COMPARISON OF PROPULSION SHAFT STRAIGHTNESS USING NEW D.I.Y ARDUINO MEASUREMENT DEVICE WITH THE CONVENTIONAL DIAL INDICATOR

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ABSTRACT

In propulsion, shaft misalignment and bending are some of the essential topics discussed among industrialists. A marine propulsion shaft is often subjected to high stress and loading, which may lead to shaft bend—this causes the shaft to lose its straightness. Shaft straightness is a vital part of maintaining life other components. It is crucial to maintain its straightness and correctly identify such failure to avoid future misfortune. However, less study has been focusing on the technology development regarding shaft straightness tests. Therefore, this paper is a comparative study of a shaft straightness test using a newly developed measuring kit with the conventional dial indicator, which was typically used. The result of the study and analysis has been recorded and discussed

Keywords: ship propulsion shaft, shaft straightness, misalignment, vibration, dial indicator

INTRODUCTION

The propulsion shaft plays an essential role on ships as it is the main drive connecting the main engine with the propeller. A marine propulsion shaft is often subjected to really high stress and loading. Load and stresses acting on the shaft tend to bend, causing misalignment as its axis of rotation move away from its original. A bent shaft generates high vibration and causes stresses on other components during operation, resulting in the shaft's failure if it is left unaddressed. Therefore, it is crucial to be able to identify such defects. Shaft straightness can be identified by conducting a shaft straightness test. The most well-known method in determining shaft straightness is by using the dial indicator test.

The usage of dial indicators does provide greater accuracy, but they also pose specific problems: the reading accuracy of the device and the surface level. A dial indicator is a precision measuring instrument. Reading accuracy will be affected even with slight disturbance. Conducting this method demand an immense level of technical skills, and the process is practically time-consuming. A study by Li (2018) and Liu et al. (2015) also focuses on the shaft measuring method while prioritizing the reading accuracy.

Most of this innovation and development aims to develop a measuring instrument that improvises the present method. Simm et al. (2016), Huang (2016) and Wolf (2016) conduct studies that focus on developing a straightness measuring instrument and methods to overcome the shortcoming of the current straightness testing device. Therefore, in this study, a D.I.Y. Arduino based measuring kit is developed to

help the issues. Studying the currently used straightness measurement method aims to develop straightness measuring kit using a microcontroller interface, the Arduino, without taking the way of shaft straightness test original functionality and conduct for granted. The developed D.I.Y. Arduino kit will be tested, and the data collected will be compared with the conventional dial indicator method. It is anticipated that this Arduino measuring kit may benefit the industry and ease the current shaft's straightness test method.

LITERATURE REVIEW

A   Bend in Propulsion Shaft

A bend occurs on the shaft when it loses its symmetrical structure to its axis of rotation. After a shaft happens to bend, a vibrational motion which is the shaft whirling, emerge. When the shaft rotates, it will deviate far from its ideal centre line because centrifugal forces on the centre of gravity are not the same as the ideal shaft's centre line. Sometimes, due to machining accuracy or wear and tear, the propulsion shafts face certain eccentricities. Therefore, it suffers from a vast unbalance excitation when it rotates (Zou et al., (2016). Failures in the propulsion shaft did not happen regularly, but it is challenging to detect and rectify when it does. There are two primary failure contributors in causing a shaft to bend: mechanical overload and internal stress. Vizentin et al. (2017) also found that an area with a high-stress concentration on the propulsion shaft will highly fail.

