and tasks. The flexible manufacturing workshop scheduling control system is the basis for ensuring the robustness and reliability of Holon model. Figure 4 is a system architecture design based on Holon model. Through system analysis, the main roles of the system are defined. The scale realized by using the scheduling control system is smaller and there are more roles in the system. Then flexibility and adaptability of the system structure will be stronger. By analyzing the problem, the relationship with Holon model is determined, and then the structure of flexible manufacturing workshop scheduling control system based on Holon model is determined. When the scale of the scheduling control system is small, the organization structure and the complexity of the control system are increased, and the operation efficiency of the system is reduced.

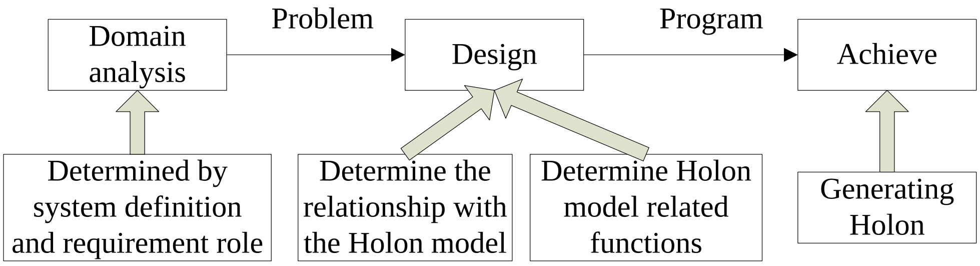


Fig. 4 System architecture design based on Holon model

4 STUDY ON INTEGRATED SCHEDULING CONTROL OF FLEXIBLE MANUFACTURING WORKSHOP BASED ON HOLON MODEL

4.1 Bottleneck control strategy of flexible manufacturing workshop based on Holon model

The bottleneck control of the manufacturing workshop is the core of the overall integrated scheduling control. Once the bottleneck appears in the manufacturing workshop, it will directly affect the next work of the entire workshop. The production of components in the workshop is carried out in batches, and there will be corresponding production and processing in each process. The bottleneck problem in the flexible manufacturing workshop is usually caused by the fluctuation of the material distribution in the production process, which has a negative effect on the whole production process. In the flexible manufacturing system, the more processes of any product are, the greater the probability of producing uncertainty factors will be, the more likely it is to lead to product surplus or shortage in some processes, resulting in production logistics bottleneck. Figure 5 shows disturbance factors of a flexible manufacturing workshop, including processing disturbance factors and logistics disturbance factors, wherein processing disturbance factors include unskilled skills, processing fatigue, aging or failure of processing equipment and emergency; and logistics disturbance factors include unskilled sorting, aging or failure of logistics equipment, insufficient energy and change of logistics route.

According to the principle of predictability, the production bottleneck of flexible manufacturing workshop can be predicted according to the disturbance factors, and can be predicted and eliminated by analyzing the real-time production data. In practical flexible manufacturing workshop scheduling, the minimum value of production time is taken as the objective of decision-making scheduling. However, once the bottleneck occurs, the whole decision-making scheduling will be completely disrupted. Thus, multi-objective optimization strategy can better resist the risk brought by the bottleneck. In general, the objective factors for the optimization of flexible manufacturing workshop scheduling include the factors of operation time, delivery time and utilization rate.

