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DIAGNOSTIC SIGNALS ON BOARD VESSELS WITH DYNAMIC POSITIONING SYSTEM

SYGNAŁY DIAGNOSTYCZNE NA STATKACH Z SYSTEMAMI DYNAMICZNEGO POZYCJONOWANIA

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Abstract: The article presents the issues related to the analysis of signals monitoring the operation of ship equipment. Monitoring systems, purpose of their application and functions are briefly discussed. Signals used in monitoring and control systems of the ship power plant using additional, more detailed analysis can be used for additional diagnostic systems. The article presents research done in the real state of the ship system operation. Focus has been put on characterizing damages of sensors or devices. The problems of poor interpretation of failure symptoms by the operator and the alarm system were discussed.

Keywords: diagnostic, ships system, monitoring and controls system, dynamic positioning, safety, sensors.

Streszczenie: W artykule przedstawiono problematykę związaną z analizowaniem sygnałów monitorujących pracę urządzeń okrętowych. Systemy monitorowania, cel ich zastosowania oraz główne funkcje zostały w skrócie omówione. Sygnały wykorzystywane w systemach monitoringu i sterowania siłownią okrętową przy zastosowaniu dodatkowej bardziej szczegółowej analizy mogą być wykorzystane do algorytmów układów diagnostycznych. W artykule przedstawiono badania dokonane w stanie realnej pracy systemu okrętowego. Skupiają się one na scharakteryzowaniu występujących uszkodzeń sensorów lub urządzeń. Omówiona została problematyka złej interpretacji symptomów awarii przez operatora i system alarmowy.

Słowa kluczowe: diagnostyka, systemy okrętowe, systemy monitoringu i sterowania, dynamiczne pozycjonowanie, bezpieczeństwo, sensory.

1. INTRODUCTION

Modern vessels with dynamic positioning systems are developed with extensive control and monitoring systems. During operation duty engineer needs to the consider safety precaution for all units working at the same time in the engine room

and which are spread around the vessel. In normal duty, operator's responsibility in the engine control room is to make sure that equipment implemented to operation is in good working condition [DNV GL 2015].

Design of newest monitoring and control systems [Śmierzchalski 2004] installed on vessels gives for engineer on watch possibility to more efficient supervision. In case of critical situation, i.e. failures or malfunction all alarms are presented for operator. Unfortunately, when failures appeared it is too late to take action for counteracting for them. Person responsible for the correct operation of system is also burdened with a number of factors which affect his work characteristic. Group of those factors can include fatigue, moods and attitude to his work.

Today's ships systems are built of a few hundred devices whose work is monitored by a group of sensors. For this reason, control and monitoring systems are using algorithms for detecting alarm states. Functions such as control of correct working of systems should reduce amount of failure mode [Kosmowski and Śliwiński 2015]. Unfortunately, due to increasing of critical operation for dynamic positioning vessels, old fusion of design control systems are cases to fulfil their tasks. In order to increase safety of work, the engineer on watch must be supported by additional diagnostic algorithms [Charchalis and Pawletko 2012]. Design of diagnostic systems requires learning about proper functioning of units installed on vessel. Recognition of all working states for ships equipment is often very difficult. Characteristics of diagnostic system needs to be supported by knowledge of failures which may lead to destruction of the ships objects.

Diagnostic of ships equipment refers to the evaluation of current state of the monitoring objects. For this purpose, direct and indirect research should be used. Direct studies determine the correct work of units. Indirect, called residual processes affect a given object. These include electrical, mechanical and vibration factors. Very important is to find point of wear in equipment which will be lower than alarm point. At this point we need to do inspections, adjustments or repairs. On vessels we can observe continuous changes of working quality which are gradually affected by operating characteristic. Unfortunately, duty engineers are not fully familiar with short changes like slowly increasing temperatures or small vibrations which are most popular symptoms of breaking of vessel's equipment.

2. DESIGN OF SHIPS AUTOMATION CONTROL UNITS

Design of ships automation systems is used to control all part of vessel equipment.

