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Ships and marine technology — Determination of the shaft power of ship propulsion systems by measuring the shaft distorsion —

Part 2: Optical reflection method

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 2, *Marine environment protection*.

A list of all parts in the ISO 20083 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Selecting the optimum rating of a ship's main engine is important for ship owners, because it greatly affects the expenses of operations, maintenance and management as well as the ship's construction cost.

Measuring the output of the ship's main engine is important for confirming the ship efficiency, as well as for assessing the possible deterioration of the propulsion equipment or the accumulation of fouling on the hull over time. There are many methods of measuring an engine's output: (1) measuring the distortion of the shaft, (2) determining the fuel consumption, and (3) observing engine indicators such as cylinder pressure gauges.

Among these methods, ISO 20083 addresses the shaft distortion measurement with a shaft power meter, a method commonly used as the principal measurement of engine power output.

The purposes of shaft power measurement are:

— to provide a measurement of the ship's main engine output,

— to provide information regarding the ship's most efficient speed,

— to select optimum engine operational characteristics,

— to estimate maintenance and repair costs, and

— to monitor heavy propeller running.

Ships and marine technology — Determination of the shaft power of ship propulsion systems by measuring the shaft distortion —

Part 2:
Optical reflection method

1 Scope

This document specifies a procedure to determine the shaft power of engine ships, by measuring the shaft distortion using an optical reflection type device. It gives the principles of the measurement, the components of the device and the calculation method. It also describes the factors for determining the measuring accuracy, including the calibration procedure, and specifies the on-board documentation for the device.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/s

3.1
shaft
propeller shaft or intermediate shaft that transmits the engine power to the propeller, and on which the shaft power meter is installed

3.2
shaft torque
Q
turning moment transmitted to the shaft that is generated by the engine to rotate the propeller

Note 1 to entry: It is expressed in newton meters.

3.3
shaft power
P_S
power transmitted to the shaft that is generated by the engine to rotate the propeller

Note 1 to entry: It is expressed in kilowatts.

4 Principles of the measurement

The shaft power meter is a device that measures the shaft revolution and the torsional deformation of the shaft caused by the shaft torque. The shaft power, P_s [kW], is calculated using Formula (1):

$$P_s = \frac{2 \cdot \pi \cdot N \cdot Q}{60} \times \frac{1}{1\,000} \tag{1}$$

where

N is the rate of shaft revolutions per minute [min^{-1}];

Q is the shaft torque [Nm].

The shaft torque, Q [Nm], is calculated from the torsional deformation angle rate at unit length of the shaft using Formula (2):

$$Q = \frac{G \cdot I_p \cdot \theta'}{1\,000} \tag{2}$$

where

G is the G-modulus [N/mm^2];

I_p is the polar moment of inertia [mm^4];

θ' is the shaft torsional deformation angle rate at unit length [1/mm].

The polar moment of inertia, I_p [mm^4], is calculated using Formula (3):

$$I_p = \frac{\pi}{32}\left(D_o{}^4 - D_i{}^4\right) \tag{3}$$

where

D_o is the outer diameter of the shaft [mm];

D_i is the inner diameter of the hollow shaft [mm].

The shaft torsional deformation angle rate at unit length, θ' [1/mm], is calculated using Formula (4):

$$\theta' = \frac{\theta}{l} \tag{4}$$

where

θ is the shaft torsional deformation angle [rad] as shown in Figure 1;

l is the length between the shaft rings [mm].

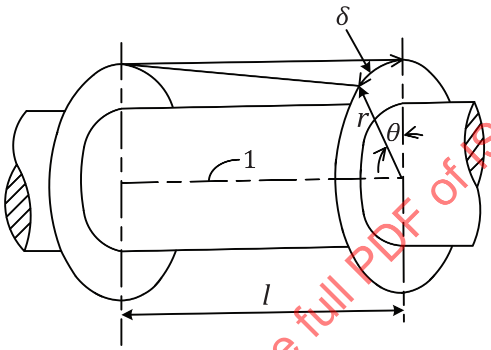
The torsional deformation angle, θ [rad], can be calculated from the displacement of the detecting point measured by the torsion meter as given in Formula (5):

$$\theta = \frac{\delta}{r} \tag{5}$$

where

δ is the displacement of the detecting point [mm];

r is the distance of the detecting point from the shaft center line [mm].