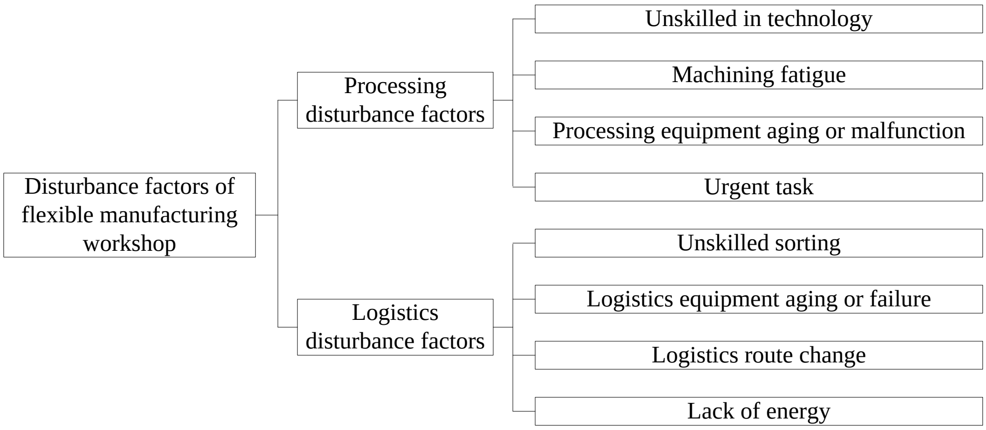


Fig. 5 Disturbance factors of flexible manufacturing workshop

4.2 Verification of workshop comprehensive scheduling based on Holon model

The analysis in the previous section shows that the use of multi-objective decision-making factors will be more comprehensive and universal. Through taking an assembly shop as an example, this study probes into the multi-objective integrated scheduling problem based on Holon model. Table 1 is the processing procedure and average processing time of a sample in a processing workshop, showing that the three processing products do not all contain six procedures. The control chart is a graphic tool for analyzing and judging whether the production state is stable and the center full line is taken as the control center line. Figure 6 is the integrated scheduling real-time data control, showing that the production scheduling in this study is within the upper and lower limits of the control. Formulas 1-3 are calculation formulas for the center line and upper and lower limits. After the mean value and variance of the integrated scheduling sample statistic are added, the control limit expression is shown in Formula 4-Formula 6.

The calculation formulas for the center line and upper and lower limits are:

Center line: $L=\mu$ (1)

Upper control limit: $UL=\mu+3\sigma$ (2)

Lower control limit: $DL=\mu-3\sigma$ (3)

Where, μ is the mean value of characteristic value. If the mean value E(x) and variance D(x) of the integrated scheduling sample are known, the control limits can also be expressed as:

Center line: $L=E(x)$ (4)

Upper control limit: $UL=E(x)+3D(x)$ (5)

Lower control limit: UL=E(x)-3D(x) (6)

Based on the integrated contract model and the average delay and average load range, this study explores the integrated scheduling of workshop based on Holon model. Figure 7 is a comparison of manufacturing workshop integrated scheduling allocation based on Holon model and the integrated contract model. Figure 7 (a) shows an average delay result and it is obvious that the average delay of Holon model is shorter. Figure 7(b) is an average load range result, showing that the average load range of Holon model is smaller. Compared with the integrated contract model, Holon model shows remarkable advantages in average delay and average load range for flexible manufacturing workshop scheduling, and the two have significant differences.

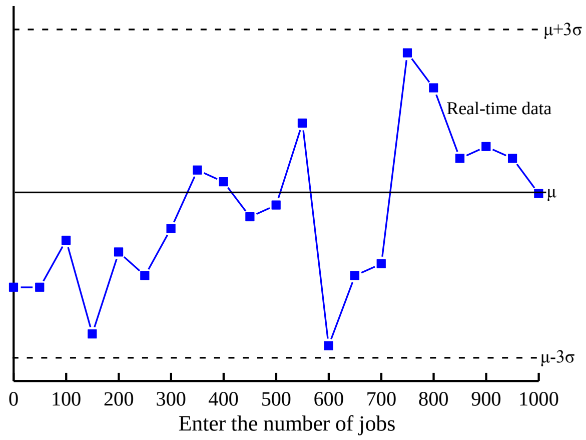
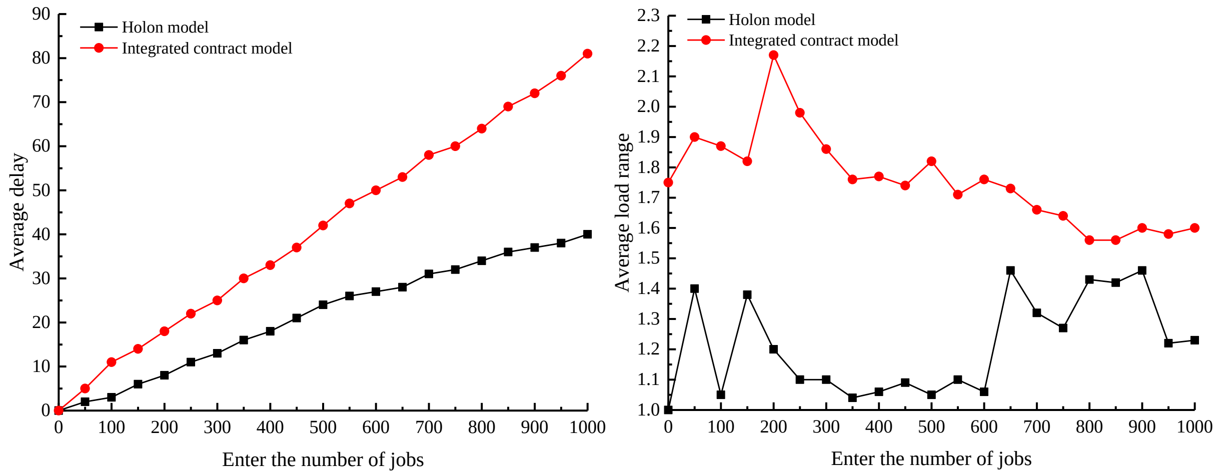


Fig. 6 Real time data control of integrated dispatching

Table 1. Processing procedure and average processing time of a sample in processing workshop

