Всеукраїнський науково-технічний журнал

All-Ukrainian Scientific & Technical Journal

ISSN 2520-6168 (Print)

DOI-10.37128/2520-6168-2021-3

Machinery
Energetics
Transport
of Agribusiness

№3 (114)

2021

ТЕХНІКА ЕНЕРГЕТИКА ТРАНСПОРТ АПК

Всеукраїнський науково-технічний журнал

ТЕХНІКА, ЕНЕРГЕТИКА, ТРАНСПОРТ АПК

№ 3 (114) / 2021

м. Вінниця - 2021

ТЕХНІКА, ЕНЕРГЕТИКА, ТРАНСПОРТ АПК

Журнал науково-виробничого та навчального спрямування
Видавець: Вінницький національний аграрний університет

Заснований у 1997 році під назвою «Вісник Вінницького державного сільськогосподарського інституту».
Правонаступник видання: Збірник наукових праць Вінницького національного аграрного університету. Серія: Технічні науки.
Свідоцтво про державну реєстрацію засобів масової інформації
КВ № 16644–5116 ПР від 30.04.2010 р.

Всеукраїнський науково – технічний журнал «Техніка, енергетика, транспорт АПК» / Редколегія: Токарчук О.А. (головний редактор) та інші. Вінниця, 2021. 3(114). С. 164.

Друкується за рішенням Вченої ради Вінницького національного аграрного університету (протокол № 2 від 28.09.2021 р.)

Свідоцтво про державну реєстрацію засобів масової інформації №21906-11806 Р від 12.03.2016р.

Журнал «Техніка, енергетика, транспорт АПК» включено до переліку наукових фахових видань України з технічних наук (Категорія «Б», Наказ Міністерства освіти і науки України від 02.07.2020 року №886);

- ***присвоєно ідентифікатор цифрового об'єкта (Digital Object Identifier – DOI);***
- ***індексується в CrossRef, Google Scholar;***
- ***індексується в міжнародній наукометричній базі Index Copernicus Value з 2018 року.***

Головний редактор

Токарчук О.А. – к.т.н., доцент, Вінницький національний аграрний університет

Заступник головного редактора

Веселовська Н.Р. – д.т.н., професор, Вінницький національний аграрний університет

Відповідальний секретар

Полєвода Ю.А. – к.т.н., доцент, Вінницький національний аграрний університет

Члени редакційної колегії

Булгаков В.М. – д.т.н., професор, академік НААН Украъни, Національний університет біоресурсів і природокористування України

Граняк В.Ф. – к.т.н., доцент, Вінницький національний технічний університет

Іванчук Я.В. – к.т.н., доцент, Вінницький національний технічний університет

Іскович – Лотоцький Р.Д. – д.т.н., професор, Вінницький національний технічний університет

Купчук І.М. – к.т.н., доцент, Вінницький національний аграрний університет

Севостьянов І.В. – д.т.н., професор, Вінницький національний аграрний університет

Спірін А.В. – к.т.н., доцент, Вінницький національний аграрний університет

Твердохліб І.В. .т.н., доцент, Вінницький національний аграрний університет

Цуркан О.В. – д.т.н., доцент, Вінницький національний аграрний університет

Яропуд В.М. – к.т.н., доцент, Вінницький національний аграрний університет

Зарубіжні члени редакційної колегії

Йордан Максимов – д.т.н., професор Технічного університету Габрово (Болгарія)

Відповідальний секретар редакції **Полєвода Ю.А.** – к.т.н., доцент, Вінницький національний аграрний університет
Адреса редакції: 21008, Вінниця, вул. Сонячна 3, Вінницький національний аграрний університет, тел. (0432) 46– 00– 03

Сайт журналу: *http://tetapk.vsau.org/* **Електронна адреса: *pophv@ukr.net***

ЗМІСТ

UDC 621.436
DOI: 10.37128/2520-6168-2021-3-13

DIAGNOSIS OF FUEL EQUIPMENT OF DIESEL ENGINE BY REMOVING VYBRO INDICATORS OF FUEL SUPPLY

Serhiy Burlaka, Ph.D., Senior Lecturer
Svitlana Kravets, Assistant
Vinnytsia National Agrarian University

Бурлака Сергій Андрійович, доктор філософії, старший викладач
Кравець Світлана Миколаївна, асистент
Вінницький національний аграрний університет

Modern cars are increasingly equipped with control and diagnostic equipment. These methods are used to optimize the working process in the engine, improve traffic safety and simplify operation and maintenance.

You can adjust the chip to your liking, adjust the "performance" of the engine, because comfortable driving conditions give us a lot of pleasure.

The current control of technical conditions is carried out by the onboard system of self-diagnostics, which is an integral part of the controller. Problems that occur are signaled visually and stored in electronic memory. The full list of actual settings of codes of self-diagnostics and parameters of working process is carried out on HUNDRED with automobile indicators of brand. The problem is determined only by connecting a tester or scanner to a special diagnostic connector available in the car.

However, there are often complaints about objective and comprehensive examinations.

Misdiagnosis of "standards" with obvious signs of external problems is often given for many reasons. First of all, the use of information is limited electrical signals. In fact, the state of the circuit of sensors and actuators of engine automation is determined. Degradation of complex structures is usually based on the "domino principle": one local problem leads to another, another to a third, etc., which leads to the complete failure of the whole device. Problems with electricity may not be the cause but the consequences of other problems, including non-electrical causes. For example, the "ringing" of the piston fingers may indicate early inflammation and wear of the relevant components. The instability of the spark discharge in the spark plug may be the result of decompression of the working volume of the cylinder or improper preparation of the working mixture. The problem of the intake manifold or contamination of the fuel injector is usually recognized by the self-diagnostic system as a fault of the lambda detector. The list of such ambiguities can be expanded. When it is necessary to "restore" the accident of "decent age", branded diagnostic equipment may be useless.

Key words: *diagnostics, engine, vibration indicators, pulsation, fuel equipment, pressure*

Fig. 12. Ref. 13.

1. Formulation of the problem

Complex protocols for the exchange of information between external computers and vehicle controllers equipped with similar self-diagnostic systems have a significant complexity of design and require highly skilled workers. This ensures the inviolability of the current course on the subject orientation of diagnostic equipment (only for VAG - group, only for TOYOT and, only for FORD, etc.). The high cost of such equipment stimulates the specialization of large service stations and warranty service of new cars. They are usually limited to checking the condition of electrical circuits, components of automation, regulated replacement of oils, spark plugs, filters and other consumables. The possibility of significant wear of the structure is not taken into account [1].

