Increasing the efficiency of automation in shipbuilding and ship-repairing by building a control system using lean manufacturing principles

Sergey Sokolov†, Alena Antonova†, and Tatiana Knysh†
†Admiral Makarov State University of Marintime and Inland Shipping, 5/7 Dvinskaya str, 198035, Saint-Petersburg, Russia

Abstract. Shipbuilding companies often suffer from long production cycles, low staff utilisation and an unbalanced production line. To solve these problems, a lean shipbuilding regime is used which involves work breakdowns, production plans and virtual flow operations that combine lean production with modern information management technology in shipbuilding. Production planning manages all the production activities of a shipbuilding facility. Production plans are achieved just-in-time through intelligent organisation, reducing loss of staff and time. A virtual flow operation is then carried out, achieving high efficiency in flow production and high flexibility in production. By implementing a lean shipbuilding regime based on task package planning and its production system, the ship’s production cycle is reduced, the number of workers is reduced, but the level of production balance is increased.

1 Introduction

The shipbuilding industry is one of the largest and most important industries. If shipbuilders want to survive and increase their competitiveness, they must improve shipbuilding efficiency, reduce labour costs and shorten the production cycle [1-3].

Lean manufacturing is a type of management philosophy developed by Toyota Motors. One of the goals of lean manufacturing is to eliminate waste, which can increase job satisfaction and turn waste into value. It should be emphasised that lean manufacturing must go beyond the company. In other words, lean manufacturing should be from product development to the set of activities provided to the end user. Lean production techniques aim to eliminate all types of waste in production and reduce lead times [2]. The best results of lean manufacturing are achieved by reducing cycle time, productivity, material costs, rejects, resulting in lower overall costs and high competitiveness.

Lean manufacturing has been established in China for a relatively long time. It is most widely used in the conveyor and multi-product industry. However, it is not usually used in the shipbuilding industry. In order to make production faster and more organised, the

* Corresponding author: sokolovss@gumrf.ru
shipbuilding industry has undergone changes. In the 1990s, the Chinese shipbuilding industry began to learn from the global experience - an improved shipbuilding regime. After a decade of development, the Chinese shipbuilding industry has made breakthroughs in segmented digital production and automation. The lean shipbuilding mode is developing rapidly in the shipbuilding industry, dominated by the China State Shipbuilding Corporation (CSSC). However, its overall level of integration is still not at a first-class global level. The majority of local small and medium-sized shipbuilding enterprises still use the traditional extensive mode of production management. The evolution of the shipbuilding industry over 30 years is shown in Figure 1.

![Shipbuilding orders by country](image)

**Fig. 1.** Dynamics of shipbuilding industry development.

As labour costs rise, the competitive advantage diminishes. At the same time, the development of new industrial production technologies has led to a new industrial revolution, Industry 4.0 [4, 5]. With the rapid development of Industry 4.0 technology and the wave of intelligent manufacturing, a large number of enterprises have started using a production management system to monitor the production process and achieve lean management of the production plan, production progress, inventory and product quality. This has been done to maximise rational resource allocation, optimise production schedules and significantly improve production efficiency.

To deliver more and better products in shorter lead times and to meet customer expectations with lower costs and higher quality, companies must develop a more competitive product development strategy [1]. Ships are equipped with thousands of devices and items consisting of hundreds of parts. A shipbuilding project is characterised by a long life cycle and many related activities. This requires interdisciplinary cooperation such as structure, equipment, piping and machinery. Thus, a large number of technical documents for a ship will be produced during shipbuilding. The long-term accumulation of documents
and the constant expansion of computer systems have placed a heavy burden on shipbuilders. This point pushes the need to invest more capital in software and hardware development [4].

2 Study of the lean shipbuilding regime

The theory of work breakdown, which is mainly used in engineering management and systems analysis of the national defence, aerospace and construction industries, originated in the United States. It is a theoretical method of gradually decomposing projects and finally forming basic management units that are easy to manage and use. This method has been used extensively in shipbuilding, automotive, aircraft and other industries.

