Research on adaptive ship type for new channel of Three Gorges Project

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Abstract—Under the background that ships waiting for locks is becoming normal and increasingly intensified, the need to build a new channel of Three Gorges to enhance the navigability of the golden waterway of the Yangtze River is very urgent. The construction of new channel ship locks will inevitably involve the coordination of the new channel representative ship types and existing ships and ship locks and joint scheduling. This article studies the rules of necessary freight rate (RFR), energy efficiency design index (EEDI), transportation efficiency with the length and the width of the ship based on the limitation of channel and lock on the main dimensions of ships. The main dimension series of representative ship types suitable for the new passage of the Three Gorges Project are put forward.

1. RESEARCH CONDITION SETTING OF ADAPTIVE SHIP TYPE FOR THREE GORGES NEW CHANNEL

(1) The construction plan of the Three Gorges New Channel is to build a new shipping channel on the basis of the existing hub, and the existing ship lock facilities do not constitute a limiting factor for the enlargement of ships. Considering that the construction of the new channel in the future will inevitably involve the issue of joint scheduling, so the scale of the new channel on behalf of the ship type should be coordinated with the existing ships and locks. The scale of large ships should be able to take into account the existing navigation facilities as much as possible.

(2) According to the real ship test data, after the existing three gorges permanent shiplock floating bollards are completely reconstructed, large ships can safely pass through the lock when the displacement is controlled at about 9000 tons through load reduction, and the corresponding cargo capacity is about 6000 tons. Taking the current allowable draft of 4.3 m as the control standard, the modified floating bollards can meet the requirements of 10000 ton cargo ships passing through the Three Gorges Lock.

(3) Considering the limitation of the existing loading and unloading equipment on the ship width of 22m in the middle and upper reaches of the wharf, the lock width of the Three Gorges New Channel is 40m as a constraint[1]. 22m can be used as the control width of the new channel to represent the ship type (the ship with the width of 22m can be combined with the ship with the width of 16.3m[2]).

(4) Considering the current situation and planning of the channel, the draft of the ship in the future should meet the requirements of the depth of 6m channel, so as to reserve space for the development of ships after the improvement of other conditions in the future. The height above the waterline of the ship shall not exceed the clearance height limit of 18m required by the lock.
2. EFFECT OF DIFFERENT CHANNEL CONDITIONS ON SHIP TYPE

According to the depth of navigation maintenance, the Yangtze River waterway can be divided into three sections: Shanghai ~ Wuhan, Wuhan ~ Yichang, and Above the Three Gorges Dam ~ Chongqing. Among them, the Shanghai ~ Wuhan channel is above 6m all the year round, and the Dam ~ Chongqing channel is above 4.5m all the year round. At present, the main bottleneck of navigation is in the Section of Wuhan ~ Yichang. At present, the lowest navigable water depth of The Wuhan-Yichang section is 3.5m, which will be increased to 4.5m in the medium term and 6m in the long term[3]. According to the technical and economic performance of ships under different channel conditions, the curve chart of each index varying with the length and width of the ship is drawn as follows.

Figure 1 RFR variation pattern with length and width of ships

Figure 2 EEDI variation pattern with length and width of ships

Figure 3 Transportation efficiency variation pattern with length and width

It can be seen from the calculation results that the different channel conditions have a certain impact on the optimal ship type scale, but overall, the impact on the range of the preferred captain is not as significant as the impact on the range of the preferred ship width. Generally, the length of the ship is more reasonable from 110 to 135m, and the width of the ship is not less than 20m. With the improvement of the channel water depth conditions, it is more appropriate to take a larger ship width (within the calculation range).
3. DEMONSTRATION OF NEW CHANNEL ADAPTING SHIP TYPE

Taking into account many factors such as the dominant transportation market and the existing infrastructure and supporting facilities, the following new channel design typically represents the ship type of bulk carriers that dominate the market for research and demonstration. According to the existing ship operation statistics, required freight rate (RFR), energy efficiency design index (EEDI), cargo capacity and other main indicators with the length and width of the ship are drawn in isoline [4]. From the perspective of RFR-EEDI, the length of 110-130m is more reasonable under the condition of "645" channel.

