CONSIDERATIONS UPON THE NOISE GENERATED BY SOME DIESEL ENGINES USED IN AGRICULTURE

CONSIDERAȚII ASUPRA ZGOMOTULUI GENERAT DE UNELE MOTOARE DIESEL UTILIZATE ÎN AGRICULTURĂ

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Abstract: *A high level of noise characterizes internal combustion engines. This problem primarily affects the environment. In this work, the most important sources of noise for internal combustion engines and their characteristics are presented. Based on experimental measurements, performed in testing laboratory conditions, the variation of noise levels in terms of the parameters that characterize the working of the engine was studied.*

Rezumat: *Motoarele cu ardere interne sunt caracterizate printr-un nivel de zgomot ridicat. Acesta afectează în primul rând mediul înconjurător. In această lucrare sunt prezentate cele mai importante surse de zgomot ale motoarelor cu ardere internă şi caracteristicile lor. Pe baza măsurărilor experimentale efectuate în condiții de laborator s-a studiat variația nivelelor de zgomot şi a parametrilor ce caracterizează funcționarea motorului.*

Key words**:** *noise levels, internal combustion engines, sources, parameters, measurements*
***Cuvinte cheie*:** *nivele de zgomot, motoare cu ardere internă, surse, parametrii, măsurări*

INTRODUCTION

The problem of noise is nowadays one of the important issues in internal combustion engines development.

It is known that diesel engines generally deliver less power for a given size and they produce more noise. Lately, the noise have been decreasing toward a level that is comparable to that of gasoline engines grace of technological improvements of the fuel injection system.

As the number of internal combustion engines continues to increase steadily, the effects of noise emissions have become increasingly disturbing. Everyday life demands internal combustion engines, especially for the vehicles, but they are also used in other fields of industrial practice. The noise level is one of the performance indicators of working for any heat engine and it is evaluated by specific methods in the design and manufacturing phase on stand, as well as in real working conditions.

The subject developed in the paper is the determination of the noise and vibration level for an internal combustion engine, located in laboratory conditions. Together with the specific noise determinations, it was performed the measurement of the specific performance indicators: effective power, effective moment, hour consumption, Hartridge smoke degree and effective specific consumption.

The disadvantages found in the working of the tested Diesel engines consist of the soot evacuation in smoke, appearance of nitrogen oxide and, the most important aspect, the trepidation, with a high noise level, caused by vibrations.

All these disadvantages are primarily caused by the inhomogeneous character of fuel mixture formed by the fuel injection in the compressed air from the combustion room. So, taking into account that for a Diesel engine or gasoline injection engine, the injection process is the most important for the noise generated levels, the study was developed using the standard injectors, provided by the producer and then, modifications were effected to the injection installation. These modifications consist in increasing the number of atomizer's orifices and the discharging pressure of the injector, in order to improve the combustion.

CHARACTERISTICS OF THE NOISE OF INTERNAL COMBUSTION ENGINES

The main sources of noise at Diesel engines are the air admission-gas evacuation systems, as well as the vibrating surfaces of the block, cylinders, cylinder heads etc. Important vibrations are generated by the forces of inertia, developed in the mobile equipment in the cylinder block, forces due to the masses in rotation or translation motion, that depend on the mass and dimensions of the different moving machine parts. These vibrations generate the appearance of a noise with frequencies between 30 Hz at the light running number of revolutions and 200 Hz, at high number of revolutions. The forces of inertia and their torque can be, generally, entirely or partly balanced and, in this way, their action can be much attenuated.

Another category of noises is generated by the reported shocks in the motion of the tappet levers and valves, as well as by the ventilation system for the engine cooling, that can reach even 100 dB.

A particularity of Diesel engines consists in their variable working regimes that produce the increase of intensity of the generated noises. The most high noise levels appear at the engines with air cooling, as well as at the two-stroke engines.

A more high total level of noise characterizes Diesel engines, depending on the number of rotations of the engine and its cylinder volume. It is known that the noise level at Diesel engines increase approximately proportionally with the third power of the number of rotations. It was also established that Diesel engines, of little cylinder capacity, but of high number of rotation, could produce a noise, bigger than in the case of the silent engines, of big cylinder capacity.