Key

1 center line of the shaft

θ shaft torsional deformation angle [rad]

l length between rings [mm]

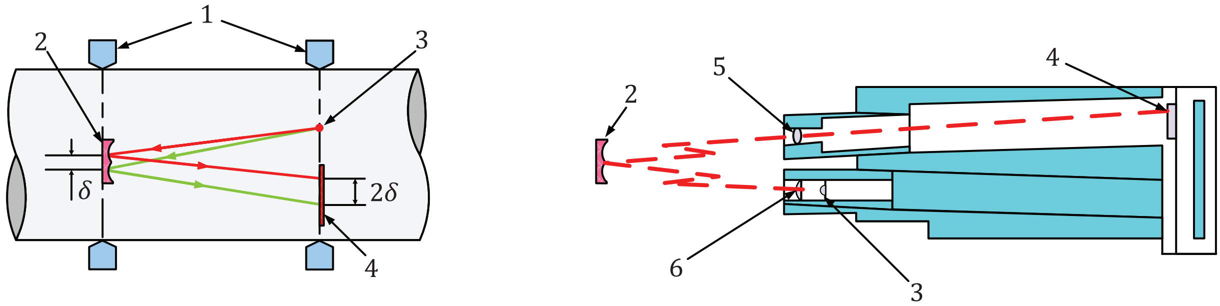
δ displacement of the detecting point [mm]

r distance of the detecting point from the shaft center line [mm]

Figure 1 — Torsional deformation angle of a shaft

The optical reflection type device measures the displacement by torsional deformation of the shaft (δ) using a light source, a reflecting mirror, and a charge coupled device (CCD) sensor as shown in Figure 2. The image of the light source, which is made by the concave mirror, moves twice as the real displacement of the mirror (δ). The image of the light source is then magnified about 5 to 10 times by the magnifying lens set before the CCD sensor. As a result, the total magnifying rate of the displacement at the CCD sensor is around 10 to 20 times.

The total magnifying rate and the calibration factor, which relates the real displacement value and CCD's count number, are determined by the calibration process as shown in Clause 7.



Key

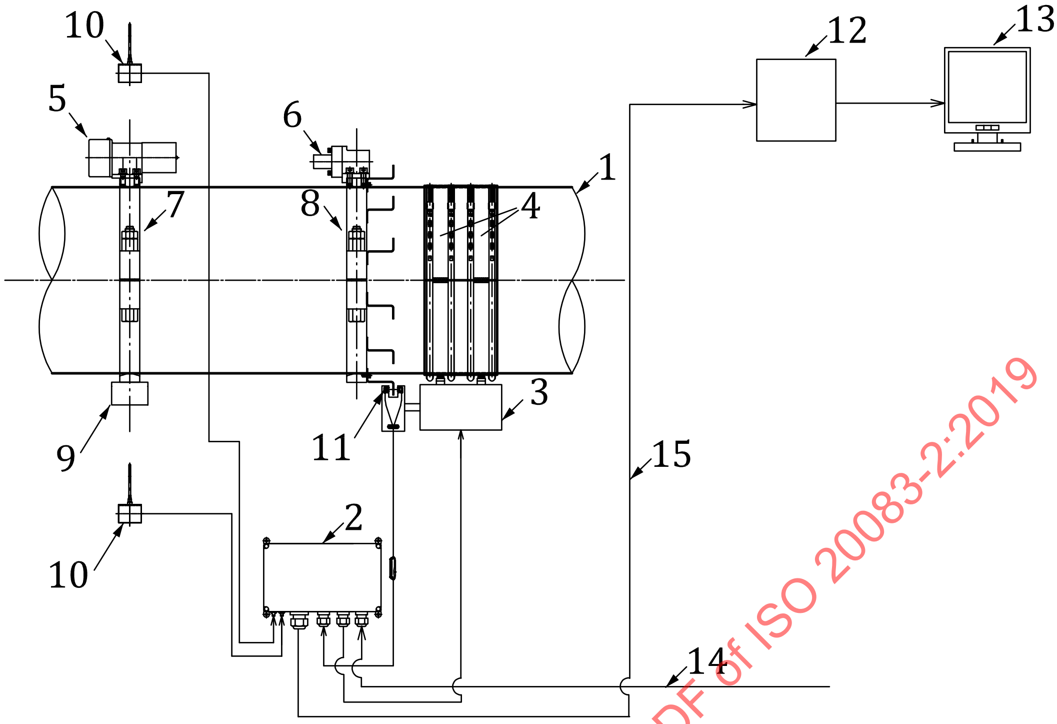
- δ displacement of the detecting point
- 1 ring
- 2 mirror
- 3 light source
- 4 CCD
- 5 lens
- 6 slit

