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STRAIN AND VIBRATION MEASUREMENTS ON AN INTERMEDIATE SHAFT STRUT OF DE49

by

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PERSONNEL

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ABSTRACT

A single-arm intermediate propeller shaft strut of DE49, a new escort vessel built by the Philadelphia Navy Yard, was subjected to vibration to determine the resonant frequencies of the strut and of the propeller shaft and to permit a correlation of strains measured on the strut arm both inside and outside the vessel. It was hoped by this method to permit a determination of the strains in the strut arms outside the vessel when the latter was operating on the open sea and when strain measurements could not be made on the water side of the hull with existing equipment.

The general arrangement of the test set-up is shown, and curves are given showing the relationships between 1. the amplitude of vibration of the strut barrel with reference to the frequency of the forced vibration applied to it, and 2. the measured strains on the strut arm, measured inside and outside the hull.

INTRODUCTION

Information received from the Bureau of Ships (1) (2)* concerning the performance of the new DE1 to 50 class of escort vessels at sea indicated that on one vessel at least, the single arm of the intermediate propeller shaft strut on one side of the ship had fractured just outside the hull and that the arm of the strut on the opposite side of the ship had developed a crack, at the corresponding point, indicating early fracture of that strut as well.

In accordance with a telephone request of the Bureau of Ships on 22 May 1943, arrangements were made by the David Taylor Model Basin to make special tests on DE49, which was scheduled to be dry-docked at the Philadelphia Navy Yard on 27 May 1943. In the interval between the receipt of the first reports as to the unsatisfactory condition of the intermediate struts on this class of vessels an alteration had been made by which the maximum thickness of the single arm of the intermediate strut was increased from 2 1/2 inches to 3 1/2 inches. This change had been made on DE49 prior to the docking in question.

The purpose of the test was to apply a vibration generator to the barrel of the new single-arm intermediate strut, set this strut in forced vibration and then measure the strains on the strut arm just outside and just

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* Numbers in parentheses indicate references on page 6 of this report.

inside the shell plate. The original request from the Bureau of Ships asked tentatively for the attachment of metalectric strain gages to the strut arm just outside the hull of the ship, with the idea of measuring the strains at this point when the vessel was underway at sea. However, since the technique of applying these gages to exposed surfaces and of taking readings with the gages submerged in salt water had not been developed, it was decided to abandon this scheme and to obtain instead a correlation between the strain gage readings inside and outside of the hull. It was expected, by the procedure adopted, to use the inside strain observations made while the vessel was underway at sea to estimate with reasonable accuracy that certain related strains existed in the strut arm outside the ship's hull.

Figures 1, 2, and 4 show the general arrangement of the propeller shafts and struts and the shape of the single-arm intermediate strut. It should be pointed out here that the new thick strut arm enters the hull in

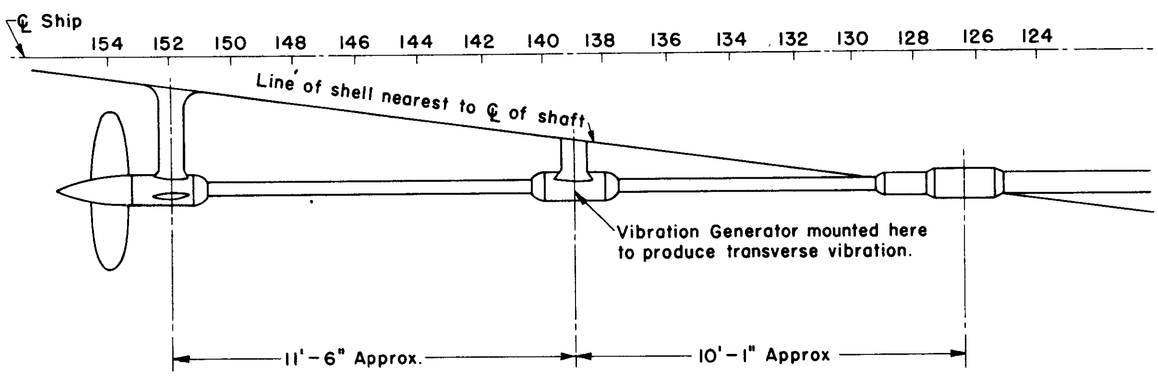

Figure 1 - General Arrangement of Starboard Outboard Shafting, Looking Down

line with a main longitudinal, the web of which is cut away to accommodate the arm. There is a transverse frame in line with the middle of the strut arm, and there are doubler plates both outside and inside the shell around the arm. The internal support of the strut is thus very rigid; see Figure 3.