Experimentally it was established that the maximum levels, generated by internal combustion engines are of 110-112 dB and, in case of modification of the number revolutions between minimum and maximum values, the noise levels increases with 12-18 dB. Also, at the load increase, the total noise level increases. In the engine noise spectrum there are the following component fundamental series:

$$f_1 = k\frac{n}{60},\ f_2 = k\frac{ni}{60\tau},\ f_3 = k\frac{nz}{60}i' \qquad (1)$$

where: k-is the number series 1,2,3,..n; n-number of rotations of engine crankshaft; i-cylinder number; i'- reduction ratio; τ-working rhythm (τ=1 for two-stroke engines; τ=2 for four-stroke engines); z- tooth number at gear wheels or blade number at ventilators.

The first series is caused by incorrect balance of the machine parts, which turn with the same rotation speed as the crankshaft. The noise impulses, which appear in the combustion process at the opening and closing of the admission valves and the pressure impulses in the fuel filling installation determine the second series. The series usually corresponds to the noise impulses, which appear in the work of the tooth gears ventilators.

The main components, which correspond to the indicated series, are localized in the low frequency field of the acoustic spectrum. The noise generated by the admission system is a result of the air current pulsation. Proper and forced vibrations compose the air column vibrations in the admission system. The frequency of the fundamental component of the forced vibrations is equal with the admission number on a second. If the evacuation noise is not taken into account the engine total noise is dominated by the admission noise. The engine acoustic level value increases with 8-10dB, thanks to noise produced by the admission system.

The load influence on the noise level, which appears in the combustion period for a Diesel engine, is relatively small. The engine noise level varies with the load variations with 2-4 dB, but at the same time, working characteristics vary in large intervals. As a rule, the Diesel engine noise level can be reduced by the fuel injection law modification.

EXPERIMENTAL SETUP

The experimental researches were performed on a Diesel engine, made in Romania, under Fiat license, homologous to the Fiat 8045.02.300 engine. This one is a four-stroke engine, with direct injection, with combustion chamber of "bucket in piston" type, having "ω" shape, code D115.

The standard equipment of the engine is composed by: injection pump with rotary distributor, type DPA M 3233 F, produced by MEFIN Comp. of Sinaia, under CAV Lucas license; injectors type RO-KBL 27D S23, equipped by atomizers RO-DLLA-145-8-448-JR, produced by "Hidrojet" Comp. of Breaza, with 4 spray orifices, of D.30 mm diameter, disposed on a cone of 145^0 angle, the initial opening pressure of the injectors being fixed at 230±5bar, in accordance with the producer prescriptions: high pressure pipes having the internal diameter of 1,5mm, the external diameter of 6 mm and the length of 825±25mm.

In order to study the influences that the modification of injection system have on the main performance indicators of the engine (turning torque, effective power, effective specific consumption), on the polluting emissions (smoke degree) and on the engine noise and vibrations, experiences with another variant of the equipment were performed.

Thus, it was emphasized the influence of the number of orifices, in order to improve the spraying fineness. So, determinations were made with an atomizer with 5 orifices, inclined, on the same spraying cone of 145^0, as the standard one, the orifices being equidistant and having a diameter of 0.275 mm, only.

A series of complementary quantities were measured, influencing the engine working state. Ambient conditions of barometric pressure p_b, ambient temperature t_a, relative humidity e, pressure and temperature of lubrication oil, temperature of lubrication oil, temperature of exhaust gases at different distances to the engine evacuation, air temperature at the engine admission, cooling temperature were measured.

The speed of rotation was measured by two methods: on the one hand with the help of a classic centrifugal speed counter, on the other hand with the help of a piezoelectric sensor from the GATS 1000 GND opacimeter (device for the measurement of smoke degree and exhaust gaze opacity). This was mounted by means of a clamp on the high-pressure pipe of one of the injectors. It records, in fact, the number of injection by perceiving the pressure pulsation in the pipe interior, that are then transformed from the injection pump number of rotations to the crankshaft number of rotations.

