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VIBRATION OF VERY LARGE SHIP EXCITED BY MAIN ENGINE

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Ship global vibration and main engine excited resonance is studied. Added water mass is taken into consideration by virtual mass method. Main engine is one of the important excitation of ship vibration. Based on three dimensional finite element model of whole ship, the influence of main engine excitation (H overturning moment, X overturning moment and 4th vertical moment) on ship vibration is investigated. According to frequency analysis, vibration response of wheelhouse due to engine excitation is obtained. Evaluate vibration situation by the related criterion conditions. Added water mass can effect vertical natural vibration. Under excitation frequency of the 4th vertical moment, response due to the 4th vertical moment is larger. While above this frequency, response due to the H overturning moment is larger. H overturning moment leads to the largest acceleration. And the 4th vertical moment leads to the largest velocity.
Keywords: ship, main engine, added water mass, vibration

1. Introduction

The resonance of ship and ocean structure will lead to structure damage[1-3] and people uncomfortable. Floating ship is an elastic structure that can be forced to resonance. The increasing of ship displacement needs larger main engine. The periodic excitation from main engine is an important vibration source.

Ship's surrounding water influences vibration by taking the role of effective mass. Study on global vibration and its type can help judge the resonance condition and avoid low harmonic vibration. Larger ship can reduce the use cost. Output power of main engine increases with ship displacement. Main engine excitation raises together with output power. Ship resonance causes crew unformatable and structure fatigue damage and influences the electronic equipment precision. Investigate main engine excitation, important source of ship vibration, can help deepen understanding of this phenomenon.

In this paper, ship global vibration is analysed and resonance excited by main engine is studied. Ship resonance is evaluated by the corresponding criterion condition.

2. Ship global vibration analysis

Ship vibration is one kind of multi-freedom resonance, which can be described by natural frequency and mode. Ship vibration is a combination of these modes. Figure 1 to Figure 9 are ship natural modes. Global mode is a combination of these natural modes. To what extent will added water influence natural mode is discussed.

