SOME MEASUREMENTS OF ACCELERATION OF HULL VIBRATION AND HUMAN SENSITIVITY TO VIBRATION

KUMAI, Toyoji
Research Institute for Applied Mechanics, Kyushu University

https://doi.org/10.5109/7162048

出版情報：Reports of Research Institute for Applied Mechanics. 5 (17), pp.21-26, 1957. 九州大学応用力学研究所
バージョン：
権利関係：

Reports of Research Institute for Applied Mechanics
Vol. V, No. 17, 1957

SOME MEASUREMENTS OF ACCELERATION OF HULL VIBRATION AND HUMAN SENSITIVITY TO VIBRATION

By Toyoji KUMAI

Abstract This paper is produced as a preliminary progress report on some results of the measurements of the acceleration of the ship vibration by the use of the accelerometer. The acceleration of the ship vibration has directly been observed for the range from the two-node frequency to the blade frequency of the hull vibration on the weather deck and in the rooms of a cargo ship and of two tankers. The threshold of unpleasantness of the horizontal vibration in the cabin of ship is confirmed to be about 15 gal with a maximum accceleration by the present observations.

The duplication of the resonance of the shaft frequency with the blade frequency of the hull vibrations in two tankers has also been observed and the human reaction to the vibration in the state of those double resonance has been measured by the accelerometer more clearly than by the vibrograph.

1. Introduction. The application of the accelerometer or the accelerograph both to the seismometry[1] and to the observation of the vibration of the land vehicles[2] have already been put into practice. As far as the author is aware any result obtained from the direct measurements of the acceleration of the ship vibration has not been published. It is of more importance to measure the acceleration of the hull vibration than the amplitude of the vibration because the vibration which is presented with an acceleration indicates directly the vibratory force as well as the response to the human sensitivity to the vibration for wide range of the frequencies of the ship vibrations. The present report deals with some results of the preliminary observations of the acceleration of hull vibration by use of a portable accelerometer on the actual ships in trial trips.

2. Accelerometer. The accelerometer used in the present observation is of the portable type with a dial indicator of the sensibility of the deflection 15 mm for 100 gal (cm/sec^2). The natural frequency of the pendulum is 420 c.p.m. with an air damper. The vertical and the horizontal vibra-

1) M. Ishimoto; "Un sismographe accélérométrique et ses enregistrements." Earthq. Res. Inst. Tokyo Imp. Univ., Vol. IX. 1931.

2) M. Ishimoto and R. Takahashi; "Construction d'un accéléromètre-enregisteur dans le but de mesurer les mouvements des automobiles, des trains, etc.,, Earthq. Res Inst. Tokyo Imp. Univ. Vol. VII. 1929.

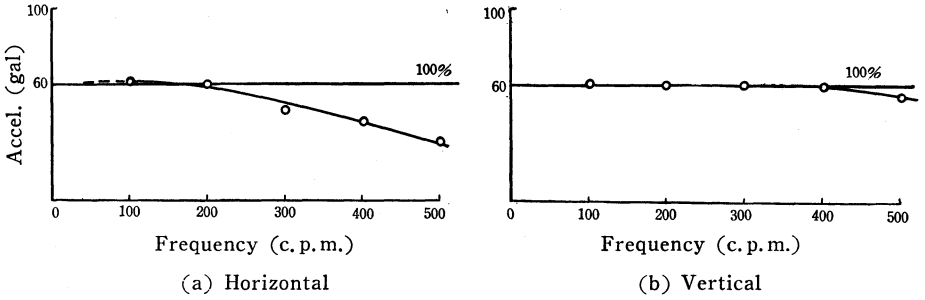

Fig. 1. Response curves of portable accelerometer.

tions respectively can be measured by the use of a converter. The response curves of the accelerometer are shown in Fig. 1 (a) and (b).

3. Human Reaction to Ship Vibration. It is necessary to define the permissible degree of ship vibration, for it is objectionable to the passengers and the crew and frequently to limit the hurtful vibration of the navigation instruments and fittings. Richards[3] suggested from the existing informations of the experiments obtained by the numerous investigators that the threshold of perception is a vibration with a maximum acceleration about 0.3 to 0.6 gal (cm/sec^2) and the threshold of unpleasantness of a vibration with a maximum acceleration of about 10 gal for the range of the frequency from the two-node to three-node vibrations of ships.

