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UNDERWAY VIBRATION SURVEY OF THE HULL AND PROPULSION SYSTEM OF THE USS DEALEY (DE1006)

by

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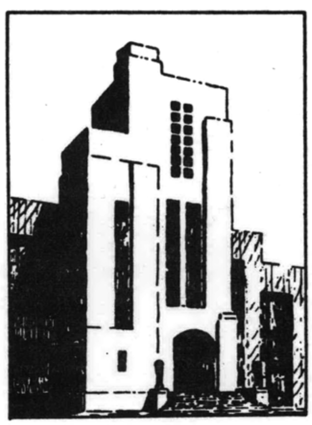

August 1955 Report 980

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ABSTRACT

Records of vertical and athwartship vibration were obtained at the bow and at the stern, and of fore-and-aft vibration at the thrust-bearing and reduction-gear housings. Vibration was recorded while the vessel was operated over a speed range and during full-speed hard turns and crashback maneuvers.

Fifth-order vertical hull vibration was measured with resonances observed at 98 and 234 shaft rpm. A constant athwartship hull frequency of 180 cpm was found regardless of the shaft speed. Fifth-order fore-and-aft vibration was recorded at the reduction-gear and thrust-bearing housings with resonances at 165 and 226 shaft rpm.

INTRODUCTION

An underway vibration test[1*] was performed on the USS DEALEY (DE1006), the first of its class, off Key West, Florida, in December 1954 as part of the special performance trials. Measurements were made of the vibratory response of the hull in the vertical and athwartship directions and of the fore-and-aft response of the thrust-bearing and reduction-gear housings, at various constant ship speeds over a selected speed range, during full-speed hard turns, and during crash-back maneuvers.

In this report, modes of vibration corresponding to the resonance frequencies of the hull are identified where possible. The fore-and-aft resonance frequencies at the thrust-bearing and reduction-gear housings were obtained for later use in a general study of propulsion systems.

TEST PROCEDURE

The overall length of the DEALEY is 314 ft 6 in. and the beam is 36 ft 8 in. The length between perpendiculars is 308 ft, and the displacement during the test was

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* References are listed at end of report.

1818 tons with a mean draft of 11 ft 8 in. and a trim by the stern of 4 ft $3\frac{1}{2}$ in. The vessel has one NACABS, solid-type, 5-bladed propeller and a full-power design speed of 27 knots at 270 shaft rpm. During the test the DEALEY was operating in water over 200 ft in depth with the sea state varying from 1 to 3.

Type V pallographs[2] were used to detect vertical hull vibrations; a Type H and a Type C pallograph were used to detect athwartship hull vibrations. Pallographs are mechanical instruments whose sensitive elements are seismic pendulums. Consolidated Type 4-102-A velocity pickups, together with TMB integrators, Brush amplifiers, and a Brush 2-channel recorder were used to record fore-and-aft vibration at the thrust-bearing and reduction-gear housings.

At the stern, a Type V and a Type H pallograph were installed on the main deck near the after perpendicular on the hull centerline over stiffeners at Frames 174 and 175 respectively, to detect vertical and athwartship hull vibrations. At the bow, a Type V and a Type C pallograph were installed on the main deck near the forward perpendicular at Frames 2 and 3, respectively, to detect vertical and athwartship hull vibrations. All pallographs were clamped to mounting frames welded to the deck. In the engine room one Consolidated pickup was installed at the top of the thrust-bearing housing and another was installed at the top of the reduction-gear housing. Both were oriented in the fore-and-aft direction and were positioned close to the fore-and-aft centerline of the housings.

Vibration records were taken at the bow, stern, and engine room stations while the ship's speed was held constant at each 10-shaft-rpm increment from 20 to 270 shaft rpm. Records were taken at 5-shaft-rpm increments in the vicinity of suspected critical frequencies of hull vibration or of thrust-bearing and reduction-gear housings.