Figure 2 — Principles of the measurement

5 Components of the device

5.1 General

The components of a typical optical reflection type device include two mounting rings, a torsion meter, a reflecting mirror, a transmitter, a receiver and a power supply system, a revolution sensor and a monitoring system. See Figure 3.



Key

1 shaft
2 receiver and power supply system
3 brush and stand (power supply to slip ring)
4 slip ring
5 torsionmeter
6 mirror
7 ring
8 ring
9 transmitter
10 receiving antenna
11 shaft revolution sensor
12 CPU
13 LCD
14 power supply cable
15 LAN cable

Figure 3 — Example of equipment arrangement

5.2 Mounting rings

Two mounting rings are attached to the shaft for setting the main body of the torsion meter and the mirror. One of the two rings is set up for the main body of the torsion meter and the other for the mirror. They shall be set with an interval of a specified length (l) in the longitudinal direction.

5.3 Torsion meter

The main body of the torsion meter is composed of the light source, a slit, a zoom lens, and a CCD sensor. It emits light from the light source through the slit and detects the reflected light from the mirror. This CCD sensor is composed of thousands of elements arranged in a line, equally spaced, and the position of reflected light can be detected by the CCD's element number.

5.4 Reflecting mirror

The concave mirror receives and reflects the light emitted from the light source, and makes the light strike the CCD in the main body. The mirror shall be set so that the reflected light enters the CCD sensor correctly.

5.5 Transmitter

The following three functions shall be performed by the transmitter set on the shaft:

a) it shall detect the amount of torsion by counting the element number of CCD sensors;

b) it shall wirelessly transmit the amount of torsion;

c) it shall receive power from the slip ring (or electromagnetic induction voltage system as an alternative) and supply the necessary electric power to the torsion meter.

The transmitter is installed on the ring attached to the shaft, as well as the torsion meter, and performs these three functions.

5.6 Receiver and power supply system

The following functions shall be performed by the device set on the hull close to the shaft:

a) it shall receive the data of torsion signals from the transmitter;

b) it shall receive the data of shaft revolutions from the revolution sensor;

c) it shall send the received data of shaft torsion and revolution to the central processing unit (CPU) via local area network (LAN) cable;

d) it shall supply electric power to devices on the shaft (the transmitter and the torsion meter).

The receiver and power supply system is integrally installed on the dedicated stand fixed to the hull to perform these functions. In addition, two external antennas are installed on the starboard and port sides of the hull in the vicinity of the shaft. Electric power is supplied to the transmitter on the shaft through the slip rings or electromagnetic induction system.

5.7 Revolution sensor

The revolution sensor detects the rate of shaft revolution. The detected rate of shaft revolution is sent to the receiver. The revolution sensor shall be installed on the dedicated stand fixed to the hull.

6 Calculation of the shaft power

6.1 Shaft torque

The shaft torque, Q [Nm], is calculated using Formula (6):

$$Q = \frac{1}{1\,000} \times \frac{\pi \left(D_o^{\,4} - D_i^{\,4} \right) G}{32} \times \frac{K_s \left(C_m - C_o \right)}{l \cdot r} \tag{6}$$

where

D_o is the outer diameter of the shaft [mm];

D_i is the inner diameter of the shaft [mm];

G is the G-modulus [N/mm^2];

K_s is the calibration coefficient of the torsion meter [mm/count];

l is the length between mounting rings [mm];

r is the distance of the detecting point from the shaft center line [mm];

C_m is the measured point [count];

C_0 is the zero point [count].

