Journal of the Korean Society of Marine Engineering, Vol.30, No.7, pp.800~807, 2006(ISSN 1226-9549)

Hull Deflections Affecting on the Ship's Propulsion Shafting Alignment in 46K Oil/Chemical Carrier

Yong-Jin Lee† · Ue-Kan Kim* · Jong-Su Kim**

(Manuscript : Received SEP 22, 2006 ; Revised NOV 14, 2006)

Abstract : This paper introduces the hull deflection analysis method by using the direct measurements. Accordingly, this paper demonstrates how the hull deflection data is obtained by the reverse calculations using the bending moments from the stain gauge and bearing reactions from jack-up method. Where the hull deflection data provided by this research is used for the shafting alignment calculations for identical or similar vessels, shafting failures due to hull deflections can be minimized. It will also save time and expenses associated finite element method to predict hull deflections.

Key words : Shaft alignment, Hull deflections, Reverse calculation, Strain gauge, Jack-up

1. Introduction

Hulls of modern large oil and container carriers have become more flexible with the scantling optimization and an increase in ship length. On the other hand, as the demand for power has increased with the ship size, shaft diameters have become larger and stiffer. Consequently, the alignment of the propulsion shafting system has become more sensitive to hull girder deflections, resulting in difficulties in analyzing the alignment and conducting the alignment procedure. Accordingly, the frequency of shafting alignment related bearing damages has increased significantly in recent years. The alignment related damages are mostly attributed to inadequate analyses, changes in the design of the vessel, inadequate practices of the shipyard in conducting the alignment, and a lack of well defined analytical criteria.

Hull girder deflections are the most significant disturbance that affects the bearing offset after vessel construction. Inability to account for hull deflections may result in poor alignment design with serious consequences on the bearing life. The problem, however, is the difficulty in predicting and evaluating hull deflections. Hull deflections can be estimated by an

---

† Corresponding Author(The American Bureau of Shipping(ABS)), E-mail:yjlee@eagle.org, Tel: 051)460-4137

* Korea Maritime University

** Korea Maritime University

analytical approach and by measurements. The analytical approach is time-consuming and expensive. It requires detailed modeling of the vessel, in particular the stern part, with a comprehensive model of engine room structure, engine and shafting.

The American Bureau of Shipping(ABS) has conducted the hull deflection analysis by using analytical and measurement approach for a container vessel and similar results from both methods were obtained.[1]-[3] The measurement approach has been the preferred method to analyze hull deflections due to the substantial time and cost involved in the analytical approach.

Hull deflection analysis and the verification of analysis by measurements have been carried out by shipyards as a joint investigation with class societies. However, only one or two vessels have been studied for research purpose. Accordingly, the analysis results from these researches are not adequate for future application.

In this paper, hull deflection analysis using the direct measurement method will be introduced and will be applied to the actual vessel and the results of the hull deflection analysis will be shown.

2. Bearing Reaction Measurements

The most commonly applied methods to measure the bearing reactions are jack-up and strain gauge method. In this chapter, details for the jack-up method and strain gauge method to get the bearing reactions are described.

2.1 Jack-up method[4]

Bearing reactions are measured directly and indirectly. The jack-up measurement is a direct reaction measurement where a hydraulic jack is used to lift the shaft and measure the load at the particular bearing. Due to its simplicity, it is the most widely applied method to measure the bearing reaction in the shipbuilding industry.

Fig. 1 shows the bearing reaction measurement method for intermediate shafting bearing and Fig. 2 shows the bearing reaction measurement methods for main engine bearings installed inside the diesel engine.

