

# METHODS AND INSTRUMENTS FOR MEASURING TORQUE AND SPEED OF MARINE DIESEL ENGINES

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**Abstract:** Torque and speed measurement has always been a great challenge for many industries such as aviation, shipbuilding and automotive industry. These forces are of substantial importance for the research of the deformation processes developing in the modern marine diesel engines. The values of these forces provide the input data for calculating the overall strength of ship power plants. Continuous monitoring of these parameters while the ship is in service ensures safe operation of all machinery, reduces the risk of unplanned repair works and improves the engine performance in view of low fuel consumption and reduction of CO<sub>2</sub> and NO<sub>x</sub> emissions.

**Keywords:** SHAFT TORQUE METER, TORQUE TRANSDUCER, MEASUREMENT, TORQUE MEASUREMENT SYSTEM, SPEED MEASUREMENT SYSTEM.

## 1. Introduction

Ship's shaft line is an elastic system loaded with driving and reaction moments that have variable magnitude and direction. The moment generated by the pressure of the gases in the cylinder and the moment created by the mass of the pistons and connecting rods are examples of driving moments whereas the propeller moment and the frictional moment in the cylinders and bearings are classified as reaction moments. The inertia moments of the connecting rod assembly, of the flywheel and the propeller have a specific function. Upon accelerating they serve as reaction moments because they counteract the speed changes as opposed to slowing down when they have the same direction of the driving moments. As a result of the combined action of the driving, reaction and inertia moments, the shaft line is twisted, this twist being different for each shaft section.

## 2. Problem discussion.

The magnitude of these forces is determined in a different way:

- the torque is determined by means of torque meters which can be two types – mechanical and electrical;
- speed is measured by direct and indirect methods by means of instruments called speedometers.

All measuring instruments shall meet certain requirements in compliance with the international standards and the Bulgarian Register of Shipping (BRS). BRS has ISO 9000 certification.

## 3. Objective and research methodologies.

### 3.1 Indirect measuring with sensors

Measurement of shaft torque assists in determining the fuel consumption of ships. The company KYMA aims at ensuring that the newly-built ships are as energy efficient as possible. For this purpose KYMA [1] Norway uses indirect measurement of torque by means of sensors (strain gauges).

Generally the active part of the sensors is about 2-10 mm<sup>2</sup>. They have elastic insulation base on which metal foil is laid down. The sensor is attached to the shaft with the help of suitable adhesive, for example, cyanoacrylate glue. Strain gauges are mounted in pairs on the shaft, one of them measures the increase in length (in the direction in which the surface is under tension) and the other measures the decrease in length in the opposite direction.

The elements are located on the shaft axis in such a way that the resistance of the elements increases, if the axis is subjected to tensile forces.

Modern electronics for torque measurement is based on resistance changes in Wheatstone bridge

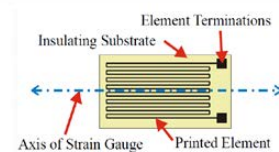


Fig.1 Torque sensor (strain gauge)

### 3.2 Direct methods for shaft twist measurement

Here follows an overview of some of the leading companies and their modern methods and instruments:

#### 3.2.1. LEMAG Marine Instruments [2]

LEMAG Marine specializes in the field of fuel systems for reduction of emissions and reduction of fuel consumption. LEMAG offers shaft twist measurement by means of induction sensors that measure displacement.

In order to measure the twist of rotating shafts:

- 2 rings are mounted on the shaft, spaced 500 mm apart
- 2 precision sensors are mounted opposite to the electrical arms
- The data measured are transmitted by radio waves from the shaft to the stationary unit.

Advantages of LEMAG method:

- no external (shore) maintenance is required
- the crew can calibrate the system when the engine is stopped by means of turning device
- stability and long life of the system

The following parameters are displayed on the touch screen:

- Torque (kNm)
- Shaft speed (rpm)
- Output power (hp)
- Mean output power (hp)

- Comparison of the limit curves of the nominal power and of the propeller.

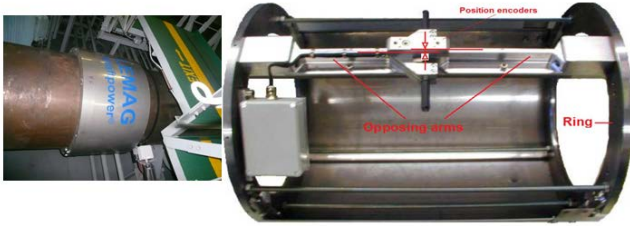


Fig. 2 Position of the induction sensors

3.2.2 VAF INSTRUMENTS – Holland [3]

VAF Instruments is a leading company in the design, production and sales of measurement and control systems worldwide.