In Ukraine, the physical aging of technology, for obvious reasons, is accelerating. A significant part of the vehicle fleet consists of old cars with naturally worn and deformed structural parts.

How to be service and repair companies de aling with the widest range of cars and the action of natural "age" defects in them (increased gaps, damaged contact surfaces, changed shapes and sizes, etc.).

How to detect mechanical damage, such as abrasion of the camshaft cams, the formation of soot on the outside of the valve, contamination of the injector or damage to the catalyst.

Decision-making on the scope and timing of future repairs often depends on subjective opinion, or even the simple interest of certain individuals or organizations.

According to some experts, the best is the design, which maintains a working condition throughout the standard service life. It is implied that failures will occur immediately after this period and simultaneously in all parts and systems. Repair of such a structure is not provided. Otherwise, it is recommended to replace components and parts completely and completely, without taking into account their actual technical condition.

This understanding cannot be accepted. A number of significant circumstances are not taken into account here. First, any complex structure continues to improve during operation. Success is achieved consistently in its individual components, which has a positive effect on the overall duration of the "life cycle". Secondly, even in parts of the same name, which are, it would seem, in the same operating conditions, the rate of consumption of the source resource is different. This is because of technological and operational errors, different lubrication conditions, heat dissipation, and so on. In various combinations, the combination of such "little things" can lead to both relative acceleration and slowing down of degradation processes. It takes time to develop various problems before the critical mark. It is not necessary to expect failure of all components at the same time. This non-diagnostic approach actually eliminates the consequences rather than the causes of the anomalies and is not a guarantee of well-being even in the short term. For car maintenance owners, this often becomes a financial problem [2].

2. Analysis of recent research and publications

No matter how different car engines look, they have the same principle of operation, many systems, components and even parts have the same function (housing, cylinder-piston group, bearing, ignition coil, injector, etc.). The current loads are due to the same work processes of defect formation. The causes, mechanisms and even external manifestations of structural degradation coincide (abrasive wear of contact surfaces, fatigue microcracks and deformations, weakening of fastening, clogging of through channels, tightness, breakdown of electrical insulation, deterioration of performance, appearance of extraneous sounds, etc.) [3].

Design and scale differences are virtually insignificant for diagnosis. "Tavria" and "Mercedes" can be viewed from a single angle. And this indicates the fundamental possibility and feasibility of developing a universal methodology (technology and tools) for diagnosing the structures of different cars. The following conditions are sufficient for this:

1. Knowledge of the principle of operation of a particular structure and accounting for a set of parameters of working processes and defect formation processes.

2. The presence of functionally oriented equipment, ie one that allows you to perform the same type of operations in the same functional systems of different mechanisms.

3. Information support should be suitable for answering the following questions:

4. Where is the defect (approximate coordinates)

5. The bell "of which details is listened to

6. How the defect affected the parameters of work processes

For example, guided by the above, in CJSC "Cyclone" in Lugansk on the basis of a modern household computer was developed stand "Dolphin-1M" [4].

Fig. 1. Stand "Dolphin-1M"

The following are used as information carriers:
- ultrasounds; vibrations of sound and infrasonic frequency domains;
- pressure; pressure pulsations;
- electrical signals operating in automation systems (ignition, injection, exhaust and fuel supply, etc.).

A total of 8 independent information channels based on different physical principles have been implemented. The main attention is paid to the information aspects of vibroacoustic radiation and their connection with the manifestations of anomalies in the parameters of pressure and voltage.

Any problem is an event that may affect the structure and the workflows in it. Researchers are provided with a large number of facts, unmasking descriptive signs of problems, as well as tips from an expert subprogram.

According to the results of the stand use become known:

- approximate geometric coordinates of the source of vibroacoustic radiation - anomalies;
- phase of the operating cycle, in which the anomaly appeared;
- amplitude-frequency spectrum of structural elements involved in the anomaly;
- trajectories of points during vibrational motion;
- connection of anomaly with working processes;
- conclusion of the expert program of the computer.

It only remains to properly dispose of a priori known and operationally measurable information. A negative defect search result is accepted as the "norm" [5].

Exchange of information with the car controller via the self-diagnostic line "K" (reading and erasing the codes of defects of sensors and actuators of motor automation, calling settings of mode parameters) is not provided, as it requires highly specialized equipment, which is widely represented in the car service market. However, it is possible to display on the monitor any current on the car control or measuring electrical signal in volts, the number of pulses of self-diagnosis. Diagnosis is reduced to comparing the measured values of the form, numerical parameters and phase-time relationships with their normative values. In terms of information, this is similar to the information obtained with the help of highly specialized and expensive imported equipment based on the analysis of electrical signals [6].

The proposed approach to diagnosis, which includes comprehensive objective measurement data and subjective analysis of the physical side of the observed phenomena gives meaningful, convincing and easily perceived results. The reliability of the diagnosis obtained in this way can be verified by making all sorts of common sense objections [7].

3. The aim of the study

To analyze the methods of diagnostics of fuel equipment of diesel engines and to determine the effectiveness of the vibrodiagnostic method.

4. Presenting main material

Basically, the inspection procedure begins with stopping the diesel engine, the high-pressure tube is dismantled on the high pressure fuel pump (HPFP), and the proposed device is installed instead. The diesel starts. The fuel equipment (FE) of the selected HPFP is carried out on the rate of increase of fuel pressure for a certain, set number of cycles of operation of the engine (as a rule from 5 to 12) from the beginning of increase of pressure of fuel in the closed cavity.

The procedure is performed at the starting speed of the crankshaft. When determining the degree of efficiency of the FE is taken into account: the temperature coefficient, which is responsible for changing the viscosity characteristics of the fuel; the coefficient of active stroke of the plunger; coefficient characterizing the degree of wear and microgeometry of the friction surfaces in the connection "plug-plunger". The latter factor is of particular interest. It is determined in advance on the basis of the maximum pressure developed by the pump that checks the cyclic flow. In addition, it remains unclear how to implement the mode of operation of the engine with startup for a given number of cycles [8].