TEST ARRANGEMENT AND PROCEDURE

A 1/2-inch steel plate with brackets cut to fit the contour of the strut barrel was tack-welded in place on the barrel, to serve as a clamping plate for the generator. The latter was placed with the shaft axes parallel to the plane of the strut arm and the shaft axis, so as to produce a transverse vibration of the starboard strut, corresponding to that which was assumed to be taking place at sea. The vibration generator was fastened to this plate by C-clamps.

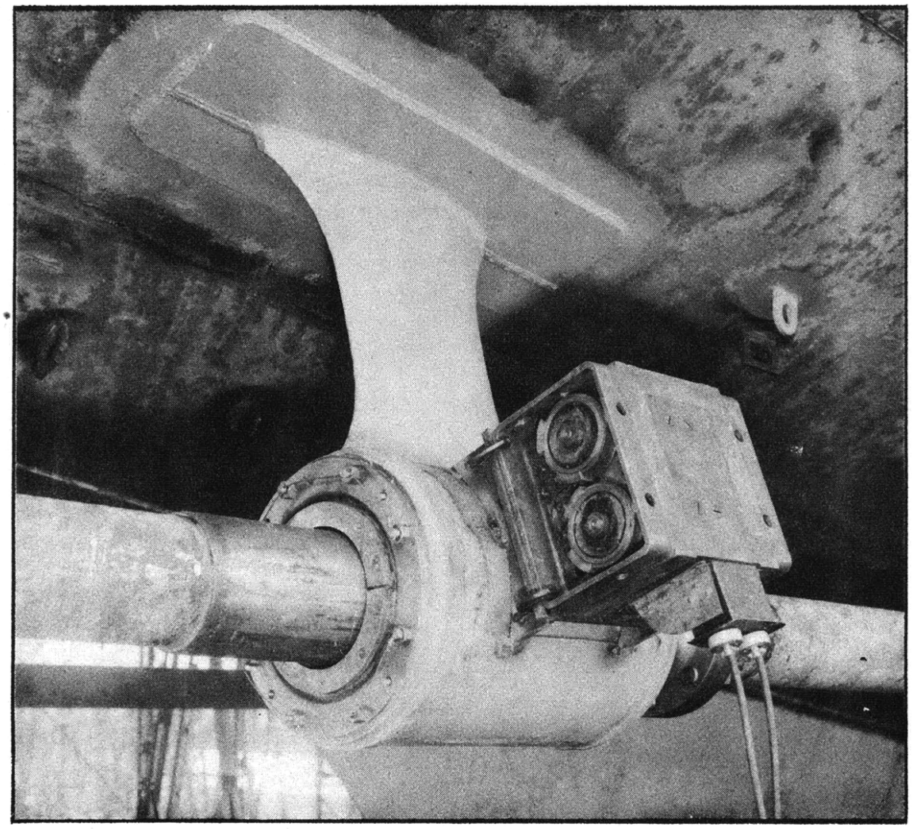

Figure 2 - TMB Small Vibration Generator Mounted on Barrel of Intermediate Strut, DE49

This view is taken looking inboard and ahead, on the starboard side of the vessel.

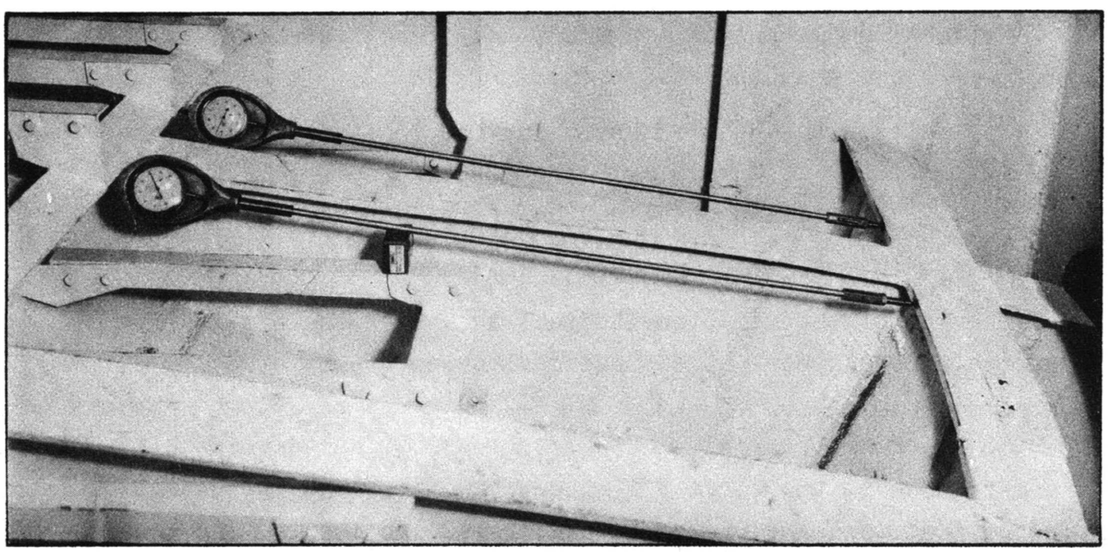

Figure 3 - Banjo Extensometers set up to Measure Torsional Deflection of Longitudinal in way of Strut, DE49

This view is taken looking aft, on the starboard side. The upper end of the strut arm is welded into the web of the longitudinal at the right. The transverse frame between the two extensometers is welded to the outboard side of the strut arm; this frame continues on the other side.

