Research on the Milestones Takt Time of the General-Assembly Shipbuilding

GUOFU SHI, XIAOBING LIU and LEI XUE

ABSTRACT

Achieving a balanced production is the most important way for a maximum production efficiency in the General-assembly shipbuilding enterprise. The design and application of milestones takt time in the General-Assembly Shipbuilding production line is vital to achieve a balanced production. This paper empirically analyzed the possibility and necessity of applying milestones takt time in the General-Assembly Shipbuilding production process and elaborate a way how to design the milestones takt time of shipbuilding by designing the takt time of production milestone of the ships built by parallel and series construction mode in dry dock. Then the historic production record of a large domestic shipbuilding enterprise was used to simulated and analyzed in milestones takt time, proving the feasibility and necessity of application of milestone takt time in the final assembly shipbuilding production process.

INTRODUCTON

General-Assembly Shipbuilding (GAS) represents the trend of modern shipbuilding, and is the production pattern which can improve the efficiency of shipbuilding enterprise. The purpose of it is to exercise the advantage of the specialized production with high efficiency and to achieve the pipelining production so as to improve the efficiency within the shipbuilding enterprise [1].

Pipelining production is the result of the maximized production smoothing of the enterprise, which is the production pattern with the highest efficiency. All the production resources in the pipeline can operate continuously with balanced work loads of all production resources; all can give full play to its function with minimum wastes. The precondition of the pipelining production is that mass production and procedures shall be carried out with the same production takt time.
GAS is a production process of single product or small-scale production. Although the GAS enterprise cannot fully undertake the real pipelining operation, it can allow the shipbuilding work to operate continuously via planning and designing the production takt time of each procedure, to minimize wasting the production resources in order to achieve standard pipeline operation [2].

The takt time is the rhythm of the production which is the interval time between the two finished product on the pipelining production. The design and application of the production takt time is the key of DAS with balance. How to design the equal production takt time or that with integral multiple of each procedure and stage, and how to flexibly apply the takt time into the General assembly shipbuilding system are the key actions to achieve a balanced production and improve production efficiency.

**RESEARCH BACKGROUND**

Under the current shipbuilding management pattern in China, the production of shipbuilding enterprise is unbalanced. Production resources are not be fully used if the pipelining production pattern is not adopted, which will not achieve ideal efficiency. Figure 1 shows the record of labor force distribution of a General–assembly shipbuilding enterprise. Among which, void input of labor force takes up 35.9% of the overall input of labor force, it has wasted large amount of manpower resources.

![Figure 1. Record of labor force distribution of an General–Assembly Shipbuilding enterprise.](image)

Although shipbuilding is a single product or small-scale production, which is not fulfill the conditions of pipelining production pattern[3]. But the shipbuilding milestones can used to design shipbuilding takt time to achieve a Toyota lean production pattern. The key of establishing pipelining DAS is to plan and design equal takt time or that with integral multiple and learn how to adjust it. As long as the scientific and reasonable takt time of shipbuilding has been established and relevant mechanism has been implemented, standard pipelining shipbuilding can be established, then the balanced production can be fully achieved and the production efficiency can be maximized.[4]

In the traditional pipelining production, the takt time has been defined as the time interval of two finished products in the pipeline, the calculation formula is:

\[ r = \frac{F}{Q} \]

Among which, \( r \) is the average takt time in the pipeline, its unit is Second/Piece; \( Q \) is the output of production planning period, its unit is Piece; \( F \) is the effective operating time in planning period, its unit is Second[5].
This calculation formula is applicable to the typical mass pipelining production, the operating time of each finished product shall be precisely controlled, equal or with integral multiple. Ships are the finished products of the DAS enterprise, with long production period and little output, it cannot be used as the output of finished product for designing the takt time of shipbuilding. Even the operating objects of each work stage (most of the intermediate products are the single products or small-scale production) are not completely in conformity with the production conditions of takt time. Among the current DAS enterprises in China, most of them do not consider letting the operating time meet the requirements of the production takt time, so that they cannot directly undertake pipelining production. However, DAS enterprises can successfully control its production schedule and improve the efficiency according to the characteristics of technological process of production and relevant theory via taking the Milestones and blocks as the objects to plan, design and apply the takt time. This paper will discuss how to take the interval time between milestones as the shipbuilding takt time.