Topology of system built by Kongsberg Company is shown in Figure 1.

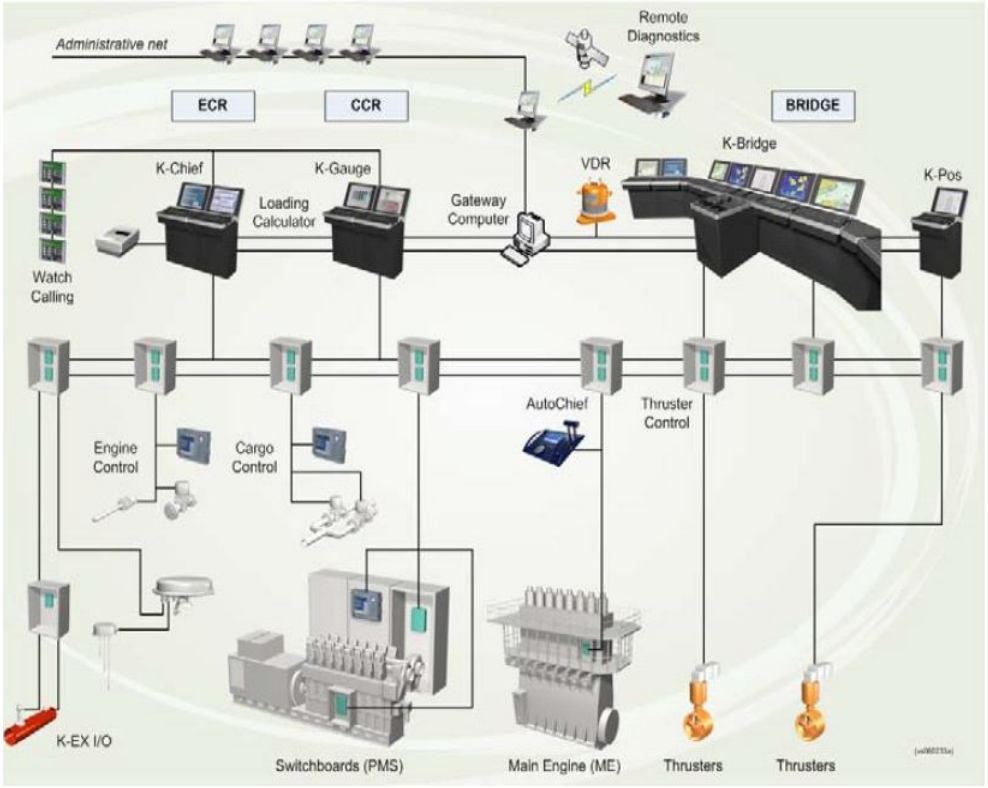

Fig. 1. Kongsberg K-Chief 600 Monitoring and control system topology [Kongsberg Maritime AS 2009]

Rys. 1. System monitoringu i sterowania Kongsberg K-Chief 600 [Kongsberg Maritime AS 2009]

The picture above shows four most important systems installed on board vessels with dynamic positioning system as:

1. K – Chief – system responsible for monitoring and control of devices installed in the engine room. Monitors data of constant work of main engines, generators, thruster and units as pumps, boilers, purifiers and supports devices that are monitoring and supporting operators during the watch. K – Chief system is builit by using input – output modules which are specially designed for specific purpose. If required by specification of the ship this system can be also responsible for cargo system. In this task cargo pumps, sensors, and valves are monitored by configurated modules. In addition, can be installed K – Gauge system which is monitoring tanks valueas as well. K – Chief system can be also responsible for control of power management systems on board vessels [Bastian 2010]. Following functions are implemented to his task: start and stop generators,

