Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. X, 2021
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ENERGY AND RESOURCE SAVING, LABOR AND ENVIRONMENTAL PROTECTION DURING RUNNING-IN AUTOMOTIVE-TRACTOR DIESEL ENGINES BY USING NEW TECHNOLOGIES AND MEANS FOR THEIR IMPLEMENTATION

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Abstract

The article is devoted to the problem energy and resource-saving, labor and environmental protection during running-in automotive-tractor diesel engines. To solve this problem, new testing technologies have been developed and implemented: separate running-in, additional running-in, hot running-in diesel engines by dynamic loading in and cold running-in by static-dynamic loading. The essence of the proposed technologies is disclosed, methods for calculating fuel consumption and the number of harmful substances in exhaust gases are presented. Technical means for the implementation of the proposed technologies are presented: automated control systems for running-in diesel engines with dynamic loading, systems for increasing gas loads and air recirculation when implementing the technology of separate running-in and device for cold running-in diesel engines by static-dynamic loading. As a result of comparative experimental studies of the proposed running-in technologies, a high quality of running-in diesel was established with a significant reduction in capital and operating costs, reduce the total energy consumption by 4 ... 5 times and reduce diesel fuel consumption by 2…3 times and emissions of harmful components in exhaust gases compared with standard running-in technologies.

***Key words**: labor and environmental protection, diesel engine, running-in, energy saving technologies, automated control systems, loading.*

INTRODUCTION

At present, enterprises engaged in the production, maintenance and repair of agricultural machinery are faced with rather high requirements for the quality of their products and compliance with legislation in the field of environmental protection.

When operating the machine and tractor fleet of the agro-industrial complex (AIC) of the country, the urgent tasks are to reduce the cost of maintaining, restoring and repairing equipment, ensuring normal working conditions for personnel and meeting the environmental safety requirements of the technologies, equipment and machines used.

Most of the mobile energy machines of the agro-industrial complex are equipped with diesel internal combustion engines (ICE), the improvement of the quality of repair of which is ensured by correctly performed running-in, which is the final operation of the technological process of production, overhaul or current repair of the internal combustion engine.

The technologies used for running in internal combustion engines are complex and laborious processes that have a number of technical, economic and environmental drawbacks, and therefore the development of new effective technologies for running in and means for their implementation is an urgent task of great national economic importance.

MATERIALS AND METHODS

Running-in diesel engines is an important component of the technological process of repair and production, which largely determines the efficiency of their operation during subsequent operation. In the process of running-in, there is a mutual running-in of movable couplings of mechanisms, correction of micro- and macro geometric deviations of their shape, an increase in the contact area of surfaces and a decrease in friction forces; faulty assemblies and parts, deficiencies in assembly and adjustment operations are identified.

Typical ICE run-in technologies are implemented using stationary electric break-in and brake stands. They provide cold running, hot running at idle speed, hot running under load at recommended conditions, as well as after running-in tests of diesel engines. A full-fledged technological run-in ensures the compliance of the main technical, economic and environmental indicators of diesel engines with the standard values during subsequent operation and a greater, up to 30%, service life of their work in comparison with non-rolled ones.

Carrying out the running-in according to standard technologies requires the presence of special sections at the enterprises for it carrying out, equipped with expensive running-in test and auxiliary equipment, is associated with a significant consumption of fuel and electricity, is accompanied by a high level of noise and vibrations, a significant emission of harmful substances with the exhaust gases of the internal combustion engine in atmosphere.

As a result of the research and development work carried out, the authors have developed and investigated a number of new technologies for running in internal combustion engines and means for their implementation, including separate running-in, additional running-in and alternative to standard ones.

The essence of separate running-in lies in the fact that after assembling the engines on conveyors or running-in sections, at the factories-manufacturers of automotive equipment and repair enterprises that carry out its overhaul, only their cold running-in is carried out with gas loads increased up to two or more times and with crankshaft cranking frequencies, shaft, up to nominal values for additional, the last stages, and hot running-in and testing is carried out after their installation on machines using the dynamic loading method (DN) and autonomous attachments, for example, at storage areas for equipment (RF patent, 2000).

