Lean Intelligent Production System and Value Stream Practice

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Abstract. This paper makes a brief introduction of the Industry 4.0 and “Made in China 2025” plan and analyzes the relationship between the lean production and intelligent manufacturing. Considering the situation of the manufacture in China, the concept of the lean intelligent production system (LIPS) is proposed. Based on the LIPS, the value stream analysis and design are implemented to the manufacturing process of a contactor product to minimize the work in process and improve the production efficiency.

Introduction

With the concept of the Industry 4.0 spreading around the world, more and more companies begin to realize that great importance should be attached to the connection among every production factors. The Industry 4.0 was proposed by the German federal government as one of the key plans of its high-tech strategy [1], which aims to build up a personalized and digital production pattern of products and services based on cyber-physical system (CPS). Meanwhile, many other countries propose their own plan to catch up with the 4th Generation Industrial Revolution such as the Advanced Manufacturing Partnership proposed by America. Similarly, China has published the “Made in China 2025” plan whose core is the digital, networked and intelligent manufacturing. However, the current state of the manufacture in China remains to be improved gradually to reach the high grade of intelligence.

Researchers have also focused on the development and implementation of the cyber-physical system. Considering the difficulties of academic research and implementing for Industry 4.0, Hermann gave a definition of Industry 4.0 and designed 6 principles for its implementation [2]. Volkan et.al analyzed the concepts and challenges of the CPS and enumerated the application of it [3]. Jay Lee et al. analyzed the trends of CPS-based service innovation and big data analytics in the Industry 4.0 eras [4]; further, he proposed a unified 5-level CPS architecture to guide the implementation of CPS [5]. These researches solve the problem of the CPS implementation to some extent, but it is still difficult to consider the current state of the manufacture and develop suitable methodology to implement Industry 4.0.

Lean Intelligent Production System

The “Made in China 2025” plan aims to transform the manufacture in China from “made in China” to “innovate in China” by the deep integration of the industrialization and informatization. The Industry 4.0, Advanced Manufacturing Partnership and “Made in China 2025” plan have the identical
core: intelligent manufacturing. The key technology in the intelligent manufacturing includes CPS, big data analysis, Internet of Things, cloud computing, embedded sensor, artificial intelligence and so on. However, to implement intelligent manufacturing, the current situation needs to be considered and analyzed.

A large amount of factories in China is still in the level of Industry 1.0 and 2.0 eras. The production in these factories is disordered and less of them have adopted the intelligent technology. In some companies, the products are produced manually and waste existing everywhere. Therefore, the factories need to focus on the improvement and optimization of the production line before the intelligent manufacturing implementation.

Lean production methodology and management have been used to eliminate the waste in the production and build up efficient one-piece flow production line. The lean production helps to make the production more controllable by introducing a set of self-regulated method. By implementing the lean production, the production is more likely to be modeled and controlled. After lean production, the digitized product lifecycle management and the CPS is easier to build. Therefore, the lean production is the basis of the intelligent manufacturing in the current situation of the manufacture in China. In addition, the lean thought such as continuous improvement is still useful for the implementation of the intelligent manufacturing, which can be taken as guidance.

On the other hand, the intelligent manufacturing gives the technological support to more efficient and outstanding lean production implementation. For example, the new information acquisition technology and big data analysis will help to solve the problems in the value stream analysis and safety inventory confirmation; the intelligent equipment can help to integrate different processes more and more. In brief, the intelligent manufacturing based lean production can achieve a higher level of lean.

With the above considerations, the lean intelligent production system (LIPS) is proposed in order to better implement the “Made in China 2025” plan in the factories in China. Based on the concept of LIPS, a value stream practice in company S was made and will be implemented as a basis of the intelligent manufacturing in the future.

Value Stream Practice

Practice specification

The scope of Company S is mainly the contactor, controller and connecter. In our case of value stream analysis and design, a kind of contactor is selected by the ABC analysis method. The main procedure of this product includes holder assembling, contactor assembling, driver assembling, final assembling, testing, packaging and shipping. The manufacturing process of the contactor is analyzed by value stream mapping and the existing wastes are found. Based on the principle of the value stream design, two different production value streams are designed to reduce the waste and improve the efficiency.

Value stream analysis

According to the rules of the value stream analysis, the current value stream mapping of the contactor is shown in Fig.1. Firstly, the customer annual requirement is analyzed to satisfy the customer-oriented lean theory. The customer of the contactor needs 11344 pieces per year averagely; the employees in company S work 7 hours per day and 250 days per year. With the above data, by virtue of Eq. 1 the takt time is calculated to be 9.26 minute per piece [6].