Other methods of checking the FE in the start-up mode are used, for example, by the value of the maximum pressure that develops HPFP, but they are not widespread.

For trucks, the degree of engine performance without disassembly of HPFP by the manufacturer offers joint work of devices D49.181.59 and 30D181.61. At the same time cavities of low and high pressure are checked separately. The HPFP must first be removed from the engine.

When checking the high pressure cavity, the test pump is installed with the fitting up, in the device with the help of the device connected to the device 30D181.61. Next, the fuel is injected into the pump to a pressure of 80 MPa and check the pressure drop for 1 minute, do not allow a drop of more than 1 MPa.

When checking the low pressure cavity HPFP is installed in a horizontal position on the device D49.181.59. Device 30D181.61 is connected to the fuel supply opening through the pipeline, the pump is pumped with fuel and after making sure that there is no air, a plug is screwed onto the pump fitting. The pump rail is output to the stop, the required distance between the lower cavity of the flange of the sleeve and the lower cavity of the roller is set. Next, the system creates a fuel pressure of 6.5 MPa. The pressure drop time from 6 to 5 MPa should not exceed 13 seconds.

Despite the simplicity of the method, when checking the high pressure cavity, the tightness of the valve is determined and the state of the FE does not affect the test, and when checking the low pressure cavity, the selected range does not correspond to real values in the pump during normal FE operation (40 MPa and above). (20 MPa) [9].

There are methods that allow us to conclude about the performance of the FE by changing the shape of the signal received from the vibration sensor installed on the pump or nearby. For example, the process of vibration diagnostics using an overhead piezoelectric sensor is described. At diagnostics before the beginning of work it is necessary to establish the piezoelectric sensor near the union of the pipeline of a nozzle. The installation site of the sensor must be cleaned and the dirt removed. The inner diameter of the piezoelectric sensor must correspond to the diameter of the pipeline on which it is installed. The sensor is extremely sensitive and is easily damaged when it hits a hard surface. In the course of regular work by means of the sensor the oscillogram of vibration on which form define various malfunctions is written down. In fig. In Fig. 2 shows an example of an oscillogram obtained from the vibration sensor in the case of wear of the FE HPFP.

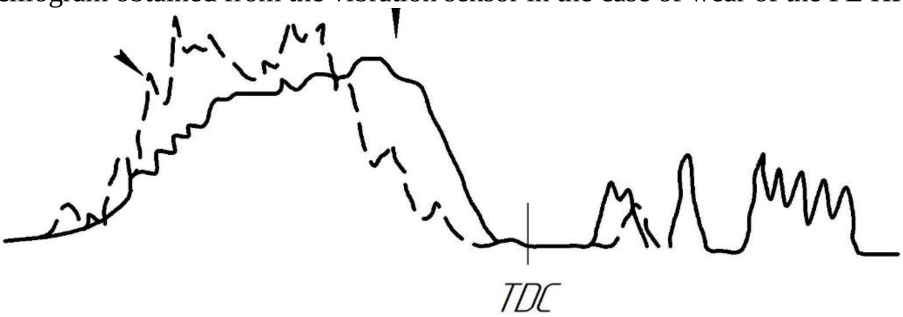

Fig. 2. Oscillograms of the vibration sensor in case of wear of the PVNT PA

Despite the apparent simplicity of the method, the determination of engine failures by the results of the analysis of vibroacoustic signals, it can be argued that in the study of FE, the spectral composition of the studied signals is heterogeneous. Thus this heterogeneity is explained not by different types of malfunctions of these or those elements, and quality of assembly and installation on the engine, various backlashes in HPFP drives, a difference in operating modes. However, the phase parameters (fuel supply duration, fuel supply advance angle, etc.) remain stable. It is impossible to determine the degree of FE efficiency by phase parameters. Thus, vibration diagnostics is difficult to recommend for the diagnosis of FE in general.

The most informative way to determine the degree of efficiency of FE units, which has become widespread abroad, is a method of diagnosing the shape of the fuel pressure signal obtained using a pressure sensor in the high pressure line. Below are some of the proposed solutions [10].

To begin with, it should be noted that these methods are based on the analysis of the fuel pressure waveform. The fuel pressure pulse generated by the HPFP contains information about the functional properties of the FE and the technical condition of its elements. Figure 3 shows an example of a pressure waveform during injection. It can be divided into several characteristic areas.

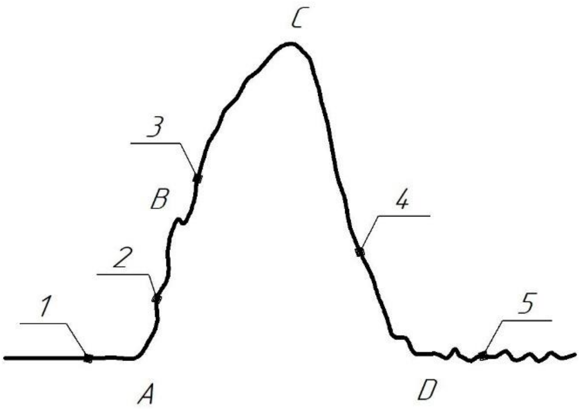

Fig.3. Pressure waveform during injection

Section 1 to point "A" can be judged on the residual pressure in the HPFP after pre-injection. Section 2 shows the start of the fuel pump supply. At point "B" is the lifting of the injector needle and fuel injection begins, and further growth in section 3 is due to the continued injection of the plunger. Point "B" characterizes the maximum pressure. Throughout the entire section 4, fuel injection continues and only at point "C" the needle lands on the seat. At the last section 5 there are damped pressure fluctuations in the HPFP. Thus, it is possible by the deviation of the sections and points on the pressure waveform to assume the failure of a node FE.

Based on this, Vasiliev Y.A. the following technique was described. It is proposed to superimpose the reference oscillogram obtained during the operation of the reference on the oscillograms obtained during the operation of the with malfunctions. And according to the results of overlapping and comparison of two oscillograms to determine the type of fault. Scheme (Fig. 4) of the relative position of the fuel pressure oscillograms in the HPFP for the reference FE (solid line) and for worn FE (dashed line) [11].

