Research on the mooring arrangement of a small ship against typhoon in harbor

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Abstract. Based on the time domain coupled model, the feasibility of a small vessel moored at the berth against typhoon is studied using the numerical simulation method. Considering the nonlinear characteristics of mooring lines and fenders, the dynamic response characteristics of the coupled system of ship, mooring lines and fenders are analyzed for different mooring arrangement. The reasonable and feasible layout is recommended for typhoon protection, and the influence law of cable load with different pretensions is discussed. The calculation results show that: when the number of mooring lines is increased to 16 and 422 mooring arrangement is adopted, then the mooring safety can be met under the survival condition. At the same time, it is found that the cable load does not decrease with the increase of pretension, but has a trend of decreasing first and then increasing. Therefore, it is necessary to select a reasonable pretension during mooring operation.

1. Introduction

Typhoon is a weather system with strong destructive force on the tropical ocean surface and a kind of marine disastrous weather, which seriously threatens the safety of ships on the sea, and the threat to the ships working in the port should not be underestimated [1]. There are three methods to prevent the operation of ships in the port against typhoon: first, mooring at the wharf; second, anchoring at the anchorage away from the port; third, preventing typhoon at sea navigation. The success or failure of ship's anti typhoon work is related to the safety of life and property of ships and personnel. Many scholars have carried out the discussion and Research on this aspect. Yuan Zhangxin et al. [2] studied the typhoon proof mooring scheme for large bulk carriers in the Yangtze River estuary area; Xu Zhiwei [3] analyzed the force situation of outfitting ships at the wharf through formula, and put forward the mooring scheme for 30000 DWT ships; Yue Zhijun et al. [4] and Liu Chengyong et al. [5,6] Xu Yuan et al. [7] carried out research on typhoon resistant mooring scheme for large ships; Wei Xin et al. [8] calculated PSV (platform supply) for offshore engineering ships Yang Yonggang, et al. [9] analyzed the typhoon prevention scheme of a certain unpowered platform supply ship by using numerical simulation software, and verified the cable stress during mooring; Lei Zhuzhi [10] calculated and evaluated the typhoon prevention and control scheme of the deep-sea mining ship, and in practice, the ship withstood the influence of Typhoon "Maria", which proved that Discuss the feasibility of the scheme. Traditional ship types such as bulk carriers, oil tankers and ships are mostly selected as the research objects in the above studies. The mooring scheme for small barges is less. Considering that mooring at wharf is also an important typhoon prevention method, it can effectively avoid the situation that the typhoon cannot leave the port due to insufficient warning time before typhoon. Therefore, this paper makes a detailed study on the specific small barge combined with the wharf layout scheme, to provide reference for the safe berthing of ships.
2. Simulation model

2.1. Ship
The main dimensions of the ship used in the calculation are shown in Table 1, and the mesh model is shown in Figure 1.

| Length | Breath | Full Draft | Ballast Draft | Depth | Cog | Rxx | Ryy |
|--------|--------|------------|---------------|-------|-----|-----|-----|
| 90 m   | 26 m   | 3.5 m      | 2.62 m        | 6.85 m| 5.28 m | 9.1 m | 22.5 m |

![Figure 1 Mesh model of the ship](image)

![Figure 2 Performance curve of cable and fender](image)

2.2. Cables and Fenders
The calculated cable material is polyamide double braided cable with diameter of 38mm, the minimum breaking force is 210kN and the safe working load is 105kN. The fender type is SANP E1.1, with a design reaction force of 1081 kN and a spacing of 6.6m. The performance simulation curves of cable and fender are shown in Fig. 2. The mooring arrangement of the ship is shown in Figure 3. It is necessary to check whether the arrangement meets the requirements of survival conditions.

2.3. Calculation Cases
Based on the location of the project, 35 typhoons were selected and the wave parameters (including wave height, wave direction and period) at the berthing were obtained. Offshore crosswind, onshore crosswind and offshore oblique wind are selected as the representative wind directions. The calculation cases is shown in Table 2.
3. Calculation Analysis

3.1. Calculation of original mooring layout
The hydrodynamic parameters calculated in frequency domain are imported into Ariane software, and the comprehensive effects of wind, wave and current environment are considered. According to the mooring arrangement scheme in Fig. 3, the time domain analysis of survival condition under mooring condition is carried out, and the results of mooring load and ship motion are obtained. Finally, the maximum statistical value is obtained according to the 3-hour regression period. The calculation results are shown in Table 3. The pre tension of each cable is set as 15% of MBL, i.e. 31.5 kN.

Table 3. Check results for survival condition

| Load condition | Full load | Ballast |
|----------------|-----------|---------|
| Wind direction | W         | E       | NW |
| Head (kN)      | 121       | 119     | 154 |
| Spring fore (kN)| 183 | 132     | 142 |
| Spring aft (kN)| 179 | 177     | 213 |
| Stern (kN)     | 130       | 93      | 100 |
| Fender load (kN)| 12  | 13      | 12  |

It can be seen that, most of the cables exceed the safe allowable load, and the original mooring layout does not meet the requirements of the survival conditions. Therefore, on the basis of the original layout, the optimal layout as shown in the figure is proposed.

3.2. The optimal layout analysis
According to the characteristics of the ship's load, the load along the captain's direction is larger. It can be seen from the calculation results in Table 3 that the over standard of the inverted cable is more serious. Therefore, on the basis of the original layout, the number of mooring lines is increased. Firstly, the number of cables is increased to 14, and 322 type (3 head and stern cables, 4 spring fore and spring aft cables) and 421 (4 head and stern cables and 3 spring fore and spring aft) are used for calculation respectively. The calculation results show that, the cable load still exceeds the standard under these
layouts, and the longitudinal stiffness still needs to be increased. Therefore, in the final optimization layout 1, both head, stern cables and spring-fore, spring-aft cables are added. 422 layout mode is adopted, with a total of 16 cables, as shown in Fig. 4.