![Figure 4 Contour diagram of main indexes changing with the length and width of ships](image)

![Figure 5 EEDI～RFR solution set and non-inferior solution](image)

Figure 5 shows the deterioration degree of each index when the ship width is limited by 22m and 19.2m. It can be clearly seen from the figure: when the ship width is limited by 22m and 19.2m, the corresponding ship form schemes of non inferior solution set are worse than those without restriction; within the calculation range, some better ship form schemes with 22m ship form restriction are basically close to those without restriction; the ship type schemes corresponding to noninferior solution set of 22m ship width restriction are obviously better than those of 19.2m, both of which are better than three Gorges ship types.
Figure 6 RFR ~ EEDI non-inferior solution set corresponding to the total length and width of the ship

It can be seen from Figure 6 that when the channel state is "645", corresponding to the non-inferior solution set, the length of the ship should be greater than 115m within the calculation range.

![Corresponding scale combination of non-inferior solution set (6.0-4.5-4.5)](image)

Figure 7 Relative deterioration degree of indicators under different ship width restrictions

![Relative deterioration degree of index under different ship width limitation](image)

It can be seen from figure 8 that when the channel state is 6.0-3.5-4.5, the length of the corresponding non inferior solution set should not exceed 135m within the calculation range.

4. CONCLUSION

Based on the above discussion, various situations are summarized as shown in Table 1.

| Considerations | Channel Conditions |
|----------------|-------------------|
|                | 6.0-3.5-4.5(m)    | 6.0-4.5-4.5(m)    |
|                | Length(m) | Width(m) | Length(m) | Width(m) |
| RFR            | 110-135   | 21-24    | <=135     | B>=22    |

Table 1 STRUCTURAL STRESS MEASURING POINTS
EEDI >=120 22-25
Transport efficiency >=130 22-25
RFR-EEDI 110-115 23-24 110-130

Non Inferior solution

| Width Limited 22m | Length Limited 150m |
|-------------------|---------------------|
| Width Limited 19.2m | Length limited 150m |
| No limited | <=135 >=24 |
| Width Limited 22m | 110-196 |
| Width Limited 19.2m | 108-194 |
| 110-117 | 24 |
| 140-150 | |
| 110-150 | 24.2 |
| 128-150 | 24.4 |
| 136-150 | 24.6 |
| 144-150 | 24.8 |

On the basis of the above conclusions, the scale series of representative ship types are formulated based on the following principles:

1) The length of the scale series is bounded by 135m;
2) Considering the process of ship type development, we need to take into account the existing conditions and future planning, and set up a 22m width series;
3) Considering the coordination of the scales, ships with a width of less than 22m should be compatible with the existing scale series as far as possible;
4) In line with the principle of reducing grades, the ship width series should be reduced if the economic performance is not significantly different. More than 22m, a 25m wide ship is set, which can meet the needs of multi-purpose containers.

Based on the above analysis and demonstration, the final recommended representative ship type scale series is shown in the following table[5].

| Number | Width (m) | Length (m) | Reference design draft (m) | Reference tonnage (t) | Remarks |
|--------|-----------|------------|---------------------------|----------------------|---------|
| 1      | 16.3      | 82~88      | 4.3~5.5                   | 3500~4500            | Coordinate with cargo-35 of Yangtze River ship type |
| 2      | 16.3      | 90~105     | 4.3~5.5                   | 4000~6500            | Coordinate with cargo-36 of Yangtze River ship type |
| 3      | 16.3      | 125~130    | 4.3~5.5                   | 5500~7500            | Coordinate with cargo-37 of Yangtze River ship type |
| 4      | 19.2      | 110~135    | 5.5                       | 7500~9000            | Including 19.2m scale series of 2010 Edition[6] |
| 5      | 22        | 110~135    | 5.5                       | 8500~10500           |         |
| 6      | 25        | 110~135    | 5.5                       | 9000~12000           |         |

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