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STATISTICAL ANALYSIS OF MAXIMUM POWER OF CHOSEN DIESEL ENGINES

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Abstract

Testing of production quality and control of assembly operation requires test of each engine. The paper presents results of statistical analysis of maximum power for chosen engines. There were tested 40 the same type engines in engine test house.

Keywords: *engine, maximum power, statistical analysis*

1. Introduction

In order to unify methods of measuring engine power produced within the European Union and to prevent technical barriers to trade, the European Council introduced the EWG type-approval procedures [2,3,4]. Directive related to research engines determines what documentation that must be submitted to the authorities. It also defines "netto power", the "maximum netto power," "standard equipment ". This document includes also accurate measurements of power, torque, engine speed, fuel consumption, inlet air temperature to the engine, barometric pressure, exhaust manifold pressure, pressure in the exhaust pipe of the vehicle. There are also listed the components that are necessary to conduct a reliable test.

All these ensure the quality of manufactured engines. Nominal parameter values that characterize the type of engine as the power and maximum torque are given as a specific value. This is a generalization because the actual values of both maximum power and torque are within specified tolerances.

Typical parameters of the engine are used for the monitoring system. The authors conducted some research on vibroacoustics signals application for monitoring the engine [5,9].

2. Types of engine tests

Testing of production quality and control of assembly operation requires test of each engine Presented results of engine testing apply to company (name couldn't be presented) where are tested all produced engines in engine test house, checking the assembly operation for 100% producing population. Moreover this company had special engine test house for characteristics test, COP (Conformance of Production), LOK (Lublication Oil Consumption), durability test, and other tests to be commissioned by the company or on client's request [1,6,7,8].

Every engine, which is taken off the line is sent to a separate stand of the so-called subassembly. There passes the leak test, which consists of introducing air under pressure into the cooling system, then the pressure measurement is made. In this stand, the engine is flooded with oil, coolant and fuel. The so-called cold test is made. It involves the simulation of engine work by turning the crankshaft. This process is designed to distribute the fuel, oil and coolant throughout the system, as well as validation of the submission an assembly of crankshaft, pistons and connecting rods .

Hot tests are made on the working engine (a few minutes). Nearly 90% of the engines are tested for short time while the remaining 10% are tested longer (the longest tests are designed for prototype engines). The main task of this type of testing is to validate the correctness of the assembly and operation of the engine. Sealing elements are controlled, and the visible water or oil leaks are being checked.

It is only when the engine passes through a hot test can be taken to another test that is made for a randomly selected engines. The frequency of these tests is changed depending on the number of engines produced.

During the hot test are checked and recorded: numbers: the engine and its model, etc., oil pressure and fuel injection temperature for a selected speed, idle speed, engine management system diagnostics, automatic assessment of the turbocharger noise, vibration, beating the flywheel and crankshaft pulley, exhaust fumes, leaking coolant, oil, fuel, unusual noises).

Characteristics test - during the test, speed range is tested and on its basic a characteristic of the engine (power and torque) is formed. It is also verified: fuel flow, torque, maximum power, smoke, characteristics of the controller, specific fuel consumption, oil pressure, the maximum exhaust temperature, boost pressure.

COP test (Conformance of Production) is carried out based on customer requirements. Preparation is the same as for the characteristics test. The first step is the automatic warm-up, which is used to determine the required parameters of the engine (coolant temperature, air pressure and exhaust gas). Then characteristics test is made. The next step is a few hours test of engine operation at given parameters with variable load, then re-test characterization is carried out with the assessment that is reported to the client.

Test LOC Lublication Oil Consumption test is performed during by tens of hours the test duration is a few hours. During this test, every 30 minutes are monitored and recorded torque, fuel flow, the cooling temperature at the inlet and outlet, the oil parameters (temperature and pressure), exhaust temperature, exhaust pressure, boost pressure. The test is made at a constant speed. The purpose of this test is to measure the oil consumption. Oil consumption is evaluated by the ratio of oil used during the test to the duration of the entire test.

