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A Database of Selected Marine Diesel Engines for Diagnostic Needs

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Abstract: The article describes an electronic database of selected marine piston combustion engines created for diagnostic purposes. The database was made for vessels of the biggest Polish shipowner. It is used for archiving and comparing measured parameters of diagnosed engines with model parameters. To facilitate the search for and use of required data, they have been collected and catalogued. For this purpose the database has been prepared by using a computer program included in the Microsoft Office suite. The database search relies on the details concerning the type of vessel. The fields displayed include such items as the year and place of construction, the parameters of the ship, flag, etc.. For each vessel special forms are available for main and auxiliary engines, enabling easy and quick check of the necessary parameters during operation of the engine. The database contains parameters of the main propulsion and auxiliary engines, as well as model characteristics to help determine the diagnostics, prognosis and genesis.

Key words: Marine diesel engines, reference parameters, technical diagnostics.

1. Introduction

Technical diagnostics is utilized in the following phases of object existence: valuation, design, production, operation and reuse. It is important in the phase of operation serving as a tool for enhancing quality, safety and reliability. At present diagnostics is a significant area of science that influences the development of objects. Results of diagnostic examination contribute to the assessment of technical condition, its prognosis and genesis [1].

The essence of technical diagnostics consists in indirect determining the condition of a machine, without its disassembly, based on the measurement of diagnostic symptoms and comparing them with boundary values. It is pointed out there is a need for computer-assisted diagnostics of ship's machines, where essential role is played by systems of databases and knowledge bases [1].

Bases are developed by means of card files, binders, files with documents, etc. and recently in an electronic form. The construction of databases aimed at an accumulation of the knowledge on the use of internal combustion engines is in progress.

Thanks to the continually extended knowledge and upgraded technologies engines are constantly modernized. Engine manufacturers, owing to information collection systems, have access to constantly gathered data on technical condition of engines. Data also come from examinations carried out during acceptance tests and sea trials. On some ships data from acceptance tests, however, are hardly available.

At present systems for gathering information are maintained by specialized research teams that introduce information into electronic databases. The database is called a collection of data, placed in a specific way in the structures, corresponding with the diagram of data.

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2. Problems of Technical Diagnostic

Diagnostics, as a field of knowledge, deals with recognizing a technical condition by assigning it to distinct classes, by explaining the causes, degree and/or quality of the condition, defining its current phase and prediction of its development [1, 2].

Technical diagnostics is an organized set of methods and means for the technical assessment of condition (its causes, evolution and consequences) of technical systems [1]. Technical diagnostics can examine a group of objects, one object, an assembly, sub-assembly, even a single element.

The characteristics diesel engines are used for an assessment of technical-operating properties throughout their entire scope of work. Apart from general characteristics, those in use are based on speed, load and control [2, 3].

The internal combustion engine is in an up state if the values of measurable parameters describing this object at any given time t do not exceed preset boundary values:

$$S_z \Leftrightarrow \bigcap_{i=1}^{i=n} y_{imin} \leq \quad y_i \quad \leq y_{imax} \qquad (1)$$

where:

y_i—i-diagnostic parameter;

y_{imax}—the upper limit value of the i-th parameter diagnostic;

y_{imin}—the lower limit i of diagnostic parameter.

The up state exists when each of the significant diagnostic symptoms s_i assumes values from the interval specified by Eq. (1), where it makes up the superior vector of technical conditions of object elements.

To diagnose ship's internal combustion engines in the phase of operation, currently measured parameters have to be compared with the model state. The model state is the state of the operational engine right after it was manufactured. Shipboard technical documentation does not contain such details of characteristics, and the results of tests passed are mostly reported in tables where data are difficult to interpret [4].

3. The Existing Databases

There is presently a need to collect data from various sources, store and analyze them. A database is a set of interrelated data through which logical, mathematical or textual operations are carried out. The particular role in present technical diagnostics belongs to systems of knowledge discovery [1].

Procedures of knowledge acquisition can be understood as a sequence of complex operations, which take place between sources of knowledge, a knowledge engineer or a team of knowledge engineers and users of knowledge databases, which are the right recipients of the results of this process [1].