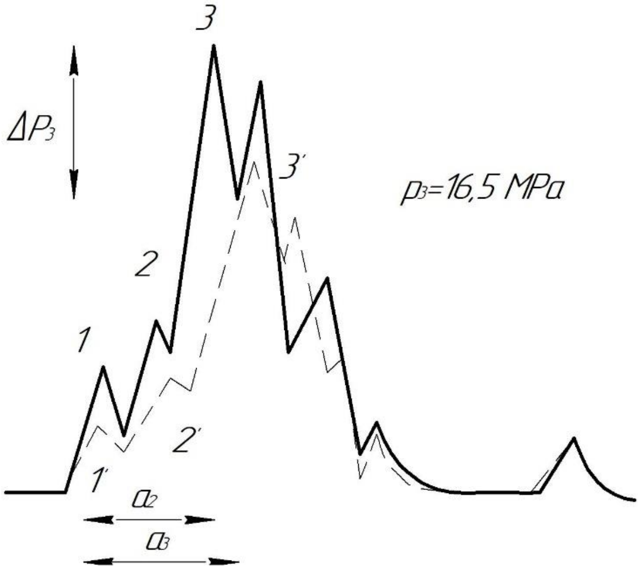

Fig.4. Superimposed oscillograms of fuel pressure in HPFP

In fig. 4 shows a manifestation of a slow increase in pressure and a decrease in the value of the maximum pressure. On the basis of these signs it is offered to draw a conclusion about excessive leaks of fuel on precision surfaces of FE.

The approach of finding characteristic points on the characteristics of the fuel supply process. The essence of the approach is to approximate the fuel pressure pulses obtained at different load modes during operation of a working FE. It is proposed to approximate a complex figure consisting of six segments (Fig. 5).

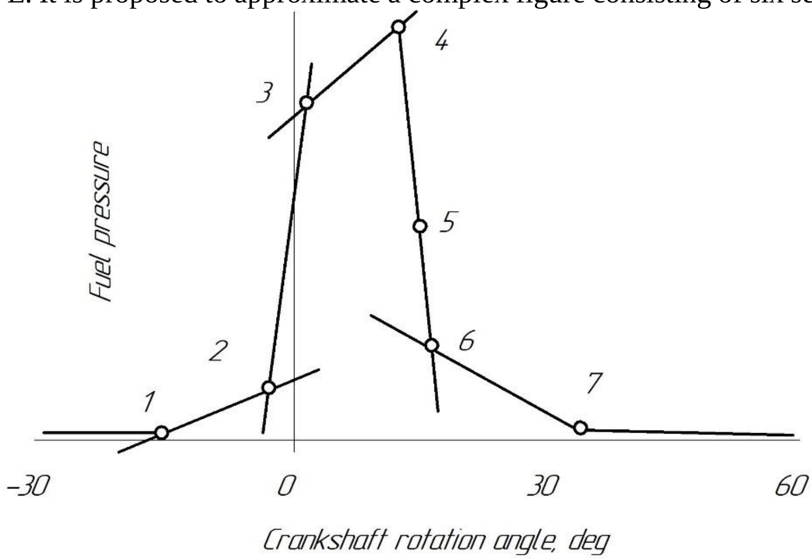

Fig. 5. Approximation of the fuel pressure pulse by portion-linear functions

This approach allowed to automatically generate the reference characteristics of the process of diesel fuel supply for further implementation of the procedure for diagnosing FE.

A method for diagnosing FE motors based on the statistical theory of pattern recognition. According to the results of tests of the FE in accordance with the algorithm for finding characteristic areas (Fig. 5) determines the state of the FE:

- normal condition;
- too early (late) fuel injection;
- too low (high) nozzle opening pressure;
- too low (high) injection pressure;
- too long (small) duration of injection;
- too slow (rapid) increase in pressure.

These factors can serve to reveal the root causes of these disorders. For example, faults such as "too slow pressure rise" and "too low injection pressure", according to the author, can be caused by an increased gap between the plunger and the FE sleeve.

The received experience of computational and experimental researches on definition of malfunctions and adjustment of elements of FE was embodied in system of technical diagnostics of FE of the engine with system "self-learning". "Self-learning" means the principle of automated obtaining of the reference characteristics of injection, adapted to the studied mode of operation.

Another technique based on the analysis of the injection chart, which allows you to determine the faults of the PA where it is proposed to use a diagnostic card, in which a combination of 19 features of the diagram can identify 17 faults. The list of faults includes, among other things, FE wear. It is suggested to judge wear on the following diagnostic signs:

- low residual pressure;
- a gentle increase in pressure (or "too slow increase in pressure" from the previous method);
- low pressure peaks;
- wide range of wave oscillations;
- delayed increase in pressure;
- late start of injection;
- reduced supply;
- reduced duration of the curve.

In practice, it may be difficult to determine such relative parameters without establishing clear quantitative deviations. Thus, all responsibility for the conclusion on the operability or non-operability of the node rests entirely with the operator [12].

There is a method of creating a diagnostic model used for the most time-consuming process of establishing correlations between structural and diagnostic parameters, mathematical models of the injection process. The diagnostic model is created not on the basis of a probabilistic-static approach, but by an exact deterministic method. It becomes possible to accurately account for the permissible deviations of the structural parameters of the fuel supply equipment and the parameters of technological instability. At the first stage diagnostic parameters are revealed. As an example, Figure 6 presents some parameters plotted on the pressure curve.

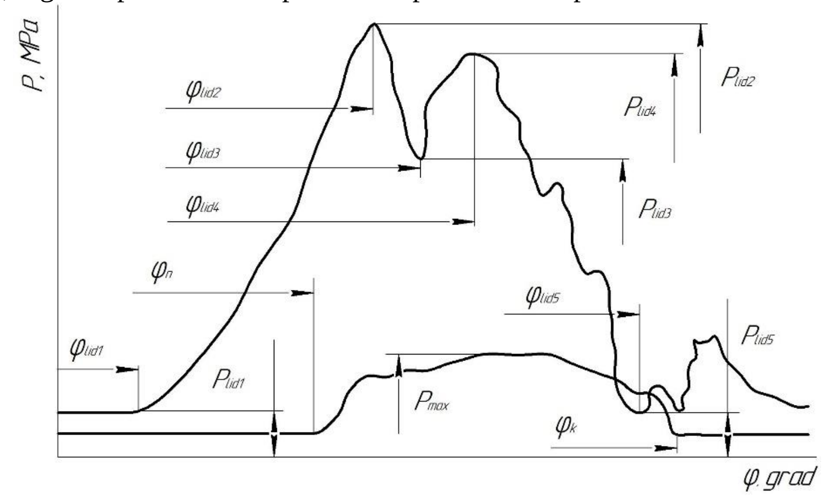

Fig.6. Designation of diagnostic parameters using a pressure curve in a high pressure line

In the second stage, a unique code (a set of quantitative deviations of diagnostic parameters in diagnostic modes) allows you to uniquely identify the fault. The author found that none of the thirty diagnostic parameters, including maximum pressure and a slight increase in pressure are not informative in determining the degree of efficiency of the PP, because the change of diagnostic parameters does not exceed the tolerances.