Durability test continues until about tens of hours. The engine is prepared identically to the characteristics test. The first step is the automatic warm-up, which is to identify all the engine parameters (temperature, etc.). After this test, the engine is disassembled into pieces, with a precise measurement of torque on each connection. These parts are to be reviewed. There is checked the wearing of all components. After that the engine is assembled and re-passes the characteristics test.

3. Engine parameters

Figure 1 presents a sample graph of the torque and power from the diesel engine. The maximum power output value is determined for the assumed speed (which in this case is 4500 rpm). Similarly, the torque value is determined for a speed of 2300 rpm.

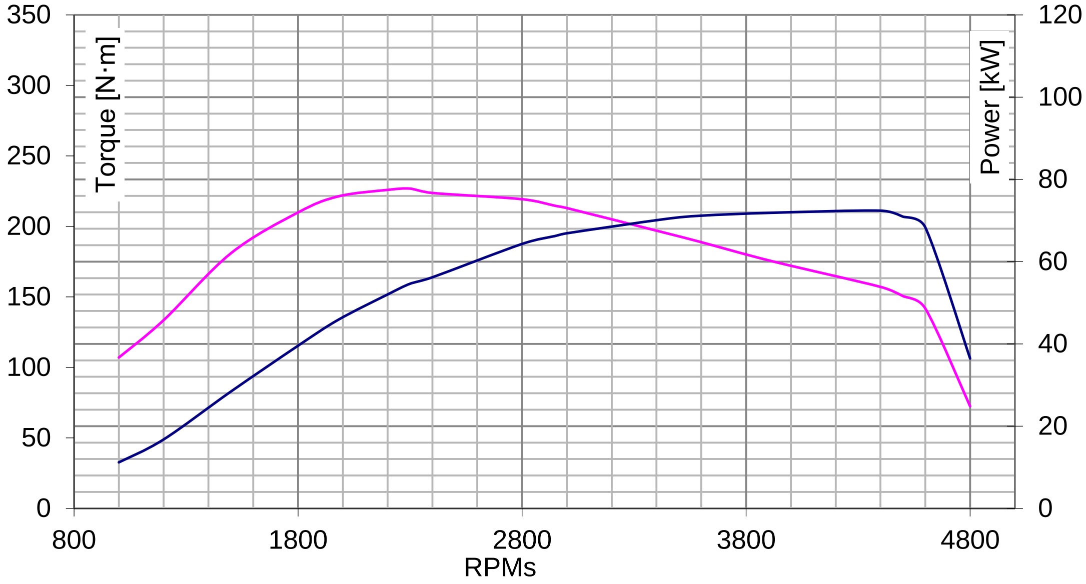

Fig.1. Power and torque characteristic for Diesel engine :pink line-torque; blue line-power

4. Statistical analysis

Table 1 presents the results of measurements of maximum power for a sample size of 40 engines.

Tab.1 Results of measurement

	Maximum Power			Maximum Power	
No.	kW		No.	kW	
1	73,84		21	73,36	
2	73,32		22	73,22	
3	73,39		23	73,91	
4	74,37		24	71,61	
5	73,32		25	72,22	
6	71,51		26	71,67	
7	73,08		27	72,94	
8	73,43		28	71,94	
9	70,21		29	73,52	
10	71,94		30	72,64	
11	71,91		31	71,91	
12	72,01		32	71,72	
13	72,76		33	73,08	
14	72,68		34	72,64	
15	70,92		35	73,53	
16	72,36		36	73,14	
17	71,54		37	69,92	
18	71,78		38	73,86	
19	71,93		39	72,21	
20	72,85		40	72,4	

The statistical analyzes were made in Statistica. In order to conduct a statistical test procedure the distribution of the data in Table 1 was grouped into six classes (fig. 2). Due to the similar values of mean, median and dominants it was hypothesized that the normal distribution describes the values of maximum engine power.