B   Shaft Misalignment and Vibration

Shaft misalignment is often associated with the stability of rotating machinery as an incorrectly aligned propulsion shafting, resulting in the loss of its stability. A study by (Xu et al., 2018) shows that around 60% of malfunctions involving rotating machines are related or caused by misalignment. The excessive misaligned shafting system led to vibration. A ship with an unacceptable level of vibrations is utterly unsafe for operation. It can damage other working machinery. This excessive vibration can result in a casualty to sensitive machinery and the ship's structure (Dasanayaka & Perera, 2017). All machinery such as main engines, propulsion shafts, and propeller convey vibration as it operates but at a tolerable amount. When this vibration exceeds the safe level, it becomes a significant concern. Dasanayaka and Perera (2017) also stated that a ship's vibration sources mainly originate from the propulsion systems.
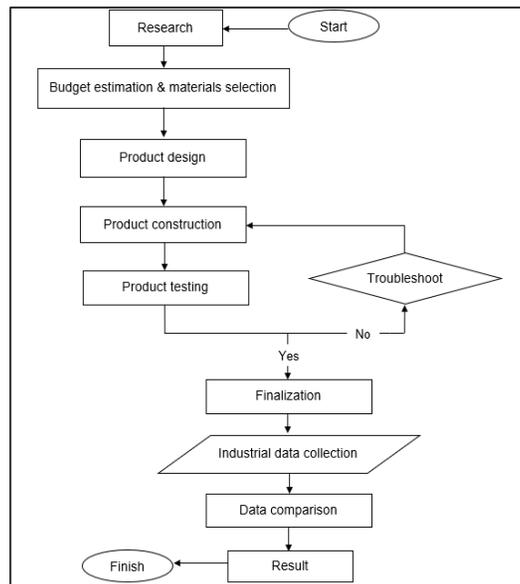
C   Shaft Straightness Test

The homogeneity of the shaft diameter and its longitudinal deviation from the original axis is called the shaft straightness value. The shaft must not be subjected to any load or stress during the value measurement or reading process to obtain such value. The shaft straightness value is also known as 'shaft axial runout' A shaft losses its straightness and consider bend when the centreline of the shaft is no longer parallel with the axis of rotation. This lack of straightness, called centreline runout, can result from a bent shaft (Examiner & Jones, 2007). Runout is the displacement of the surface of a rotating object. Various methods can determine shaft straightness but as previously suggested, using the dial indicator method is the most conventional way to get the readings at different points on a shaft (Huang, 2016) (Kumar et al., 2018). A v-block is usually used to support the shaft in a condition of its actual deviation from the initial dimensions. A dial indicator main target is comparing measurements between two surfaces (Kumar et al., 2018). It verifies the conformity of one object, during the second object act as the reference.

RESEARCH METHODOLOGY

The research was conducted using two devices: using the conventional dial indicator (CDI) method and developing a measuring kit using the digital dial with an Arduino-based microcontroller. The D.I.Y. Device required several assembly processes as well as the coding of the Arduino microcontroller. The Arduino

will read the incoming data from the digital dial indicator through the IDE software. Before the product is developed, the project's planning is laid out to ensure the project runs smoothly without problems.

Figure 1 Project flow chart

Figure 2 Assembly of D.I.Y. device

In this study, the shaft straightness is determined by using the shaft runout measurement method. The shaft is rotated slowly, and the reading at each point is obtained. The shaft runout is then obtained from both methods' readings, tabulated into tables and graphs. The runout measurement is taken at several points along the entire shaft length at four different sides of the shaft at each point: Port, Starboard, Top and Bottom. The straightness test data obtained using the Arduino Device will be compared with the straightness test data from the CDI method.
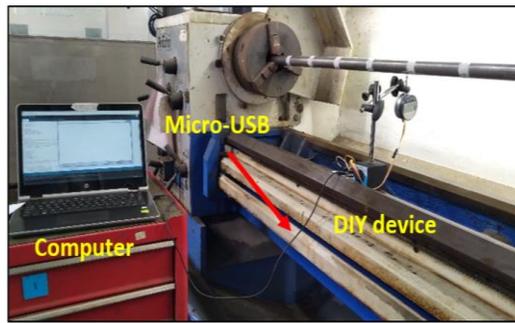
Figure 3 Shaft runout measurement