Apart from printed databases, there are mainly those contained in electronic database management systems. One disadvantage of printed databases is that they require a lot of time for organizing and coordinating information from many sources and are often kept in different locations [1, 5-9].

In contrast to printed databases, electronic systems of managing databases enable the information storage in one place and offer easy access to chosen data retrieved from a huge storage area [10]. The main advantage of such databases is that the form of data presentation can differ and data can be ordered by various criteria. Another strong point is the possibility of forming data sets, grouping data and calculations.

Electronic databases considerably shorten the time of adding, modifying, supplementing and removing datasets. A well devised database enables using all necessary information by means of one file. In such file information is divided according to a specific criterion into datasets and is stored in tables. A table is a collection of data and contains a natural form sheets in physical systems [10, 11].

The database under consideration was developed at the Institute of Basic Technical Sciences, Gdynia Maritime University, in the form of cards containing several of input pieces of information. As a result of research with the help of INPT—A system, where operation cards and failure cards were utilized [12].

Input information was transferred from ship documents by technical inspectors of shipowners (The Polish Ocean Lines and the Polish Steamship Company) onto carriers of input information. Then sets of indicators and statistics describing RD and RND engines from Sulzer, their subassemblies and elements were acquired.

Balcerski and Kneba [13] have developed a relational database with real working conditions of marine engines that can be used for diagnostic purposes. While gathering these data they used characteristics and working parameters recorded in ship's engine log books, in reports of the ship's command sent to the shipowner, as well as data from current examinations and measurements conducted by shipbuilding teams and research institutions.

Those authors also used reports from research and voyages, and from onboard training record books of students. The database was designed to accumulate information characterizing the ship as a technical object, and data on states and operating conditions of the machines and devices of the marine power plant [13]. The database was developed with the use of Fox Pro for Windows software.

Machine automation enables quick identification of a failure, which was first introduced in the car industry [1]. The database in aviation was of different nature. It was connected with the system of wear standards of exchangeable parts and warehouse documents. In the 1980s, the Air Force Institute of Technology initiated work on modernizing the existing system of collection and processing of information on damaged aircraft [14].

This author also dealt with this issue by cooperating and building a database on ships and ship's internal combustion engines for the purposes of examining their reliability [7] and diagnostic [15]. The electronic database encompasses a wide scope of knowledge on the operation and maintenance of marine diesel engines and facilitates using that knowledge. It even offers a possibility of analyzing the entire process of company growth on the basis of ships' capacities or the quantities of transported cargo. The electronic database comprises vessels-related data, regularly examined for safety and reliability [7]. Intelligent expert systems play a very important role in the diagnostics of marine diesel engines, especially in diagnostic inference [1, 2, 4, 12].

Databases have been maintained, updated and upgraded for decades parallel to the development of computer science. The dynamic development of technology allows creating databases for the purpose of diagnosing marine engines, as such databases facilitate creating standard characteristics, to which one can add characteristics based on the results of current inspections of the technical state of internal combustion engine. Databases can be accessed via the Internet available on marine vessels through satellite communications.

4. The Method and Objects of the Study

4.1 Marine Reciprocating Internal Combustion Engines Operated by the Shipowner

The purpose of this work was to elaborate an information system related to diagnostic parameters of marine internal combustion engines. The scope of work includes ship's internal combustion engines installed on different types of sea-going vessels of one shipowner. The fleet under consideration is mainly equipped with MAN Diesel and Wärtsilä engines [16, 17]. During acceptance tests and normal service the operation of engines is evaluated by a number of selected parameters. The parameters are different for specific design solutions of ships and their diesel engines. A set of measured parameters is used to determine the correctness of the working process and to assess the technical state of the engine [3].

The article presents basic parameters from tests on some engines installed on ships of the shipowner, whose many vessels are fitted with a MAN Diesel-made engine of the 5S50MC-C type for main propulsion [7, 16].