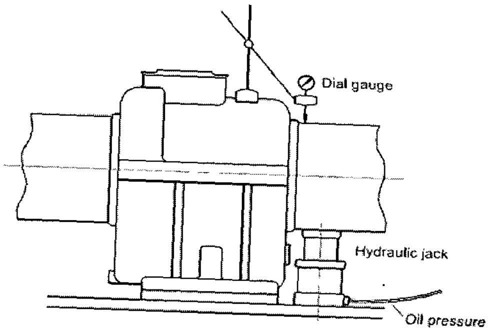


Fig. 1 Reaction measurement of intermediate shaft bearing

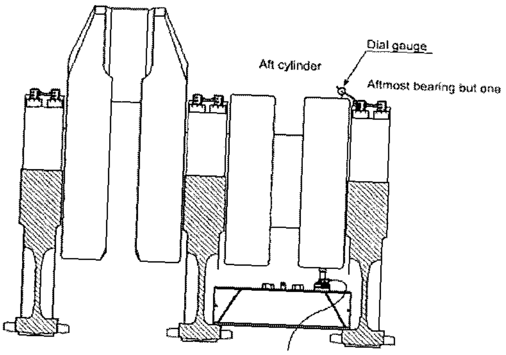


Fig. 2 Jack-up measurement of bearing reactions inside diesel engine

2.2 Strain Gauge Method[5]-[8]

The strain gauge procedure is an indirect method to measure the deflections and strains in the shaft and those measurements are correlated to the bearing reactions.

The strain gauge method can provide relatively accurate information on the loading condition of the bearings which are not accessible for jack-up measurements. Once the strain gauges are mounted, measurement can be easily repeated within a very short time. However, the strain gauge method requires a relatively long time for equipment installation and relatively sophisticated and expensive equipment for measurements. The accuracy of the data depends on system modeling.

The strain gauge technique for shaft bending moment measurement is based on a basic beam relationship.

$$M = \varepsilon \cdot E \cdot W \qquad (1)$$

where, ε = strain, E = Young′s modulus,
W = section modulus

Strain gauges measure strains on the gauges glued on the shaft′s surface. Accordingly, the strain can be calculated using the following formula.

$$\varepsilon = \frac{\Delta R}{R \times k} \qquad (2)$$

where
△R = change in bridge resistance, in Ω?
R = bridge resistance, in Ω?
k = bridge factor

To increase the precision of the measurements, four gauges are installed. Two pairs of gauges are positioned 180° apart from each other and connected in Wheatstone bridge as shown in Fig. 3.

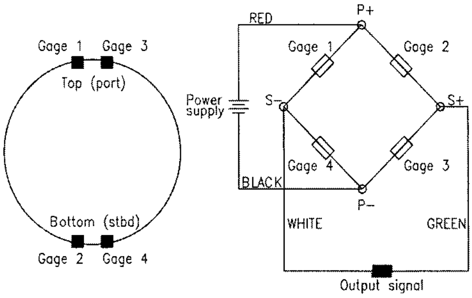


Fig. 3 Wheatstone bridge connections

3. Modeling and Measurement Results

This paragraph chapter explains the shafting system, its modeling, strain gauge, strain gauge equipment used in this study and analyzes the measured results. Table 1 shows the specifications of the shafting system for this study.

Table 1 Specification of the shafting system

Vessel type	45,900 DWT Oil/Chemical carrier
Main engine	B&W 6S50MC-C, MCR 12,900BHP at 127 rpm
Crankshaft Dia.(OD/ID)	600 mm/ 85 mm
Intermediate shaft Dia.	395 mm
Propeller shaft Dia.	470 mm
Propeller	4 blade fixed pitch, Dia. 6000 mm