Thus, summarizing all the above about the methods of checking the degree of efficiency of the PP on the shape of the pressure signal in the high pressure line, you can create a table that will compare all the proposals.

The results of the comparison of methods show that among the methods there are contradictions about the presence or absence of signs found on the oscillogram of fuel pressure obtained in the high pressure line, the deviation of which can determine the performance of the FE.

Code number:

1 - low residual pressure;

2 - a gentle increase in pressure;

3 - low pressure peaks;

4 - wide zone of wave oscillations;

5 - delayed increase in pressure;

6 - late start of injection;

7 - reduced supply;

8 - reduced duration of the curve.

A study was conducted to determine the effect of FE wear on engine performance. The experiment was as follows. FE with different hydraulic densities of 1.5 and 12 seconds were alternately installed in the pump. It should be noted that the FE with a hydraulic density of 1.5 seconds is considered worn, and 12 seconds new. The experiments were performed under the same conditions. During the experiment, an oscillogram of fuel pressure in the high pressure line was recorded. Next, the recorded oscillograms for comparison were superimposed on each other.

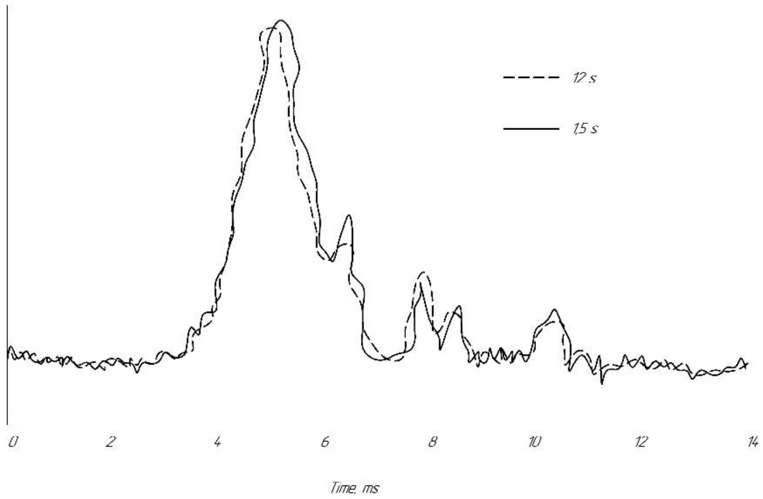

Fig.7. Oscillograms of pressure in a tube of a high pressure in the union of the pump at installation of PA with a different condition

According to the results of experimental studies, it is seen that the pressure waveforms obtained during installation in HPFP FE, with different hydraulic density are almost completely superimposed on each other. The oscillogram obtained when installing in the pump FE with a density of 1.5 seconds (dotted line), there is no such sign as a slight increase in pressure, but there is a slight decrease in maximum pressure compared to the error of the measuring equipment.

Similar results were obtained in the study of FE with different, artificially altered density. The reduction of the FE density was achieved by removing the metal from the surface of the plunger by circular grinding with a paste and joint grinding with a process sleeve, selected separately for each plunger. Oscillography of fuel supply processes and analysis of injection characteristics did not reveal changes in maximum pressures, advance and duration of supply in all studied fuel systems. In addition to the comparison of oscillograms, the authors determined the cyclic supply of HPFP when installing it in FE density. Experimental data on the change in the supply of engine pumps at modes corresponding to the rated power and idling, depending on the average diametric clearance of the spool part of the FE are presented in Fig. 8.

It is established that the volume of supplied fuel does not decrease up to the critical degree of wear of precision surfaces of FE. However, as the density increases, there is a sharp drop in pump performance.

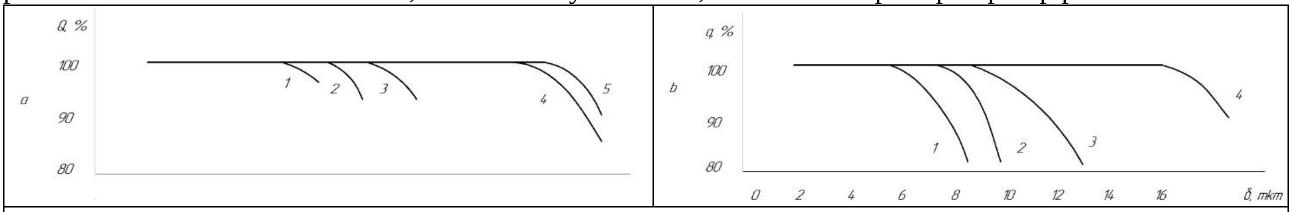

Fig.8. Change of supply Q, q HPFP of the engine depending on increase in average diametric backlash in FE: a - the nominal mode; b- idling; 1-5 types

The invariance of the pump supply is explained as follows. The speed of movement of the fuel layers in the gaps between the precision surfaces is very small. The movement of fluid in this case is largely determined by physical laws and limit state. The boundary layer can be held by the precision surfaces at relative rest, and its thickness can be commensurate with the interprecision gap. The conditions of the boundary layer depend not only on the size of the gap, but also on a number of other factors: the shape and roughness of the connected surfaces, the physical characteristics of the fuel, the levels of its working pressures. When the gap increases so much that the influence of the boundary layers on each other weakens, the appearance of internal flow is possible. The reduction of the supply begins from the moment when the time of movement of the flow in the interprecision gap from the high pressure cavity to the low pressure cavity becomes comparable to the injection time. With a further increase in the gap, the density of the PP reaches a limit value at which fuel leaks are compared with the cyclic supply [13].