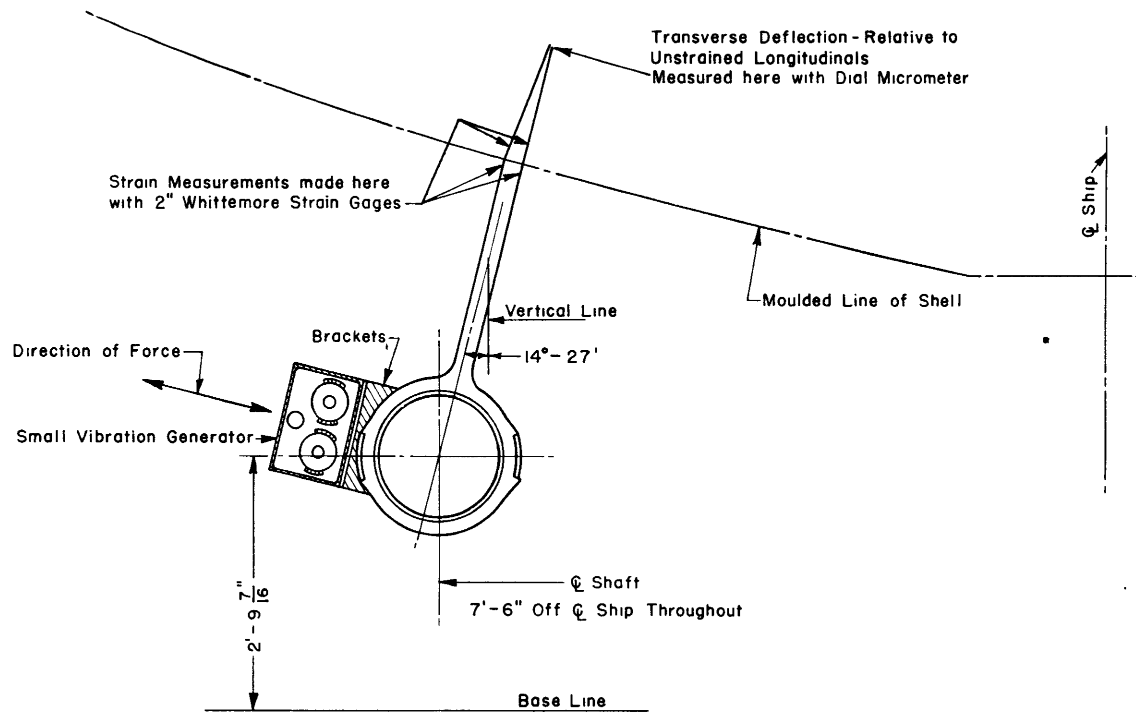

Figure 4 - Single-Arm Intermediate Strut, with TMB Vibration Generator Mounted on Barrel, Looking Aft

The following observations were made during this test:

1. Transverse resonant frequencies of the shaft-strut system out of water.

2. Deflection pattern of the shaft and of both struts during transverse resonant vibration.

3. Stresses on both the outboard and the inboard sides of the intermediate strut arm at the top, near the hull, for a measured amplitude of vibration of the barrel.

4. Stress on the strut arm just inside the hull.

5. Torsion of the main longitudinal in way of the strut for a measured external stress and deflection of the strut.

TEST RESULTS

As shown in the curves, Figure 5, two resonant frequencies were observed, one at 480 and the other at 1320 cycles per minute. In the mode of the lowest frequency, a double amplitude of 40 mils was produced in the barrel with an exciting force of 140 pounds.

The shaft had a considerably greater amplitude than the barrel at this point, 60 mils double, owing to the flexibility of the rubber bearing.