After these runs were completed, full-speed hard turns were executed to port and starboard; then a crashback maneuver from full-speed ahead to full-speed astern was performed. Vibration was recorded during these operations at the bow and engine room stations.

TEST RESULTS

For the speed runs all vertical hull vibrations at the stern were of fifth-order or blade frequency. A hull critical frequency was indicated at 98 shaft rpm and an apparent local critical of 234 shaft rpm (Figure 1a). At the bow, fifth-order vertical hull vibration occurred also with a resonance at 98 shaft rpm (Figure 1b). In addition, first-order vibration occurred from 220 to 270 shaft rpm. Vertical hull vibration at shaft speeds below 80 rpm was too small to detect at both the bow and the stern.

The graphs of hull vibration in Figure 1 need some explanation. The points denoted by ▲ are those at which no detectable vibration amplitude was recorded. The pallographs have a magnification factor of 6, and the smallest double amplitude which can be read on the record is 3 mils. Therefore, the smallest single amplitude of vibration which can be detected is 0.25 mils. It may be assumed that the hull vibration produced by the propulsion system remained below 0.25 mils single amplitude at the points denoted by ▲.

At the stern, athwartship hull vibration was first detected above a speed of 110 shaft rpm; at the bow it was first detected above a speed of 120 shaft rpm. Above these speeds the frequency of athwartship vibration measured at the bow and stern remained constant at approximately 180 cpm. There was a general increase in amplitudes up to full speed, 270 shaft rpm, at which vibration of 26.5 mils single amplitude was measured at the bow and 10 mils single amplitude at the stern.

Fore-and-aft vibration obtained at the reduction-gear and thrust-bearing housings during the speed runs was of fifth order. Two resonances, one at 165 and the other at 226 shaft rpm, occurred at both positions; see Figure 2. Vibration was first detected at both positions above 90 shaft rpm.

Peak vibration amplitudes and corresponding frequencies obtained at the bow and in the engine room during the hard turns and crashback maneuvers are listed in Table 1. During the hard turn to port the peak vertical single amplitude measured at the bow as 38 mils, and fore-and-aft vibration of 9.3 mils was measured at the reduction-gear housing in the engine room. During the hard turn to starboard, a peak single amplitude of 2.5 mils was measured at the bow and 9.7 mils in the fore-and-aft direction at the reduction-gear housing. The crashback maneuver produced a peak of 91 mils single amplitude in the vertical direction at the bow and 16 mils in the athwartship direction. A peak single amplitude of 4.6 mils in the fore-and-aft direction was measured at the reduction-gear housing. No records were taken at the stern during these maneuvers because water was shipped