To implement this method, a system for increasing the pressure of the end of air compression in the internal combustion engine cylinders has been developed, the diagram of which is shown in Figure 1. It contains a receiver 1, connected to the outlet 2 and inlet 3 of the internal combustion engine manifolds, compressor 4, pressure gauge 5, bypass flap 6, inlet flap 7, air cleaner 8, valve 9 for pressure regulation in receiver 1, line 10 for the release of excess air with oil separator 11.

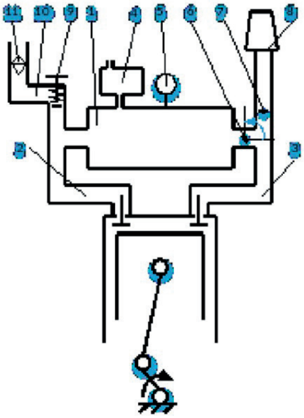

Figure 1. System for increasing the pressure of the compression end: 1 - receiver; 2, 3 - exhaust and intake manifolds, respectively; 4 - compressor; 5 - manometer; 6 and 7 - bypass and intake flaps;
8 - air cleaner; 9 - control valve; 10 - line of release of excess air, 11 - oil separator

At the first stages of cold running, typical modes are implemented, with compressor 4 off, bypass flap closed, and flap 7 and valve 9 open. At the additional, last stages, compressor 4 is turned on, the bypass damper is open, damper 7 is closed, and valve 9 maintains the pressure required for this stage in the receiver and at the inlet of the internal combustion engine, providing the design pressure of the end of air compression and the load on the parts and interface of the internal combustion engine.

Increased load-speed modes of cold running-in make it possible to ensure the necessary loading of ICE interfaces, to identify shortcomings in their production or repair, to remove the hot running-in of ICEs from the production area of enterprises, to obtain a higher degree of running-in of interfaces and, as a result to reduce the duration and number of stages of the subsequent hot run-in with LP, which leads to fuel savings and a reduction in emissions of harmful substances into the atmosphere.

Reducing the running-in wear, increasing the running-in efficiency and the absence of harmful emissions is ensured by the developed method of cold running-in with static-dynamic hydraulic impulse loading (SDP) of ICE interfaces (RF patent, 2007).

The essence of the method consists in scrolling the crankshaft of an internal combustion engine (Figure 2) through a torsion bar 1 with an ultra-low portable angular speed by a drive station 2 with a worm gear motor within one or several revolutions of the crankshaft, with closed valves 3, 4 of the gas distribution mechanism with simultaneous impulse supply to above the piston space of the break-in or engine oil by the pumping station 5.

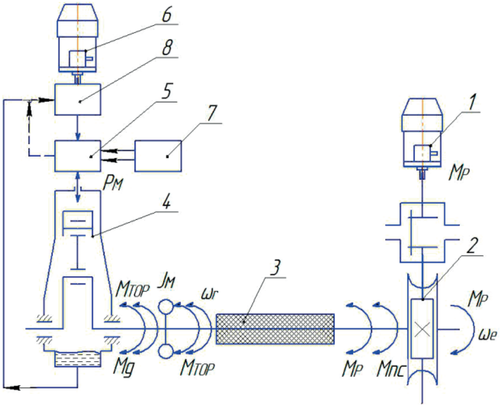

Figure 2. Functional-kinematic diagram of the device for cold running-in with SDV using the example of a single-cylinder internal combustion engine: 1 - gear motor; 2 - worm gear; 3 - torsion bar; 4 - ICE; 5 - electrohydraulic distributor; 6 - electric motor; 7 - control unit; 8 - oil pump

In the initial state, the crank mechanism of the internal combustion engine is, for example, at the top dead center, the torsion bar 3 is untwisted (MTOP = 0).