The present author has examined directly measuring the acceleration of the vibrations on three ships by the use of the accelerometer mentioned above, and the sensitivity of the author to the vibration in ships has been obtained by the direct observation of the ship vibration with an acceleration.

With regard to the results of the observations for the range from the frequencies of the two-node vibration to the blade frequencies of the hull vibration of 10,000 ton d.w. cargo ship, 20,000 ton d.w. and 35,000 ton d.w. tankers with a four-bladed single screw in each of the three vessels, the threshold of unpleasantness has been found about 15 gal as the author's sensitivity for the horizontal vibration in a cabin. The threshold of unpleasantness which has been obtained by the present author is slightly higher than that which is suggested by Richards.

Moreover, the author's upper limit of the measured frequency of the ship vibration is extended to the blade frequency, namely, it reaches about 480 c.p.m. and corresponds to the frequency of the five-node or six-node vibration of the hull. The results are shown in Fig. 2.

It will be supposed that, in the higher region than the blade frequencies, the threshold of unpleasantness is presented to be almost proportional to

3) J. E. Richards; "Summary of Existing Information on the Human Reaction to Vibration." British Shipbuilding Res. Assoc. Rep. No. 28. 1949.

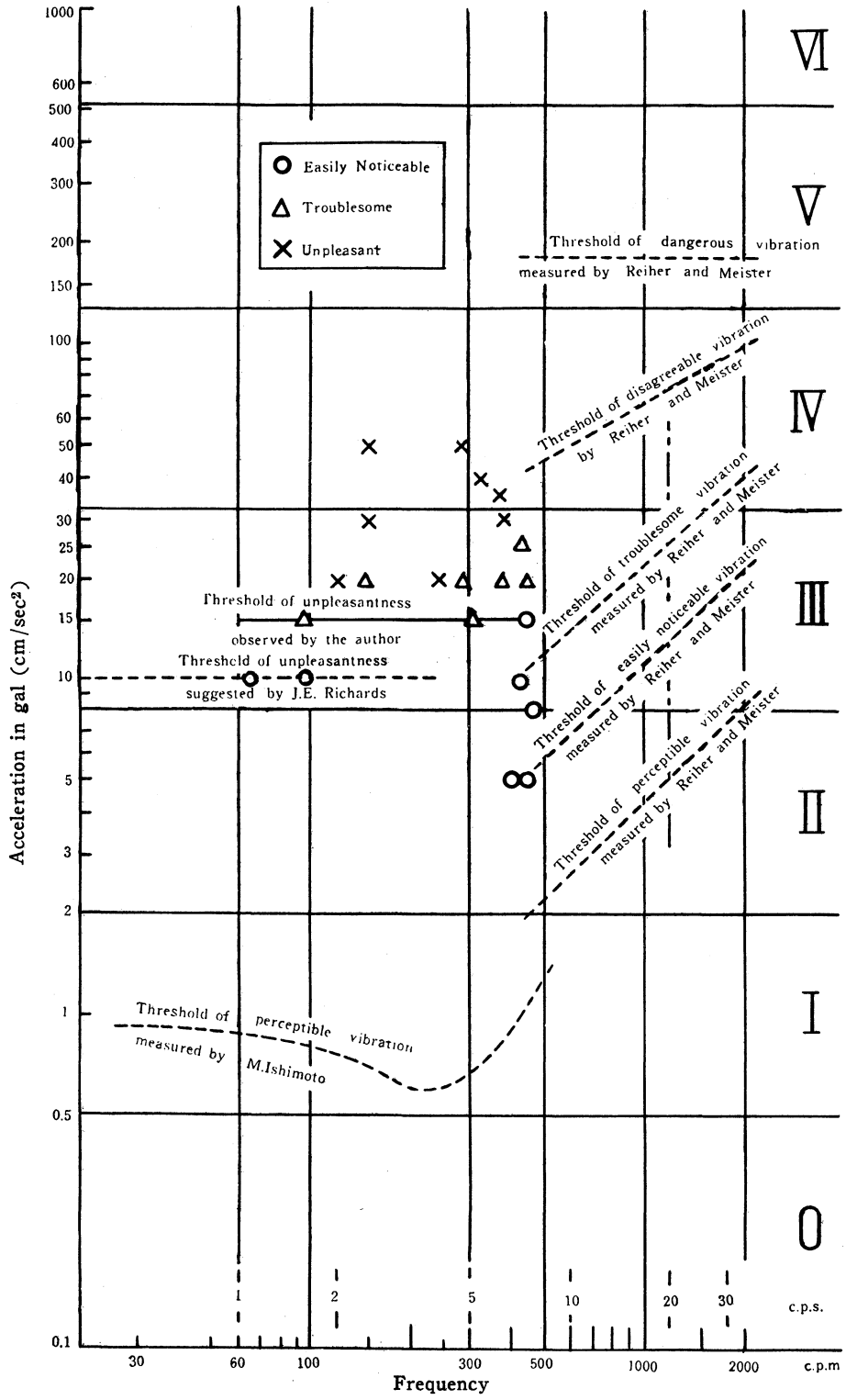

Fig. 2. Sensitivity for horizontal vibration represented by acceleration versus frequency.

the frequencies up to the low note of the sound frequency. In the higher frequencies of the vibration, the threshold of unpleasantness has been obtained by Reiher and Meister[3] as shown in Fig. 2.

On the other hand, the threshold of perceptibility of the horizontal vibration obtained from the experiments by the tests on vibrating seat with an accelerograph has already been measured in details by Dr. M. Ishimoto[4] as shown in the figure.

It is convenient to express the human reaction to the ship vibration compared with the scale of the seismic intensity that has been defined by the Central Meteorological Observatory of Japan with the expression of the acceleration in gal unit which has been classified by Dr. M. Ishimoto[5] as shown in the figure.