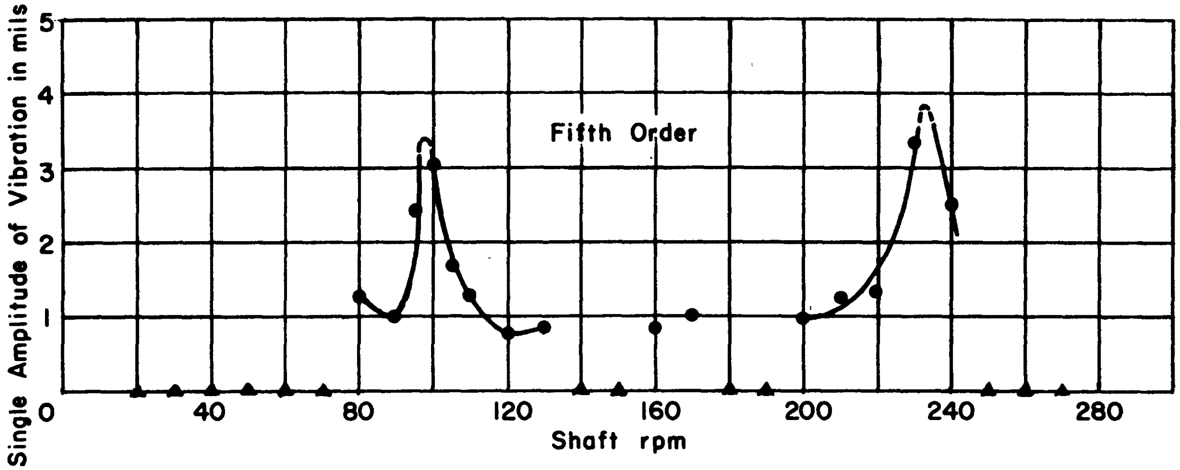

Figure 1a - Stern, Frame 174

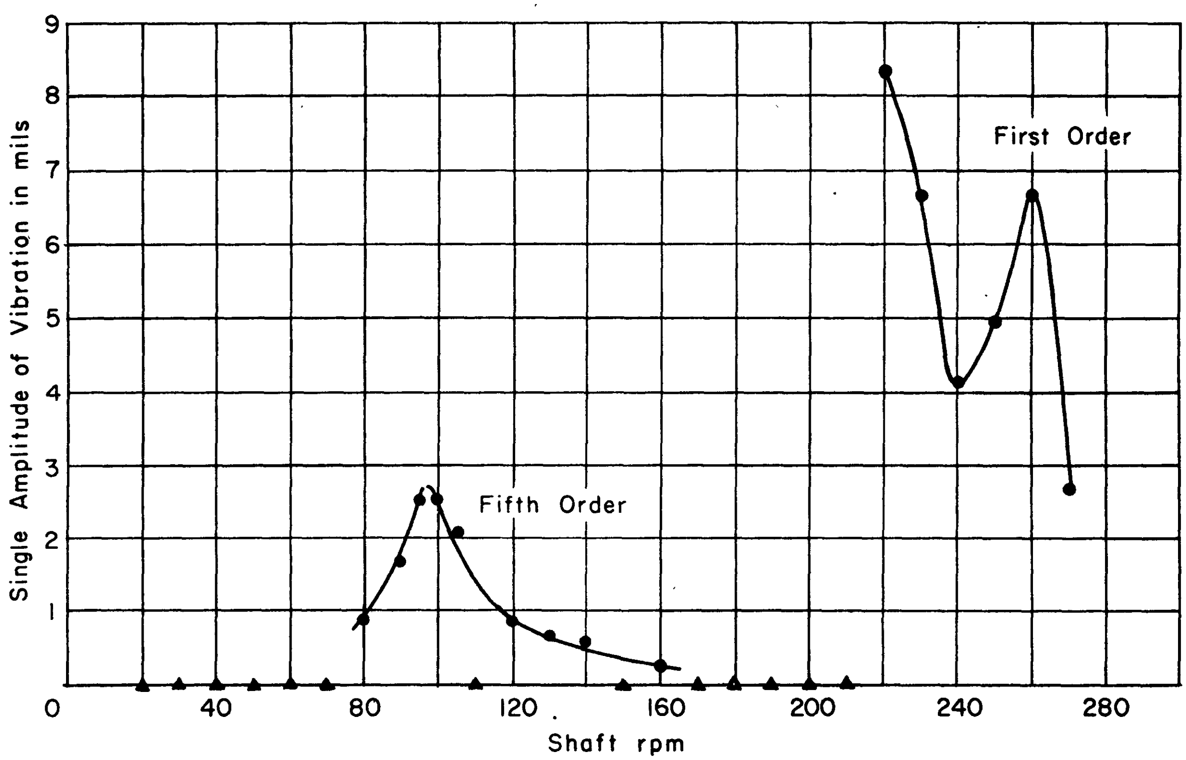

Figure 1b - Bow, Frame 2

Figure 1 - Vertical Hull Vibration

Points denoted by ▲ on the graphs indicate speeds at which no vibration was detected.