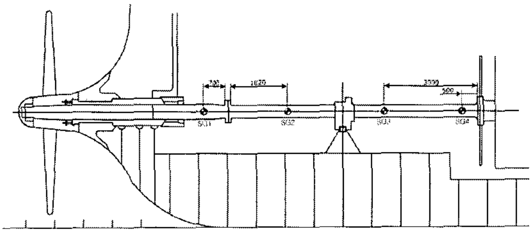


Fig. 4 Installed strain gauge positions

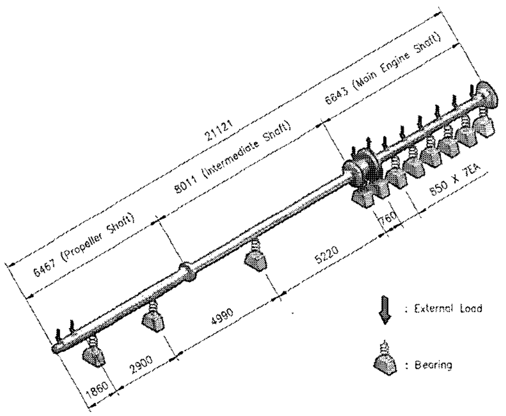
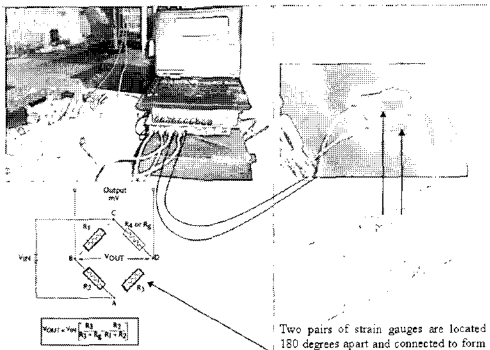


Fig. 5 Modeling of shafting system for shafting alignment calculation

Three strain gauges were installed on the intermediate shaft and one strain gauge was installed on the propeller shaft as shown in Fig. 4.

Fig. 5 indicates the modeling of shafting system for shaft alignment calculations. Engine manufacturer provides the crank-shaft modeling of only four aftermost main engine bearing. However, all main engine bearings have been modeled to increase the accuracy of calculation.

Fig. 6 shows the connections on the strain gauge and strain gauge equipment. For each measurement, strains are recorded while the shaft is slowly rotating for two revolutions. The shaft is rotated first in the ahead direction and then in the astern. The resulting moments are the average between the two directions.



Strain gauge schematic – full bridge is apply at each measurement location

Two pairs of strain gauges are located 180 degrees apart and connected to form Whitestone bridge

Fig. 6 Strain gauge installation and equipment

From the strain gauges, the data is further conditioned as it passes through the strain gauge module and is filtered and converted from analog into a digital signal in the A/D converter.

From the A/D converter, the digital information is sent to the PC, where acquired data is further processed before being logged onto the computer's hard disk.

Data acquisition software on the PC controls the acquisition process and further samples, filters and maps the collected information into the moments. During the acquisition, data is continuously monitored on the screen and simultaneously stored on the disk. Fig. 7 indicates the above data processing.

The following five conditions are measured for the bearing reactions by strain gauge and jack-up.

(1) dry dock - cold
(2) after launching before final adjustment-cold
(3) after launching after final adjustment-cold
(4) Sea trial: laden-cold
(5) Sea trial: laden-hot

The change of bending moments caused by each loading condition is shown in Fig. 8.

Fig. 9 indicates the bearing reactions by the jack-up method for each condition. Bearing reactions of No. 8 main engine bearing is almost zero after bearing final adjustment. However, bearing has suitable load under the laden condition due to hull deflections.

