

Article

Database and Knowledge about Essential Manufacturers of Marine Self-Ignition Engines

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Abstract: During scientific studies on reciprocating self-ignition marine engines, varying data are often needed. Such data are often in various collections and obtaining some of these is very difficult. Therefore, as it was elaborated in the electronic database about the important marine reciprocating combustion engine producers for the needs of operating scientific investigations aiming at gathering the essential information and technical data in one set. This article also presents a reference to existing databases. Important and globally known companies, as well as their constant and variable data, were described. These data were obtained from various printed and virtual sources of information. These data were selected and compiled in the environment of the Microsoft Access computer program. The collected information was divided between main propulsion and auxiliary engines, containing data about manufacturers, types, and technical parameters of slow, medium, or high-speed combustion engines. This database is constantly updated and rebuilt according to the constructions and changes on the engine production market as the result of economic and ecological functions. It is a relative type database, which contains information about technical data of combustion engines. Marine combustion engines are usually operated for dozens of years after they have been produced, whereas producers merge, change their names, or stop existing. Therefore, a digital-knowledge-management platform was developed in the virtual space in which information on scientific and technical resources was integrated of competing manufacturers with the option of introducing updates.

Keywords: marine engines; important producers; technical parameters; electronic database; knowledge base

1. Introduction

Any information is characterized by its content and form. Because of its usefulness, information is divided into [1] useful, redundant, and parasitic, whereas the useful information can be divided into: basic, secondary, and additional. The purpose of the information is to select a specific behavior by the recipient of the product. Information is not understood physically and energetically, but these processes are equivalent to physical phenomena needed by the recipient or received from the sender [1].

The database is an orderly collection of data, including thematic categories of data which are designed, grouped, and archived for customer satisfaction information on the needs of organization and that represent the current state of the objects [2,3]. These databases are appropriately arranged computer representations of existing (not necessarily physical) fragments of the real world, which is of interest to database users [4].

For the propulsion of sea-going vessels, internal combustion piston engines are mainly applied [5,6]. Information about the ship engines' specifications and functions is expansive and scattered. To more effectively gather information about them, it is possible to use modern information technologies, including databases.

Internet website about marine engine manufacturers contains 144 names of companies sorted alphabetically and divided into subgroups for the first letters [7]. This website has a disclaimer that this list may not reflect recent changes.

In publications and websites, there is not even information about construction changes, company status, and information about engine production in the world. The authors of this publication want to gather dispersed and partial information about the manufacturers of marine engines and their products into one whole to get to the basic data and introduce updates in constructions and on the market.

In recent years, a significant increase of the ecological and economical requirements for marine combustion engines has emerged [7–13]. This tendency is realized by the further limiting the standards of exhaust emission on sea and land, a development that aims not only at reduction of fuel consumption but also at reducing the negative impact of emissions. Therefore, databases should now contain ecological information.

2. Databases

2.1. Types of Databases

The term ‘database’ as a single word appeared in Europe in the early 1970s, and at the end of this decade was used in most American magazines. Data sets, are often properly ordered [14]:

- computer representations of fragments of the existing (not necessarily physically) real world that is of interest to database users;
- the method of structuring information management;
- data sets with a specific structure are stored on an external computer storage medium, which can meet the needs of many users take advantage of them in a selective manner at a convenient time.

Many types of databases organize data in the form of tables containing records divided into fields in which information of individual categories is stored. They consist of several fields storing information, and each field has data of the separated category. Thanks to this, computer databases enable fast sorting of records by individual categories or searching for information within only selected fields.

The databases can be divided according to the data organization structures on:

- simple bases: filing and hierarchical;
- complex databases: relational, object, object-relational, streaming, temporal, and non-relational.

Of these structures, relational databases are most often used in practice.

The following models of databases were distinguished [4]:

- hierarchical—the real world is described by means of trees;
- network—the modeled world is described using graphs;
- relational—utilization of two-dimensional tables (relations) to describe fragments of the real world;
- object-oriented—components of object-oriented programming (objects) used to describe reality;
- logical (deductive)—the use of logic, otherwise can also say about using natural language to describe reality.

The current version of database also refers to the relational and object model of databases.

2.2. Relational Database in Mathematical Terminology

The relational model was proposed in the IBM research department in 1970 by E. F. Codda. The features of the Codda relational model are as follows [14]:

- is based on the concept of a mathematical relationship that somewhat resembles a table of values;
- relationships play the role of basic elements that make up structures;

- is based on set theory, first order logic and predicate calculus;
- data independence;
- uses data processing languages based on the processing of files;
- introduction of tools to solve problems of semantics, consistency and data redundancy.

