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A STUDY ON THE LOW VIBRATION DESIGN OF 4,100 TEU CONTAINER CARRIER SUPERSTRUCTURE USING THE STRUCTURAL INTENSITY ANALYSIS

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Abstract
The structural intensity analysis, which calculates vibration energy flow from vibratory velocity and internal force of structures, can give information on source power, dominant transmission path and dissipation of vibration energy. In this study, the structural intensity analysis is carried out for a 4,100 TEU container carrier. The purpose is to seek for the most efficient way to change the vibratory response of superstructure by the structural modification using the information of structural intensity. From the various numerical studies, it comes to a conclusion that the structural modification for dominant transmission path of vibration energy from the excitation source to the superstructure is one of the most effective methods in changing the natural frequency and its resonant response of the superstructure.

INTRODUCTION

Recently, it is on an increasing trend that the vibration criteria required by the ship owners are getting severer, not only for the consideration of ship durability but also for the more comfortable habitability of crew and passenger. Therefore, most of shipyards have carried out the conventional vibratory response analyses for a ship structural design using F.E model that takes too much time in order to construct ship which satisfies the criteria of the ship vibration. However, in case that troublesome vibration is expected from the analysis, it is very difficult to know how to effectively modify the design to reduce the ship vibratory response with the only results for the natural frequency and the vibratory response.

On the other hand, several studies for the structural intensity analysis[1-7], which calculates the vibration energy flow from the vibratory velocity and the internal force of the structure, have been carried out. The structural intensity analysis can give information on the source power, the dominant transmission path and the dissipation of the vibratory energy. Hence, from the structural intensity analysis, we can get the additional information on vibration characteristics of the structure. But it is difficult to find the studies which suggest how to utilize the results of the structural intensity analysis in the low vibration design of the structure.

In this study, the structural intensity analyses as well as the conventional vibratory response analyses have been carried out for a 4,100 TEU container carrier in case of the unit excitation in vertical on hull surface above propeller top and the unit excitation in longitudinal on thrust block, which are the major excitation forces to the longitudinal vibration of the superstructure. From the analyses for the original and the modified designs of the ship structure, it comes to a conclusion that the structural modification for the dominant transmission path of the vibration energy from the excitation source to the superstructure is the one of the most effective methods in changing the natural frequencies and its resonant response of the superstructure.

VIBRATION ANALYSIS FOR A CONTAINER CARRIER

In this study, the free vibration analysis, the frequency response analysis and the structural intensity analysis have been carried out for a 4,100 TEU container carrier at the designed draft. The purposes are to find the transmission characteristics of the vibration energy from the excitation source to the superstructure and to evaluate the effect of the structural modification on the natural frequency and the vibratory response of the superstructure. The main particulars and the loading condition of the concerned vessel are shown in Table 1.

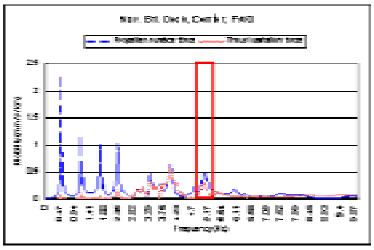
Table 1 Main particulars and loading condition of the container carrier

Length (overall)	:	About 263.33 m
Length (between the perpendiculars)	:	251.88 m
Breadth (moulded)	:	32.20 m
Draft (scantling)	:	19.30 m
Displacement	:	67,746.50 ton
Main engine type	:	MAN B&W 8K90MC-C
MCR(maximum continuous rating)	:	49,000 BHP x 104.00 RPM
NCR(normal continuous rating)	:	44,712 BHP x 100.40 RPM
No. of propeller blade	:	5EA

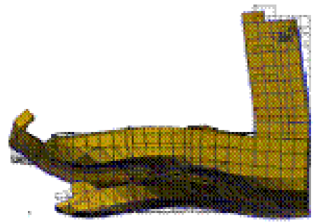
Target resonant response to reduce the superstructure longitudinal vibration

The propeller surface force acting on the hull surface above the propeller top in vertical and the thrust variation force acting on the thrust block of the main engine in longitudinal are normally regarded as the dominant excitation sources for the superstructure longitudinal vibration of the container carrier. Fig. 1(a) shows the longitudinal frequency response functions at the navigation bridge deck of the superstructure due to the unit excitation of the propeller surface force and the thrust variation force.