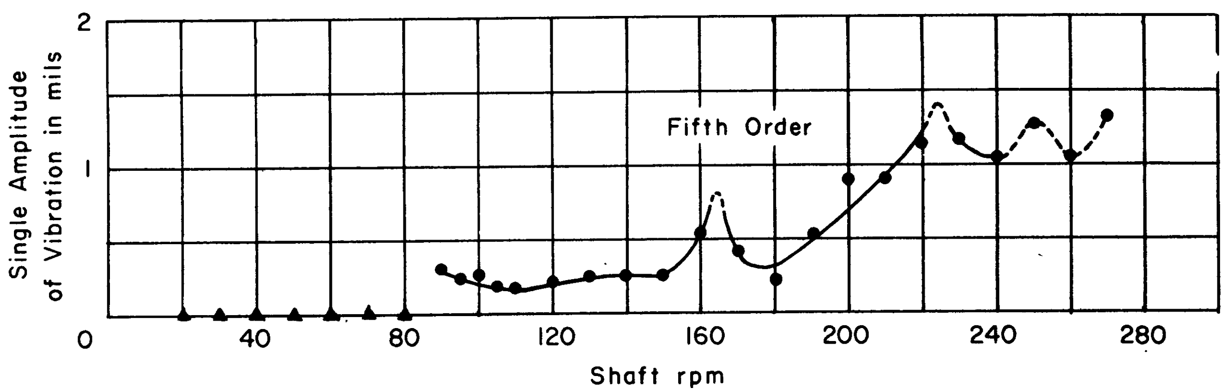

Figure 2a - Thrust-Bearing Housing

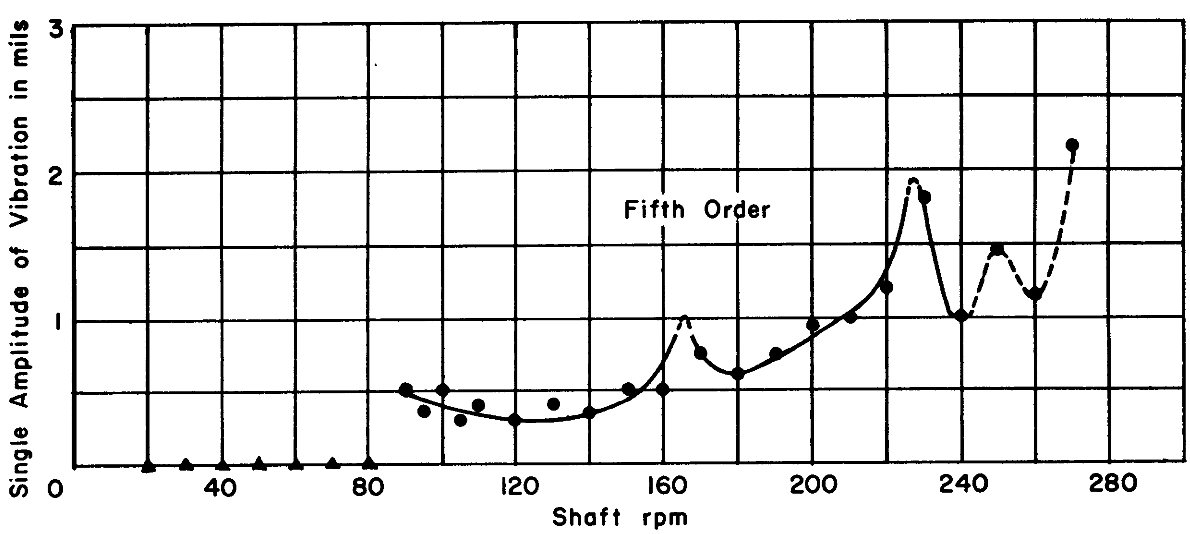

Figure 2b - Reduction-Gear Housing

Figure 2 - Fore-and-Aft Vibration of Propulsion System Units

Points denoted by ▲ on the graphs indicate speeds at which no vibration was detected.