If is a set $U = \{A_1, A_2, \dots, A_n\}$, whose elements are called attributes. A tuple (data structure) r U type is often equated with a string value. A tuple of this is the function, therefore requires write $r = \{(A_1, a_1), (A_2, a_2), \dots, (A_n, a_n)\}$, where $a_i = r(A_i)$, $i = 1, 2, \dots, n$. When $U = \{A_1, A_2, \dots, A_n\}$ tuple $r(U)$, it can present in the form of a table

$$r = \frac{A_1 A_2 \dots A_n}{r(A_1) r(A_2) \dots r(A_n)} \tag{1}$$

Each of these tuples can be represented using the table. Because the collections of arguments for all these tuples are identical, they can be written in the header of the table, and the value of individual tuples (function) in the following lines. In this way, the tabulation of the relationship is obtained as

$$U \rightarrow \cup\{DOM(A) : A \in U\} \tag{2}$$

Let be the relationship $R(U)$ and let $X, Y \subseteq U$. In R exhibiting dependency $X \rightarrow Y$ function, which writes out the $R| = X \rightarrow Y$, if for everyone two tuples $r_1, r_2 \in R$ is [4]

$$r_1[X] = r_2[X] \Rightarrow r_1[Y] = r_2[Y] \tag{3}$$

For the collection of attributes, and let F be the function of an ordered pair, the laws of $R = (U, F)$ are called the relational schema of a set of attributes and the collection of F depends on the function.

The definition of the relation R is no coincidence (instance) of the relational schema $R = (U, F)$ or that her schedule is, what we $R| = R$ or $R| = (U, F)$, if R is the type and complete is each function dependency $X \rightarrow Y \in F$.

Relational database systems have been distinguished:

- θ every datapoint is represented according to the concept as a set of ordered values in the form of rows and columns and the relationship between them,
- θ given quantities are scalar—this means that any position of relationship at the intersection of a column and a row always contains one value,
- θ every operation applies to the whole relationship, and the effect is also the relationship.

For the given sets Z_1, Z_2, \dots, Z_n : in mathematical terminology, the relational database is a collection of relationship. The mathematical relation R over these sets Z_1, Z_2, \dots, Z_n was named any subset of the product Cartesian over these sets [4]

$$R \subseteq Z_1 \times Z_2 \times \dots \times Z_n = \{(z_1, z_2, \dots, z_n) : z_i \in Z_i, i = 1, 2, \dots, n\} \tag{4}$$

Relationship (n —segmental) R is the set of n -tuples of strings, and i -th string element is the set of Z_i , $i = 1, 2, \dots, n$. The n -member of n -element relationships as strings in collection of Z_1, Z_2, \dots, Z_n , where $f(i) \in Z_i$, treats them as features of the n -element field a set of symbols, called attributes.

3. Important Modern Combustion Engine Manufacturers in the World

3.1. Admission

In the marine engines market, there are fundamentally a few important companies that have a considerable share in practically in many sectors [15]. The development directions in the low speed engines in the second half of the XX century sector were such that three designer and licensors was dominant in the in world production. These were companies MAN Burmeister & Wain, Mitsubishi and then Sulzer (later Wärtsilä) dominate the international arena.

The other rivals are: AEG-Hesselman, Deutsche Werft, Fullagar, Krupp, McIntosh and Seymour, Neptune, Nobel, North British, Polar, Richardsons Westgarth, Still, Tosi, Vickers, Werkspoor and Worthington and the Doxford, Götaverken, Stork, and others.

Wärtsilä was definitely the market parent in four-stroke medium-speed engines, followed was MAN Diesel, and then the others. MAN Diesel was the significant manufacturer of two-stroke crosshead engines, Wärtsilä and Mitsubishi companies were much smaller contributors in production.

In the year 2010, orders for self-ignition engines, the medium speed four stroke reciprocating and the low speed two stroke crosshead engines, for residual fuel feeding, were small [16]. There was an increased demand for the number of purchased dual fuel engines with residual or distillate fuel as a pilot fuel system and natural gas as primary fuel.

Particularly, the transportation of liquid natural gas by gas tankers and the LNG tankers is increasing. The application of dual fuel engines in power plants is rapidly increasing, in relation to the total quantity of orders of self-ignition engines in 2011, it had low participation [16]. For the large manufacturers (Figure 1), part of the production concerned: MAN Diesel, Wärtsilä, Caterpillar MaK, HHI Himsen and others.

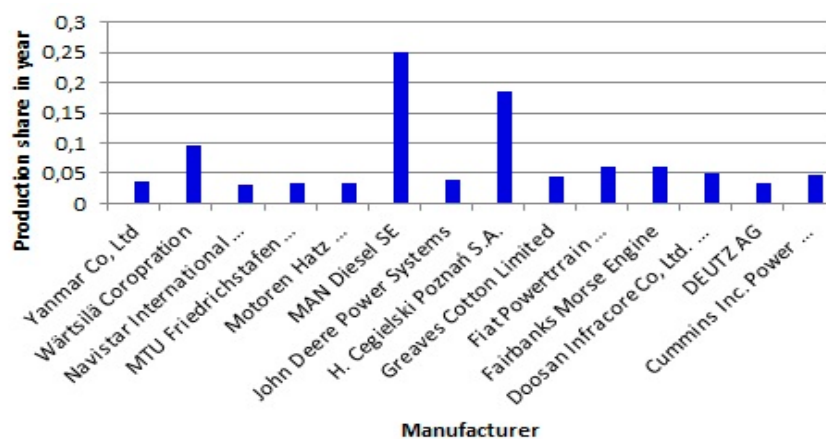


Figure 1. Comparison marine diesel engines with a capacity above 0.5 MW ordered worldwide in 2010.

3.2. Sulzer Marine Diesel Engines Manufacture

Sulzer Brothers Company in Winterthur (Switzerland) have participated in four-stroke and two-stroke design and production since 1879. The Sulzer company historically built the first marine self-ignition engine in 1898. In 1950, the company produced its first two-stroke marine self-ignition engine that was reversible. In 1954, was used the concept of turbocharging in its marine engines.