The target of this study is to reduce the longitudinal resonant vibratory response of the superstructure at 5.141Hz, whose mode shape is shown in Fig. 1(b).



(a) Frequency response function at the navigation bridge deck(longitudinal direction)

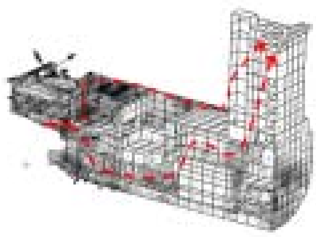


(b) Mode shape of the superstructure longitudinal vibration at 5.141Hz

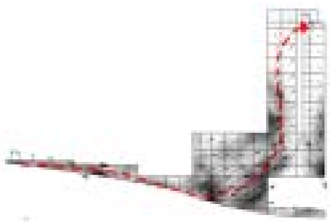
Fig. 1 Longitudinal frequency response functions for the propeller surface force and the thrust variation force and relevant mode shape of the superstructure

Structural intensity analysis in case of the excitation in vertical on hull surface above propeller top

The results of the structural intensity analysis in case of the unit excitation in vertical on the hull surface above propeller top at 5.141Hz are shown in Fig. 2. It is evaluated that the two dominant transmission paths of the vibration energy to the superstructure are the internal longitudinal bulkhead in the engine room via the longitudinal girder in the aft body and the upper deck via the outside longitudinal bulkhead in the engine room.



(a) Aft body

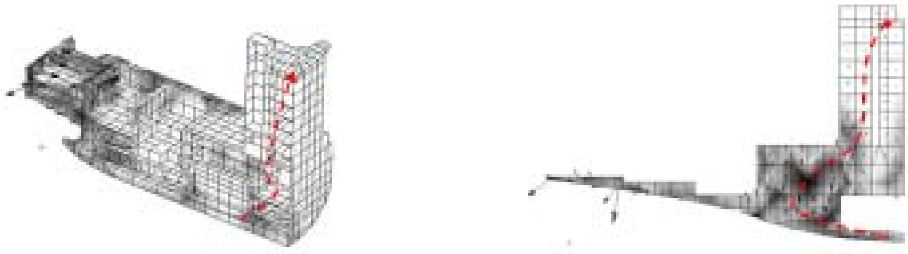


(b) Internal longitudinal bulkhead

Fig. 2 Structural intensity in case of unit excitation on hull surface above propeller top at 5.141Hz

Structural intensity in case of the excitation in longitudinal on thrust block

The results of the structural intensity analysis in case of the unit excitation in longitudinal on the thrust block at 5.141Hz are shown in Fig. 3. It is evaluated that the dominant transmission path of the vibration energy to the superstructure are the internal longitudinal bulkhead in the engine room via the top of the engine room double bottom.



(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 3 Structural intensity in case of unit excitation on thrust block at 5.141Hz

STRUCTURAL MODIFICATION USING THE INFORMATION OF STRUCTURAL INTENSITY

The conventional vibration analysis and the structural intensity analysis have been carried out to investigate how to utilize the information of the structural intensity for four structural modification cases. The Case 1A and the Case 1B of the structural modifications are for the specific area excited directly, the Case 2 for the structure located at the dominant transmission path of the vibratory energy and the Case 3 for the superstructure itself. The structural modifications have been done by means of independently doubling the plate thickness of each local structure. The details of the structural modifications and their effects in the changes of the light weight including the targeted natural frequency of the ship are described in Table 2.