Here it is appropriate to note that the actual shape of the gap in the PP and the average radial gaps can differ significantly. This is confirmed by the results of profiling FE, for example, in the works. The reason for the complex shape of the gap in the FE are deformation changes in the geometry of precision surfaces caused by installation (power) and working (fuel pressure) loads and design features of the FE.

According to research, a decrease in the maximum fuel pressure in the injector, increasing the duration of injection and as a consequence of reducing the rate of increase of combustion pressure, changes in power and economic performance of diesel are clearly manifested only at maximum wear in PP. Indicator diagrams obtained when used in HPFP FE with intermediate operating stages of wear, almost coincide, and the maximum combustion pressure is within the measurement accuracy. It was also found that the untimely replacement of worn-out sets of FE leads to uneven load distribution on the cylinders in different modes of operation.

Oscillograms of vibration acceleration and acoustic research of the D-240 engine depending on speed and loading operating modes are shown in fig. 9 - 10.

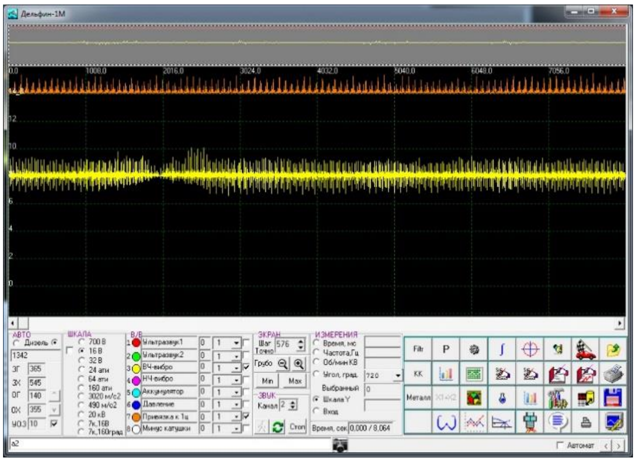

Fig. 9. General view of the oscillogram of the vibration acceleration of the engine D - 240 when using diesel fuel

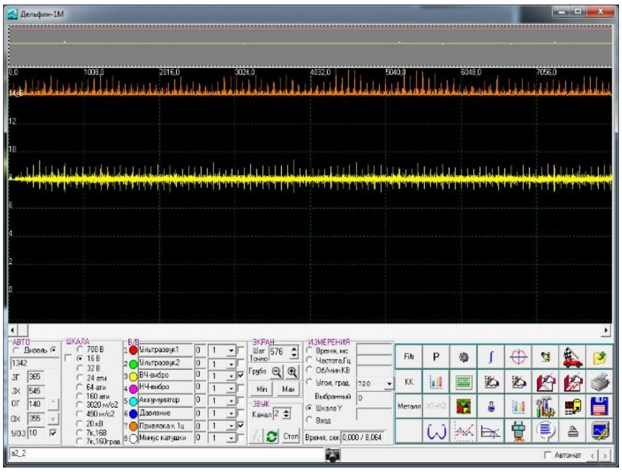

Fig. 10. General view of the oscillogram of vibration acceleration of the D-240 engine when using biofuel

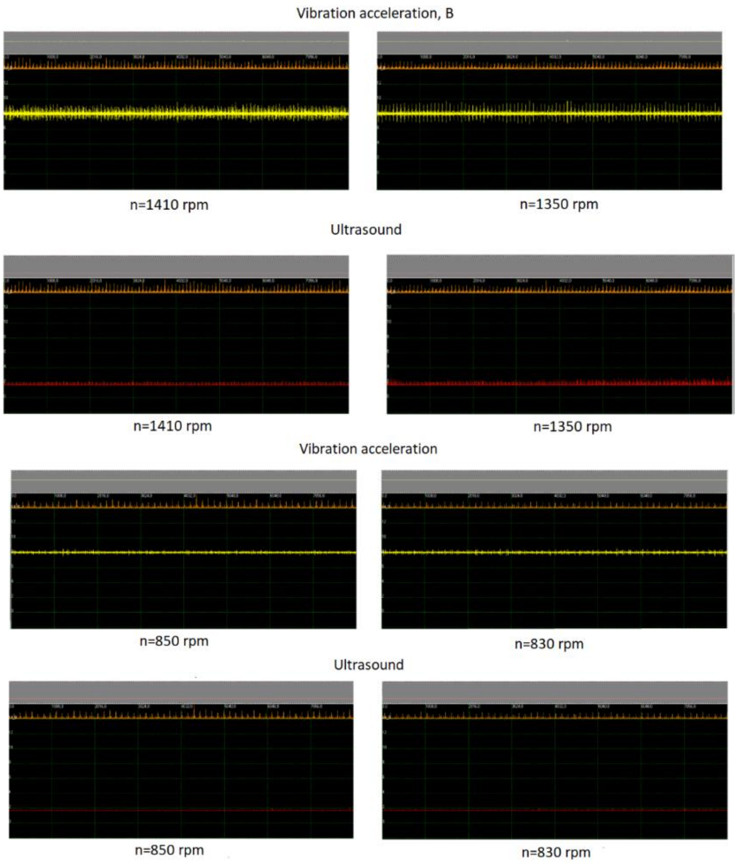

Fig. 11. Oscillograms of vibration acceleration and ultrasound for the D-240 engine at idle