Wärtsilä (Sulzer) was the producer of two-stroke marine engines of the RD, RND, RND-M, RLB, RN, RTA, RL, RT-flex series, and four-stroke AL series marine engines [15]. The number on the engine model indicates the diameter of the piston, egg RTA38: RTA—engine type, 38—piston diameter.

Then the New Sulzer Diesel company was transformed into part of the Wärtsilä Corporation, and the more modern and electronically controlled engine of Wärtsilä is the RT-flex series.

These engines are equipped with high pressure fuel, oil rails, and electronic control [15]. The use of electronic control in the engine made it possible to simplify the mechanical system by giving up the camshaft and the mechanical drive of the injection pumps and the mechanical drive of the batteries controlling the operation of the outlet valves. The Wärtsilä Corporation currently offers a wide range of solutions of marine self-ignition engines for various applications. Wärtsilä also produces four-stroke engines.

3.3. Wärtsilä NSD Company

Wärtsilä (værtsilæ) is a Finnish corporation which constructs, manufactures and maintains drive sources and other equipment in the marine and energy industry. The main creations of

Wärtsilä company include high-power piston self-ignition engines used on passenger ships. In 2016, the corporation employed more than 18,000 workers in more than 70 different countries around the world [7]. Wärtsilä and Marine Solutions businesses focus on developing and providing sustainable solutions for recipients, and Wärtsilä Services have been supporting one's design solutions and delivery the innovative technologies to manufactured installations by implemented updates and modernizations [17].

Wärtsilä NSD was next to company MAN Diesel the largest company engaged in the production of marine internal combustion engines. In 1997, Wärtsilä merged with the New Sulzer Diesel, based in Switzerland, and changed was name to Wärtsilä NSD Corporation. The company manufactures two-stroke and four-stroke marine engines to drive a ships or as auxiliary engines driving generators.

Wärtsilä, Anqing CSSC Marine Diesel Corporations, and other companies have elaborated constructions and technologies of dual-fuel low-speed self-ignition engines for marine applications.

3.4. MAN Diesel Marine Diesel Engine

MAN Maschinefabiek is located in Augsburg Nurnberg in Germany. This company has a large different plant in the production of main propulsion low speed marine combustion engines built with single acting two-stroke cycle and crosshead construction solutions. These engines are characterized by simplicity of design solutions, easy operation, and economical fuel consumption [18]. MAN produced series of KSZ-A, KSZ-B, KSZ-C, and the later of the KEZ-B type containing separated electronically controlled fuel injection subsystems. In the mid-1980s, MAN company merged with a Danish based company called Burmeister & Wain and the name was changed to the MAN B&W Marine Diesel Engine Manufacturer [15]. MAN Diesel & Turbo was renamed in 2018 as MAN Energy Solutions and is a partnership subsidiary from the German automotive group Volkswagen [19,20]. MAN Energy Solutions is a worldwide corporation headquartered in Augsburg, Germany that manufactures large-bore combustion engines for sea use in propulsion systems, marine and land power plant uses, and also turbochargers.

MAN company had a contract with Hyundai Heavy Industries Engine & Machinery Division for manufacturing of MAN B&W ME-LGIP dual-fuel combustion engines in 2018.

The MAN B&W construction two-stroke combustion engines from the 300 to 950 mm bore sizes may have a power section from 1560 kW to 82,440 kW, with objects that vary in total height from 5912 to 16,156 mm [20]. They belong to this the ME (400 to 950 mm bore), ME-GI (400 to 950 mm bore), ME-B (300 to 500 mm bore), and MC (350 to 700 mm bore) series.

Compliance with existing and upcoming emission regulations with best possible fuel consumption have been CO₂ emission reduced, a reduced in particulates and total hydrocarbons, and a reduction for NO_x as a result of a variety of optimization strategies and exhaust after-treatments. Common rail permits continuous and load-independent evaluation of injection and pressure course in the injector nozzle chamber.

3.5. Mitsubishi Company

This company has served its home market, and has earned installations in ships built for European and other overseas owners in Japan and Europe. The Kobe factory produces slow speed engines with up to 600 mm bores which can be built by its Yokohama works and the Japanese licensees Akasaka and Kobe Diesel [15].

3.6. Caterpillar Marine Self-Ignition Engines

Caterpillar Marine Diesel Engine is one of the major producers of medium speed and high-speed marine self-ignition engines. They also manufacture marine self-ignition engines C series and MaK types suitable for a variety marine uses, including main propulsion on ferries, in yachts, tugs, and salvage vessels.

The Worldwide Power Products website reported [21] that Caterpillar was the leading source of new, surplus, used, and repaired engines and generators. The searchable database includes diesel, natural gas, and biofuel engines from major manufacturers, including Caterpillar and Cummins engines, and an authorized HIpower distributor.

From offshore generator set engines to used marine combustion engines for propulsion or auxiliary use, Worldwide Power Products offers a broad array of tested and inspected, used marine engines.

3.7. Other Producers

The progress in two-stroke and four-stroke design solutions for main propulsion and auxiliary power drives in the time in the publication of Pounder's Marine Self-ignition Engines has also been maintained in seven versions. Innovations were also introduced in the engine design and construction sector, where giants absorb or withhold production of long-known types.