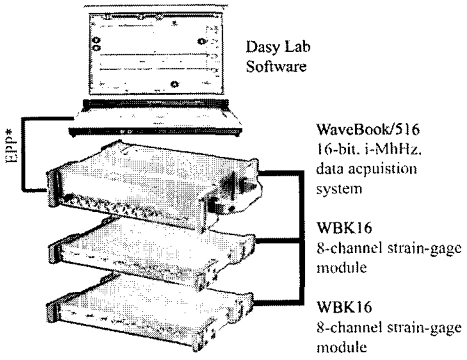


Fig. 7 Data processing

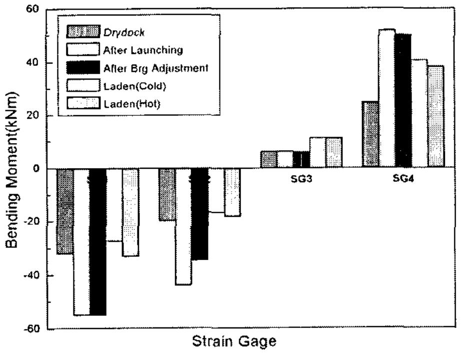


Fig. 8 Shaft bending moments of each condition

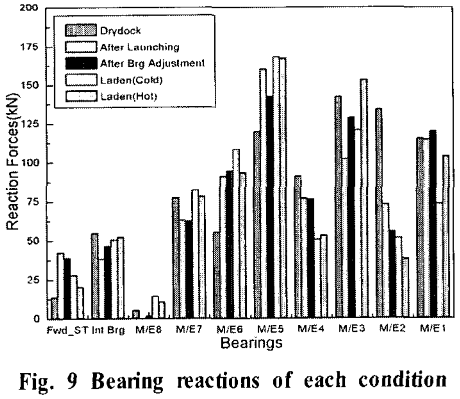


Fig. 9 Bearing reactions of each condition

4. Hull Deflection Analysis

4.1 Reverse Calculation

Reverse analysis is a procedure in which bearing offset is obtained from the measured bending moments and bearing reactions. The genetic algorithm is used for this calculation.[9],[10] We first recalculated the absolute bearing offsets for the dry dock and measured draught each condition of the vessel.

Fig. 10 shows the bearing offset recalculated from the measurements conducted in dry dock and after launching. We note that forward end of main engine lifted when the vessel condition changed from dry dock to after launching.

Fig. 11 shows the bearing offset between after bearing final adjustment condition and the designed offset. We can see that the bearing offset of the final shaft alignment condition is closed to the designed offset.

Fig. 12 and Fig. 13 show the differences of the bearing offset between the bearing final adjustment and laden(cold & hot) conditions. Forward end of main engine lowered when the vessel condition changed from light ballast condition to full load condition.

Fig. 14 shows the differences of the bearing offset between laden cold and laden hot conditions. In general, the engine sump tank located below the main engine is expanded to upper side due to the heating under the hot condition. We know that the measurement results are coincident with those predicted theoretically.

4.2 Hull Deflection

Hull deflections are evaluated as a difference in bearing offsets at respective bearing locations between two different vessel conditions. Accordingly, the hull deflections are calculated as a change of the bearing vertical offset from the dry dock condition to one of the different vessel conditions.

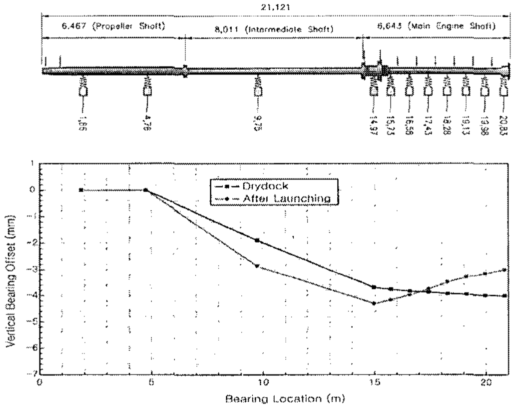


Fig. 10 Bearing offset under dry dock and launching conditions

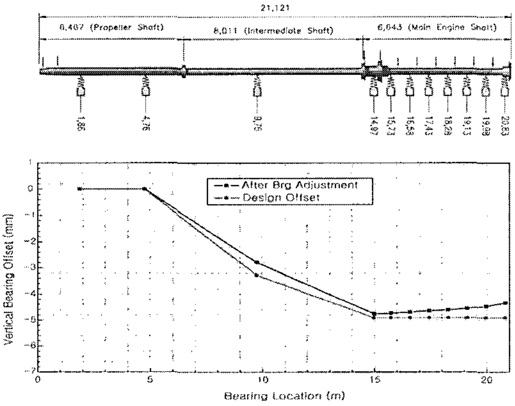


Fig. 11 Bearing offset between bearing final adjustment condition & designed offset