The test consisted in the tracing of the regulator characteristic of the Diesel engine, equipped with mechanical centrifugal regulator, at a load of 75%, with the recording, for each regime, of the power parameters of performance, of the smoke degree and noise level.

The noise measurements were effected in accordance with STAS 7150-77, concerning "Measurement methods for the noise level in industry", in normal conditions of engine test on a laboratory stand. For this purpose it was used the 2237 Bruel and Kjaer noise investigator that made possible the recording of the following quantities concerning the noise: MaxP, MaxL, MinL, L_{eq}.

The measuring time interval for each one of 32 tests was of 60 seconds, the microphone being mounted in the position where the worker is placed when he supervises the engine in working conditions.

RESULTS OF EXPERIMENTAL INVESTIGATION

Staring from the theoretical aspects concerning the noise and vibration generated by Diesel engines, experimental researches were performed in order to emphasize their contribution to the pollution of the environment with noise.

Tests were performed following the method of tracing of the regulator characteristic at partial loads; thus, the number of rotations was varied with a ratio of 150 rot/min between 1100 and 2150 rot/min, passing by the number of rotations corresponding to the maximum torque.

A first set of experimental results was obtained for the standard variant of injector at the injection pressure, indicated by the producer, it means, of 230 bar. The second set of determinations was obtained for the same standard type of injector, at a high pressure, of 300 bar. The third set of determination corresponds to the modified atomizers, at the standard injection pressure of 230 bar and the fourth and last determination set is effected with a modified atomizer and injection pressure of 300 bar.

Table 1.

The characteristic noise parameters

No.	[rot/min]	MaxP	MaxL	MinL	Leq
1	**2150**	111.6	96.4	91.5	95
	2000	115	100	93.2	97.8
	1850	111.5	97	95	96
	1700	111	95.6	93.7	94.7
	1550	108.9	94.2	89.8	93
	1400	109.4	94.5	91.8	92.7
	1250	106.9	92.1	89.6	90.7
	1100	107.5	91.6	87.7	89.5
2	**2150**	111.8	96.2	92.1	95.2
	2000	114	100.4	98.2	99.2
	1850	113	98.8	96.1	97.6
	1700	112.8	96.4	94.7	95.6
	1550	109.6	95.8	91.7	94.7
	1400	109.9	95.2	91.4	93.7
	1250	108.3	92.8	87.7	90.6
	1100	107.1	92.7	86.8	90.1
3	**2150**	112.5	96.5	92.5	95.6
	2000	114.6	100.4	95.7	99.4
	1850	113.4	99	94.5	97.8
	1700	112.7	98	93.6	96.6
	1550	109.7	95.9	91.8	94.8
	1400	108.9	95.6	91.8	94.6
	1250	108.3	94	89.9	92.9
	1100	108.6	93.2	87.6	90.7
4	**2150**	12.2	97.2	92	95.7
	2000	114.4	100.5	96.2	99.6
	1850	114.6	99.6	94.9	98.8
	1700	112.3	97.6	92.8	96.6
	1550	109.9	96.4	92.7	95.4
	1400	110.9	95.7	92	94.9
	1250	109.1	94	90.6	92.8
	1100	108.6	94	88.7	92

The characteristic noise parameters recorded in 32 measurements are presented in table 1. For a better illustration, in the diagrams from figures 1-4, the L_{eq}, MinL, MaxP and MaxL were represented, corresponding to 8 levels of angular speed.