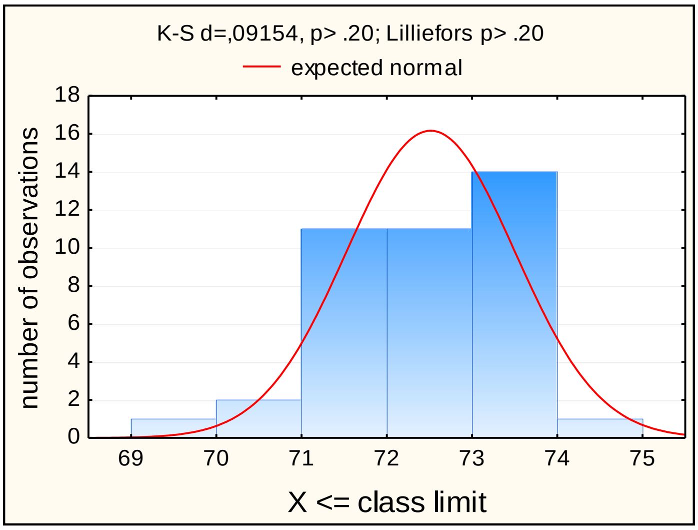

Fig.2. Maximum power grouped in classes

Figure 3 presents the median, lower and upper quartile of maximum power. Median and average values are similar and provide a symmetrical distribution. It also confirms the low value of the kurtosis.

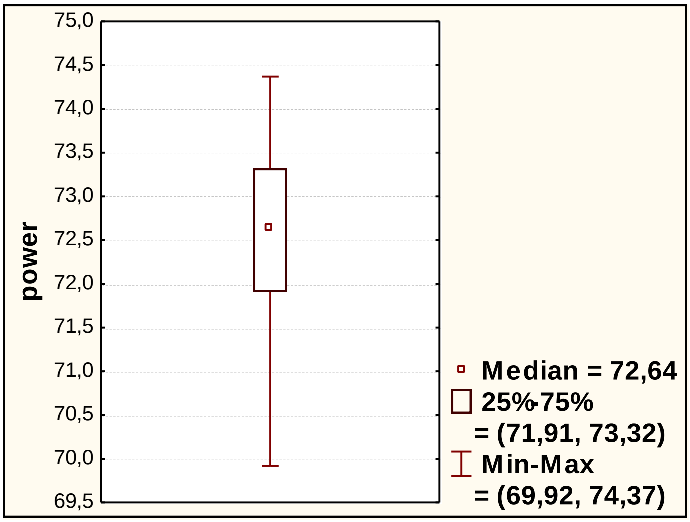

Fig.3. Median, lower and upper quartile

N = 40,000000
% valid=100,000000
mean= 72,514750
confidence interval -95,000%= 72,199031
confidence interval 95,000= 72,830469
Median = 72,640000
Sum=2900,590000
Minimum= 69,920000
Maximum= 74,370000
lower quartile 71,910000
upper quartile 73,320000

Percentile 10,00000= 71,525000
Percentile 90,00000= 73,685000
range= 4,450000
quartile range = 1,410000
variation= 0,974544
standard deviation= 0,987190
confidence interval of standard deviation. -95,000%= 0,808667
confidence interval of standard deviation +95,000%= 1,267587
kurtosis= 0,277375

The next figure (4) shows the empirical distribution function for the cumulative value of the maximum engine power with the curve representing the normal distribution and confidence intervals.

