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Prevention of vibration in small FRP fishing boats*

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Abstract: Vibration measurements were made on the deck of five small FRP fishing boats sized 4 - 6 tons. Horizontal vibration exceeding 40 mm/s was noted in one of the boats. Assuming that this heavy vibration was ascribable to the resonance of the lateral vibration excited by the propeller shafting system, reinforcements were arranged for the bearing base located in the proximity of coupling between the propeller shaft and intermediate shaft. As the result the horizontal vibration could be reduced to 12 mm/s or less. Vibration measurements on the bottom plating immediately above the propeller in three of the five boats have shown that there was vertical vibration exceeding 170 mm/s in one of them. In view of the facts that the number of propeller blades of this boat is three and the gear ratio of the reduction gear is 3.05, the high intensity of vertical vibration was considered to be attributable to the resonance caused by the main engine excited force and the propeller excited-force, and the number of propeller blades was changed to four. As a result, the vertical vibration at a rotational speed of 2,000 rpm or more of the main engine could be reduced to 1/5 or less, with the eventual benefit of successfully preventing peeling of breast scales of skin-jack.

1. Introduction

Hull vibrations of small FRP fishing boats used for coastal fishing operations sometimes have adverse effects upon fishing equipment and tackles, fish catches, and people. However, very few reports have so far been available except those by Koike (1989, 1990). In Koike's (1989) report, measurements were taken on vertical and horizontal vibration on the deck of five small FRP fishing boats in an attempt to grasp the actual state of vibration in fishing boats falling within this category, and horizontal vibration exceeding the gravitational acceleration was observed in B-Maru, one of the five fishing boats.

The vibration measurements taken with C-Maru, D-Maru and E-Maru of the five boats in a space inside the bottom shell plating directly above the propeller have shown that a vertical vibration as much as three times the gravitational acceleration was generated in D-Maru (Koike, 1990).

Consequently, reinforcements were made to the installation of the bearing base in the proximity of coupling between the propeller shaft and intermediate shaft in B-Maru. On the other hand, the number of propeller blades was changed from three to four in D-Maru. As a result, horizontal vibration on deck and vertical vibration at the bottom shell plating right above the propeller could be reduced. The measured results after these modifications are reported.

2. Vibration measuring procedures for fishing boats

The principal particulars of B-Maru and D-Maru that were modified for the present experiments as given in Table 1.

Measuring procedures used in B-Maru

Vertical and horizontal vibrations of the deck were measured by connecting a 50 mm/G accelerometer to a signal analyzer fitted to each frame in the longitudinal direction under sailing conditions without slamming while proceeding at the rotational speed of the main engine of 1,920 rpm.

Measuring procedures used in D-Maru

Vibrations of the bottom shell plating immediately above the propeller were measured while the boat was proceeding at varying rotational speeds of 100 rpm interval from the minimum to the maximum rpm. The measurements at the bottom shell were taken by arranging accelerometers of a sensitivity of 10 mm/G in three axial directions, fore-aft,

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Table 1. Principal dimension of the fishing boats.

Ship	Mater.	Tonnage	Length L (m)	Breath B (m)	Depth D (m)	Power HP	Reduction ratio	Propeller(1st meas.)			Propeller(2st meas.)		
								blade	dia. (mm)	pitch (mm)	blade	dia. (mm)	pitch (mm)
B-Maru	FRP	6.45	11.82	3.14	1.12	360	3.04	3	940	980	3	940	980
D-Maru	FRP	4.82	10.47	2.67	0.76	320	3.05	3	840	960	4	840	950

vertical and horizontal directions. The measured values were amplified 10 times and 100 times, and recorded with a cassette data recorder.

3. Analysis method

Vibrations of the deck of B-Maru, whichwere obtained directly using a signal analyzer, were subjected to frequency analysis from 0 to 100 Hz at 1 Hz intervals, and the power spectra were recorded on a floppy disk of a personal computer through an RS-232C interface.

Analog data of vibrations of the bottom shell plating of D-Maru were inputted into the signal analyzer, subjected to frequency analysis from 0 to 200 Hz at 1 Hz intervals, andthe power spectra thus obtained were recorded on floppy disk of a personal computer as in the case of B-Maru. A 5 Hz Hi-pass filter was, however, used for the low frequency region.