4.2. Description of the Database Developed

The database was designed for collecting information on chosen internal combustion engines. To build relevant data sets their creators used documentation supplied by the shipowner and parameters of engines in operation obtained from ships calling at ports or the shipyard of the Szczecin region.

Access to the database is obtained through Microsoft Office programs, used for building databases and for data management, above all, for instant retrieval of information needed.

Searching the database is based on adequate queries. Selected data are retrieved by activating a proper query. To improve data entry and viewing, special forms can be designed. The obtained data can be viewed or printed in reports.

The data are stored in database tables. A database table is a set relating to one subject. Data are stored in records and fields. A record is a set of data on a single item and is made up of individual fields. Each field contains one piece of information.

The access to the database is ensured by a database management system, i.e., programs that recommend such access. Data in Microsoft Access [18], Excel and Word can comprise text information, numbers, dates, pictures, files and many other elements. Designing a database starts from determining its purpose and ways of using it. This, in turn, is done by determining tables and storing in them uniform information and defining fields, i.e., properties characteristic of the table.

Directly after program activation, a start form will appear on the display screen (Fig. 1). After pressing the command button operated ships, the form will show fleet types (Fig. 2).

After entering this form, access to data of the ships of the chosen type is obtained, i.e., ferries, panamax (Fig. 3), sulfur carriers or handy-size ships. These data include the year and place of construction, flag, cargo capacity, the type of vessel, its length and breadth. The given vessel is selected from the list that will expand after pressing the field vessel's name.

Fig. 1 A view of form start.

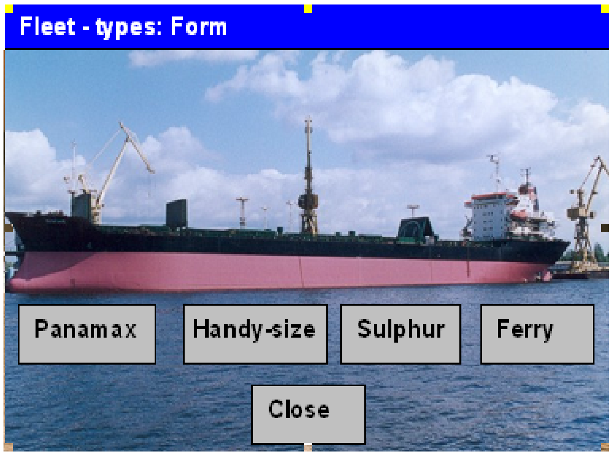

Fig. 2 View of form fleet-types.

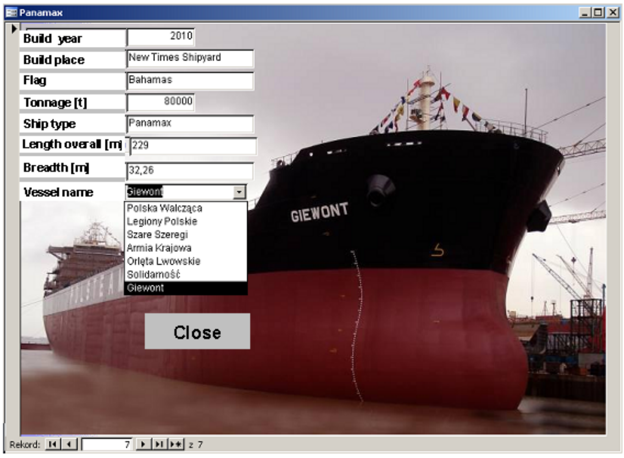

Fig. 3 View of the panamax vessels form and method of selecting ship's name and view of the displayed information.

After pressing the command button main and auxiliary engines in the form start, the relevant form will open (Fig. 4).

In this form access is obtained to the selection of engine installed in the given ship. The example data set on the engine and the method of selecting the relative load and a view of the information contained therein are shown in Fig. 5.