synchronization of generators, monitoring failure for safety operation in power management.
2. K – Bridge – integrated system of all bridge units. All tools as ECDIS, Radar, sensors are connected in one system and presented on operator station. In this case navigators have access to all important information about ships navigation. Data from Gyrocompasses, echosounder, speedlog and GPS system are collected and distributed in one place. Those data are transferred to other systems as e.g. K – Chief. In the latest design of system, signals from Radars and ECDIS are available on each station.
3. Auto – Chief – system installed on ships with main engine. Main task of this system is to control proper work of main engine. Control and checking all safety subsystems such as shut down system, slow down, overspeed control. Auto – Chief is also responsible for control of speed and load on main engine.
4. K – POS – main dynamic positioning system of the vessels. K – Pos is connected with other systems controlling all vessels as K – Chief, Auto – Chief, K – Bridge and units responsible for steering of thrusters. The system is collecting data from navigation positioning sensors, and is sending command to thrusters, propeller and rudders.

For diagnostic system most important parts are units which control all engine room units as switchboards, main engine and auxiliary generators and thrusters. The above design shows that configuration is going to connect all independent systems. It can be observed that all systems are connected with each other. Bridge control systems are now in communication with unit responsible for main engine and thrusters control. The reason for do this configuration is the reduced signal going to equipment when vessel is in dynamic positioning operations. Double network lines are showing redundancy required by Marine Associations. Concentration on all signals should reduce human error during duty watch. Together with this value safety of operation of vessel is increasing to high level.

3. DIAGNOSTICS SIGNALS MEASURED ON VESSEL

In control and monitoring systems are installed many different kinds of measuring points. Vessel equipment is monitored by many different types of sensors. Mostly common are temperature and pressure transmitter and switch, thermocouple, vibration sensors and level sensors. Each kind of sensors must be matched correctly to data input in reading module.

For monitoring condition of work on board vessels are used below types of signals [Wyszkowski 1991]:

- Normal close and normal open;
- 4–20 mA loop;
- 0–10 V.

Reading value as temperature, pressure or flow are transmitted into the above signals. In this type of process signals have more opportunity to reach wrong reading value. Noise in distortion has influence on measuring circuit which causes incorrect readings of the measuring values.

Measuring signal reading by monitoring and control system is used to be presented for operator. Main function for monitoring is informing the engineer on watch when signals value reach alarm setting. For the correct use of signals transmitted from measuring point are used additional variables. Parameters used to describe monitoring of marine signals are:

- alarms value high and high high – operator receiving information when parameter reached warning value as high or high high value which can cause stop of monitoring equipment;
- alarms value low and low low – operator receiving information when parameter reached low value or low low value which can cause stop of monitoring equipment;
- refreshing time – time for refreshing information for operator on computer screen. Different signals not need to be refreshed all time only when signal change information is presented for operator;
- sampling time – frequency of reading and transferring signal from measuring circuit;
- sensors type – input channel can be calibrated for different type of sensors;
- range of sensors – each type of sensors have own range which need to be added to monitoring systems;
- alarm contact type – description if alarms value is activating by open or close signal;
- delay time – time for delay alarm signal presented on operator station.

The above description shows that the parameters used to describe signals are only for information purpose condition of equipment. Operator needs to follow all parameters all time. In normal monitoring and control system for vessel with dynamic positioning system total sum of all signals is a few thousand. Alarm points added to this signal as reference informed only when device is in an undesirable condition of work.

4. WRONG MEASUREMENTS OF DIAGNOSTICS SIGNALS

All engineers should have knowledge about signals which they can read on monitoring and control system operators stations. Incorrect understanding of changes in measured values can lead to misinterpretation of a diagnostic signals. According to IMCA 218 around 37% [IMCA 2012] failures on offshore vessel are caused by a human error. Due to many orders, poor knowledge of ships systems and

stress, officers watch-keeping on DP vessels are not able to properly analyze each signal values.

There are many different failures of electrical equipment on board vessels. Starting with mechanical damage of electrical devices, faults on measuring circuits to erroneous calculation in monitoring and control systems. Good and quick interpretation of error in analyzed signals by the operator can prevent against more series damage in due time.