The power of the component frequency obtained from the contributory factor of the high frequency component was determined in terms of acceleration (mm/s^2). In view of the fact that it is the normal practice to use acceleration in gal (cm/s^2) when dealing with the effects of vibration on human bodies, and to use speed (mm/s) when handling hull vibrations, the accelerations obtained were converted into speed. The vibration components created by the main engine-excited force and the propeller-excited force are assumed to be included in these power spectra.

If the basic frequency of vibration excited by the main engine is denoted by F_e Hz, and the rotational speed of the engine at that time is denoted by N_e rpm, the following equation holds:

$$F_e = N_e/60 \qquad (1)$$

and this was assumed as the primary vibration by the main engine.

If N_p denotes the rotational speed of the propeller when the gear ratio of the reduction gear is denoted by G_r, the basic frequency F_p of the propeller-excited vibration is expressed by the following equation,

$$F_p = B_n(N_p/60) = B_n((N_e/G_r)/60) \qquad (2)$$

where the number of propeller blades is denoted by B_n, and this was assumed as the primary vibration by the propeller.

4. Results

Horizontal vibration of B-Maru

If the ship length (m) is put on the x-axis, frequency of vibration (Hz) on the y-axis, and power of vibration (mm/s) on the z-axis, the power spectra in the lateral direction for B-Maru before modification are as shown in Fig. 1. There are distinct peaks at the location of the main engine and the areas fwd and aft of it. The frequency of this distinct power agrees with the primary frequency 32 Hz, which was determined by substituting the rotational speed of 1,920 rpm of the main engine in Equation (1). Furthermore, the frequencies of the distinct power spectra of the four other FRP fishing boats, which were measured concurrently, were also identified to be the primary vibration caused by the main engine.

Fig. 2 shows the primary horizontal vibrations of the five FRP fishing boats using the ship length L_{pp} as references. The figure shows the distinct power spectra of 30.0 mm/s afore the main engine, 46.8 mm/s at the location the main engine is installed, 37.5 mm/s abaft the main engine, and 18.2 mm/s at the end of the stern of B-Maru. In the other four fishing boats, the power spectra of 13.6 mm/s at the end of the stern of A-Maru and 13.3 mm / s of E-Maru represent large

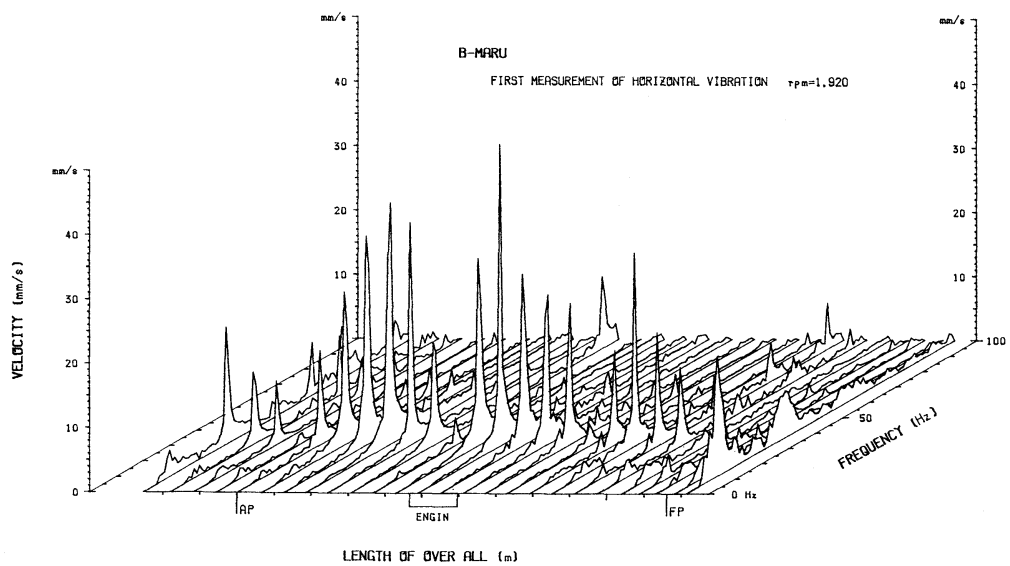

Fig. 1. Power spectrum of horizontal vibration of B-Maru at the 1st measurements.