In conclusion, the threshold of the unpleasantness approximately corresponds to the mean of the two extreme values of the scale III of seismic intensity in the ships' cabins and its acceleration response is accounted about 15gal for the range from the frequency of the two-node vibration to the blade frequency of the horizontal vibration of the ships.

Other numerous experiments on human reaction to vibration have been shown in Richards' paper and has also been represented by Prof. Jaeger[6] with the "pal" unit which expresses a maximum energy of the vibration as the human sensitivity to vibration.

4. Observation of Duplication of Resonance of hull vibration. Since the relations between the natural frequencies of the vibrations and the number of nodes are represented almost linear in the vertical, the horizontal and the torsional vibrations of 20,000 ton–35,000 ton d.w. tankers,[7] the resonance of the higher mode of the hull vibration to the blade frequency, as well as that of the two-node natural frequency which is excited by the shaft frequency occures, for instance, if the two-node natural frequency of the horizontal vibration of 20,000 ton d.w. tanker in full load condition is measured 100 c.p.m., the blade frequency is accounted 400 c.p.m. in the tanker with the four bladed single screw. Since this tanker has the five-node natural frequency of 400 c.p.m., the blade excitation to the hull vibration also resonates to the five-node natural frequency. Thence, the state of duplication of the resonance of the hull vibration is presented as will be seen in Fig. 3. The records of such duplication of resonance of the hull vibrations as observed above, have been already seen in the previous vibration test of a super tanker.[7] Fig. 4 shows a sample record of the Geiger vibrograph

4) M. Ishimoto and M. Ôtuka; "Détermination de la limite perceptible des secousses" Earthq. Res. Inst. Tokyo Imp. Univ. Vol. XI. 1933.

5) M. Ishimoto; "Echelle d'intensité sismique et accélération maxima" Earthq. Res. Inst. Tokyo Imp. Univ. Vol. X. 1932.

6) H. E. Jaeger; "Bepaling van de Eigenfrequentie van Sheepstrillingen" Netherland Research Centre for Shipbuilding and Navigation, Report No. 1 May, 1950.

7) T. Okabe, K. Hirata and T. Kumai; "Vibration Measurement on a 32,000 ton d.w. Super Tanker" Res. Inst. Applied Mech., Kyushu Univ., Vol. IV, No. 13, 1955, International Shipbuilding Progress. Vol. 3, No. 24. Aug., 1956.

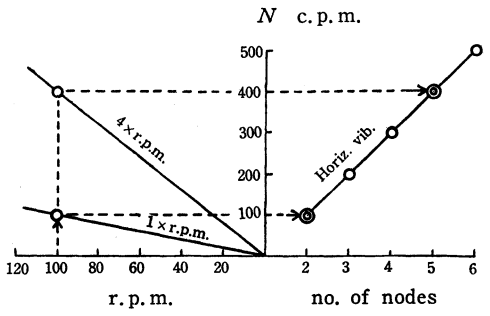

Fig. 3. Example of duplication of resonance of hull vibration.