Table 1 Details of shaft tested

Shaft	Ship Origin	Testing Location	Length (mm)	Diameter (mm)	Permissible Variation (mm)
A	EX-KD Kelantan (Port Side)	Unikl Mimet Workshop	1235	100	+0.127 -0.024
B	EX KD Kelantan (Starboard Side)	Unikl Mimet Workshop	6480	100	+0.127 -0.024
C	Wheeler Boat	Long Chong Foundry Sdn. Bhd.	1930	31.75	+0.076 -0.024

RESULTS AND DISCUSSION

The testing has been successfully carried out by measuring the shaft runout at each point on the shafts. The data is measured and recorded in table form from the test before converting it into graphs of comparisons. The test was able to be done on three different shafts with different lengths and different diameters. The particular of the propulsion shafts examined is shown in table 1. The data is then compared between the D.I.Y. device and the CDI method.
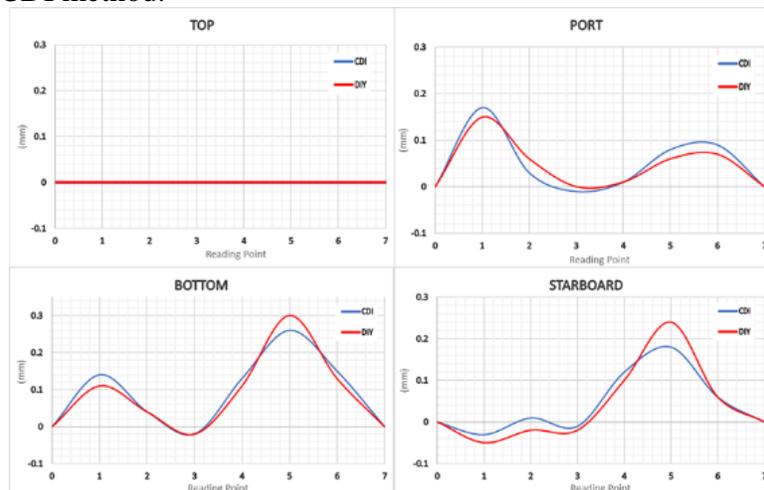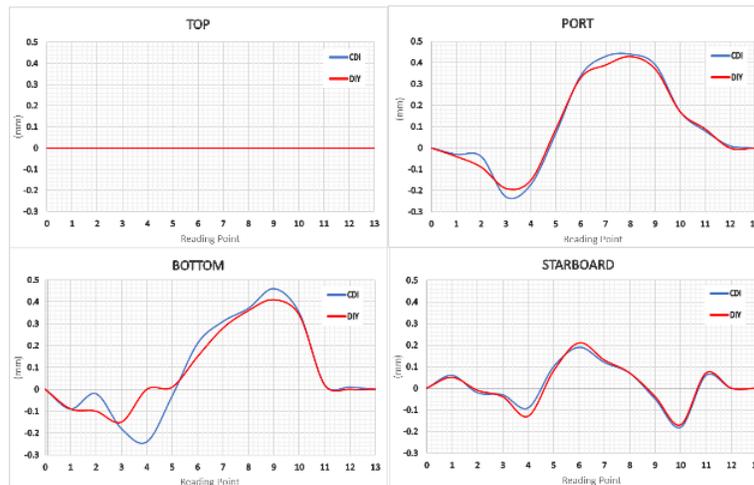

Graph 1 Straightness test for Shaft A

Several parts of the shaft have the same readings of CDI and D.I.Y., while most of the readings are slightly different. From the graphs, it can be said the shaft failed to meet the permissible variation at several points along the shaft, especially from points 4-6. The shaft bend toward the top and port side from point 4-6, while point 5 has the maximum reading. For Shaft A, it shows that the shaft undergoes bend at several

points on the shaft. At the port side, the runout reading is no longer in the permissible range at point 1. The bottom side reading shows the shaft exceeds the permissible variation at most points, indicating the shaft is more bend toward the top direction. The shaft exceeds the permissible range at most points from the port side, which indicates it bends toward the starboard side the most at this point.