After a decade of development, the work breakdown designed for modern shipbuilding has gradually formed two basic models. The first model can be described as "regionally divided, adopting the component as the basic unit of management". On the other hand, the second model can be described as "divided by work object, taking the task package as the basic management unit" [5]. The first model is widely used in shipyards with higher requirements for production conditions, operational control and execution. The second mode is widely used in enterprises where more emphasis is placed on the influence of complex factors such as equipment, organisational structure, personnel and materials.

All production activities of shipyards are defined by production plans. They are usually divided into four types: line schedule plan, preliminary construction plan, installation plan, post construction plan.

The line schedule plan mainly refers to the production line schedule, which is based on customer orders. This type of plan defines the construction sequence, dock layout and timing of the main production units of each vessel in accordance with the anticipated construction cycle of the vessel and the docking period. The production line schedule is an important basis for the progress of vessel construction. The preliminary construction plan includes a hull section as the management facility and an installation plan as the basis for organising the schedule for all key processes from installation to handling. The preliminary construction plan is prepared taking into account the production load limitations of each process, the nodes of the production line schedule and the installation date. The installation plan is based on a line schedule plan. At the designated dock and period, the lifting and closing of the hull is completed to ensure that the entire vessel meets launching conditions. The assembly plan basically includes the lifting sequence, the date and time of hook-up. The post-construction plan is based on rigging in accordance with the main timing units of the production line schedule. The equipment installation plan is prepared after closure of the enclosure, which mainly includes the installation of mechanical and electrical equipment, instruments, meters, piping and other equipment. In addition, the equipment installation plan includes finishing, coating and other operational plans. A post-construction plan is drawn up to ensure the integrity of the system and the commissioning date as a deadline.

3 Results

The sectional manufacture of shipboard curved surfaces is a typical multi-batch and variable series production with high complexity and complexity. The hull consists of curved plates of different shapes and sizes. Since the shape of the hull has a significant impact on the overall performance of the vessel, the efficient and accurate manufacture of curved plates is one of the most important processes in shipbuilding [1]. Although the similarity of curved profiles is very small for the same ship, there is a great deal of similarity between curved profiles when several ships are manufactured simultaneously [6-8]. This is particularly valid when several ships of the same type are being manufactured simultaneously. The forming of
curved plates consumes a considerable amount of time and energy and is considered to be one of the bottlenecks in the shipbuilding process. Regardless of how complex the components of the various curved surface segments are, the machining technology can be divided into the following basic operations: welding, assembly and auxiliary operations such as marking and grinding. In addition, the process requirements of the operations are also similar. The similarity in structure and process of curvilinear surface segmentation provides the basis for using a flow operation [9-13].

The efficiency of a specialised production line is much higher than that of a flow operation in the production of large and heavy products. It's much easier to use a combination of equipment, tooling and personnel flow than a flow of machined parts. Using virtual flow to organise production can also completely increase production efficiency. Thus, the virtual flow mode enables high efficiency in flow production and high flexibility in production at fixed workstations. Different operational groups move between sections to perform their respective production tasks, thus forming a virtual flow production system of the entire shipbuilding enterprise.

4 Conclusion

The production efficiency of shipbuilding enterprises can also be effectively improved by implementing lean production management. Both automation and lean production have their advantages and disadvantages. Nevertheless, lean manufacturing is currently the best option to improve production efficiency and benefit shipbuilding enterprises, especially small and medium shipbuilding enterprises. Lean production is characterised by low costs, low investment and great advantages over automation.

Lean shipbuilding system integrates such lean shipbuilding ideas as work breakdown, task package planning and virtual flow operation into a software system. In this way, the shipbuilding enterprise has the available technology to implement lean production and overcome the shortcomings of the traditional system, which focuses only on planning and monitoring the production process. The production balance can be effectively improved, personnel and time losses can be significantly reduced through the use of a lean shipbuilding system.

Lean production fundamentally changes existing shipbuilding methods and it also represents the future direction of the shipbuilding industry and smart shipbuilding. In addition, the shipbuilding operation process will be further optimised, equipment will be continuously improved to improve the production efficiency of shipbuilding enterprises and to increase the market competitiveness of small and medium-sized shipbuilding enterprises.

References