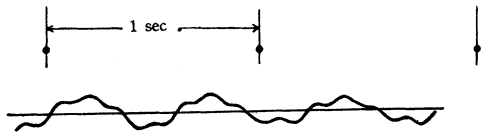

Fig. 4. Sample oscillogram of horizontal vibratin of a 20,000 ton d.w. tanker obtained by Geigel vibrograph.

of the duplication of resonance of the horizontal vibration of a 20,000 ton d.w. tanker.

The amplitude of the vibration which has been measured by the vibrograph in the above resonant state does not show so remarkably in the higher mode of the vibration compared with that of the two node frequency, but the human reaction to vibration is more sensible to the higher mode of the vibration than to the two-node frequency of the hull vibration.

Since the human reaction to the vibration is presented by the acceleration of the vibration for the range of the frequencies of the hull vibration, the human sensitivity to the ship vibration will directly be obtained if we measure the hull vibration by the accelerometer. It is easily understood that the reaction to the hull vibration in the higher frequency is more sensible than that in the lower frequency such as two-node natural frequency provided that the acceleration curve is computed from the duplicated amplitude curve of the hull vibration mentioned above. The amplitude of duplicated sinusoidal vibration and its acceleration which is computed from the amplitude curve is presented, as an example, in Fig. 5. As will be seen in the figure, it will be clearly shown that the vibration represented by an acceleration is available to express the human sensitivity to the vibration as described above.

If the four-bladed propeller of the tanker would be replaced by the five-bladed one, for example, the resonance of the blade frequency of 400 c.p.m. changes to 500 c.p.m. and it corresponds to the frequency of the six node hull vibration. The blade force

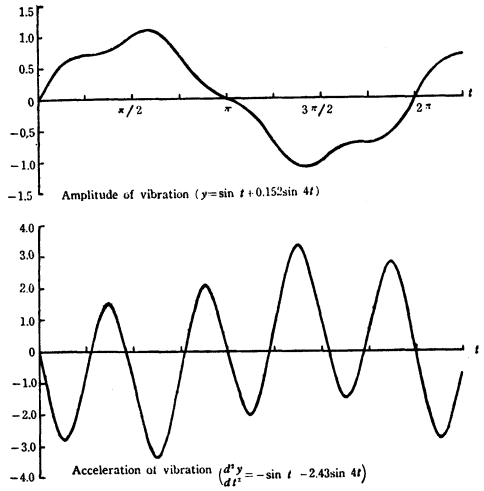

Fig. 5. Amplitude and acceleration of duplication of resonance of sinusoidal vibration.

of $5\times$ r.p.m. of the five-bladed propeller, however, is not so considerable compared with that of the four-bladed one. The blade excitation of the five-bladed propeller is more considerable in the frequency of $10\times$ r.p.m. than that of $5\times$ r.p.m.[8] Thence, the blade frequency which resonates to the hull vibration is accounted 1,000 c.p.m., but such a higher frequency of the nodal hull vibration as 1,000 c.p.m. is difficult to measure by the vibrograph. The local vibration with such a higher frequency is frequently observed on ships. Though the higher frequencies as mentioned above have small amplitudes in ship vibration, the acceleration of the vibration appeared of comparatively high value. The accelerometer is also available to practical use for the measurements of the higher frequencies such as the local vibration of ships.

5. Conclusions. The threshold of unpleasantness of the ship vibration was confirmed about 15 gal by the direct measurements of the accelerations of the hull vibration of a cargo ship and two tankers in trial trips.

The duplication of the resonance of the hull vibration to shaft frequency and to the blade frequency in tankers with the four-bladed single screw was clearly observed by the accelerometer.

In conclusion the author wishes to express his thanks to the shipbuilders, Ishikawajima, Tokyo Works, Mitsui, Tamano Works and Hitachi, In-no-shima Works for the permission to carry out the tests on their ships.

He is also grateful to the Science Research Division of the Department of Education whose support made the work possible.

(Received January 10, 1957)

[8] Hans Brehme; "Der Einfluß der Flügelzahl eines Schiffspropellers auf die Erregung von Schiffsvibrationen" Schiff u. Hafen, 1954.

ERRATA

Some Notes on the Local Vibration of Ships

By Toyoji KUMAI

(Reports of Research Institute for Applied Mechanics, Vol. III, No. 12, Note. 1955)

Page 173, equ. (4) and page 174, equ. (10);

for $\sqrt{1-\left(\frac{a}{b}\right)^2}$ read $\sqrt{1+\left(\frac{a}{b}\right)^2}$