In Shaft B, the reading between the D.I.Y. device and the CDI method shows minor differences at most points. There are several visible differences in readings that can be detected from the bottom side. Point 2 and point 4 shows a significant difference in readings of the D.I.Y. device to the CDI from the bottom side.

Graph 2 Straightness test for Shaft B

The shaft has a severe bend at most points of the readings. The port side of the shaft bend toward the port from point 2 to point 4. While in the other direction from point 5 to point 11. From the bottom side reading, the shaft bends toward the bottom at the first reading point, and then it bends toward the top side from point 6 to point 10. On the starboard side, the shaft starts to experience bend higher toward the port side from point 5 and point six while it bends in the starboard direction in point 10. Primarily most of the readings on this shaft exceed the permissible variation.
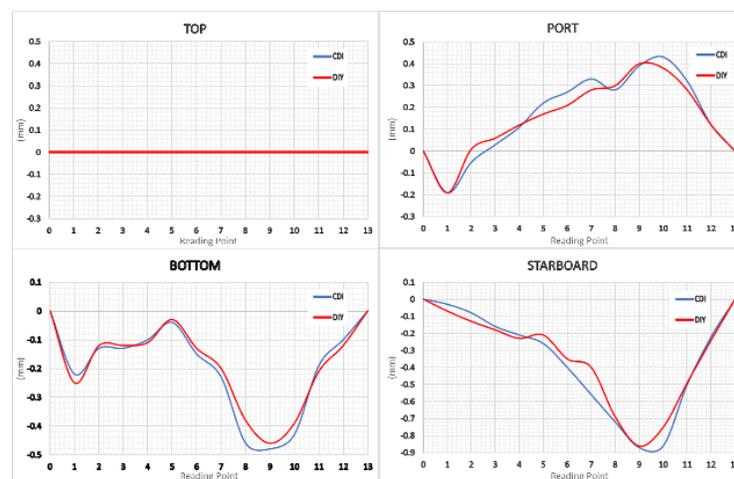
Graph 3 Straightness test for Shaft C

From Graph 3, there are differences in readings between both methods. The reading of the D.I.Y. device and CDI method are different at almost all points except for only a few where both recorded readings are the same. Shaft C show more significant negative readings in the bottom and starboard side, indicating

the shaft undergoes bending toward the direction of testing. The reading of the D.I.Y. device is somehow consistently higher than the CDI reading. Shaft C undergoes severe bend starting from point 7 to point 10. The shaft bends toward the Starboard side the most at point 7 and point 10.

Meanwhile, at point 1 and point 9, the shaft bend toward the Portside direction. The shaft bends upward toward the Topside at P1 and P9 of the reading points from the bottom side. This shaft is out of straightness and no longer fit for usage; thus, it needs to be treated for further use. Figure 4 illustrates the location and direction of the most maximum bending occurring on Shaft C.
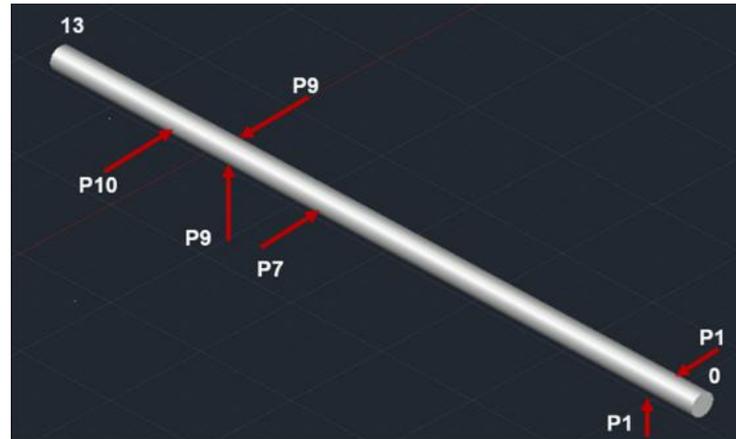