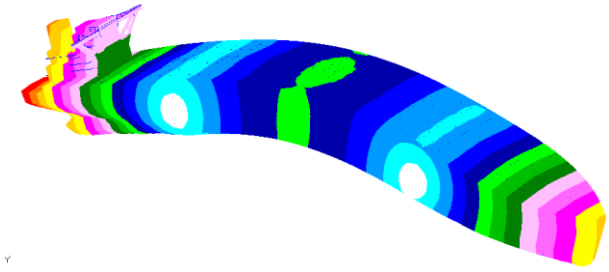

Figure 1:The 1st order vertical vibration mode

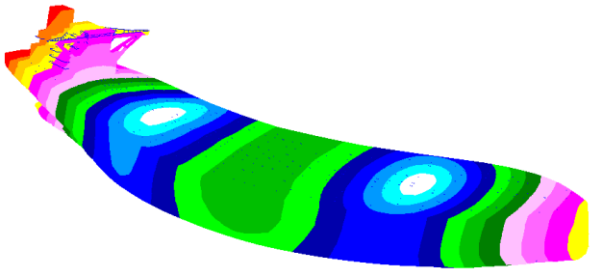

Figure 2:The 1st order horizontal vibration mode

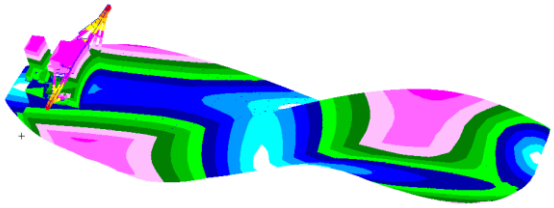

Figure 3:The 1st order torsional vibration mode

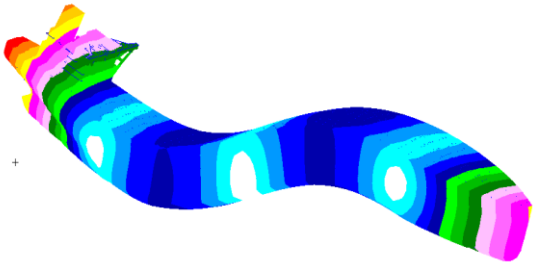

Figure 4:The 2nd order vertical vibration mode

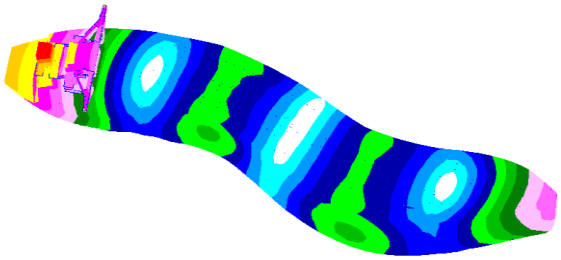

Figure 5:The 2nd order horizontal vibration mode

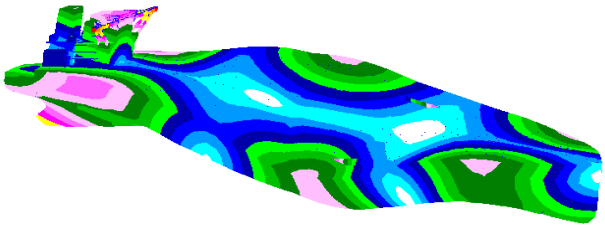

Figure 6:The 2nd order torsional vibration mode

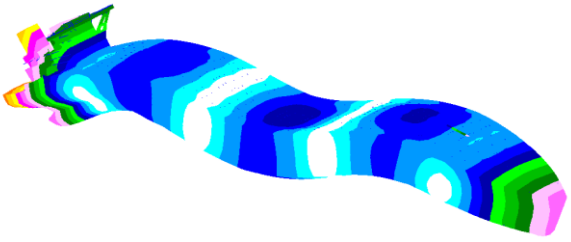

Figure 7:The 3rd order vertical vibration mode

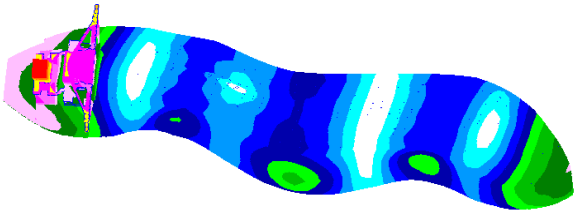

Figure 8:The 3rd order horizontal vibration mode

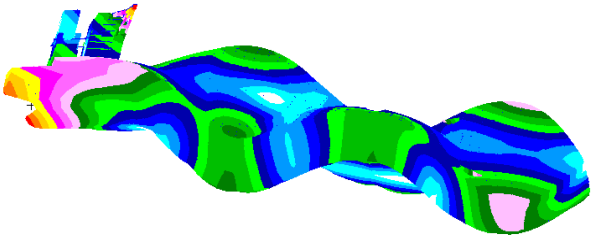

Figure 9:The 3rd order torsional vibration mode

Ship sailing in the sea is surrounded by the water. The water moving with the ship is called added water, which can effect ship vibration modes. The influence of added mass is taken into consideration by virtual mass method. As one kind of fluid-structure interaction method, virtual mass method imposes an added mass matrix to analyse the effect of fluid on structure. Equation for mode calculation taking fluid-structure interaction into consideration can be expressed as:

$$[M+m]\cdot[\ddot{s}]+[K+k]\cdot[s]=\{0\} \quad (1)$$

Where, M is mass matrix of the structure, K is the stiffness matrix of the structure, m is the added mass matrix of the fluid, k is added stiffness matrix of the structure, s is displacement vector.

For marine structure vibration, the added stiffness of fluid is much smaller than that of the structure. Thus, ignore the added stiffness and only take the added mass of fluid into motion equation.

错误!书签自引用无效。 lists the influence of added water. Natural frequency of wet mode is different from that of dry mode. The influence of added water on vertical vibration is remarkable.

Table 1：The differences between wet modes and dry modes.

Natural mode type	Differences
1st order vertical natural mode	48.7%
1st order horizontal natural mode	17.8%
1st order torsional natural mode	13.6%
2nd order vertical natural mode	43.0%
2nd order horizontal natural mode	17.3%
2nd order torsional natural mode	18.6%
3rd order vertical natural mode	39.6%
3rd order horizontal natural mode	16.9%

3. Vibration response evaluation of main engine

Initial forces of main engine parts generated during operating come into unbalance forces and moments. Besides, gas pressure and inertia force from burning fuel in cylinder lead to overturning moment. Moving phases between cylinders generate X overturning moment, H overturning moment. Excitation frequency for the 4th vertical moment is 4.2 Hz. Excitation frequency for the H moment is 7.4 Hz. Figure 10 is the finite element model of the main engine. The couple between engine and ship vibration is analysed. Figure 11 is the acceleration response excited by the main engine. Figure 12 is the velocity response excited by the main engine. Under frequency of 4.2, the response excited by the 4th vertical moment is largest. Above frequency of 4.2, the response excited by the H moment is largest.