6.2 Shaft power

The shaft power, P_s [kW], is calculated using Formula (7):

$$P_s = \frac{2\pi \cdot N \cdot Q}{60} \times \frac{1}{1\,000} \tag{7}$$

where

N is the rate of shaft revolutions per minute [min^{-1}];

Q is the shaft torque [Nm].

7 Factors for determining the measuring accuracy

7.1 General

The installation, setting, and shaft power measurement shall be carried out in accordance with the manufacturer's instructions. In the installation and setting process, the following parameters shall be checked and set carefully because they have a direct influence on the measured value of the shaft power. The procedures for zero adjustment and calibration are specified in 7.7 and 7.8, respectively.

7.2 Shaft diameter

The shaft diameter shall be checked with drawings. It is recommended to check it with the direct measurement of the shaft's outside circumference around the mounting rings as well.

7.3 G-modulus

If no certificate based on an actual shaft torsional test is available, a G-modulus of 82 400 N/mm^2 shall be used.

NOTE A G-modulus of 82 400 N/mm^2 is also given in ISO 15016:2015[1].

7.4 Distance between mounting rings

The distance between mounting rings shall be set in accordance with the manufacturer's instructions.

7.5 Thickness of the mounting ring

The thickness of the mounting ring at the base of the torsion meter shall be checked with drawings. It is recommended to check it with the direct measurement of the distance between the shaft surface and the base of the torsion meter as well.

7.6 Vibration of the shaft

In order to measure the shaft torque precisely if the shaft is vibrating, the sampling of the shaft torque shall be carried out with frequency greater than twice the vibration frequency. The sampling frequency shall be set in considering the probable torsional vibration frequency.

7.7 Zero adjustment

7.7.1 Zero point

The zero point is the output of the torsion meter when the shaft is free from any torque. It is important as the base of the torque measurement. For a few days after installation, before the initial stress of installation is released, the zero point may move due to vibration or an abrupt change of the shaft revolution. A zero point check shall be undertaken at regular intervals and if the measured values seem to be incorrect.

7.7.2 Procedure for zero adjustment

Zero adjustment shall be carried out by following the manufacturer's instructions. Generally, zero adjustment is carried out to obtain the torsion meter's output by turning the shaft very slowly. The average of the measured values at one rotation in the ahead and astern directions shall be adopted. It shall be carried out while the ship is anchored and the engine is not running. The ship movement or current flow around the propeller is a cause of error.

7.8 Calibration

7.8.1 General

The purpose of the calibration is to obtain the calibration coefficient, which correlates the CCD's count number and the amount of displacement. Calibration shall be carried out for every pair of a torsion meter and a reflecting mirror by using the dedicated calibration stand. The calibration stand holds the torsion meter and the mirror firmly, and displaces the position of the torsion meter horizontally. The displacement of the torsion meter is measured with a precise displacement sensor, and the CCD's count number is displayed by a CCD counter.

7.8.2 Calibration procedure

a) The torsion meter and the mirror shall be installed on the calibration stand so that the distance between them coincides with the specified measurement span.

b) The position of the torsion meter shall be adjusted so that the CCD counter shows around the specified minimum count number. After adjustment, the starting point is determined.

c) The torsion meter shall be displaced by the specified interval. The values of displacement measured by the displacement sensor and count number shown by the CCD counter are then recorded. This process shall be repeated until the count number reaches around the specified maximum value.

d) The reverse process of c) shall be carried out. (From maximum count number to minimum count number.)

e) Processes c) and d) shall be repeated at least two times. (At least two up and down each.)

f) A calibration coefficient that represents the relationship between the horizontal displacement and the count number shall be determined by a regression line.

8 On-board documentation for the device

Two types of documents shall be stored on board:

a) the manufacturer's instructions or operation manual;

b) the calibration results.

Annex A provides a sample form of the calibration results.