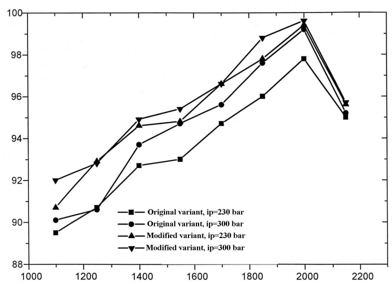

Figure 1

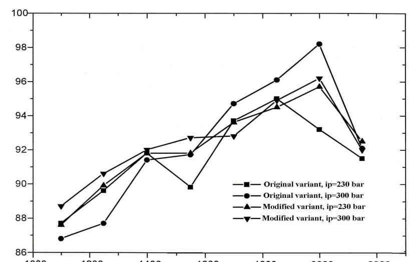

Figure 2

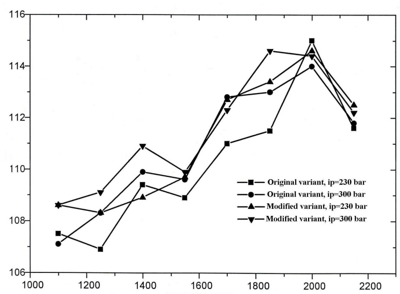

Figure 3

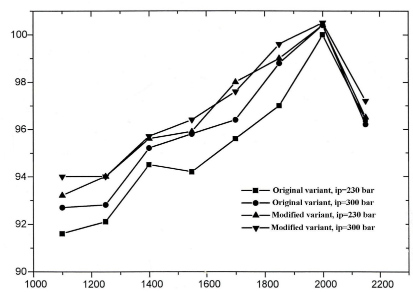

Figure 4

CONCLUSIONS

Analysing the values of the noise characteristics, presented in table 1 and diagrams in the fig.1-4, it results:

- The maximum peak level MaxP exceeds for each test 107.1 dB corresponding to the test number 16 for the number of rotations of 1100 rot/min at the original variant with the injection pressure of 300 bar, reaching 114.6 dB in the case of the tests 18 and 27 at the numbers of rotations of 2000 rot/min, modified variant at the injection pressure of 230 bar, respectively 1850 rot/min for modified variant at the injection pressure of 300 bar.

- The maximum level MaxL recorded values between 91.6 dB corresponding to the test 8, original variant, number of rotations of 1100 rot/min and injection pressure of 230 bar and respectively, of 100.5 dB for the test number 26, modified variant at the injection pressure of 300 bar and number of rotations of 2000 rot/min.

- The minimum level MinL was between 86.8 dB for the test number 16, standard variant, number of rotations of 1100 rot/min, injection pressure of 300 bar and respectively 98.2 dB for the test number 10, original variant, injection pressure of 300 bar, number of rotations of 2000 rot/min.

- The equivalent noise level recorded reached the smallest value of 89.5 dB for the test number 8 - original variant injection pressure of 230 bar and number of rotations 1100 rot/min and respectively the biggest value of 99.6 dB at the test number 26, number of rotations of 2000 rot/min, modified variant injection pressure of 300 bar.

When the injection pressure increases, a bigger quantity of injected fuel is mixed and burns in the combustion phase. Thus, the power performances of engine increase, the pollution with smoke degreases and the combustion becomes more noisily with the fast increase of the combustion pressure and from here it results the noise increase.

The used pressure of 300 bar exceeds the working pressure of the used injection pump so that the noise increases. At high number of rotations, the injection pressure increases with the second power of the number of rotations, which explains the intensification of noise characteristics at this number of rotations.

It is possible that the adopted pressure jump from 230 bar for the standard variant to 300 bar for the modified variant is too big. It results therefore the necessity to develop researches in order to determine the best intermediary pressure, which satisfies the demand to increase the power performance and to decrease the noise level.

The intensity of the engine's noise increases with the raise of the number of orifices and with the raise of the pressure of the injection.

- Switching from a 4-hole atomizer to a 5-hole one and keeping the same injection pressure, leads to an equivalent noise level bigger with 1,73%.
- In the case of an injection pressure fixed to 300 bar, switching from a 4-hole to a 5-hole atomizer leads to an average raising of the equivalent noise level with 1,2%.

By raising the injection pressure one observes that for the original variant, the equivalent noise level have an average raising with 0,9% while for the modified variant, the raising attains just 0,4%. Employing a simultaneous modification of the number of holes and of the injection pressure, the equivalent noise level raises on the whole with 2,18%.

Taking into consideration the noise measurement conditions and the admissive level for motor vehicle, which is 90 dB and the fact that the studied engine belongs to an agricultural vehicle, one can consider that this noise is not very elevated.

In the conditions of the increase of power performances by using the modified variant of injection system, accompanied by a reasonable increase of noise levels, it is possible to develop new researches in order to decrease the noise intensity. This could be made by corresponding adjustments of the injection advance so that all engine performance indicators could be improved without any constructive modification at the engine.

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