Inspection of emissions of selected exhaust components—such as nitrogen oxides, sulfur oxides, and particulate—has limited it locally and internationally, forcing engine designers to introduce common rail fuel subsystems, fuel–water emulsions, direct water injection, charge air humidification, and selective catalytic reduction systems. Fuels, lubricating oils, and pollution—as well as low sulfur fuels—were also dealt with.

The world's largest producers of marine ignition engines were mainly located in South Korea, China, and Japan. In 2017, China's shipbuilding industry generated one-third of global self-ignition engines, an increase of 2.2% over the year.

Dalian Marine Diesel Engine Co., Ltd. (DMD) is a wholly-owned subsidiary of China Shipbuilding Heavy Industry Co., Ltd. Founded on 1984, it mainly engages in the introduction, development, production, and maintenance of marine high-power low-speed self-ignition engines [15]. The company mainly produces MAN series and WinGD series low-speed marine main frames.

Hudong Heavy Machinery Co., Ltd. (HHM), is a state-owned enterprise that belongs to China State Shipbuilding Corporation (CSSC) [22]. HHM is the manufacturer of low and medium speed self-ignition engines for ship propulsion. Since 1978, HHM is also MAN-B&W and Wärtsilä's. Hedong Heavy Machinery Co., Ltd.

The Wärtsilä, MAN, and Caterpillar companies were significant in the production of medium-speed combustion engines, which represented a total share in this branch of 86% (in 2017), and the products of high-speed combustion engines were represented by MTU, Deutz, MWM, SACM, Pielstick, Ruston, and Paxman. At present, the marine self-ignition engine will have to be environmentally friendly and ecological.

The global marine self-ignition engines companies were [15]: MAN Corporation, Wärtsilä, Caterpillar, Hyundai Heavy Industries, Mitsubishi Heavy Industries, and MTU. Main marine self-ignition engine companies in China include [22]: Hudong Heavy Machinery, Dalian Marine Diesel, Yichang Marine Diesel Engine, Weichai Heavy Machinery, Shaanxi Diesel Engine Heavy Industry, CSSC Marine Power, ZICHAI Power, Henan Diesel Engine Industry, among others.

4. State of Knowledge and Technique of Marine Database

4.1. Overview of Databases

Machines, devices, and processes are supervised by systems based on knowledge. Information can be discovered in databases, which contain elements of [3]: design, measurements, and simulation plans. The credible reliability assessments of self-ignition engines of the main drive inform a great deal about the reliability of the entire ship. In the event of incidents involving the summoning of assistance or law enforcement inspections, it is important to maintain the high level of shipowner's of service in the world. Estimating the level of engine reliability will also reduce the costs associated with engine critical damages of combustion engines at sea. The DEREL (Diesel Engine Reliability)

database consisted of four coherent database tables: hardware information table, preventive service table, corrective service table, and damage information table [5].

When planning reliability investigations, it is good to gather a large amount of data on the main propulsion of self-ignition engines. This paper addresses the problem of building a computer database to develop engine failure data. The authors reviewed several current databases on the reliability of the engines, and also drew attention to modern concepts in this field. This information was used to build a functional prototype database using Microsoft Access 95 software called DEREL [5]. The DEREL database is implementable to accelerate the start of data collection in the future.

Ships' self-ignition engines should be serviced periodically to maintain optimum levels of performance and reliability. The purpose of the maintenance schedule is to reduce maintenance costs by minimizing ongoing repairs and downtime. The components ideally undergo long-term exploitation, without reducing the efficiency of the internal combustion engine or exposing the combustion engine to adverse events. Such events may be the result of design or operational errors [1]. The database contained data such as [5]: hull number, engine model, serial number, installation date.

The authors argue that file analysis does not have to be slow [23]. Apache Spark is an advanced module for fast data processing. Work on this project began in 2009, later Spark was made available. If it is necessary to get the highest performance in information processing to get answers to difficult questions in real time, Spark can meet such expectations.

The authors address advanced issues related to statistical analysis of data, anomaly detection, and image analysis. The book [23] contains the basics of data entry for Scala and Apache Spark. It also enables semantic analysis and, in practice, analyses the co-occurrence networks using the GraphX library. This book provides information on how to process geospatial and genomic data, as well risk estimation using the Monte Carlo simulation method.

In the producing of self-ignition engines, cutting-tool machining is the main processing technology. To improve productivity and increase the benefits of machining, a cutting database and parameter optimization method were built for five important parts of the marine ignition engine for rational cutting parameters. Microsoft Visual Basic and Microsoft SQL Server 2000 were used to manage data using the capabilities Deform 5.03 software modeling [24].

Production intelligence can be used by advanced data manipulation possible in modern production assessment software. In the MES/MOM version of PINpoint, multifaceted databases are created every hour using input data from relational databases used. Often access to relational databases is accomplished using a Structured Query Language (SQL) formula. The multidimensional database allows the user to formulate questions, e.g. "How much damage occurred in a period of 90 d, about what registration numbers and for what determined reasons?" Similar specific questions regarding the assessment of production operations and tendency are also possible.

Databases have been maintained for many years and existing ones are being improved. In publications and on the Internet, one can find information about producers of internal combustion engines and their finished goods.