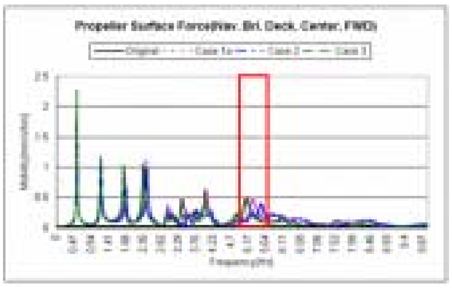
Table 2 Natural frequency changes of the superstructure by structural modifications

	Description	**Increased weight (ton)**	**Natural Frequency (Hz)**	**Nat. Freq. Changes (%)**
Original	-	-	5.141	-
Case 1A	Doubling the plate thickness of the bottom shell in the aft body acting above the propeller surface force	42.3	5.3008	3.1
Case 1B	Doubling the thickness of the engine room double bottom top acting on the thrust variation force	40.2	5.1443	0.06
Case 2	Doubling the thickness of the internal longitudinal bulkhead in the engine room as the dominant transmission path of the vibration energy flow	44.9	5.3176	3.4
Case 3	Doubling the thickness of the internal longitudinal bulkhead in the superstructure as the vibration control subject	43.7	5.1484	0.14

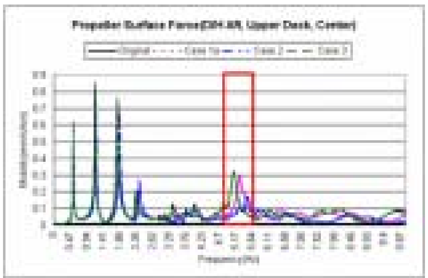
The differences of the increased weights among the structural modifications are negligible within 4.7 tons, compared with total ship weight. However, their effects in the targeted natural frequency change are somewhat different and the structural modification case for the dominant transmission path of the vibratory energy is the most effective in view of the change of the natural frequency.

Vibration reduction of the superstructure in case of the unit excitation in vertical on hull surface above propeller top

The results of the frequency response analyses for Case 1A, Case 2 and Case 3 in case of the unit excitation in vertical on hull surface above propeller top are shown in Fig. 4. And, Fig. 5 ~ Fig. 7 show the results of the structural intensity analyses for the modification cases, respectively. In Table 3, the maximum value of the structural intensity at the aft body is represented.



(a) Navigation bridge deck (longitudinal)



(b) Aft upper deck of superstructure(Vertical)

Fig. 4 Frequency response functions for the propeller surface force after modification

From Fig. 4, it can be seen that the Case 3 have an insignificant or adverse effect on the change of the vibratory response as well as the natural frequency. It is supposed that the additional inertia by means of doubling thickness of the superstructure internal longitudinal bulkhead removes its stiffening effect. However, for the Case 2, the resonant response of the superstructure is reduced to 19.9%, which is more effective than the 4.07% of Case 1A. This remarkable effect of Case 2 also appears well at the change of the maximum value of the structural intensity shown in Table 2. The reason is that the longitudinal bulkhead structure in the engine room modified as a dominant path of the vibratory energy plays a role on supporting the superstructure longitudinal vibration and the aft body vertical vibration.

Table 3 Maximum structural intensity in case of the unit excitation in vertical on hull surface above propeller top after modifications (Unit: Watt/m)

Part	**Original**	**Case 1A**	**Case 2**	**Case 3**
Aft body	6.79E-3	9.21E-3	1.91E-3	6.93E-3
Deck house	1.31E-3	9.58E-4	3.25E-4	1.39E-3
Internal longi. Bulkhead	3.19E-3	3.85E-3	6.62E-4	3.21E-3
Deck house aft wall	1.27E-3	1.30E-3	4.00E-4	1.39E-3

(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 5 Structural intensity in case of unit excitation in vertical on hull surface above propeller top for Case 1A

(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 6 Structural intensity in case of unit excitation in vertical on hull surface above propeller top for Case 2

(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 7 Structural intensity in case of unit excitation in vertical on hull surface above propeller top for Case 3

Vibration reduction of the superstructure in case of the unit excitation in longitudinal on thrust block

The results of the frequency response analyses for Case 1B, Case 2 and Case 3 in case of the unit excitation in longitudinal on thrust block are shown in Fig. 8. In addition, Fig. 9 ~ Fig. 11 show the results of structural intensity analyses for the three modification cases, respectively. In Table 4, the maximum value of the structural intensity at the aft body is represented.