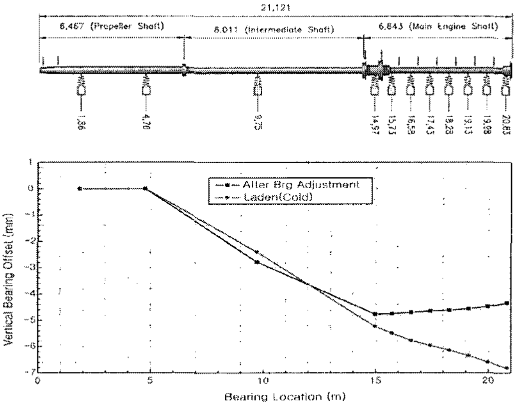


Fig. 12 Bearing offset under bearing final adjustment and laden(cold) conditions

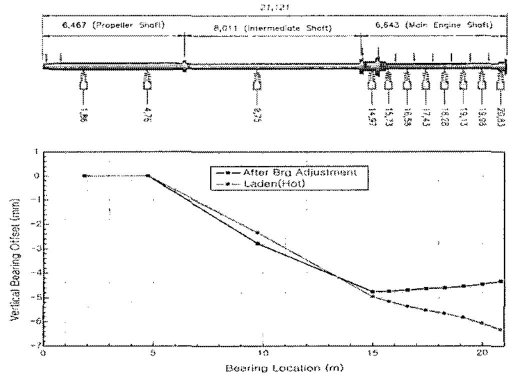


Fig. 13 Bearing offset under bearing final adjustment and laden(hot) conditions

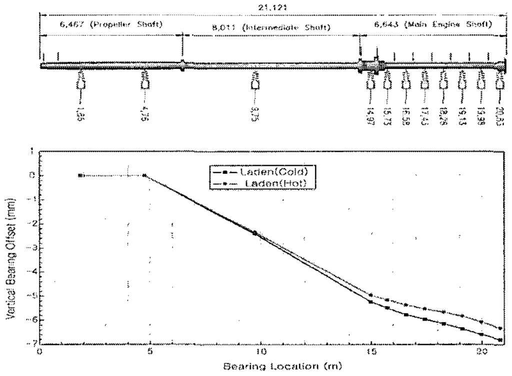


Fig. 14 Bearing offset under laden(cold) to laden(hot) conditions

Since the hull deflection in the shaft alignment is effected from after stern tube bearing to No. 1 main engine bearing, the offset of two bearings is defined as zero to make the reference point.

Fig. 15 shows the absolute bearing offset mapped from the actual bearing offset. The bearing offset is finally adjusted to match with the designed bearing offset after launching. Accordingly, the differences between before and after bearing final adjustments are called as correction values. Fig. 16 shows the hull deflections taking into consideration the correction values. Fig. 17 shows the lower and upper limits of hull deflections excerpted from Fig. 16.

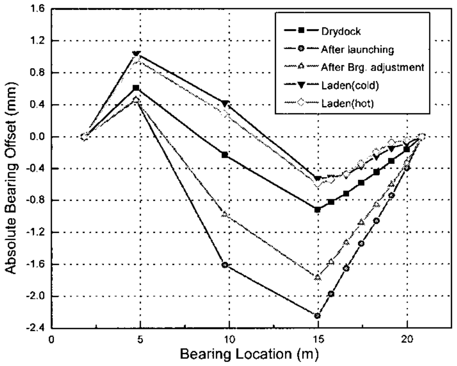


Fig.15 Absolute bearing offset for each condition

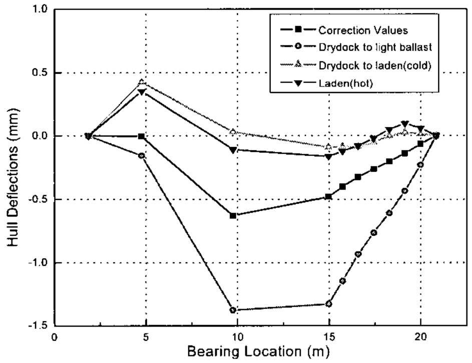


Fig. 16 Hull deflection from dry dock to each condition

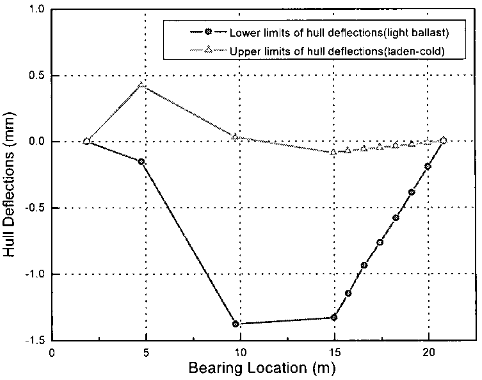


Fig. 17 Lower and upper limits of hull deflections

5. Conclusion

The following conclusions are made in this study:

(1) The methods to calculate the actual bearing offset on the installed bearing and to get the hull deflection values using the bending moments from the strain gauge and bearing reactions from jack-up method are introduced.

(2) The bearing reaction at the aftmost main engine bearing is designed as an unload condition after bearing final adjustment. However, since hull deflections are not big in 46,000dwt oil/chemical carrier, the aftmost main engine bearing has to have a suitable load after bearing final adjustment to get the reliable bearing load in the operating condition.

(3) Where the hull deflection data provided by this research is used for the shafting alignment calculations for identical or similar vessels, shafting failures due to hull deflections can be minimized. And also, it will save time and expenses associated finite element method to predict hull deflections.

(4) Since the hull deflection data

provided in this paper is based on the dock condition, the shafting alignment work can be completed in the dock and this means that the ship construction schedules can be abbreviated.

References

[1] Davor Sverko, "Design Concerns in Propulsion Shafting Alignment", Proceedings of the ICMES Conference 2003, Helsinki, May 2003.

[2] Davor Sverko, "Investigation on Hull Deflection and Its Influence on Propulsion Shaft Alignment", SMTC &E: October 2005 - Houston.

[3] Holger Mumm, "The Need for a More Considered Design Approach to Engine-Hull Interaction" Germanischer Lloyd, Ship Propulsion Systems 2002.

[4] American Bureau of Shipping, "Guidance Notes on Propulsion Shafting Alignment", April 2004.

[5] Kvamsdal, R. "Shaft Alignment Control by Means of the Strain Gauge(Bending Moment) Technique", Det Norske Veritas, Research Dept. Report 68-19-M(1968), pp. 11.

[6] Forrest, A. W. and Labasky, R. F., "Shaft Alignment Using Strain Gauges", Marine Technology, Vol. 18, No.3, July 1981, pp. 276-284.

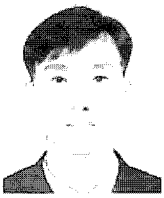
[7] M. N. Keshava Rao and M.V. Dharaneepathy, "Computer-Aided Alignment of Ship Propulsion Shafts by Strain Gauge Methods", Marine Technology, Vol. 28, No. 2, March 1991, pp. 84-90.

[8] K.S. Kim, W.S. Jang, "A Study on Shaft Alignment of the Rotating Machinery by Using Strain Gauges", Journal of the Korean Society of Precision Engineering Marine Technology, Vol. 18, No.5, May 2002.

[9] Davor Sverko, "Shaft Alignment Optimization with Genetic Algorithms", SNAME Propellers and Shafting 2003 Symposium, Virgina Beach, October 2003.

[10] Novkovic, S. and Sverko D. (2003): 'A Genetic Algorithm with Self-Generated Random Parameters", Journal of Computing and Information Technology, 11, 4:271-283.

Author Profile



Yong-Jin Lee

He received his B.E. and M.Eng. from Korean Maritime University. He is currently an engineering specialist in Engineering Service Department of the American Bureau of Shipping.

Ue-Kan Kim

He received his B.E. and M.Eng from Korean Maritime University and his Dr.Eng. from Kyoto University in Japan. He is currently a professor in Division of Mechanical and Information Engineering at Korea Maritime University in Busan.

Jong-Su Kim

He received the M.E. and Ph. D. degree from Korea Maritime University. He is currently assistant professor in the Division of Mechatronics Engineering at Korea Maritime University in Busan, Korea. His research interests include electric machinery control, power electronics and AC drives, etc