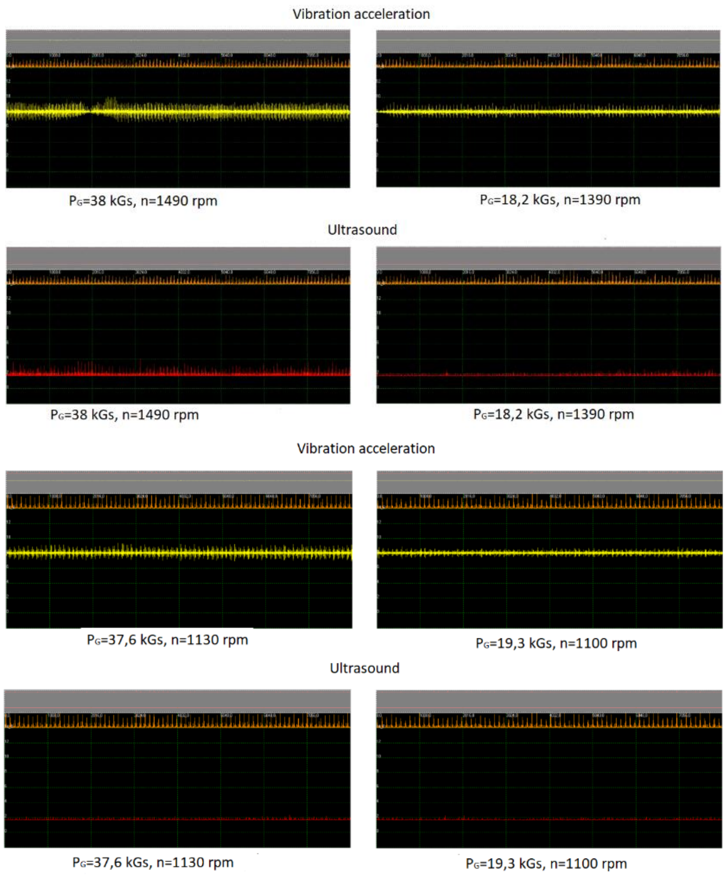

Fig. 12. Oscillograms of vibration acceleration and ultrasound of the D-240 engine on modes of partial loadings

We determine and analyze the vibration parameters of the unit and the pressure pulsations in the fuel line of high pressure diesel when using an advanced supply system with a mixer and when using different types of fuel.

5. Conclusions

From the analysis of experimental data of oscillograms of vibration acceleration and ultrasound taken for idling and partial loads of regular and upgraded engines, it can be concluded that the non-uniformity of the crankshaft speed of the upgraded engine increases at idle as the speed increases by 39% (from 13.7 to 13.7 This is due to uneven fuel supply to the cylinders, and the lower the frequency - the greater the uneven supply, and with increasing supply - its unevenness on the cylinders decreases, and with increasing speed - the frequency of alternating strokes per second increases and decreases the amplitude of vibration. The effect on the non-uniformity of inertial forces of unbalanced masses does not increase significantly with the rotational speed. The unevenness also increases as the load increases (from 6.0 to 10.1%). This is due to the increase in the average effective pressure in the engine cylinders due to the increase in the cyclic fuel supply.

References

[1] Mel′nyk, V. M., Voytsekhivs′ka, T. Y., Sumer, A. R. (2018). Doslidzhennya osnovnykh tekhniko-ekspluatatsiynykh kharakterystyk al′ternatyvnykh vydiv palyva dlya dyzel′nykh DVZ. *Mashynobuduvannya ta transport*. № 2. 1–13. [In Ukrainian].
[2] Gunko, I.V., Burlaka, S.A., Yelenych, A.P. (2018). Otsinka ekolohichnosti naftovoho palyva ta biopalyva z vykorystannyam metodolohiyi povnoho zhyttyevoho tsyklu. *Visnyk Khmel'nyts'koho natsional'noho universytetu*. 2. 6 (267). 246–249. [In Ukrainian].
[3] Eberhart, S. A., Russel, W. A. (1966). Stability parameters for comparing varieties. *Crop Sci.* 6. (1). 34–40. [in English].
[4] Okocha, A. I., Antypenko, A. M. (1996). *Palyvno-mastyl'ni ta inshi ekspluatatsiyni materialy*. K.: Urozhay. [In Ukrainian].
[5] Muzychuk, V.I., Nakhaychuk, O.V., Komakha, V.P. (2012). Vyznachennya zmistu i ob″yemu robit pry tekhnichnomu servisi. *Zb.nauk.pr. VNAU. Seriya: Tekhnichni nauky*. Vinnytsya: VNAU, 11(65). 242–247. [In Ukrainian].
[6] Muzychuk, V.I., Anisimov, V. F. (2012). *Orhanizatsiya robit pidpryyemstv tekhnichnoho obsluhovuvannya: navchal'nyy posibnyk*. Vinnytsya: FOP Rohal′s′ka I.O. [In Ukrainian].
[7] Murugesan, A., Subramanian, R., Nedunchezhian, N. (2009). *Biodiesel as an alternative fuel for diesel engines*. Renew sust energy rev. 653–662. [in English].
[8] Semenov, V. (2007). Biodyzel′ne palyvo dlya Ukrayiny. *Visnyk Natsional'noyi akademiyi nauk Ukrayiny*. 4. 18–22. [In Ukrainian].
[9] Hryhor′yev, M.A., Ponomarev, N.N., Karpenko, V. V. (1979). Metodyka otsinky resursu dvyhuna zalezhno vid resursiv yoho detaley. *Avtomobil'na promyslovist'*, 10, 4–6. [In Ukrainian].
[10] Anisimov, V. F., Yatskovs′kyy, V. I., P′yasets′kyy, A. A. Ryaboshapka, V. B. (2011). Napryamky stvorennya bahatopalyvnykh dvyhuniv na bazi dyzel′noho tsyklu. *Promyslova hidravlika i pnevmatyka*. *2(32).* 100–105. [In Ukrainian].
[11] Burlaka, S.A., Yavdyk, V.V., Yelenych, A.P. (2019). Metody doslidzhen′ ta sposoby otsinky vplyvu palyv z vidnovlyuvanykh resursiv na robotu dyzel′noho dvyhuna. *Visnyk Khmel'nyts'koho natsional'noho universytetu*, 2(271). 212–220. [In Ukrainian].
[12] Malakov, O.I., Burlaka, S.A., Mykhal′ova, Y.O. (2019). Matematychne modelyuvannya ta osnovy konstruyuvannya vibratsiynykh zmishuvachiv. *Visnyk Khmel'nyts'koho natsional'noho universytetu*. *5(277).* 30–33. [In Ukrainian].
[13] Kaletnik, H.M. (2010). *Biopalyva: efektyvnist' yikh vyrobnytstva ta spozhyvannya v APK Ukrayiny: navch. posibnyk.* K: Ahrarna nauka. [In Ukrainian].

ДІАГНОСТУВАННЯ ПАЛИВНОЇ АПАРАТУРИ ДИЗЕЛЬНОГО ДВИГУНА ШЛЯХОМ ЗНЯТТЯ ВІБРОПОКАЗНИКІВ ПАЛИВОПОДАЧІ

Сучасні автомобілі все більше оснащуються контрольно-діагностичним обладнанням. Ці методи використовуються для оптимізації робочого процесу в двигуні, поліпшення безпеки руху та спрощення експлуатації та обслуговування.