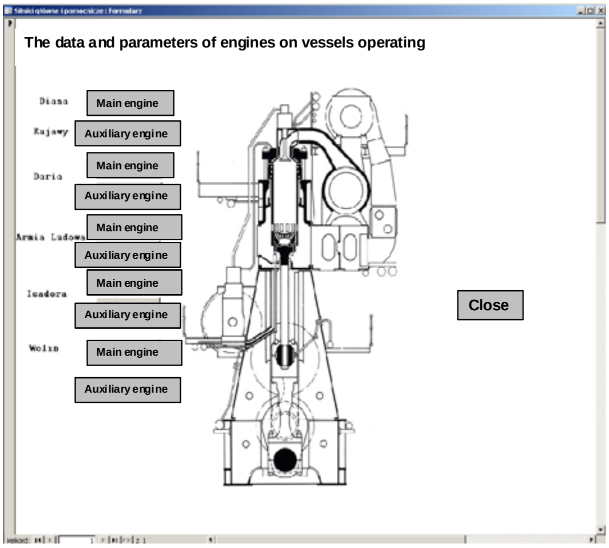

Fig. 4 View of the form main and auxiliary engines.

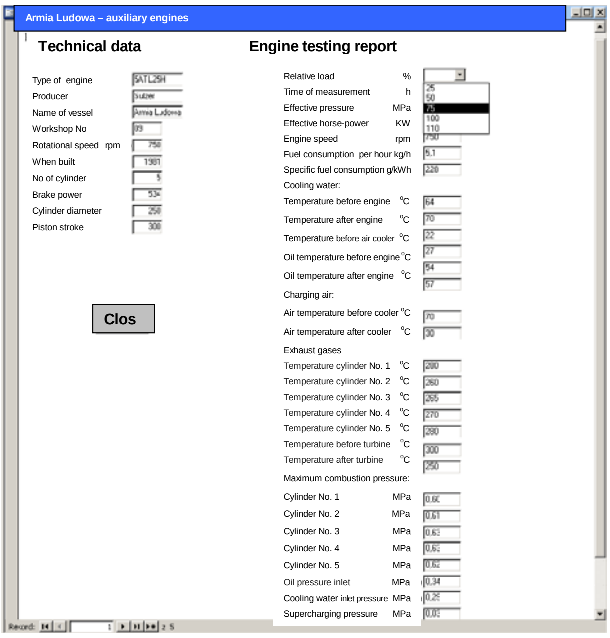

Fig. 5 View of the form auxiliary engine with the selection of relative load, and view of information contained therein.

The form presents example data and a complete report from tests of a Sulzer 5ATL25H engine, one of three auxiliary engines installed on this type of ship. Here the choice of relative load appears, and then parameters measured during those tests change.

Example data from the auxiliary engine propulsion tests are shown in Table 1. The diagnostic parameters observed during acceptance tests correspond to the process and residual variables monitored in the operation.

Table 1 The data contained in a testing report: auxiliary engine type 4S20H.

On	Parameter	Unit
1	Time of measurement	(min)
2	Effective pressure	MPa
3	Relative load	%
4	Effective horse-power	kW
5	Governor load indicator	–
6	Load indicator position	–
7	The engine power measured	kW
8	Engine speed	1/min
9	Fuel consumption per hour	kg/h
10	Specific fuel consumption	g/(kWh)
11	Cooling water:	–
12	Pressure before engine	MPa
13	Temperature before engine	°C
14	Temperature after engine	°C
15	Lubricating oil	–
16	Lubricating oil pressure inlet	MPa
17	Temperature before engine	°C
18	Temperature after engine	°C
19	Charging air	–
20	Ambient pressure	hPa
21	Ambient temperature	°C
22	Relative humidity	%
23	Supercharging pressure	MPa
24	Temperature before air cooler	°C
25	Temperature after air cooler	°C
26	Exhaust gases	–
27	Temperature after cylinder No. 1	°C
28	Temperature after cylinder No. 2	°C
29	Temperature after cylinder No. 3	°C
30	Temperature after cylinder No. 4	°C
31	Temperature before the turbocharger	°C
32	Exhaust gas temperature after turbine	°C
33	Average temperature after cylinders	°C
34	Counter-pressure in funnel	MPa
35	Maximum combustion pressure	–
36	Cylinder No. 1	MPa
37	Cylinder No. 2	MPa
38	Cylinder No. 3	MPa
39	Cylinder No. 4	MPa
40	Fuel oil pressure before engine	MPa

One can notice that some test records do not contain complete documentation. Also individual documents lack records of certain diagnostic parameters. Some tests were not made in the full load range of the engine.