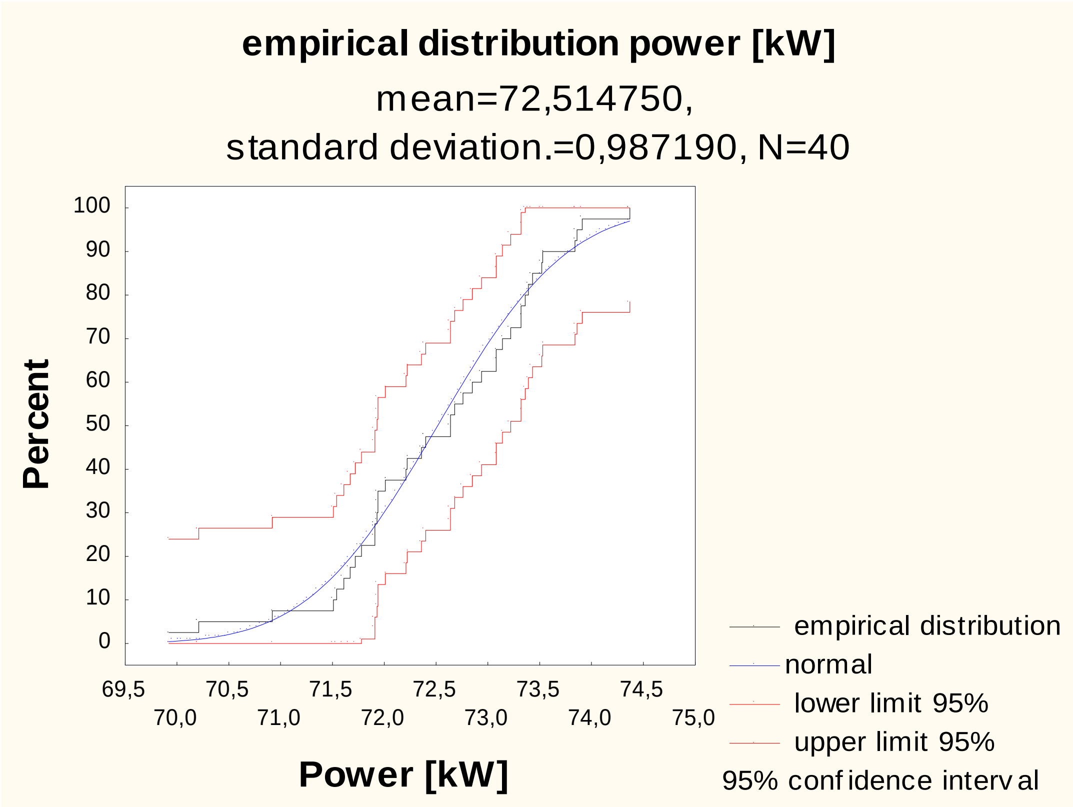

Fig.4. Empirical distribution

5. Summary

Presented results of statistical analyses show the extent of the real values for the analysed maximum power Diesel engines. Narrow range of the standard deviation of the order of 1 kW proves the high quality of our engines. The mean value is lower by 1.5 kW from the nominal value. It is worth to give by the nominal value with tolerance limits allowable by manufacturer of engines.

References

[1] Luft S., *Pojazdy samochodowe. Podstawy budowy silników*, Wydawnictwo Komunikacji i Łączności, Warszawa 2003.

[2] *Dyrektywa 80/1269/EWG W sprawie zbliżania ustawodawstwa Państw Członkowskich dotyczących mocy silników pojazdów silnikowych*.

[3] *Dyrektywa 98/69/EC dla wszystkich pojazdów*.

[4] *Dyrektywa 2007/715/EC dla lekkich samochodów osobowych*.

[5] Burdzik, R., Konieczny, Ł., *Wpływ wybranych uszkodzeń silnika pojazdu samochodowego na poziom generowanego hałasu*, VII Sympozjum Naukowo-Techniczne „Silniki spalinowe w zastosowaniach wojskowych", Czernica 17-20 października 2010.

[6] Ferguson C., R., Kirkpatrick A., T.: Internal Combustion Engines. John Wiley & Sons, INC, 2001.
[7] Heywood J., B.: Internal Combustion engine fundamentals. 1988,
[8] Kin Wong P., Mou Tam L., Li K.: Automotive engine power performance tuning under numerical and nominal data. Control Engineering Practice 20 (2012) 300–314
[9] Konieczny, Ł., Burdzik, R., *Research into noise emissions by a car combustion engine exhaust system*, Zeszyty Naukowe Akademii Marynarki Wojennej rok LII NR 1 (184), pp. 7-12, 2011.