For measurement of the twist of rotating shafts the company offers the following:

- two rings mounted on the shaft, spaced 250 mm apart
- the displacement between both rings is determined on the principle of optical measurement
- extreme accuracy of the optical sensor (within nanometer range)
- possibility for analysis of torsional vibration
- 4 GHz wireless transmission of data
- induction control by a transmitter
- difference of 3 mm between the fixed and running parts

Advantages:

- mounting of sensors is not time-consuming
  - easy mounting and starting-up
  - total costs for mounting are not big
  - no wear, no need for maintenance and re-calibration
- no maintenance fees, low costs throughout the whole service life.



Fig.3 LEMAG mounted instruments

3.2.3. HOPPE Marine – Germany [4]

One solution that the company offers is as follows: two identical toothed wheels are mounted on the shaft at a certain distance and measure the angular displacement – fig.5 and fig.6. They can be mounted on shafts rotating up to 150 rev/min.

HOPPE POWER METER

- measures shaft twist
- two pairs of toothed wheels are mounted at a distance of 7-10 m; the number of teeth  $z_1 = 480$  and  $z_2 = 48$ .

The calculation of torque is proportional to the phase displacement of the electrical impulses. The bigger the phase difference, the bigger the torque.

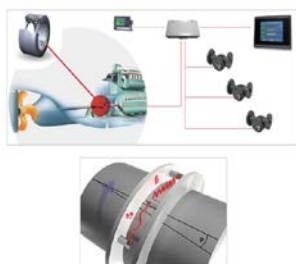


Fig.4 VAF measurement and control systems

3.2.4. KONGSBERG MARITIME – Holland [5]

The company has developed another interesting method. Two identical disks with openings (code wheels) are mounted on the shaft at a certain spacing apart – fig.7 and fig.8. A photocell is exposed to LED light passing through both wheels. As torque occurs, one of the wheels overlaps the other, the light flow is changed and the photocell detects this change.

- measures the twist of rotating shafts
- light is transmitted by LEDs through the openings of the code wheels mounted at a distance of 1 to 4 m.
- digital electronic signal is transmitted for processing and calculating of torque.

Advantages in comparison with the conventional methods for torque measurement:

- no sensitive electronics
- no mechanical wear
- no zero point displaced in the course of time
- not affected by the ambient temperature
- easy re-fitting after inspection of the shafting ( no replacement of torque sensors)
- not affected by centrifugal forces
- insensitive to electrical fields

Maintenance

- no wear, no tear of LEDs
- maintenance made by crew
- lenses and rings are cleaned by compressed air



Fig. 5 Scheme of the toothed wheels on the shaft



Fig. 6 Shaft twist measurement

3.2.5 GREX – Bulgaria [6]

The firm GREX with president Vladimir Grigorov from the city of Varna offers another method for torque measurement: two identical magnetic bands are mounted on the shaft at a certain length and they measure the phase displacement as shaft torque occurs – fig.9.

- Non-contact, digital measurement of torque by means of
- two metal bands with magnetic properties located at a distance of 0,8 -1,2 m
- two magnetic sensors at 0,8 – 1,6 mm from the shaft

The magnetic sensors are easy to install on three-dimensional adjustable arms. They generate 128-628 impulses per revolution of shafts with  $D = 0,2 - 1.0$  m. The microprocessor in the transmitter measures the delay -  $s_0, s_1, s_2, .. s_n$ , between the impulses caused by the shaft twist. The accuracy of the digital measurement is very high with a resolution of 100 nanoseconds (ns).

Accuracy

The torque is measured digitally by the phase displacement of the magnetic impulses of the band at periods of 100 ns.

Advantages:

- digital method for measurement of shaft twist, not affected by ambient temperature changes, thrust bearing or power supply
- connected with non-contact digital magnetic sensors, no sensitive electronics
- no need for provision of power supply for shaft elements
- no need for transmitting of the rotating parts data by telemetric signals
- not affected by centrifugal forces

- no mechanical wear
- high accuracy, resolution time – 100 ns
- no zero point displaced in the course of time
- simple and easy installation
- low installation costs, no costs for maintenance
- easy re-fitting after inspection of the shafting
- zero calibration by pressing a button
- no maintenance and easy to operate

**4. Literature.**

1. [www.kyma.no](http://www.kyma.no)
2. [www.lemag.de](http://www.lemag.de)
3. [www.vaf.nl](http://www.vaf.nl)
4. [www.hoppe-marine.com](http://www.hoppe-marine.com)
5. [www.kongsberg.com](http://www.kongsberg.com)
6. [www.grex-v.com](http://www.grex-v.com)

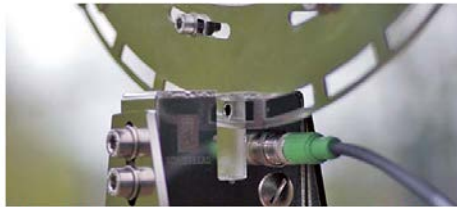


Fig.7 Position of code wheel and photocell by



Fig.8 Measurement of shaft twist



Fig.9 Scheme of GREX torque measurement

**4. Conclusion.**

International practice of leading companies dealing with measuring torque and speed, includes two primary ways to solve:

- indirect measurement using strain gauges;
- direct measurement based on the measurement of the twist shaft.