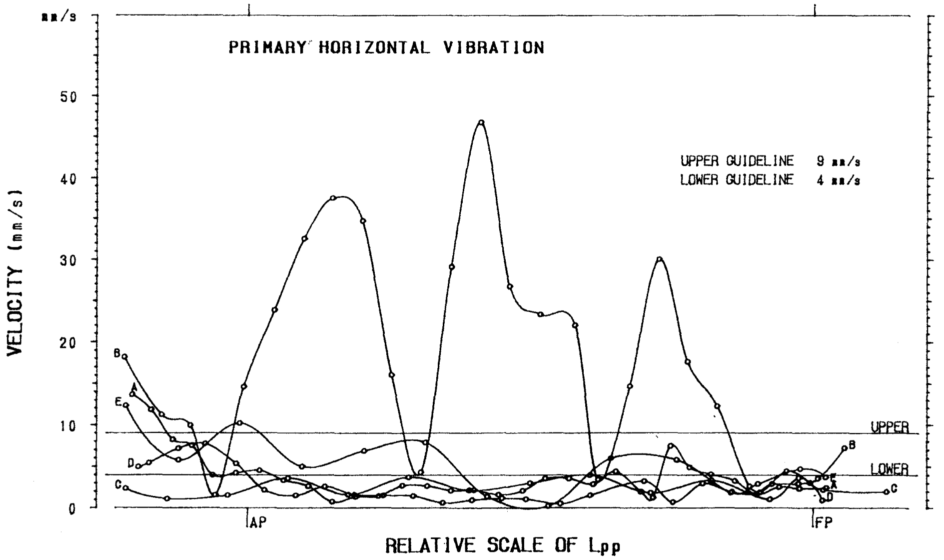

Fig. 2. Primary horizontal vibration of five fishing boats.

values of power spectra, and with the exception of 10.2 mm/s at AP of E-Maru, all of the power spectra of vibrations measured in these four boats were 10 mm/s or less. Thus, it was found that the horizontal vibrations of B-Maru were relatively large as compared with those of the other boats.

The horizontal lines of 4 and 9 mm/s in the Fig. 2 are the indexes corresponding to vibration in the living quarters specified in ISO 6954 (Guidelines for the overall evaluation of vibration in merchant ship) (Aoki *et al.*,1981 a), where the values in the range of 4-9 mm/s are considered to be in the average area.

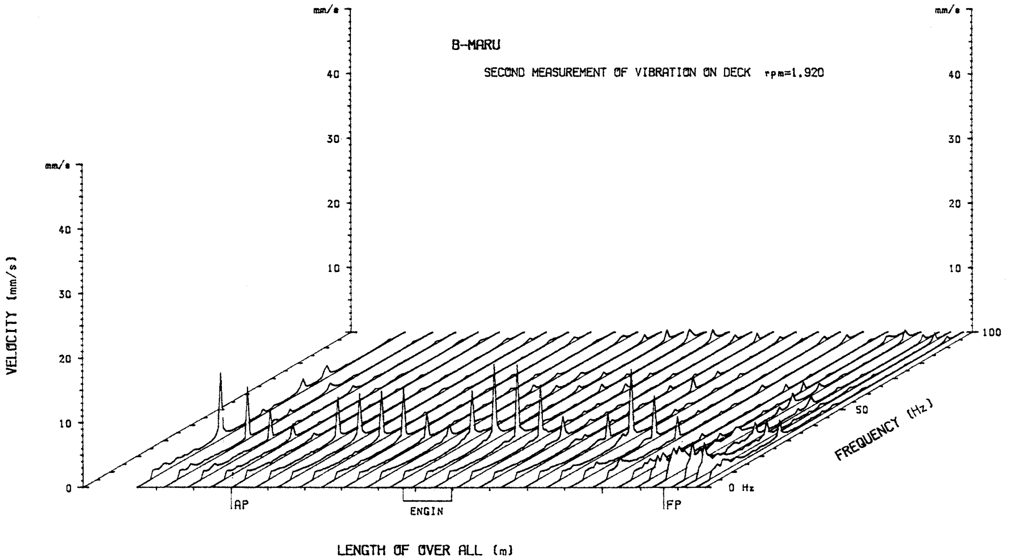

Fig. 3. Power spectrum of horizontal vibration of B-Maru at 2nd measurements.

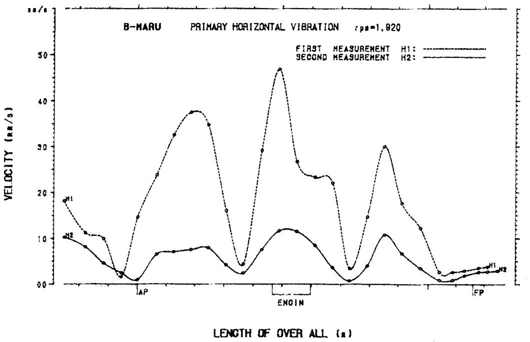

Fig. 4. Primary horizontal vibration of B-Maru. H1,1st measurements; H2, 2nd measurements.