Table 4. Check results for survival condition (Trial layouts)

| Mooring layout | 322 | 421 |
|----------------|-----|-----|
| Wind direction | W   | E   | NW  | W   | E   | NW |
| Head (kN)      | 90  | 101 | 108 | 71  | 75  | 83 |
| Spring fore (kN)| 107 | 121 | 129 | 106 | 112 | 127|
| Spring aft (kN)| 81  | 68  | 65  | 80  | 71  | 70 |
| Stern (kN)     | 131 | 103 | 98  | 78  | 69  | 68 |

Figure 4 Optimal layout 1 (4:2:2)

Table 5. Check results for survival condition (optimal layout1)

| Load condition | Full load | Ballast |
|----------------|-----------|---------|
| Wind direction | W         | E       | NW  |
| Head (kN)      | 101       | 86      | 93  |
| Spring fore (kN)| 98        | 86      | 92  |
| Spring aft (kN)| 98        | 86      | 52  |
| Stern (kN)     | 89        | 70      | 63  |
| Fender load (kN)| 15        | 19      | 12  |

It can be seen from Table 5 that, under the two loading conditions, the cable tension under three wind directions meets the safety requirements, and the load of each cable is less than 105kN, meeting the mooring requirements. However, there are cross cables in the arrangement, so the mooring arrangement is further optimized to avoid the cross of cables, which is conducive to the operation of field personnel. According to the arrangement of mooring bollards on the wharf, this paper puts forward the optimization scheme as shown in Fig. 5. The calculation results (see Table 6) show that under optimization scheme 2, the maximum load of the cable corresponding to full load occurs on the spring fore cable, which is 101kN, as shown in Figure 6.
Table 6. Check results for survival condition (optimal layout2)

| Load condition | Full load | Ballast |
|----------------|-----------|---------|
| Wind direction | W E NW W E NW |
| Head (kN)      | 85 74 82 53 41 61 |
| Spring fore (kN)| 101 86 96 58 42 68 |
| Spring aft (kN)| 63 53 57 51 57 56 |
| Stern (kN)     | 94 70 79 67 82 78 |
| Fender load (kN)| 11 15 12 9 21 9 |

Figure 6 Load time history for each cable (under the optimal layout 2 with wind direction W full load)

4. Conclusion
In order to ensure the feasibility and safety of typhoon prevention for small ships in harbor, the mooring safety verification is carried out in this paper. Based on the three-dimensional time-domain model, the dynamic response of the coupling system of ship, mooring lines and fenders is studied for
different mooring line layout schemes. The reasonable and feasible layout for typhoon protection arrangement is recommended. The main conclusions are as follows:

1) When the original mooring line arrangement is adopted, most of the cables suffer large load and the maximum cable tension reaches 213kN, which is far greater than the allowable safety load of the cable. Therefore, the mooring scheme must be optimized.

2) When the number of mooring lines is increased to 16, the 422 mooring layout can meet the mooring safety under survival conditions, that is, 4 head cables, 4 spring fore cables, 4 spring aft cables and 4 stern cables are used.

3) In practice, the layout of optimization scheme 1 and optimization scheme 2 can meet the requirements. If it is necessary to avoid the phenomenon of cable crossing, the layout form of optimization scheme 2 is preferred.

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References
[1] Xiao Weiyi Discussion on anti typhoon, China water transport, 2009, 9(5): 39-40.
[2] Yuan Xin Zhang, Tu Haiyang, Ding Linsen, Anti typhoon safety demonstration of h1002 mooring system [J]. Journal of Shanghai Institute of shipping science, Ministry of communications, 2004, 27(1): 14-33.
[3] Xu Zhiwei, Research and calculation of anti typhoon mooring method for ship for ship launched from shipyard [J]. Jiangsu ship, 2008,25(3): 1-4.
[4] Yue Zhijun, Gao Xinhua, Huang Tao, Discussion on the mooring method to defense typhoon for the large warships [J]. Ship and ocean engineering, 2007,36(1): 18-21.
[5] Liu Chengyong, Guo Guoping, Gan Langxiong, Safety research of typhoon preventing for large unpowered vessel moored alongside the wharf[J]. Ship and ocean engineering, 2009, 38(2): 156—159.
[6] Xu Yuan, Chen Yue, Ding Jian, Yang Ji angang, Mooring hawer system applicable to anti-typhoon mooring system for large non-powered vessels[J]. Port and waterway engineering, 2012,12(12): 14-16.
[7] Wei Xin, Wu Gongxin, Shi Danda, Yang Dongyan, Design and calculation analysis of anti-typhoon mooring plan for offshore ships[J]. Shipbuilding technology research,2017,6:42-47.
[8] Yang Yonggang, Ma Muyuan, Yao Zhan feng, Analysis of typhoon prevention scheme for mooring terminal of unpowered platform supply ship[J]. Jiangsu ship,2017,34(3): 22-31.
[9] Lei Zhuzhi, Anti-typhoon of sub-sea mining vessel at wharf[J]. Guangdong shipbuilding,2019,166(3): 86-89
[10] Bureau Veritas. Ariane8 User Guide.
[11] Chen Xiaobo, Flavia Rezende, S. Malenica, J.R.Fournier, “Advanced hydrodynamic analysis of LNG terminals,” Proceedings of the 10th International symposium on practical design ships ans other floating structures, USA, 2007,pp.224-233.