	Processing sample 1	Processing sample 2	Processing sample 3	Average processing time
Process 1	22	26	34	11
Process 2	15	0	42	19
Process 3	27	33	17	25.67
Process 4	0	12	16	9.33
Process 5	22	26	0	16
Process 6	0	0	15	5



(a) Average delay (b) Average load range

Fig. 7 Comparison of integrated scheduling and allocation of manufacturing workshop based on Holon model and integrated contract model

5 CONCLUSIONS

Combined with existing researches, this study, on the basis of Holon model, establishes a flexible manufacturing workshop system framework based on Holon system architecture to realize the autonomy and negotiability of integrated scheduling technology. The specific conclusions are as follows:

(1) Holon model manufacturing system is an open hierarchical system, featured with autonomy, negotiability, dynamic balance, fixed rules and flexible strategy, multiple hierarchy and reconstruction, self-similarity and self-learning ability, as well as strong robustness and survivability.

(2) The integrated scheduling system of flexible manufacturing workshop mainly involves workshop production and production scheduling problem. In the flexible manufacturing system, the more processes of any product are, the greater the probability of producing uncertainty factors will be, the more likely it is to lead to product surplus or shortage in some processes, resulting in production logistics bottleneck.

(3) Compared with the integrated contract model, Holon model shows remarkable advantages in average delay and average load range in flexible manufacturing workshop scheduling, and the two have significant differences.

6 ACKNOWLEDGEMENTS

This work is supported by Fujian Science and Technology Bureau Soft Science Fund (2018R0074); Fujian Provincial Department of Education Fund (JAS160522); Longyan Science and Technology Bureau Basic Research and Youth Talents Project (2017LY77).

7 REFERENCES

►Allahverdi, A. (2015). The third comprehensive survey on scheduling problems with setup times/costs. European Journal of Operational Research, 246(2), 345-378.

►Chinnusamy, T. R., Karthikeyan, T., Krishnan, M., Murugesan, A. (2014). A comprehensive survey of flexible manufacturing system scheduling using petri nets. Advanced Materials Research, 984-985, 111-117.

►Gu, C., He, Y., Han, X., Xie, M. (2017). Comprehensive cost oriented predictive maintenance based on mission reliability for a manufacturing system. 2017 Annual Reliability and Maintainability Symposium, Orlando, FL, USA.

►He, Y., Liu, F., Shi, J. (2008). A framework of scheduling models in machining workshop for green manufacturing. Journal of Advanced Manufacturing Systems, 7(2), 319-322.

►Huang, C.J., Zhou, X.H., Hou, D.S. (2018). Online no-wait scheduling of leather workshop supply chain based on particle swarm optimization, Journal Européen des Systèmes Automatisés, 51(1-3), 153-167.

►Li, B., Guo, C., Ning, T. (2018). An improved bacterial foraging optimization for multi-objective flexible job-shop scheduling problem, Journal Européen des Systèmes Automatisés, 51(4-6), 323-332.

►Liu, H., Xin, S., Xu, W., Zhao, Y. (2013). Dynamic comprehensive evaluation of manufacturing capability for a job shop. Advances in Swarm Intelligence. Springer Berlin Heidelberg, 7929(1), 368-375.

►Liu, Q., Lv, W. (2015). Multi-component manufacturing system maintenance scheduling based on degradation information using genetic algorithm. Industrial Management & Data Systems, 115(8), 1412-1434.

►Luo, J. F., Ma, T. S. (2010). An comprehensive rating model of manufacturing enterprise's credit risk based on logistics finance. International Conference on Computer Application & System Modeling, 15, 15290-15293.

►Ma, Z. X., Lu, Q. (2014). Use the comprehensive model about gray and fuzzy to evaluate the performance of the information technology of manufacturing enterprises. International Journal of Managing Projects in Business, 41(7), 105-115.

►Tao, W., Zhang, L. P., Sang, H. Y. (2011). A SOA-based reconfigurable manufacturing execution system for a tools workshop. Applied Mechanics and Materials, 145, 499-504.

►Wu, Z. H. (2011). Research on workshop scheduling of SMT product manufacturing system. Advanced Materials Research, 189, 2577-2580.

►Zhang, Y., Yue, Y., Yang, G., Li, D. (2009). Research on performance analysis and comprehensive evaluation model of MES for machining workshop. 2009 First International Workshop on Database Technology and Applications, Wuhan, Hubei, China.

►Zhao, Y., Xu, L. (2009). Fuzzy comprehensive evaluation on the credit rating of manufacturing enterprises' suppliers based on improved algorithm. International Conference on Future Information Technology & Management Engineering, 559-563.

►Zhou, L., Zhang, L., Liu, Y. (2017). Survey on scheduling problem in cloud manufacturing. Computer Integrated Manufacturing Systems, 23(6), 1147-1166.