These indexes are applied to merchant ship with a length of 100 m and over, but are not applied to small fishing boats. However, the measured power spectra of the vibration of B-Maru are shown to be far greater than these indexes.

It was assumed from the results of measurements that the cause of the horizontal vibration in B-Maru was the bending moment created by the misalignment between the propeller shaft and the intermediate shaft, and the eccentricity involved in their coupled rotation (Aoki *et al.*, 1981 b ; Yoshida and Kaneda, 1972; Yoshida and Nishida, 1975). Considering the above, the shell plating was partially cut, and the bearing base was reinforced in the proximity of coupling between the propeller shaft and intermediate shaft, located at the aft bulkhead of the living quarters.

The second measurements were taken after completing modification work for B-Maru. Fig. 3 shows the measured power spectra. When compared with the first measurements (Fig. 1), the figure shows a remarkable reduction of horizontal vibration. Primary horizontal vibration induced from the first and second measurements of B-Maru are shown in Fig. 4. It can be seen from the figure that the intensities of vibration were reduced from 30.0 mm/s to 10.8 mm/s in the area afore the main engine, from 46.8 mm/s to 11.6 mm/s at the installed position of the main engine, and from 37.5 mm/s to 7.9 mm/s in the area abaft the main engine.

Vibration of the bottom plating of D-Maru

If rotational speed (rpm) of the main engine is taken on the x-axis, frequency of vibration (Hz) on the y-axis, power at each rpm (mm/s) on the z-axis, the power spectra of the bottom plating of D-Maru obtained at the first attempt to take measurements (before modification) are as shown in Fig. 5.

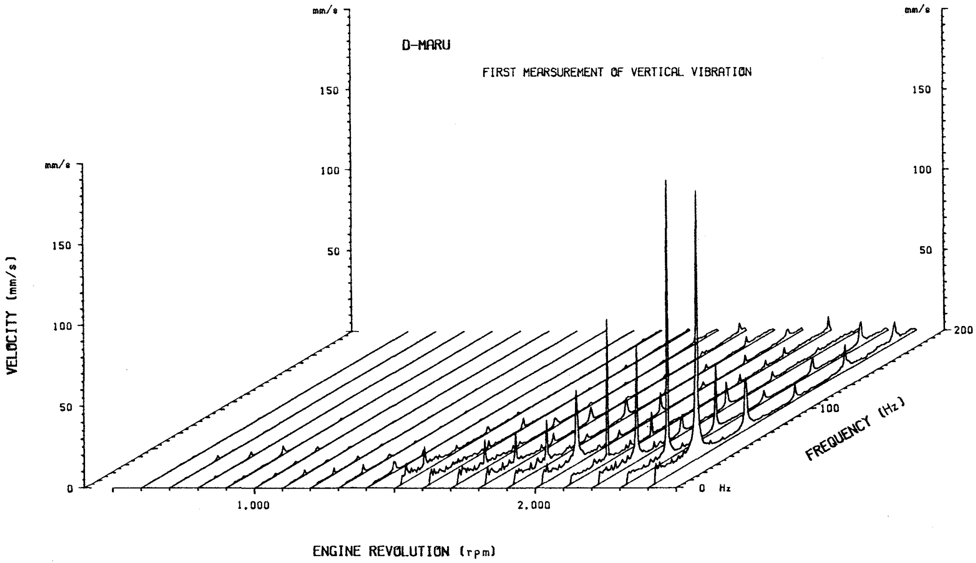

Fig. 5. Power spectrum of vertical vibration at the bottom of D-Maru at the 1st measurements.