Measuring circuit of exhaust gas temperature from main engine can only indicate a damage of the main engine parts. Thorough analysis of the measured signal may indicate failures of the sensor or measuring circuits. Design of reading of exhaust gas temperature is shown in Figure 2. Main sensor is thermocouple with range from 0 Cel deg. to 1000 Cel. Deg. Signal received from sensor is sent to current transmitter type: Thermocouple to 4–20 mA. Signal from this unit is going directly to input channel in operating module. After that signal is transferred according to scale of temperature and showed on operator station.

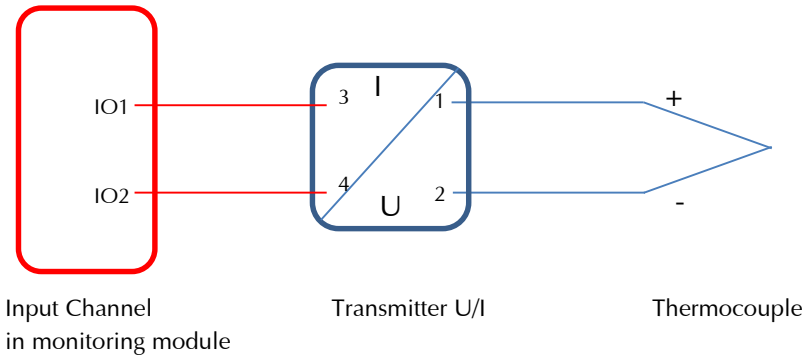

Fig. 2. Connection drawing of thermocouple sensor

Rys. 2. Schemat przedstawiający tor pomiarowy czujnika termopary

This sensor is calibrated to have following settings:

- High alarm on temperature 440ºC.;
- High high alarm on temperature 450ºC;
- Range 0–1000ºC;
- Sampling time 1 second;
- Delay alarm on 2 seconds.

The above setting shows that engineer on watch will inform about high alarm when temperature increases to 440ºC. High-high alarm will also result as slow down alarm on main engine. During normal operation exhaust gas temperature depends on load on main engine. In this case issue with measuring circuit is very difficult to recognize by the operator. In Figure 3 are shown trends with failure characterized by

sudden jumps in temperature value on exhaust gas. In case of rapid temperature change and next activation of the slow down alarm, the dynamic positioning operation of the vessel can be interrupted.

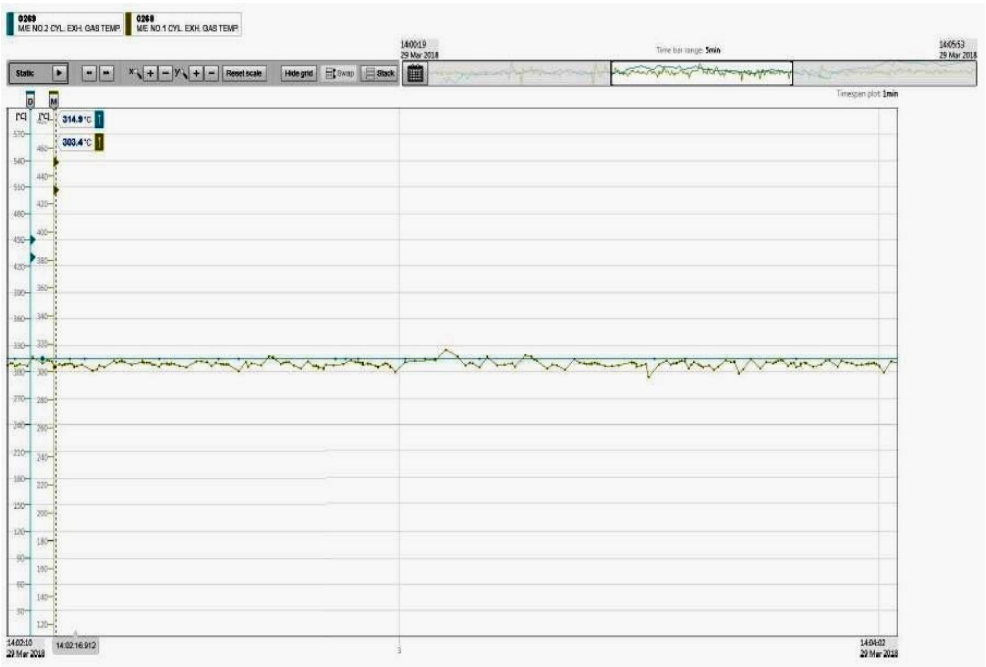

Fig. 3. Trends presenting temperature value of exhaust gas temperature on main engine

