A study on the structural characteristics and shape of outfitting equipment support in 300K DWT crude oil tanker

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Abstract. With the increase in the size and speed of recently built vessels, the output and speed (rpm) of propulsion or generation engines have continuously increased, and the high-output, high-speed engine has become a major cause of excessive vessel noise and vibration. Accordingly, resonance occurs in the equipment and other outfitting equipment installed in a vessel, and thus, periodic requests for correction are received from ship owners or officers. In this study, to resolve this problem, supports that stably fix the outfitting equipment installed in the engine room of a very large crude oil tanker and provide protection from physical or external shock were classified into seven types for three kinds of widely used standard shapes, and an optimized shape was developed and suggested by analyzing the structural characteristics of the shapes of the supports (the maximum bending moment, maximum bending stress, and maximum deformation) using DNV NATICUS HULL 3D BEAM, a structural analysis program, so that it could be used for the outfitting design of a vessel.

[KW] Vessel, Maximum bending stress, Maximum bending moment, Maximum deformation, Outfitting equipment, Support, Structural analysis

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1. Introduction
A vessel has an average life of about 25.3 years, and the performance of its installed devices or equipment should also be continuously maintained and managed until the end of the life of the vessel. With the increase in the size and speed of recently built vessels, the output and speed (rpm) of propulsion or generation engines have continuously increased and have become major causes of excessive vessel noise and vibration \cite{1,2}. Accordingly, resonance occurs in the equipment and other outfitting equipment installed in vessels, and such equipment frequently malfunctions and fails. Therefore, in this study, to resolve this problem, the types, shapes, and structural characteristics of the supports that safely fix the outfitting equipment installed in vessels were investigated, and a standard was made for application to vessels \cite{3,4}.

2. Conception of support
A support is a device for attaching outfitting equipment, such as pipes, to a hull structure using various clamps and additional devices through extension, using angles, etc., to fix and support the outfitting equipment. Depending on the position and equipment for installation, the types of support can be classified into the deck mounting type, the wall mounting type, the ceiling mounting type, the vent duct type, and the cable tray type, as shown in Figure 1 \cite{5,7}.

![Figure 1. Various types of support](image)

3. Conditions for the structural analysis
The analysis was performed based on the shapes of the supports that are widely used in vessels (Figure 2), the types summarized in Table 2, and the conditions summarized in Table 1, using the NATICUS HULL (DNV) structural analysis program.

| Table 1. Model and Load condition |
|----------------------------------|
| Model | Fig. 2 |
| h | 3.0 m |
| b | 2.0 m |
| Members | 200x8+200x12(H) |
| Load (F) | 500 KN |

For convenient calculation, only a lateral load was applied

| Table 2. Type of supports |
|---------------------------|
| Ser. No. | Description |
| 1 | Basic support shape |
| 2 | Basic + horizontal lower support structure shape |
| 3 | Basic + horizontal middle support structure shape |
4. Analysis results

As shown in Figure 3, for Case 1 (the triangular shape), the maximum bending moment was 20 KNm, the maximum bending stress was 37 N/mm², and the maximum deformation was 5.74 mm; for Case 2 (the trapezoidal shape), 179 KNm, 339 N/mm², and 18.46 mm; and for Case 3 (the quadrilateral shape), 594 KNm, 425 N/mm², and 68.99 mm. When the maximum deformation of Case 1 (5.74 mm) was assumed to have been 100%, those of Case 2 and Case 3 were 321% and 1,202%, respectively. Figure 3 shows the changes in the conditions of Cases 1, 2, and 3.

| Case | Max. Bending Moment (KNm) | Max. Bending Stress (N/mm²) | Max. Deformation (mm) |
|------|---------------------------|-----------------------------|-----------------------|
| Case 1 | 20 | 37 | 5.74 |
| Case 2 | 179 | 339 | 18.46 |
| Case 3 | 594 | 425 | 68.99 |

