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Comparative studies of the usefulness in diagnostics of marine piston engines of an in-depth analysis of indicator diagrams for selected cylinder pressure measurement points.

Abstract

This PhD thesis deals with the problems related to the parametric diagnostics of selected functional systems of marine piston engines, carried out mainly on the basis of the analysis of indicator diagrams and indicated parameters. An important supplement to the above is an in-depth analysis of indicator diagrams - heat release characteristics calculated on their basis and diagnostic parameters selected on the basis of their analysis. The diagnostic usefulness of these parameters will depend on the quality of the obtained indicator diagrams, which is significantly influenced by the proper selection of the cylinder pressure measurement site. The dissertation presents and verifies the thesis that cylinder pressure measurement, without the influence of disturbances generated by measurement channels and indicator cocks, improves the quality of indicator diagrams and the diagnostic usefulness of the indicated parameters read from indicator diagrams and heat release characteristics. Also the thesis was formulated and verified about the possibility of improving the diagnostic condition of marine engines by increasing the quality (accuracy) of obtaining indicator diagrams and their in-depth analysis based on the heat release characteristics, and that the heat release characteristics contain information about the technical condition of the engine, including the fuel injection system, the charge air exchange system and the piston - piston rings - cylinder liner.

The aim of the study was to demonstrate, basing on a comparative study, the diagnostic usefulness of an in-depth analysis of indicator diagrams obtained from the measurement of cylinder pressures at various selected measuring points. The selection took into account the measurement of cylinder pressures, disregarding the negative impact of indicator channels and the indicator cock.

Achieving the aim of the work required the implementation of several specific aims, namely:

- selection and preparation of the measurement site bypassing the measurement channels and the indicator cock so that the pressure sensor is as close to the combustion chamber as possible,
- preliminary tests determining the value of the maximum temperature at the place of pressure measurement,

- selection of the method of filtering indicator diagrams,
- selection of the calculation model of heat release characteristics based on indicator diagrams,
- selection of the method of determining position of the piston top dead centre on the indicator diagrams as a function of crankshaft angle rotation,
- selection of engine damage simulations and their preparation,
- conducting an active experiment consisting in collecting an appropriate number of data sets in the form of cylinder pressure courses from an engine working with and without simulated damage,
- development of indicator charts as well as determination and calculation of indicated parameters,
- development of charts of the heat release function and determination of diagnostic parameters,
- comparative analysis of indicator diagrams and indicated parameters, heat release functions and parameters read on their basis, from three different measurement points, in a wide range of load variability of a technically efficient engine operating with simulated damages.

The first chapter contains an introduction, a discussion of the state of knowledge on the diagnosis of marine piston engines and a literature review. The ways and methods of diagnostics of selected functional systems of engines were also presented, including the use of indicated parameters for this purpose. The errors influencing the quality of the read and calculated indicated parameters and indicator diagrams were also discussed. Then, the second chapter presents the genesis, theses and purpose of the work.

The third chapter covers the preparatory steps before starting experimental research. The construction and preparation of the test stand and preliminary tests were discussed. This chapter presents the selection of a mathematical model for the heat release function. A single-zone heat release model was selected, in which modelling of heat release was based on the first law of thermodynamics for an open system. Then, the mathematical model necessary to create a filter for smoothing indicator diagrams was selected and described. The algorithm of moving approximation with power polynomials of the third degree in three steps, based on the Savitzky - Golay filter, which is used in such computational programs as Mathematica or Matlab, was chosen.

The method of determining the top dead centre position of the piston as a function of the crankshaft rotation angle is also discussed. The position of the top dead centre of the piston on

the axis of the angle of rotation of the crankshaft is the position of the zero value of the first derivative of the compression course, and the positioning error of this point should not exceed 0.05 degrees of crankshaft angle rotation.

The fourth chapter presents the characteristics of the measuring equipment, the purpose, the scope and the description of the course of experimental research and the method of developing the research results. Types of engine damage simulations and methods of their implementation are described here. When selecting the damage simulation, the author was guided by the damage statistics described in the first chapter and his own professional experience.

The fifth chapter presents the results of the experimental research in the form of indicator diagrams, indicated parameters, heat release function and their characteristic parameters. On the basis of cylinder pressure measurements carried out simultaneously at three different measuring points of an engine cylinder working with and without simulated damage and with a different degree of load, a comparative analysis was carried out. Diagnostic symptoms were identified and detailed diagnostic conclusions were formulated.

Chapter six contains a summary and detailed conclusions resulting from the conducted comparative analysis. The aims achieved in the work are listed. Utilitarian conclusions and planned directions of further research were presented. The considerations presented in the work led to the conclusion that the elimination of measurement channels in the diagnostic process of a marine piston engine consisting in measuring the cylinder pressure increases the quality of this process. Long measuring channels, characterized by variable shape and volume that change the direction of the gas flow delay and distort the pressure pulse reaching the pressure sensor. As a result, some indicated parameters, characteristic parameters of the heat release function and diagnostic symptoms derived from indicator diagrams and heat release functions become illegible or invisible.