Reference [25] presents the constructed database of ships employed by the Polish Steam Company, helpful in reliability studies, and elaborated another database was provided for diagnostic tests [26]. These databases contain extensive information on the characteristic technical parameters of sea vessels and compression ignition engines of main and generator propulsion mounted on them. The database of damage in aviation facilities has a different structure, in which the authors describe the system of development of wear and damage of replaceable parts using existing documentation [27].

After reviewing the current state of knowledge and technology, it was found that information on the problem is limited and found in many different sources. A person who wants the information they need about marine piston engine manufacturers and/or their products sometimes has a difficult problem to solve. It is also difficult to search for some information on the Internet or in publications and research institutions on the topic of marine combustion engines.

To remain competitive on world markets, manufacturers have recently been working to improve the quality of products. Quality management instruction has been introduced in many of the world's leading market institutions and marine services [5]. The management of activities on seagoing vessels is an important area where the Coast Guard can apply its own and concerning quality. A reliable assessment of the reliability of marine machinery, such as internal-combustion piston engines, will assess the reliability of the ship's response.

All the material of marine self-ignition engine collections of library collections is used during classes in a unified database to facilitate management [28]. Trainers on the network should only open a web browser, where the accumulated knowledge is used to teach about the marine internal combustion engine, to minimize workload restrictions. This publication presents the process of creating an online database of a self-ignition engine based on a machine, the library of materials can view the remote search of the Internet search, which improves teaching.

With the rapid development of network information technology and new computer technologies, Internet databases have become one of the most popular and the most important services. Conventional multimedia training materials developed in an online database, where trainees can use a mobile phone, tablet, or computer terminal via a browser to learn specialized knowledge provides an efficient means of knowledge transfer, and network database development programs use modern information technology.

The collected data from these sources used in an electronic database was elaborated. In [29], the database was described for Polish manufacturers of marine self-ignition piston engines. In [30], they introduce an electronic database regarding reciprocating compression ignition engine manufacturers, for applications of exploitation research with the aim of gathering the necessary data. Article [30] describes the database of marine self-ignition engines in the world until 2010. Self-ignition engines of the following producers had been archived: Akasaka Diesel, Caterpillar (CAT), Cummins, Fiat Grandi Motori, Hyundai, MTU Friedrichshafen, Niigata Power Systems, Pielstick, Scania, and Volvo Penta [31], among others.

An expert system of diagnosis and control of self-ignition engines gives results of the analysis of essential parameters for the two-stroke marine combustion engine which is intended for as the basic technological know-how. Radica [32] claims that expert system it could give optimal results during implementation on the newly designed, electronically controlled marine engines.

4.2. Data about Selected Producers of Marine Self-Ignition Engines

The main directions in the technology of two-stroke self-ignition engines have been small over the past century, so now another further step is being implemented—which are computerized and electronically controlled marine diesel engines [33]. The use of computers helps to select marine combustion engines, compare between different types, increase the performance of the conventional self-ignition engines, and elaborate on the different performance capabilities for such engines.

To optimize the collected data sets, they should be catalogued and stored as required, with the option of easily searching for data resources and knowledge. For such needs, archives or computer databases are built that speed up the entry of information, organizing and finding it. An important advantage of database and information management IT systems is that they can hold very large amounts of information and greatly facilitate their forecasting. Such methods can minimize the amount of work, and virtual archiving of space reduces the problems of traditional collection [25,26].

4.3. Summary of Information Resources about Producers and of Marine Combustion Engines

Contemporary databases and knowledge about the producers of marine self-ignition engines are limited, because it is difficult to search for general and detailed information about engine manufacturers as well as about producers of marine piston combustion engines. There are difficulties related to the lack of sufficient universal knowledge and its distribution. Some manufacturers of marine self-ignition engines often merge with others, change names or discontinue production—in part or in full—while

their internal combustion engines are still in operation, and access to information and replacement elements can be difficult or impossible.

There are virtual databases of manufacturers of combustion engines produced for the shipbuilding industry. To find data and/or knowledge about products and suppliers, it is good to enter the desired password in the selected web browser. Websites are often redesigned, with limited information for fear of competitors, and contain exaggerated advantages of their products. It is difficult to search the self-ignition engines a given company has produced in the past, especially with non-existent or absorbed manufacturers, which is very limiting.

In [34], it was written that all the information provided in this work is not geo-rated. These data are for marketing and information purposes only and are not reliable. Depending on the new project editions, some formations may change depending on the version of the project. There, these data are unavailable to multimedia technology. So that they might improve the systematization of the collection of multimedia technology, material libraries are usually built.

Virtual databases can be upgraded with additional data. This is the sort of development of knowledge resources that is needed in the present context.