Ви можете налаштувати чіп на свій смак, налаштувати «продуктивність» двигуна, адже комфортні умови водіння доставляють нам масу задоволення. Поточний контроль технічних умов здійснюється бортовою системою самодіагностики, яка є невід'ємною частиною контролера. Проблеми, що виникають, сигналізуються візуально та зберігаються в електронній пам'яті. Повний перелік актуальних налаштувань кодів самодіагностики та параметрів робочого процесу виконується на СТО з автомобільними показниками марки. Проблема вирішується лише шляхом підключення тестера або сканера до спеціального діагностичного роз'єму, наявного в автомобілі.

Однак часто виникають скарги на об'єктивні та комплексні обстеження. Помилковий діагноз "стандартів" з явними ознаками зовнішніх проблем часто дається з багатьох причин. Перш за все, використання інформації обмежується електричними сигналами. Фактично визначається стан схеми датчиків та виконавчих механізмів автоматики двигунів. Деградація складних структур зазвичай *базується на "принципі доміно": одна локальна проблема призводить до іншої, інша - до третьої тощо, що призводить до повної відмови всього пристрою. Проблеми з електроенергією можуть бути не причиною, а наслідками інших проблем, включаючи причини неелектричного характеру. Наприклад, "дзвін" поршневих пальців може вказувати на раннє запалення та знос відповідних компонентів. Нестабільність іскрового розряду в свічці запалювання може бути наслідком декомпресії робочого об'єму балона або неправильного приготування робочої суміші. Проблема впускного колектора або забруднення паливної форсунки зазвичай розпізнається системою самодіагностики як несправність лямбда-детектора. Перелік таких неясностей можна розширити. Коли необхідно «відновити» аварію «гідного віку», фірмове діагностичне обладнання може виявитися марним.*

Ключові слова: *діагностика, двигун, віброПоказніки, пульсація, паливна апаратура, тиск*
Рис. 12. Літ. 13.

ДИАГНОСТИКА ТОПЛИВНОЙ АППАРАТУРЫ ДИЗЕЛЬНЫХ ДВИГАТЕЛЕЙ ПУТЕМ СНЯТИЯ ВИБРОПОКАЗАТЕЛЕЙ ТОПЛИВОПОДАЧИ

Современные автомобили все больше оснащаются контрольно-диагностическим оборудованием. Данные методы используются для оптимизации рабочего процесса в двигателе, улучшение безопасности движения и упрощения эксплуатации и обслуживания.

Вы можете настроить чип по собственному желанию, отрегулировать «производительность» двигателя, ведь комфортные условия вождения доставляют нам массу удовольствия. Текущий контроль технических условий осуществляется бортовой системой самодиагностики, которая является неотъемлемой частью контроллера. Проблемы, возникающие сигнализируются визуально и хранятся в электронной памяти. Полный перечень фактических настроек кодов самодиагностики и параметров рабочего процесса выполняется на СТО с автомобильными индикаторами марки. Определение проблемы происходят только, подключив тестер или сканер в специальный диагностический разъем, имеющейся в автомобиле.

Однако часто возникают жалобы на объективные и комплексные обследования. Ошибочный диагноз "стандарты" с явными признаками внешних проблем часто кажется по многим причинам. Прежде всего, использование информации – это ограниченные электрические сигналы. Фактически определяется состояние схемы датчиков и исполнительных механизмов автоматики двигателя. Деградация сложных структур обычно базируется на "принципе домино": один локальная проблема приводит к другой, другая третьей и т.д., что приводит к полному отказу всего устройства. Проблемы с электричеством могут быть не причиной, а следствием других проблем, включая причины неэлектрического характера. Например, «колокол» поршневых пальцев может свидетельствовать о раннее зажигание и износ соответствующих компонентов. Нестабильность искрового разряда в свече зажигания может быть результатом декомпрессии рабочего объема баллона или неправильного приготовления рабочей смеси. Проблема впускного коллектора или загрязнения топливной форсунки обычно распознается системой самодиагностики как неисправность лямбда-детектора. Перечень таких неясностей можно расширить. Когда необходимо "обновить" аварию "приличного возраста", фирменное диагностическое оборудование может оказаться бесполезным.

Ключевые слова*: диагностика, двигатель, вибропоказники, пульсация, топливная аппаратура, давление*
Рис. 12. Лит. 13.

INFORMATION ABOUT THE AUTHORS

Serhiy Burlaka – Doctor of Philosophy, Senior Lecturer, Department of Technological Processes and Equipment of Processing and Food Production, Vinnytsia National Agrarian University (3 Solnechnaya St., Vinnytsia, 21008, Ukraine, e-mail: ipserhiy@gmail.com https://orcid.org/0000-0002-4079-4867).
Svitlana Kravets – Assistant of the Department "Technological Processes and Equipment of Processing and Food Production" of Vinnytsia National Agrarian University (3 Sunny Street, Vinnytsia, 21008, Ukraine, e-mail: swkravec2017@gmail.com, https://orcid.org/0000-0001-8296-1929)

Бурлака Сергій Андрійович – доктор філософії, старший викладач кафедри «Технологічних процесів та обладнання переробних і харчових виробництв» Вінницького національного аграрного університету (вул. Сонячна, 3, м. Вінниця, 21008, Україна, e-mail: ipserhiy@gmail.com, https://orcid.org/0000-0002-4079-4867)
Кравець Світлана Миколаївна – асистент кафедри «Технологічних процесів та обладнання переробних і харчових виробництв» Вінницького національного аграрного університету (вул. Сонячна, 3, м. Вінниця, 21008, Україна, e-mail: swkravec2017@gmail.com, https://orcid.org/0000-0001-8296-1929)

Бурлака Сергей Андреевич – доктор философии, старший преподаватель кафедры «Технологических процессов и оборудования перерабатывающих и пищевых производств» Винницкого национального аграрного университета (ул. Солнечная, 3, г. Винница, 21008, Украина, e-mail: ipserhiy@gmail.com, https://orcid.org/0000-0002-4079-4867)
Кравець Светлана Николаевна - ассистент кафедры «Технологических процессов и оборудования перерабатывающих и пищевых производств» Винницкого национального аграрного университета (ул. Солнечная, 3, г. Винница, 21008, Украина, e-mail: swkravec2017@gmail.com, https://orcid.org/0000-0001-8296-1929)