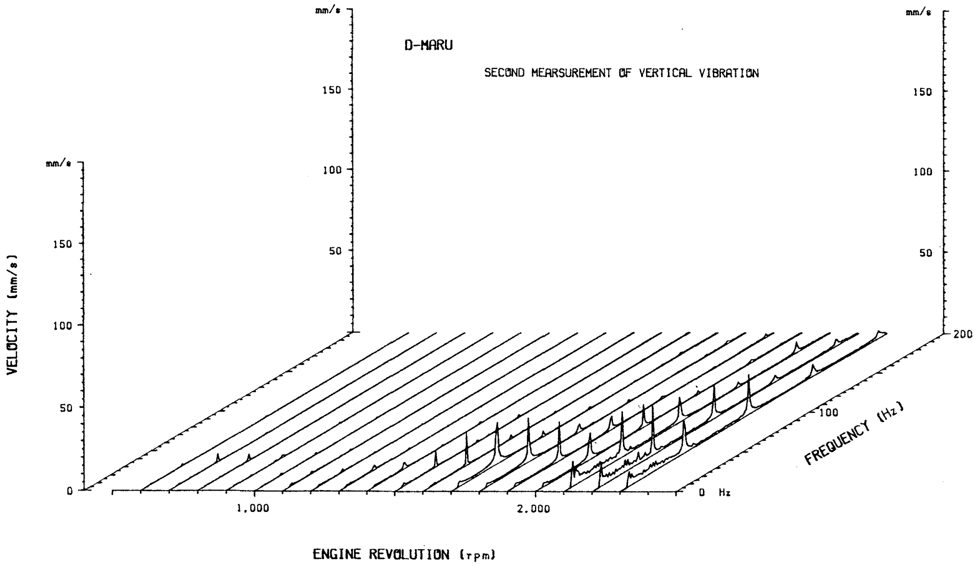

Fig. 6. Power spectrum of vertical vibration at the bottom of D-Maru at the 2nd measurements.

The figure shows the large power spectra; i.e. 173.2 mm/s at the rotational speed of the main engine of 2,300 rpm, and 44.7 mm/s even at 2,000 rpm. In the absence of any evidence to prove propeller deformation, it was assumed that vibration of D-Maru was not excited by the propeller itself (NIWA, 1972).

On the other hand, the fundamental frequencies of main engine-excited vibration F_e and propeller-excited vibration F_p are determined from Equations (1) and (2) as shown below on the basis of the fact that the gear ratio of reduction gear G_r is 3.05 and the number of propeller blades is three.

F_e at 2,300 rpm: 38.3 Hz
F_p at 2,300 rpm: 37.7 Hz
F_e at 2,000 rpm: 33.3 Hz

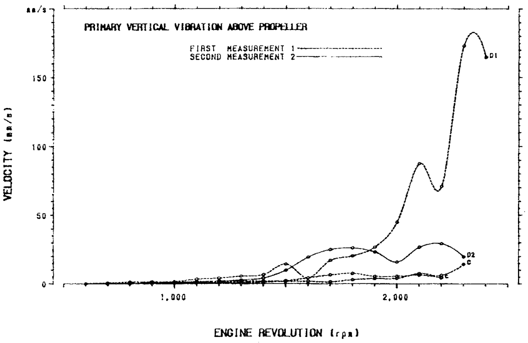

Fig. 7. Primary vertical vibrations at the bottom of three fishing boats.

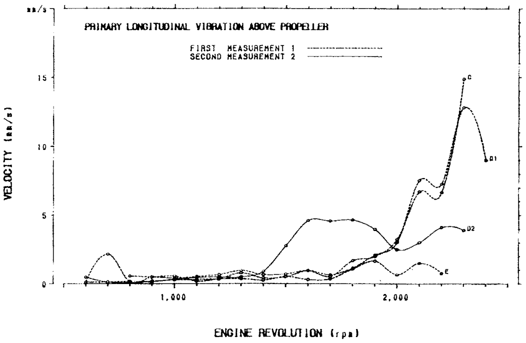

Fig. 8. Primary longitudinal vibrations at the bottom of three fishing boats.

F_p at 2,000 rpm: 32.7 Hz

The difference in fundamental frequency was extremely small at 0.6 Hz for both rotational speeds (rpm) of the main engine. It was therefore inferred from the approximate coincidence of fundamental frequencies of the main engine-excited vibration and propeller-excited vibration that resonance was caused by these vibrations. In this specific connection, the number of propeller blades was changed from three to four to change the fundamental frequencies of these vibrations. The second vibration measurements were taken after changing the number of propeller blades.

Fig. 6 shows the power spectra of the vibrations measured at the second attempt. It was verified that the peak of the power spectra was indentified in the propeller-excited primary vibrations, where a considerable reduction from the first measurements was noted.