The tables include important parameters that are measured gradually. In order to make an analysis one should draw characteristics that are easier to interpret than parameters put in tables. For analysis one should take parameters interrelated with engine load, because such parameters are usually correlated with the technical state [4, 15].

Internal combustion engines of the shipowner are diagnosed by this author by means of parameters and measuring instruments the vessel carries, as well as using a portable diagnostic system. The measured diagnostic parameters are indicated or registered at the point of measurement, or remotely, e.g., from a control room (Fig. 6).

The acquired knowledge, apart from being archived in the base, is also recorded in scientific publications [11]. The accumulated knowledge base is updated through verification, validation and supplementing.

Fig. 7 shows the changes of the maximum combustion pressure in each cylinder dependent on relative load, where a linear relationship was obtained. It is a parameter commonly used in the diagnostics of ship's internal-combustion engines, but less sensitive to changes of the technical condition than e.g., mean indicated pressure.

The relationship between the variables can be described by model function:

$$\hat{y} = f(x; a_1, \ldots, a_n) \tag{2}$$

where:

a_i—the parameters of the model;

n—number of model orders.

The function can be:

linear $\hat{y} = a_1 + a_2x$;

quadratic $\hat{y} = a_1 + a_2x + a_3x^2$;

logarithmic $\hat{y} = a_1 + a_2 lnx$, etc..

The a_i coefficient in the model equations was determined from the condition of minimum in the least squares method:

$$MIN(S) = MIN\left[\sum_{1}^{n}(\tilde{y}_i - \hat{y}_i)^2\right] \tag{3}$$

where:

MI—minimum operator;

Fig. 6 View of a manoeuvring-controlling centre.

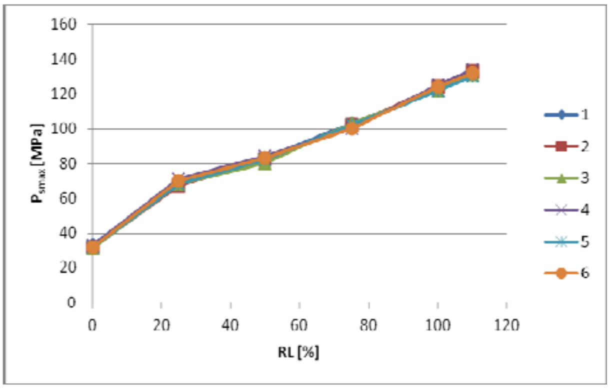

Fig. 7 The relationship between the maximum combustion pressure P_{smax} depending on relative load RL of 6AL20H type engine during bench tests of new engine.

S—the sum of square deviations;

$\tilde{y}_i$—measured values;

$\hat{y}_i$—values from approximation;

n—cardinality of a measuring set.

Findings of active and passive diagnostic experiments are a source of knowledge. Operational research is conducted for different repeatable loads, which for auxiliary engines consists in switching on different receivers of electric energy or using a water resistor. Example changes in combustion chamber pressures recorded by an electronic system of signal acquisition are shown in Figs. 8 and 9, in turn, depicts maximum combustion pressures for individual engine cylinders at 50% relative load, comparable with the model values. Here the measuring points were more scattered than for the brand new engine, and even more so between the cylinders, where the scatter from

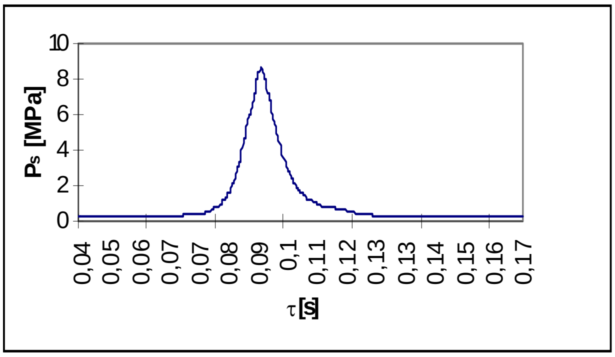

Fig. 8 Example pressure course in combustion chamber of engine type 4L20 for one cycle at relative load 25%.