MILESTONE TAKT TIME DESIGN AND APPLICATION

Control Points of the Overall Rhythm of Production for The General Assembly Shipbuilding Enterprise

DAS enterprises control the production rhythm by controlling Milestones. Milestones are the key activities or events in the production schedule. DAS is a project with complicated system, as figure 2 shows, it has tens of activity chains and Milestones are the intersection of the extra activity chains or they are the start point or end point of multiple activities. As long as the date of milestone in start or end can be controlled, then the shipbuilding schedule can be basically controlled.

![Figure 2. Relations of activity chains and milestones.](image)

Under the DAS mode, there are usually 14 Milestones, which are Contract Signing(C/S), Steel Cutting(S/C), Keel Laying(K/L), After part Erection(A/E), Sighting, Main engine Erection(M/E), Accommodation Erection(AC/E), Forward part Erection(F/E), generator Engine test(G/T), Boiler Test, Launching(L/C), Main Engine Mooring Trial(M/T), Sea Trial(S/T), Light Weight Measurement(L/M), and Delivery(D/L). Their relations are showed in Figure 3.
Among these Milestones, the Contract Signing and Delivery cannot be changed, due to the contract. They are the start and end points of the whole schedule. Date of other Milestones are determined respectively based on these two milestones. Therefore, the essence of the shipbuilding enterprise for controlling the Milestones is to control the time interval between other Milestones and with these two. Shipbuilding enterprise usually takes the time intervals between other 12 Milestones and these two milestones as the controlled objects. Among these milestones, signing of contract, Steel Cutting, Keel Laying, Launching, and Delivery have big impact on the usage of production resources, they are the emphasized controlled objects of the shipbuilding enterprise. Table 1 shows the interval time between every two milestones in these 14 shipbuilding milestones.

<table>
<thead>
<tr>
<th>S/C</th>
<th>K/L</th>
<th>A/E</th>
<th>S/T</th>
<th>R/S</th>
<th>M/E</th>
<th>AC/E</th>
<th>F/E</th>
<th>G/E</th>
<th>B/T</th>
<th>L/C</th>
<th>M/T</th>
<th>S/T</th>
<th>D/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>KP</td>
<td>PW</td>
<td>ZF1</td>
<td>ZF2</td>
<td>ZF3</td>
<td>ZL1</td>
<td>ZL2</td>
<td>FL</td>
<td>ZF</td>
<td>ZL</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>KX</td>
</tr>
<tr>
<td></td>
<td>KX</td>
<td>ZF1</td>
<td>ZF2</td>
<td>ZF3</td>
<td>ZF1</td>
<td>ZF2</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>KJ</td>
</tr>
<tr>
<td></td>
<td>PX</td>
<td>ZF1</td>
<td>ZF2</td>
<td>ZF3</td>
<td>ZF1</td>
<td>ZF2</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td>ZF</td>
<td></td>
</tr>
</tbody>
</table>

Milestones Takt Time Design and Application in The DAS

It may not be so effective only by controlling the dates of milestones for the DAS enterprise. Plan and design milestone production takt time is the best way to make the shipbuilding production more efficiency [6]. The Milestones takt time of the DAS should be designed in two ways. One is to design the reasonable milestone time intervals and multiple projects milestones time intervals considering the working loads of various production resources. Another is to design the schedule of constraint resources. Such designed Milestones interval times can be called milestones takt time of the DAS. When conducting load balancing, the resource demands of the activities on the critical production chains should be meet in the first place. Next the date of all the milestones should be decided. And try to balance the production resource loads by allocating the resource to those activities which on the non-critical production chains.
For the DAS enterprise, labor force is the largest variable resource. Therefore, it is often used to analyze the shipbuilding productivity. As figure 4 shows, the labor force working load can roughly reflect all the resources working loads condition.