5. Computer Database of Manufacturers of Marine Self-Ignition Engines

5.1. Database under Study

The current state of the database focuses on the most important manufacturers of internal combustion engines, maintaining a significant history. The databases of manufacturers of self-ignition engines and their products are relational because they [30]: contain tables, the rows of which describe objects or relationships occurring in the area, sets of semantic relations that describe general regularities (principles, rules) occurring in the developed reality sections. The database about marine engine manufactures E_{db} consists of two-stroke engines E_{2s} and four-stroke E_{4s} and the relationship between them:

$$E_{db} \subseteq E_{2s} \cup E_{4s} = \{(e_{2s}, e_{4s}) : z_i \in Z_i, i = 2, 4\} \quad (5)$$

Two-stroke engines are produced by major manufacturers, which can be saved with the formula:

$$E_{2s} \subseteq Z_1 \times Z_2 \times \dots \times Z_n = \{(z_1, z_2, \dots, z_n) : z_i \in Z_i, i = 1, 2, \dots, n\} \quad (6)$$

$$E_{2s} \subseteq \text{MAN} \times \text{Wärtsilä} \times \text{Mitsubishi} \times \dots \times \text{Henan} = \{(z_1, z_2, \dots, z_n) : z_i \in Z_i, i = 1, 2, \dots, m\} \quad (7)$$

The type of engine is characterized by basic technical parameters of E_t , which can be determined according to the formula:

$$E_{4s} \subseteq \text{CAT} \times \text{Cummins} \times \text{Hyundai} \times \text{MTU} \times \text{Pielstick} \times \dots \times \text{Yanmar} = \{(z_1, z_2, \dots, z_n) : z_i \in Z_i, i = 1, 2, \dots, n\} \quad (8)$$

The quantities characterizing marine internal combustion engines are numerical indicators that are used for comparative assessment and classification of these objects in terms of construction and technology. The indicators used by manufacturers of marine internal combustion engines were distinguished: energy, comparative, natural and operational risk rates, etc.

The group of energy indicators includes rotational speed, power, average effective or indicated pressure, average friction pressure, torque, efficiency, hourly and specific fuel consumption, etc. The values of such indicators for the reciprocating internal combustion engine load depend on the design features.

Comparative indicators determine the mechanical and thermal loads, the use of the swept space, working surface, mass of internal combustion engine materials, and usability. The most important comparative indicators include the average piston speed, volumetric power indicator, piston load factor, unit mass of the engine, volumetric mass factor of the engine, as well as the average indicated and effective pressure, and efficiency or unit fuel consumption.

Operating indicators contain information about the motor's properties in terms of operation and use, such as ranges of permissible overloads, preventive maintenance periods, level of reliability, etc. Assessment of the operation of marine engines during operation is carried out on an ongoing basis using a set of monitored parameters with the possibility of transmission.

A growing number of internal combustion engines have restrictions on the harmful effects of their operation on the environment, in particular: smoke opacity, emissions of toxic components, as well as vibrations and noise. Indicators of natural hazard I_{nh} can be written by the formula

$$I_{nh} = f(\text{PM}, \text{NO}_x, \text{SO}_x, \text{CO}, \text{CO}_2, \text{ROG}, V_b, N_o) \quad (9)$$

where PM—particulate matter level, NO_x —level of nitrogen oxides, SO_x —level of sulfur oxides emissions, CO—carbon monoxide, CO_2 —carbon dioxide, ROG—reactive organic gases, V_b —vibration level, N_o —noise level.

The engine is characterized by important technical parameters E_{tp} , which can be saved by the formula

$$E_{tp} = f(E_p, E_t, D_e, D, S, i, C_c, n_r, c_p, D_r, M_{ne}, p_d, p_e, N_e, g_e, g_s, F_t, V_c, v_s, m_e, N_f, \dots, R_{af}, I_{nh}, C_v, \dots), \quad (10)$$

where E_p —the purpose of the engine (ME—engine propelling a power screw about variable speed, AE—auxiliary engine propulsion the generator, DE—diesel-electric engine propulsion system); E_t —engine type, D_e —engine dimensions, D —cylinder bore, S —piston stroke, i —cylinder number, C_c —cylinder configuration, n_r —rated engine speed of crankshaft, D_r —direction of rotation (clockwise, counter clockwise on request), M_e —nominal engine torque, p_d —supercharging pressure, p_e —mean effective pressure, N_e —effective power, g_e —specific fuel consumption, g_s —engine unitary mass, F_t —fuel type, F_s —fuel specification, V_c —total cylinder volume, v_s —unit volume of the engine, m_e —dry engine mass, N_f —friction power, R_{af} —air/fuel ratio [35], C_v —minimum calorific value of fuel, etc.

The dimensions of a marine combustion engine can be determined by the relationship

$$D_e = (L_1, L_2, \dots L_i, H_1, H_2, \dots H_j, W_1, W_2, \dots W_k), \quad (11)$$

where $L_{1,2,\dots,i}$ —length, $H_{1,2,\dots,j}$ —height, $W_{1,2,\dots,k}$ —width.

The types of fuel F_t which can be feeding the engine are written with the relationship

$$F_t = (\text{MDF}, \text{HFO}, \text{CNG}, \text{LNG}, \text{LPG}, \text{DF}), \quad (12)$$

where MDF—marine diesel fuel, HFO—residual fuel oil, CNG—compressed natural gas, LNG—liquefied natural gas, LPG—liquefied petroleum gas, DF—dual-fuel. Some engines in the type design contain information about the type of fuel: D —distillate, H —residual, G —gas.

Recently, the importance of using gaseous fuels to power marine internal combustion engines has increased, as they are cheaper and more ecological. The areas of using residual fuels have been significantly reduced.