Rys. 3. Przebiegi temperatury gazów wylotowych silnika głównego

The above waveforms show the correct value of temperature (blue color) and value from measuring circuit with existing failure (green color). In this situation Wrong value is not reaching alarm settings. Operator is not informed about not correct measurements from Thermocouple sensors. Many of systems installed on board dynamic positioning vessels are not able to detect changes as the example presented above. In monitoring and control system to avoid activating alarm condition due to pick of temperature value are used parameters as "delay on alarm". Settings like these prevent loss of equipment needed in dynamic positioning systems. Unfortunately, at the same time, operator's knowledge about condition of the system is reduced.

In the monitoring and control systems parameters that can improve detection of damage shown in Figure 3 are not used. Such parameter as "Range" of sensors can be only detected if measuring circuit has broken line and then value jumped over scale. For diagnostic control systems that can be installed on ships with dynamic positioning system additional parameters describing the signal from sensor should

be specified. Such a factor may be a pre-warning setting. This parameter should be active when the algorithm makes comparison of reading from other sensors. This function should quickly detect a frequent change in value read by sensors. The engineer on watch can be immediately informed about possible damage to the sensor or measuring circuits by means of the pre-warning settings.

5. INTERPRETATION OF DIAGNOSTICS SIGNALS

The second important feature for engineers working on dynamic positioning vessels is correct interpretation of signals. Large number of devices used during dynamic positioning operation correspond to many characteristics of their work. Knowledge about each of them is very difficult to gain by operator. Work modes depend on many other factors that affect the object in given time.

In Figure 4 are shown work modes of tunnel thruster during start sequence. This start period and trends show correctly characteristic of this operation. After start and change over connections from autotransformer to directly supply from Mains switchboard current is steady. Increasing power consumption takes place with change of command of pitch signal on tunnel thruster. In normal operation, the operator in the engine room is not informed about changes of command for thruster. The value of command changes so often and quickly. This situation makes difficult to interpret when the current characteristic of tunnel thruster is incorrect.

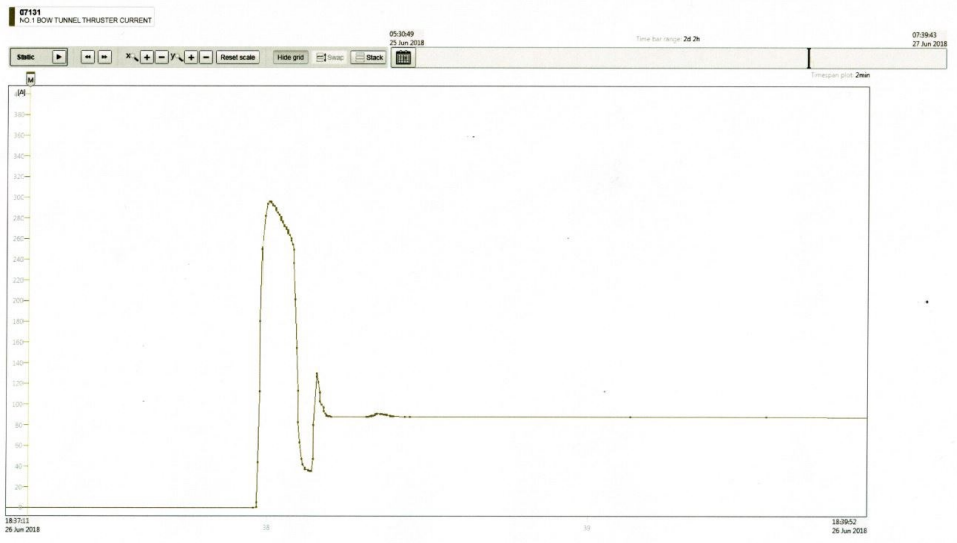

Fig. 4. Current measurements during start of tunnel thruster

Rys. 4. Przebieg prądu podczas startu steru tunelowego

Figure 5 shows also process of starting tunnel thruster but with defects. In the first stage correct and incorrect trends look the same. The problems start when the current starts to oscillate after start. At this point, focusing on current values, the operator cannot determine if any failure occurred. For full information to know if current reading is correct, the operator needs to know other diagnostic signals from the device.