Figure 3. Basic support shapes

As shown in Figure 4, for Case 1, the maximum bending moment was 19 KNm, the maximum bending stress was 37 N/mm², and the maximum deformation was 5.74 mm; for Case 2, 178 KNm, 338 N/mm², and 18.33 mm; and for Case 3, 402 KNm, 760 N/mm², and 67.98 mm. When the maximum deformation of Case 1 in Figure 3 (5.74 mm) was assumed to have been 100%, those of Case 1, Case 2, and Case 3 were 100%, 319%, and 1,184%, respectively. Figure 4 shows the changes in the conditions of Cases 1, 2, and 3.

| Case | Max. Bending Moment (KNm) | Max. Bending Stress (N/mm²) | Max. Deformation (mm) |
|------|---------------------------|-----------------------------|-----------------------|
| Case 1 | 19 | 37 | 5.74 |
| Case 2 | 178 | 338 | 18.33 |
| Case 3 | 402 | 760 | 67.98 |

Figure 4. Basic + horizontal lower support structure shape
As shown in Figure 5, for Case 1, the maximum bending moment was 25 KNm, the maximum bending stress was 47 N/mm², and the maximum deformation was 5.65 mm; for Case 2, 137 KNm, 259 N/mm², and 12.69 mm; and for Case 3, 275 KNm, 519 N/mm², and 38.08 mm. When the maximum deformation of Case 1 in Figure 3 (5.74 mm) was assumed to have been 100%, those of Case 1, Case 2, and Case 3 were 98%, 221%, and 675%, respectively. Figure 5 shows the changes in the conditions of Cases 1, 2, and 3.

|            | Case 1     | Case 2     | Case 3     |
|------------|------------|------------|------------|
| Max. Bending Moment | 25 KNm     | 137 KNm    | 275 KNm    |
| Max. Bending Stress  | 47 N/mm²   | 259 N/mm²  | 519 N/mm²  |
| Max. Deformation    | 5.65 mm    | 12.69 mm   | 38.08 mm   |

Figure 5. Basic + horizontal middle support structure shape

As shown in Figure 6, for Case 1, the maximum bending moment was 37 KNm, the maximum bending stress was 69 N/mm², and the maximum deformation was 5.59 mm; for Case 2, 187 KNm, 345 N/mm², and 12.26 mm; and for Case 3, 308 KNm, 581 N/mm², and 31.35 mm. When the maximum deformation of Case 1 in Figure 3 (5.74 mm) was assumed to have been 100%, those of Case 1, Case 2, and Case 3 were 97%, 213%, and 541%, respectively. Figure 6 shows the changes in the conditions of Cases 1, 2, and 3.

|            | Case 1     | Case 2     | Case 3     |
|------------|------------|------------|------------|
| Max. Bending Moment | 37 KNm     | 187 KNm    | 308 KNm    |
| Max. Bending Stress  | 69 N/mm²   | 345 N/mm²  | 581 N/mm²  |
| Max. Deformation    | 5.59 mm    | 12.26 mm   | 31.35 mm   |

Figure 6. Basic + diagonal support structure shape

As shown in Figure 7, for Case 1, the maximum bending moment was 1,000 KNm, the maximum bending stress was 1,888 N/mm², and the maximum deformation was 162.5 mm; for Case 2, 750 KNm, 1,416 N/mm², and 90.23 mm; for Case 3, 500 KNm, 944 N/mm², and 47.61 mm; and for Case 4, 73 KNm, 138 N/mm², and 20.45 mm. When the maximum deformation of Case 4, 20.45 mm was assumed to have been 100%, those of Case 1, Case 2, and Case 3 were 795%, 441%, and 233%, respectively. Figure 7 shows the changes in the conditions of Cases 1, 2, 3, and 4.

|            | Case 1     | Case 2     | Case 3     | Case 4     |
|------------|------------|------------|------------|------------|
| Max. Bending Moment | 1,000 KNm  | 750 KNm    | 500 KNm    | 73 KNm     |
| Max. Bending Stress  | 1,888 N/mm²| 1,416 N/mm²| 944 N/mm²  | 138 N/mm²  |
| Max. Deformation    | 162.5 mm   | 90.23 mm   | 47.61 mm   | 20.45 mm   |