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\text{Takt time} = \frac{\text{Available working time per shift}}{\text{Customer demand per shift}}
\]

With the takt time in mind, the production data in every process was collected and the work in process was counted and calculated according to the takt time. For every process, the data including processing time (PT), lot size (LS), cycle time (CT) and set-up time (ST) were collected manually. For example, in the testing process, the inspector needs to spend 12 minutes on putting the 100 contactors
in the right position and then a set of testing program was applied to the contactors for about 190 minutes. Therefore, the PT, LS, CT and ST for testing are 190 min, 100 pcs, 1.9 min and 12 min, respectively. The data of the other process were collected in the same way. After that, the work-in-process inventory and material and products inventory were counted and calculated to be the inventory available time according to Eq. 2 [6]. The larger inventory in the production line include material and products inventory, which is 81.4 days and 17.1 days, respectively.

\[
\text{Inventory available time} = \frac{\text{Inventory quantity}}{\text{X1}} \times \frac{Takt \text{ time}}{\text{Daily working time}}
\]  

(2)

The information flow of the production is also reflected in the value stream mapping. The production planning system receive the order from the customer via the customer center and then release purchasing order and production order to the corresponding department, which is a typical “pull” production system. The value-adding time for the production is 16.3 min and the manufacturing lead time is 108.14 days, which means lots of unnecessary wastes exists in the production.

In addition, the cycle time adaptation diagram is presented to better analysis the wastes in the current manufacturing of the contactor, which is shown in Fig. 2. With the combination of the above two diagrams, the wastes can be analyzed as follows: (1) The cycle time in different process are not balanced, which can cause waiting and high inventory problems; (2) The cycle time for the process of the contactor and driver assembling is not synchronized; (3) The production planning system need to control every process and receive feedback from them, which leads to over-processing problem; (4) Big gap exists between the customer cycle time and the production cycle time, which causes severe over-production wastes.
To solve the problems in the current production system and eliminate the unnecessary wastes, the value stream of the contactor was designed according to the classical principles of value stream design. Actually, 3 main principles were adopted considering the production character of the contactor and their basic theory [6] and development in the Industry 4.0 era is presented as follows:

The first principle is integration, which means to develop one-piece flow in the production line wherever possible by integrating different process together to decrease work in process. To integrate the different process, the pint-sized automation equipment and the sensors to connect all the processes are needed. For example, the five-axis machine tool and 3D printers have been integrated to produce the complex parts, which largely improves the efficiency because the integration cuts down the set-up time.

The second principle is FIFO (first in first out) logic, which connects the process that can’t be integrated to set a defined minimum inventory. The FIFO logic is very important in the small amount and many kinds production because it can help to produce the different variants according to the sequence of the customer requirement. In the production procedure, the products are given a specific ID card, which indicates its attributes of process. With the FIFO logic, the latter station can arrange the work sequence by virtue of the information from the ID card in advance. In addition, the safety inventory will be determined by the model of big data analysis, which would be more flexible and credible.

The third principle is pull system, which means to use supermarket and Kanban to control the production of the consumable parts that have long set-up time. The pull system is a self-regulated way to control the production between flows and helps to produce what the customers need just in time. With the development of CPS, the information of the Kanban will be transmitted by the sensors integrated to the different stations. For example, magnetic sensors have been fixed to the supermarket to send signals to the ERP systems when the parts nearly run out.

Based on the above 3 principles, the value stream of the contactor is designed as Fig. 3. Firstly, the different assembling processes don’t need special equipment, so these procedures are combined together. Then, the downsized automation testing and packaging machines are introduced to the production line to improve the productivity and cut down the labor cost. Therefore, all the processes are integrated and the processing time is 17.2 min. Taking the takt time into consideration, two employees are arranged in the production line to meet the customer requirement. Secondly, the FIFO
logic is applied to connect the shipping process to keep the order sequence and the safety inventory was set to be 1.1 days by experience. Thirdly, to cut down the material stock and simplify the procedure of the purchase, the pull system is introduced before the assembling process begins. The production line sends Kanban signals to the purchasing department independently when the materials in the supermarket nearly run out.

![Diagram](image)

**Figure 3.** The value stream design for the contactor.

![Diagram](image)

**Figure 4.** The cycle time adaptation diagram corresponding to the value stream design.

After value stream design, the production planning system only need to control one process and the work in process are largely reduced. The corresponding cycle time adaptation diagram is shown in Fig.4. The cycle time of the process is perfectly matched to the takt time and the manufacturing lead time is reduced to be 9.94 days from 108.14 days.

**Summary**

Considering the current situation of the manufacture in China, the lean intelligent production system (LIPS) is proposed to better implement the “Made in China 2025” plan. Furthermore, a value stream analysis and design case of the contactor products is studied to improve its efficiency and reduce the waste based on the LIPS. By integrating the lean production and intelligent manufacturing, the LIPS is more suitable for the implementing of “Made in China 2025” plan and thus has a broad developing prospect in the Industry 4.0 era.
References