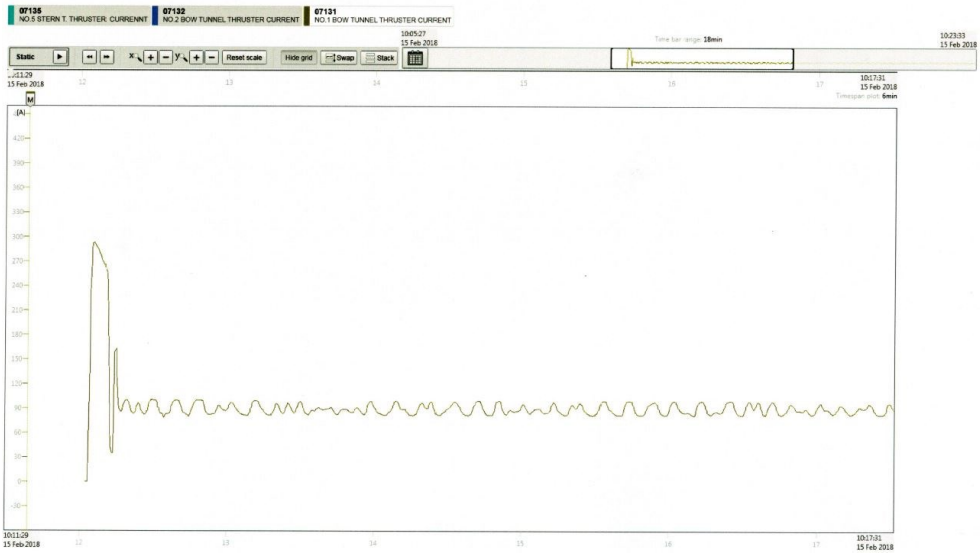

Fig. 5. Current measurements during start of tunnel thruster

Rys. 5. Przebieg prądu podczas startu steru tunelowego

Correct working of equipment such as tunnel thruster is very difficult to determine. Many work models with different characteristics are measured during dynamic positioning operation. For full information of the starting procedure for tunnel thruster or future operation, diagnostic algorithm needs to be completed with the following parameters:

- command signal for pitch;
- feedback signal from pitch;
- temperature of electric motor bearings;
- temperature of windings on electric motor.

After collecting the above information algorithm can compare depending on work state if failure is present. During normal work engineer on watch is not able to follow all parameter for the object being diagnosed.

6. CONCLUSIONS

The article presents basic knowledge about the configuration of monitoring and control system of the ships plants on vessels with dynamic positioning systems. During normal operation of ships, persons who are responsible for proper operation of vessel equipment are not familiarized with equipment on board vessels. For this reason, human error is one of the most common causes of failure.

Vessels with dynamic positioning systems has different configurations of the monitoring and control systems. Knowledge of mutual connections and data exchange between particular systems shown in Figure 1 presents the complexity of this issue.

Due to difficulty of engineer's interpretations of diagnostic signals in the article two most common problems were focused on. First, failure in measuring circuits on ships equipment is very dificult to detect. If the measured signal does not reach alarm points the operator may not notice it. In addition, pre-warning function for short term changes in measured signals can help the officer on watch to understand the issue.

The second very difficult to interpret failure occurs when the device has many operating states. In this case, measured values also do not reach alarm states. To make full diagnosis it is necessary to know other signals values from some devices. It is also important to recognize if measured value of signal corresponds to correct or incorrect operation of device.

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