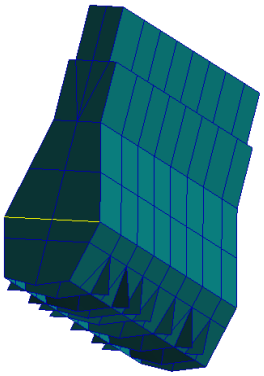

Figure 10: Finite element model of the main engine

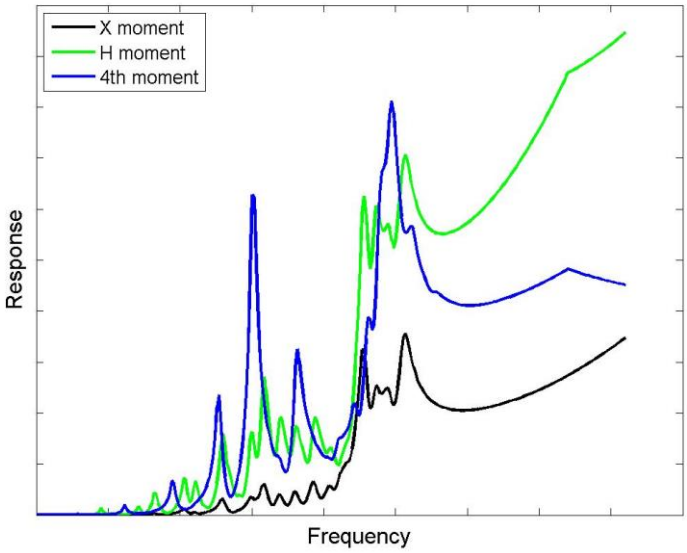

Figure 11: Acceleration response excited by the main engine

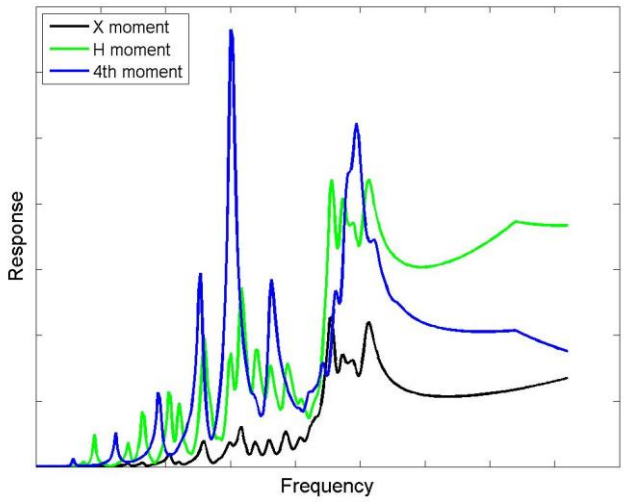

Figure 12: Velocity response excited by the main engine

'Mechanical Vibration and Shock-Guidelines for the overall Evaluation of Vibration in Merchant Ships' [4] proposes the corresponding evaluation criterion for frequency 1-100 Hz and length between perpendiculars 100 m(Table 2). This way is an important method for vibration assessment of working and living place. Vibration under lower bound is preferable. Vibration between lower and upper bound is acceptable. Vibration larger than upper bound is harmful.

Table 2： Evaluation of vibration

Frequency range	1-5Hz	5-100Hz
Upper bound	Maximum acceleration 285mm/s^2	Maximum velocity 9mm/s
Lower boudn	Maximum acceleration 126mm/s^2	Maximum velocity 4mm/s

The vibration response of the intersection between wheelhouse and fore hull is studied for two reasons:

1) The vibraton of this place is usually larger and can be regarded as a typical case for vibration analysis;

2) The vibration of this point can reduce crew comfort.

Table 3 is vibration of wheelhouse under different main engine excitation. All vibration responses meet the satisfactory of vibration criterion. Acceleration response due to H overturning moment is largest. Velocity response due to 4th vertical moment is largest.

Table 3：Vibration of wheelhouse

Main engine excitation	Acceleration amplitude（mm/s^2）	Velocity amplitude（mm/s）
H overturning moment	19.02	0.44
X overturning moment	7.21	0.23
4th vertical moment	16.57	0.67

4. Conclusions

Ship global vibration and the influence of main engine are analysed. Added water mass can inefficiently effect the calculated result of ship natural mode. Calculate ship natural mode should take the added water mass into consideration. H overturning moment leads to the largest acceleration response. The 4th vertical moment excites the largest velocity response. Ship vibration meet the satisfactory of 'Mechanical Vibration and Shock-Guidelines for the overall Evaluation of Vibration in Merchant Ships'.

ACKNOWLEDGEMENT

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