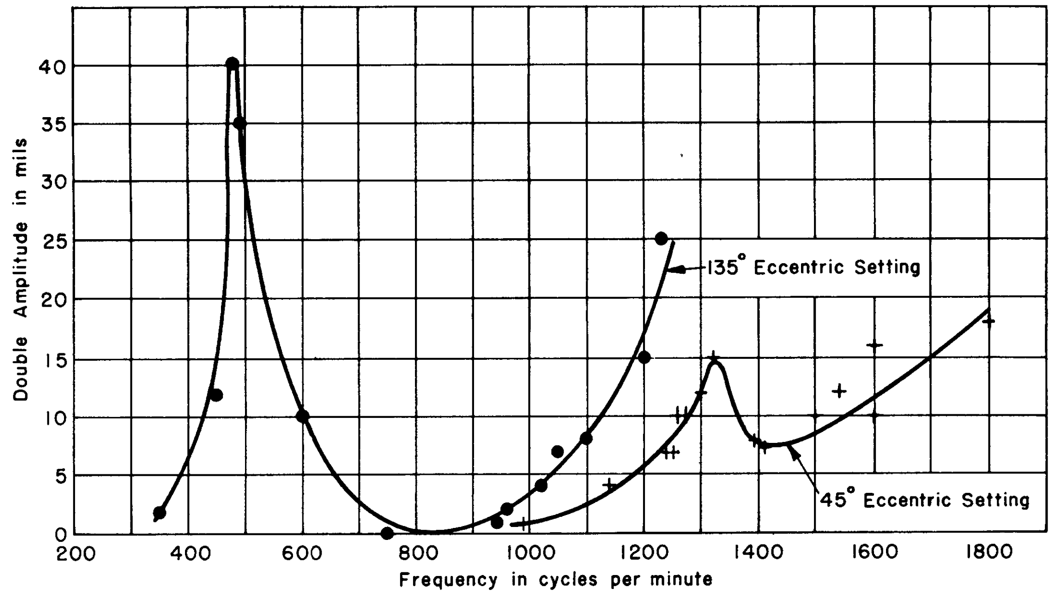

Figure 5 - Curves of Double Amplitude of Vibration of Intermediate Strut Arm, on a Basis of Frequency

The double amplitude of the shaft dropped to 3 mils at the point where the shaft enters the hull and to 10 mils just forward of the after strut barrel.

At the extreme after end of the propeller hub cap, the double amplitude was 22 mils, whereas the amplitude of the after strut barrel was less than 1 mil. This suggests that the flexibility in the single-arm strut bearing, and to a lesser extent in the other bearings, permits the propeller shaft to vibrate in flexure. A rough calculation of the natural frequency of the 8-inch shaft, assuming simple support at the after strut bearing and at the stern tube bearings, gives a value of 220 cycles per minute. This neglects any stiffening effect due to the single-arm strut bearing.

The stress double amplitude at the upper end of the single-arm strut outside the hull, as measured with a 2-inch Whittemore strain gage, was 3000 pounds per square inch on both the outboard and the inboard side of the strut. Inside the hull the stress was too small to measure, but the twist of the longitudinal to which the strut arm was attached caused a double amplitude of the inboard flange relative to the adjacent longitudinals of 5×10^{-4} inches forward of the strut and 3×10^{-4} inches aft of the strut, measured with a dial micrometer.

In the second mode of vibration, 1320 cycles per minute, the single-arm strut and barrel appeared to vibrate independently of the shaft; the amplitude of the latter was only about one-tenth as great as that of the barrel. In this case the double amplitude of the barrel was 15 mils for a vibration generator driving force of 430 pounds. Again the flexibility between the shaft and the bearing was in evidence.

DISCUSSION OF RESULTS

The resonant frequencies which would exist in water are lower than those observed, owing to the mass effect of the water. On the other hand the addition of the mass of the vibrator and its mounting plate partly compensated for the virtual mass of the water. Assuming the frequencies to be lowered 25 per cent when the ship is afloat, the two critical frequencies would be 360 cycles and 990 cycles per minute. Thus an unbalanced propeller might cause a severe intermediate strut vibration at 360 revolutions per minute, and a balanced propeller might produce blade frequency vibration at 120 revolutions per minute and 330 revolutions per minute.

CONCLUSIONS AND RECOMMENDATIONS

While the stress amplitude measured at the top of the strut arm, outside the hull, was fairly moderate for a relatively large transverse vibration at the barrel, there could easily be much higher stress concentrations in the welds at the doubling plates which could not be detected with strain gages.

Although very small distortions were observed inside the hull, it might be worth while to make observations during a trial run at sea as it would give some indication of the magnitude of cantilever vibration of the strut. If this is contemplated, the extension arms attached to the dial micrometer stem should be well supported laterally so as to eliminate errors due to vibration of the gage itself.

REFERENCES

(1) Technical Director TMB Memorandum S87-19/A11 of 22 May 1943 to Structural Mechanics.

(2) Director TMB letter S87-19/A11 of 25 May 1943 to Commandant, Philadelphia.

(3) Gibbs and Cox Plan 11401-11080-2, BuShips Number 476232; "Escort Vessels, DE1 to 50 class, Shaft Struts."