TABLE 1

Peak Amplitudes and Corresponding Frequencies during Hard Turns and Crashback Maneuvers

Operation	Station	Direction Vibration Measured	Frequency cpm	Single Amplitude of Vibration mils
Turn to Starboard	Bow	Vertical	468	2.5
	Thrust Bearing	F&A	1290	6.7
	Reduction Gear	F&A	1290	9.7
Turn to Port	Bow	Vertical	456	38
	Thrust Bearing	F&A	342 1206	4.7 1.5
	Reduction Gear	F&A	354 1206	9.3 3.9
Crashback	Bow	Vertical	204	91
		Athwartship	168 420	16 1.6
	Thrust Bearing	F&A	1134	5.3
	Reduction Gear	F&A	1134	4.6

over the stern. No athwartship records of vibration could be obtained at the bow station during the hard turns because the seismic pendulum of the pallograph bore against a stop during the turns.

DISCUSSION OF RESULTS

To identify the hull modes corresponding to the vertical resonance frequencies found during the test the first-mode resonance frequency was calculated by Schlick's formula.[3] This formula for the two-noded vertical flexural frequency of ship hulls in water is $N = C\sqrt{I_1/DL^3}$, where N is the frequency in cpm. The values used in the formula were 1.25×10^5 for C*, Schlick's empirical constant; 46,600 ft^2in^2 for I_1, the areal moment of inertia of the midship section; 1818 tons for D, the displacement of the DEALEY during the test; and 314.5 ft for L, the overall length of the ship. The calculated first-mode frequency, N, was 113 cpm. Now when the DEALEY slammed during rough seas a vertical hull frequency of 124 cpm was estimated by timing the hull oscillations. The Schlick calculation indicates that the 124-cpm frequency is the experimental first mode.

From experimental data obtained in the past dealing with ship hull frequencies, the higher mode frequencies are approximately integral multiples of the fundamental frequency for the first few modes. On this basis the vertical resonance frequency of 490 cpm at 98 shaft rpm obtained on the DEALEY would be the fourth hull mode. The mode for the vertical resonance of 1170 cpm at 234 shaft rpm could not be identified. It is not likely that a hull mode of such high order could be excited.

From previous experimental data the first athwartship mode frequency has been found to be approximately 1.7 times the first vertical-mode frequency. An athwartship hull frequency of 180 cpm was obtained on the DEALEY at all shaft speeds above 120 rpm. This frequency was 1.6 times the calculated first vertical-mode frequency of the hull of 113 cpm. When the DEALEY slammed during rough seas, an athwartship hull frequency was estimated to be 172 cpm by timing the hull oscillations. The calculation and the experimental data indicate that the 180-cpm resonance is for the first athwartship mode.

Fifth-order fore-and-aft vibration was measured

* This is an average value obtained from experimental data on ships of similar size.

at the thrust-bearing and reduction-gear housings with resonances at 165 and 226 shaft rpm or 825 and 1130 cpm.

SUMMARY

1. Fifth-order hull vibration was measured in the vertical direction during the speed run. Resonance vibration frequencies of 490 cpm and 1170 cpm were measured at 98 and 234 shaft rpm, respectively. The 490-cpm hull frequency is believed to be that of the fourth vertical mode. First-order vibration in the vertical direction was measured at the bow only between 220 and 270 shaft rpm. No first-order hull resonance was detected.

2. A constant athwartship hull frequency of 180 cpm was measured during the speed run regardless of the shaft speed. There was a general increase in athwartship vibration amplitude up to full speed. This frequency was found to be the athwartship first mode.

3. Fifth-order fore-and-aft vibration was measured at the reduction-gear and thrust-bearing housings during the speed run. Resonance vibration frequencies of 825 cpm and 1130 cpm were measured at 165 and 226 shaft rpm, respectively.

4. The largest vibration measured during the hard turns and crashback maneuvers occurred at the bow in the vertical direction and was 91 mils single amplitude at 204 cpm.

ACKNOWLEDGMENTS

The underway test was conducted with the assistance of Mr. Joseph Gesswein of the Vibrations Division and Mr. C. D. Sullivan of the Production Division at the David Taylor Model Basin.

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