Figure 4. The record of labor distribution of container vessel.

If the enterprise superposes the 4 ship’s labor force distribution curves, labor force load balancing distribution will be achieved. The production milestones interval of each ship obtained on this basis can be used as the milestones takt time for the constructing of the same type and similar type ships in the future. Figure 5 shows the milestones takt time design procedure and following three steps are most important in the procedure.

(1) Establish the intact activity chains network and allocate resource initially.
(2) Identify the critical chains and find the highest quantity of all resource which all the activities demand for.
(3) Adjust the standard and end time on the non-critical chains to make the total use quantity be equal and greater than the peak value of total resource quantity demanded by the critical chains.

Constraint resource is the bottleneck which determines the output of shipbuilding. Maximal use of the constraint resource is one of the most important way to increase the output for the shipbuilding enterprise. The takt time of constraint resource design can be designed by following steps:
(1) Establish multiple ships erection network plan, and identify critical activities chain and constraint resources.

(2) Confirm the minimum use cycle of each type of constraint resource as the takt time of this resource according to the production process of each ship.

(3) Make takt time of various production resources as the minimum time unit to reschedule multiple ships erection network plan and strive to make the use of constraint resource successive and then confirm the date of each milestone according to this.

When different products use the same constraint resource simultaneously, the enterprise can make these products has a same time for constraint resource by adapting the use of other matched non-constraint resources.

**Milestones Takt Time Application and Empirical Analysis**

In those shipbuilding enterprises which don’t consider milestone takt time, the interval of milestones takt time is generally designed by analyzing the historical statistical data. When the market environment doesn’t allow the enterprise to receive orders according to its own plan, it has to adjust the milestones time intervals according to the market demand. Figure 6 shows the 3 years records of a dock production line in a Chinese DAS enterprise. In this dock production line, the ships were built in parallel and series construction mode. In this mode that two complete ships (for launching) and two half ships (for floating and to be built in the next round with complete ones) in one dock gate open circle. We use the 9 ships (container vessels, VLOCS, and bulk cargo carriers) as example to simulate and analyze milestones takt time, to prove the feasibility and necessity of application of milestone takt time in the final assembly shipbuilding production process.

![Figure 6. Record of labor force distribution of a dock production line.](image)

As labor force is the biggest variable resource, we make labor force as the objects to analysis the production balancing result. There are two features of the labor force distribution of the shipbuilding enterprise without considering milestones takt time. One feature is unbalance on single product in each stage and another one is unbalance on the whole human resource. In this case, milestones takt time design can be done with two steps. One step is to balance the labor load of each stage, and another step is to balance the whole labor force load by milestone interval. The result after balancing can be seen from figure 8.

Among which, the time period from the 13th to the 49th is the holiday of Spring Festival which is a little bit long and labor force is lack in this period so that it cannot be
balanced. Labor force of each ship is balanced on other time periods with increased 10 days for the dock cycle from 11th to 17th time period. Its result is shown in figure 7.

![Figure 7. The labor force distribution by using milestones takt time.](image)

After balancing, no matter any working stage or the overall work load are relative balanced, non-value labor input is become small obviously. The working load will be balanced if take the these milestones time intervals as the milestones takt time and every work stage will have a balanced production by designing their takt time based on these milestones takt time.

| Table II. MILESTONES TAKT TIME AFTER BALANCING. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| K/L-L/C         | K/L-A/E         | K/L-F/E         | A/E-L/C         | F/B-L/C         |
| 114             | 55              | 55              | 59              | 21              |

CONCLUSION

Designing and applying the milestone takt time is necessary and possible for a DAS enterprise. By designing and applying milestones takt time, the DAS enterprise can achieve relative balanced working load of production resources, improving production efficiency. Using of milestones takt time shall be the foundation of each production stage. It is the foundation of achieving single pipeline of DAS, and improving the productivity of the whole shipbuilding enterprises.

REFERENCES