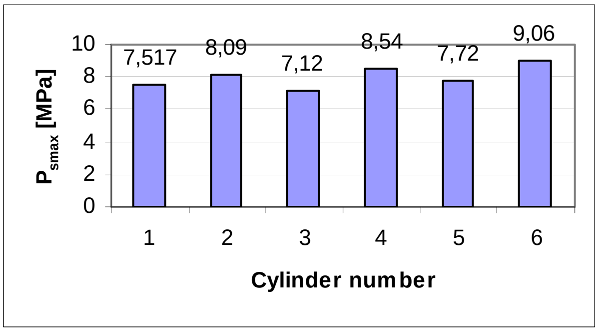

Fig. 9 The values of maximum combustion pressure of engine 6AL20D at the at relative load 50%.

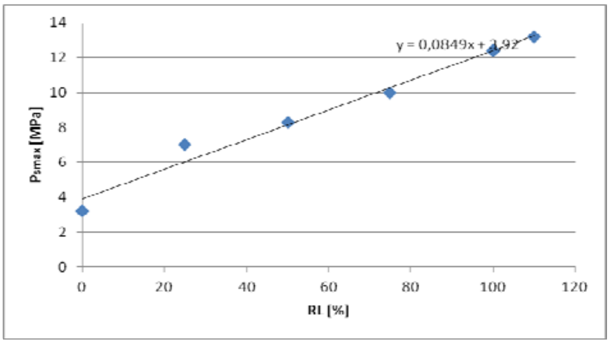

Fig. 10 The relationship between the maximum combustion pressure P_{smax} and the relative load RL in no. 1 cylinder engine type 6AL20H during acceptance tests after manufacturing.

the average value for the given load amounted to 5%. The large number of measurement data requires warehousing.

Fig. 10 presents measured values of maximum combustion pressures in the first cylinder during tests after overhaul, with the approximating linear and the equation.

In knowledge acquisition it is possible to use the attribute model, in which properties and qualities of diagnosed objects are described with many symptoms. The data set in diagnosed engines can be described by means of the matrix:

$$\begin{pmatrix} a_{11} & \dots & a_{1k} & d_{11}\dots d_{1n} \\ & \dots & & \dots \\ a_{n1} & \dots & a_{nm} & d_{n1} \quad d_{nn} \end{pmatrix} \qquad (4)$$

where, a_{ij}, $i = 1, \ldots, n \wedge j = 1, \ldots, k$ are values k of attributes;

d_{ij}—values of decision-making attributes.

Declarative knowledge can be recorded as a statement:

$$\langle o, a, v, \theta, P\rangle \qquad (5)$$

where:

o—object;

a—attribute;

v—value;

b—assessment of the degree of the truth;

θ—time of examining the statement.

5. Conclusions

The research presented in this article deals with collecting parameters from acceptance tests at the marine engine manufacturer’s and subsequent operation in databases. With the current development of the computer science it seems purposeful to build electronic databases for diagnostic purposes. Such databases should contain model parameter values and characteristics that can be extended with data and characteristics obtained from regular monitoring of the technical state of marine diesel engines.

Therefore, a dedicated engine database can be expanded at any time with new information, thus being a tool for creating sophisticated and continuously updated data banks. Thanks to this an engine operator knows whether the method he operates the engine is correct and can extend time to a major repair until the deterioration of the technical state. The values of parameters of ship’s piston internal combustion engines will be used for diagnostic needs.

The developed database may be a precursor of further research projects. It has a clear expandable structure that will facilitate its expansion with parameters of the engines in newly purchased vessels.

The knowledge accumulated in the database can be utilized in diagnostic inference on the condition of the internal combustion engine. Marine diesel engines are operated at variable working conditions, which requires support from dynamic advisory systems.

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