Figure 4 Visual of Shaft C from the port side

There are differences between the data sets collected from the D.I.Y. device and the CDI method from the collected data. Most of the measured runout readings show a difference between 0.01mm~0.05mm. The percentage errors in readings of the D.I.Y. device to the CDI method is calculated using the Mean Absolute Percentage Error (MAPE). Table 2 shows the result of the calculation for each side of the shafts. The calculated percentage error shows that the D.I.Y. device has an error of 5% in reading compared to the CDI method. Therefore, it can be said that accuracy of 95% compared to the CDI method. The errors are considered low, and it is in an acceptable tolerance.

Table 2 Percentage difference between D.I.Y. device and CDI method

Data from Propulsion Shaft	Percentage Differences of DIY to CDI			
	TOP	PORT	BOTTOM	S/BOARD
Ex-KD Kelantan (Port Side)	-	4.11%	5.13%	4.35%
Ex-KD Kelantan (Starboard Side)	-	5.41%	4.29%	6.06%
Wheeler Boat	-	5.31%	5.26%	5.54%
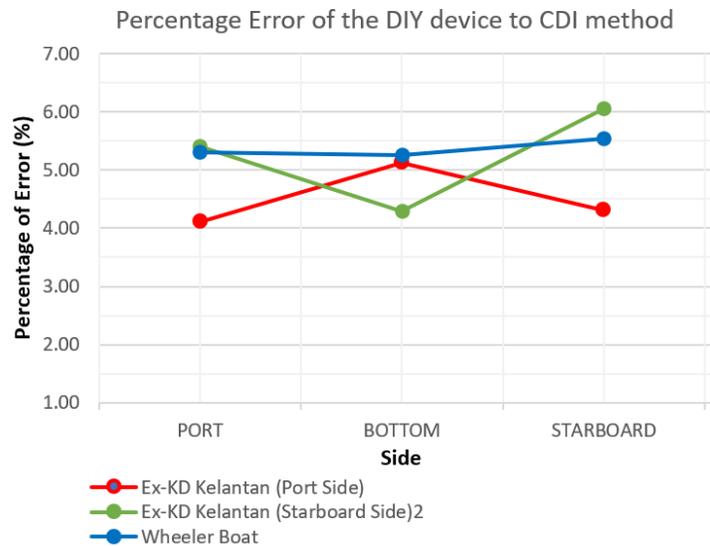
Graph 4 Percentage error between D.I.Y. device and CDI method

The three propulsion shafts, Shaft A, Shaft B and Shaft C runout measurement, fail to be within the permissible variation and need straightening or repair. The shaft can bend due to damage during manufacturing, shipment, installation or operation. This bending in the shaft might cause misalignment, unbalanced vibration, wear and tear, and even damage to the bearings and machineries involved if left unattended.

CONCLUSION AND RECOMMENDATION

In conclusion, the objective and the target of this project is accomplished. An Arduino measuring device is developed, and it can produce measurable readings. The research and product developed from this project are expected to be used as a device that can help improve the precision measuring field, especially in shaft straightness tests. With a small degree of error and more straightforward execution, the D.I.Y. device is undoubtedly beneficial. The objectives of this study have been achieved even with several obstacles and problems along the way. Several areas regarding this project can be improved and enhanced despite this project having already accomplished its initial purpose target. Further developments are:

    i.   The usage of the Arduino can be expanded, which includes much detailed data and output readings rather than raw.

    ii.   Upgrading a Bluetooth or Wi-Fi mode for data transferring from the device to the Arduino IDE Software makes it wireless.

    iii.   Using improvised programming, the output coming from the Arduino can be elaborated, such as producing the result of where the bend occurs or what kind of bend is the shaft experiencing.

    iv.   Development of Software, especially for shaft straightness test.

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