(a) Navigation bridge deck (longitudinal) *(b) Aft upper deck of superstructure(Vertical)*

Fig. 8 Frequency response functions for the thrust variation force after modifications

From the results, it can be seen that the Case 1B as well as the Case 3 have an insignificant effect on the change of the resonant response at the superstructure. In addition, the structural intensity by the Case 1B is somewhat increased at the modified engine room double bottom structure which supports main engine with thrust block although it is reduced at most of the aft body.

In other hand, the resonant response of the Case 2 is remarkably reduced to 85.9% compared with that of the original structure. Moreover, it is investigated in the most effective way to reduce the structural intensity. Especially, the structural intensity is dispersed not to superstructure but to other structure at the internal longitudinal bulkhead in the engine room compared with that of the original structure.

Table 4 Maximum structural intensity in case of the unit excitation in longitudinal on thrust block after modifications (Unit: Watt/m)

Part	**Original**	**Case 1B**	**Case 2**	**Case 3**
Aft body	8.23E-3	2.67E-3	2.03E-4	2.78E-3
Deck house	7.15E-4	6.15E-4	8.96E-5	6.65E-4
Internal longi. Bulkhead	1.09E-3	7.58E-4	6.16E-5	1.05E-3
Deck house aft wall	3.69E-4	4.09E-4	3.41E-5	4.09E-4

(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 9 Structural intensity in case of unit excitation in longitudinal on thrust block for Case 1B

(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 10 Structural intensity in case of unit excitation in longitudinal on thrust block for Case 2

(a) Aft body *(b) Internal longitudinal bulkhead*

Fig. 11 Structural intensity in case of unit excitation in longitudinal on thrust block for Case 3

CONCLUSIONS

In this study, the structural intensity analyses as well as the conventional vibratory response analyses have been carried out for a 4,100 TEU container carrier to investigate how to utilize the information of the structural intensity analysis for low vibration design of ship superstructure. From the numerical studies for the original design and the four modified designs of the ship structure, it is identified that the internal longitudinal bulkhead in the engine room is the one of the dominant transmission paths of vibratory energy from the excitation sources such as propeller surface force and the thrust variation force to the superstructure. Moreover, the structural modification at the dominant energy transmission path has been evaluated as one of the most effective methods in changing the natural frequency and its resonant response of the superstructure. Hence, it is expected that the structural intensity analysis can be usefully applied for making a proper countermeasures against troublesome ship structure vibration which is examined by the conventional vibratory response analysis.

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REFERENCES

[1| Alfredsson K.S., Josefson B.L. and Wilson M.A., “Use of the energy flow concept in vibration design”, Journal of AIAA, **34**, No. 6, 1250-1255 (1996).

[2] Hambric S.A., “Power flow and mechanical intensity calculations in structural finite element analysis”, Journal of Vibration and Acoustics, ASME, **112**, 542-549 (1990).

[3] Noiseux D.U., “Measurement of power flow in uniform beams and plates”, Journal of the Acoustical Society of America, **47**, No.1, 238-247 (1970).

[4] D.H. Lee and D.S. Cho, “Structural intensity analysis of local ship structures using finite element method”, Journal of SNAK, **38**, No.3, 62-73 (2001).

[5] D.S. Cho, S.S. Kim and S.M. Jung, “Structural intensity analysis of stiffened plate using assumed mode method”, Journal of SNAK, **35**, No.4, 76-86 (1998).

[6] D.S. Cho, S.M. Chung and J.H. Kim, “Numerical analysis on the affection of lumped attachments to the vibration power flow in cross-stiffened plate”, Journal of SNAK, **40**, No.1, 36-46 (2003).

[7] B.H. Cho, M.S. Yi and D.S. Cho, “An analysis and visualization system for ship structural intensity using a general purpose FEA program”, Journal of SNAK, **42**, No.5, 487-492 (2005).