Figure 7. Vertical + inclined support height structure shape
As shown in Figure 8, for Case 1, the maximum bending moment was 1,500 KNm, the maximum bending stress was 2,832 N/mm², and the maximum deformation was 372 mm; for Case 2, 500 KNm, 944 N/mm², and 79.71 mm; for Case 3, 500 KNm, 944 N/mm², and 47.61 mm; and for Case 4, 891 KNm, 1,684 N/mm², and 262.7 mm. When the maximum deformation of Case 2 (79.71 mm) was assumed to have been 100%, those of Case 1, Case 3, and Case 4 were 467%, 60%, and 329%, respectively. Figure 8 shows the changes in the conditions of Cases 1, 2, 3, and 4.

|                      | Case 1 | Case 2 | Case 3 | Case 4 |
|----------------------|--------|--------|--------|--------|
| Max. Bending Moment  | 1,500 KNm | 500 KNm | 500 KNm | 891 KNm |
| Max. Bending Stress  | 2,832 N/mm² | 944 N/mm² | 944 N/mm² | 1,684 N/mm² |
| Max. Deformation     | 372.7 mm (146.8) | 79.71 mm (30.8) | 47.61 mm (18.6) | 262.7 mm (103.8) |

**Figure 8. Vertical + inclined support base structure shape**

As shown in Figure 9, for Case 1, the maximum bending moment was 500 KNm, the maximum bending stress was 944 N/mm², and the maximum deformation was 47.61 mm; for Case 2, 500 KNm, 944 N/mm², and 41.183 mm; and for Case 3, 500 KNm, 944 N/mm², and 45.91 mm. When the maximum deformation of Case 1 (47.61 mm) was assumed to have been 100%, those of Case 2 and Case 3 were 86% and 96%, respectively. Figure 9 shows the changes in the conditions of Cases 1, 2, and 3.

|                      | Case 1 | Case 2 | Case 3 |
|----------------------|--------|--------|--------|
| Max. Bending Moment  | 500 KNm | 500 KNm | 500 KNm |
| Max. Bending Stress  | 944 N/mm² | 944 N/mm² | 944 N/mm² |
| Max. Deformation     | 47.61 mm (18.6) | 41.183 mm (16.3) | 45.91 mm (18.2) |

**Figure 9. Vertical + inclined support structure shape**

5. **Conclusion**

In this study, when a constant load was applied to outfitting equipment supports that are widely used in very large crude oil tankers, the structural characteristics of the shapes of the supports (i.e., the maximum bending moment, maximum bending stress, and maximum deformation) were examined and analyzed. As a result, the structural characteristics of the following seven typical types of support structure shapes were determined: the basic (triangular, trapezoidal, and quadrilateral) support shape in Figure 3; the basic (triangular, trapezoidal, and quadrilateral) + horizontal lower support structure shape in Figure 4; the basic (triangular, trapezoidal, and quadrilateral) + horizontal middle support structure shape in Figure 5; the basic (triangular, trapezoidal, and quadrilateral) + diagonal support structure shape in Figure 6; the vertical + inclined support height structure shape in Figure 7; the vertical + inclined support base structure shape in Figure 8; and the vertical + inclined support structure shape in Figure 9. The results of the experiment are as follows.

1) Among the seven types of shapes, the basic + horizontal middle support structure shape in Figure 5, which added a horizontal middle support to the basic (triangular, trapezoidal, and quadrilateral)
support shape in Figure 3, and the vertical + inclined support base structure shape in Figure 8 showed
the best performance.

2) In the case of a good support, the shape of the support determines the amount of the required
material in terms of the production cost, and the work load and productivity in the manufacturing
process should also be considered.

3) In the case of a good support, the shape of the support should be determined considering the
structural characteristics (e.g., the strength and rigidity) in terms of mechanics.

4) In the case of a good support, the support should be designed to satisfy the required structural
characteristics using the minimum amount of material and so that it can be easily manufactured in
terms of the prime cost.

6. Postscript
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