The number and order of selected parameters were determined by individual manufacturers of marine internal combustion engines. When some producers were asked to provide obvious data, however, such questions were not answered. These and other parameters can be selected by parameter ranking [36].

5.2. Presentation of the Developed Electronic Database

A computer database was developed which included selected and important producers of marine self-ignition engines. Data and knowledge from various sources—such as manufacturers' websites, technical documentation, catalogues and advertising brochures, and books and magazines about compression-ignition internal combustion piston engines—have been collected and archived in the

Microsoft Access environment. In the open program, shown in Figure 2, the start menu is presented, enriched with an image of typical marine internal combustion engine. There are two fields to choose from: “Database on Marine Combustion Engine Manufacturers” or close it. The next form contains the selection of marine two-stroke or four-stroke engines, and it is also possible to close and return to the main menu. Next is the possibility to choose from the list the base of producers of low-speed self-ignition (“two-stroke”) engines, which is presented in Figure 3, or “four-stroke” engines (Figure 4).

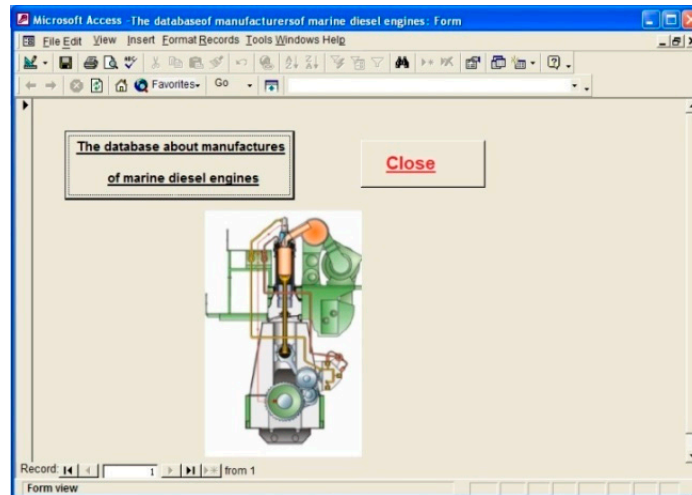


Figure 2. Graphic of the database start form.

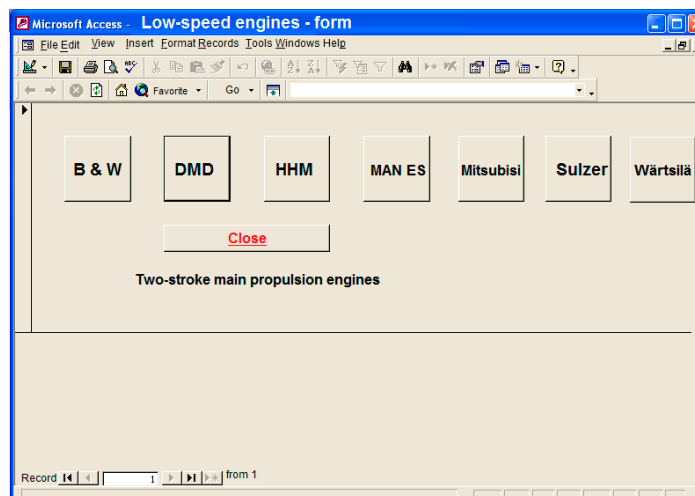


Figure 3. View form of producers the main engine: B & W—Burmeister & Wain, DMD—Dalian Marine Diesel Engine Co., Ltd. HHM—Hudong Heavy Machinery Co., Ltd., MAN ES—MAN Energy Solution.

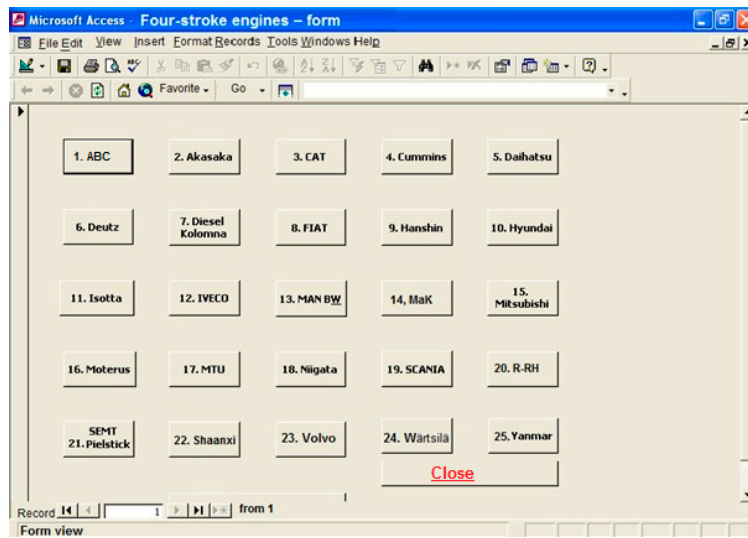


Figure 4. Form of manufacturers of the four-stroke engines: ABC—Anglo Belgian Corporation, CAT—Caterpillar, FIAT—Fiat Grandi Motori, IVECO S.p.A.—Industrial Vehicles Corporation, MaK—Maschinenbau Kiel GmbH, R-RH—Rolls-Royce Holdings.