In order to compare the conditions for reducing the vibration of the bottom plating of D-Maru with those of other two fishing boats, the measured values of C-Maru and E-Maru at their first measuring attempt, are shown in Fig. 7. If we compare the results of the first measurement (D1) with the second measurement (D2) of D-Maru, large reductions are seen from 173.2 mm/s to 19.9 mm/s at 2,300 rpm, and from 87,6 to 27.0 mm/s at 2,100 rpm, but there was an increasing tendency from 20.5 mm/s to 26.3 mm/s at 1,800 rpm and from 4.3 mm/s to 19.5 mm/s at 1,600 rpm. If we consider that the largest power spectrum with C-Maru and E-Maru was 14.3 mm/s at 2,300 rpm of C-Maru, the intensity of vibration of the bottom plating in D-Maru is still large compared with those of C-Maru and E-Maru, though it could be largely reduced by changing the number of propeller blades.

Fig. 8 shows the primary vibrations in the longitudinal direction of the three fishing boats. In D-Maru, the longitudinal primary vibration has been reduced from 12.8 mm/s to 4.1 mm/s at 2,300 rpm, and from 7.5 mm/s to 3.0 mm/s at 2,100 rpm, but it has increased from 0.9 mm/s to 4.6 mm/s at 1,600 rpm, and from 1.1 mm/s to 4.6 mm/s at 1,800 rpm. However, it can be said that these power spectra are quite small when compared with the primary vertical vibration.

5. Discussion

Horizontal vibration of B-Maru

From the results of the first and the second measurements, the horizontal vibration of B-Maru before modification is considered to be reasonably attributable to the moment created by the misalignment of the propeller shaft and intermediate shaft. The statement of the fishermen that their fatigue at sea has been mitigated by the modification suggests that the reduction of vibration has contributed to reducing the fishermen's fatigue.

Bottom vibration of D-Maru

The vertical bottom vibration of D-Maru could be successfully reduced from the largest vibration of 173.2 mm/s at 2,300 rpm to 19.9 mm/s, a reduction to approximately 1/8, by changing the number of propeller blades from three to four. It may be interpreted that the resonance of main engine-excited vibration and propeller-excited vibration was the cause of the vibration.

Vibration increased at the rotational speed of the main engine in the range between 1,600 and 1,800 rpm. The increase in the number of propeller blades is supposed to reduce variation of hydrodynamic pressure by the propeller (Taniguchi, 1958). However, the propeller diameter of 840 mm remains unchanged and only the propeller pitch has been changed from 860 to 850 mm, which is insignificant. It is therefore considered that the increase in thrust created by the propeller under the same rotational speed has contributed significantly to the vibration of hydro dynamic pressure acting on the bottom plating.

Furthermore, the propeller tip clearance of 16.8% of D-Maru, which is smaller than 20 to 30% in ordinary steel ships and 25% in high-speed patrol boats of the Maritime Safety Agency, can be counted as one of the reasons for the large bottom vibration caused by the propeller-excited force.

On the other hand, when the number of propeller blades was three, captured skip-jack were stored not in the aft fish hold, but in the fwd fish hold to avoid peeling of breast fscales. However, the use of the aft fish hold became possible after changing the number of propeller blades to four, thus contributing to the prevention of degrading of product quality arising from peeling off scales.

6. Concluding remarks

The horizontal vibration of B-Maru was caused by the improper installation of the propeller shaft and intermediate shaft, but the distortion of the hull of small FRP fishing boats caused by everyday grounding can often lead to similar difficulties.

The bottom vibration of D-Maru is considered to be ascribable to the resonance of the main engine-excited vibration and propeller-excited vibration.

It is necessary to design a hull form that allows ample tip clearance, so that propeller-induced pressure variation can be minimized.

Recognizing the growing age of crew members serving aboard small fishing boats, the author considers that studies on reducing hull vibration should be made to reduce fatigue among crew members at sea.

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FRP 小型漁船の振動防止と改善

小　池　孝　知

要旨：5隻の4〜6トン級のFRP小型漁船で甲板上の振動を計測した結果，そのうちの1隻に40mm/sをこえる水平方向の振動がみられた．この原因をプロペラ軸系による横振動の共振現象と推察し，プロペラ軸及び中間軸の継手部分の受台に補強を施した結果，水平方向の振動を12mm/s以下までに減少させることができた．また，3隻についてプロペラ直上の船底における振動を測定した結果，1隻に170mm/sをこえる垂直方向の振動がみられた．この漁船のプロペラ翼数は3枚で減速機の減速比が3.05であることから主機関及びプロペラの起振力による共振現象と推察し，プロペラ翼数を4枚に取り替えた．その結果，主機関の回転が2,000rpm以上での垂直方向の大きな振動は1/5以下にまで減少させることができ，カツオの胸甲部の鱗の剥脱の防止ができた．