Then, after selecting the drive type, a list of engine types is displayed (Figure 5). Figure 5 shows the low-speed internal combustion engines from the Sulzer-Wärtsilä family from past to present designs. Choice of the engine of the next step and review of his data shows Figure 6, where exemplary information of the low-speed and two-stroke engine RT-flex50D type produced by Wärtsilä NSD company was presented.

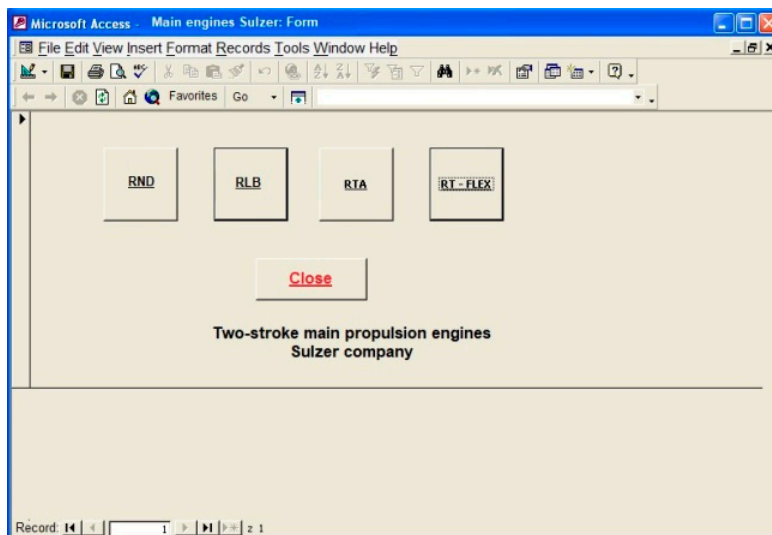


Figure 5. Types of the low speed main propulsion engines of sample producer.

ID engine		
Engine type	RT-flex 50-D	Next engine
Cylinder bore	500 mm	
Piston stroke	2 050 mm	Previous engine
Cylinder number	5.8	
Weight	200.280 t	
Speed range	99.124 rpm	Close
Effective pressure	2.1 MPa	
Effective power	1746 kW/cyl.	
Piston speed	8.5 m/s	
BSFC g _e	169 g/kWh	

Figure 6. List of selected technical parameters of the example RT-flex engine.

The MAN 51/60DF engine (Figure 7) for diesel-electric propulsion has combined diesel and gas technologies in one engine, providing fuel flexibility and keeping the engine running effectively and economically [20].

ID engine	1	
Engine type	V51/60DF	Next engine
Dimensions	10 258-13 644 mm	
Cylinder bore	510 mm	Previous engine
Piston stroke	600 mm	
Cylinder number	12-18	
Weight	187.265 t	Close
Speed range	514 or 500 r/min	
Fuel type	Diesel and gas	
Effective pressure	20.0 bar, 20.6 bar	
Effective power	1 050 kW	
BSFC g _e	180.2 g/kWh, 7.265 kJ/kWh	

Figure 7. View of the content of the data form with selected parameters exemplary four stroke engine of the MAN Energy Solution company.

Figures 6 and 7 present selected energy parameters, comparative parameters, natural hazard indicators, and operational indicators together with numerical values and units. The engine type is determined according to the rules of the given manufacturer, and the example V51/60DF means the arrangement of cylinders—V-type engine (V) about cylinder diameter 51 cm and piston stroke 60 cm, and dual fuel engine (DF)—distillation and gas fuel. Similar selected data for individual manufacturers and types of internal combustion engines is included in the electronic database.

5.3. Planned Changes in the Database

The list of manufacturers of internal combustion engines can be expanded or reduced. Perhaps the logos of some companies would be more informative to seekers than their textual names. The information contained in the database may depend on the needs of the seekers. The databases developed earlier for the needs of diagnostic tests and reliability contained the parameters sorted and ordered there [25,26]. It is possible to further develop the database and knowledge with further new

relevant information, and even delete data of discontinued products. It seems right to enter the search for internal combustion engines based on the introduced parameters.

The database may contain modern information technologies, knowledge discovery systems, diagnostic and advisory systems, and reliability data. Data can be extended to include internal combustion engine costs and environmental requirements that will allow them to be calculated during design work and purchasing.

It is planned to insert the parameters of natural hazards into the database and knowledge in the next stages of electronic database and knowledge.

6. Conclusions

The presented state of the computer database is a collection of information about the producers of piston-driven marine internal combustion engines, their products and selected technical parameters. The technical data and knowledge of manufacturers were collected and catalogued in the environment of the Microsoft Access computer program, which proved to be a friendly tool for building data banks. Modernizations were made to expand and sort accumulated knowledge and data.

This database and knowledge state contain more information than previously presented. The merger and transformation of some companies, as well as the cessation of business or the growing importance on the market of reciprocating internal combustion engines, were included here. Data on marine piston internal combustion engine manufacturers are expansive and dispersed, which is why they must be collected, ordered, and supplemented to increase their availability. Development trends of marine internal combustion engines forced by ecological and commercial requirements were also taken into account.

Data on electronically controlled piston internal combustion engines—dual-fuel, gaseous fuels, and optimized due to various criteria—are presented. Until now, these databases have aroused greater interest among customers than among manufacturers of marine internal combustion engines. The developed database reflects of what manufacturers provide, with modifications in the number and order of parameters set.

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