When the drive station is turned on, the crankshaft starts scrolling through the torsion bar 3 with a frequency of 0.1 ... 0.3 min^{-1}, while the torsion bar is spinning due to the moment of mechanical losses of the MMP ICE by a certain angle.

When the pumping station is turned on, part of the oil from the crankcase of the internal combustion engine through the pressure regulator is supplied to the main oil line of the internal combustion engine to lubricate the interfaces (P = 0.3 MPa). Another part of the oil is supplied at a pressure of more than 4 MPa to the electrohydro-distributor 5.

When the control unit 7 is turned on the electrohydraulic distributor 5 will begin to receive control pulses for the solenoid valves. When an impulse arrives at the supply solenoid valve, it will open into the over-piston space of the internal combustion engine cylinder, through which the fitting installed instead of the internal combustion engine nozzle will begin to flow oil, exerting pressure rm. on the piston.

It will begin to move downward, overcoming the resistance of the friction forces in the mates and the inertial forces of the parts associated with it, as well as the torsion moment of the torsion 3. As a result of the rapid increase in pressure, a forceful shock effect on the running-in mates occurs, which ensures the hardening of their surfaces, a rotation by a certain angle crankshaft and additional torsion. At this stroke of the pressure surge, the state of the system is described dynamics equation of the form:

$$M_i - M_{\text{ТОР}} - M_{\text{МП}} = J \cdot \varepsilon \qquad (1)$$

where: M_i, $M_{\text{ТОР}}$, $M_{\text{МП}}$ - moments from the force of oil pressure, torsion bar and friction in the mates, respectively; - angular acceleration of the crankshaft; Im - the moment of inertia of the moving parts of the system reduced to the crankshaft of the internal combustion engine.

On the pressure relief stroke, the drain solenoid valve opens and, due to the moment of the torsion bar spinning, the crankshaft turns in the opposite direction, while the piston pushes part of the oil into the drain line. Consecutive strokes of pressure rise and release in the above-piston space of the internal combustion engine form an SDP cycle.

Carrying out VOS cycles with the required value of the load, determined by the oil pressure, with a high (more than 10 Hz) frequency, within the estimated time, ensures the efficiency of the running-in process and the possibility of a significant reduction in the duration of the subsequent hot running-in under load. The total energy consumption with this technology is significantly less than with a typical cold run-in.

The essence of hot running-in of an internal combustion engine with dynamic loading lies in their operation in cyclic non-braking modes of increase (acceleration) and decrease (run-out) of the angular velocity of the crankshaft (USKV) ω (Figure 3) in a certain interval from ω1 to ω2 with a gradual, as running-in, an increase in the angular acceleration of acceleration εp, which is achieved by controlling the fuel supply according to a certain law, which ensures that the fuel supply is switched on at the acceleration stroke t1, with the possibility of setting its value for each stage of the run-in and turning off the fuel supply at the coasting stroke t2.

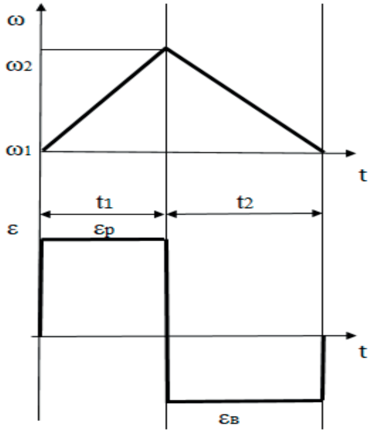

Figure 3. Dynamic loading cycle:
t1 and t2 are the acceleration and coasting cycle times; ω1 and ω2 - initial and final angular velocity of the crankshaft; εp and εв - acceleration of acceleration and run-out

The amount of fuel supply during acceleration determines the amount of torque MK developed by the internal combustion engine, and equal to it in magnitude, counteracting the load dynamic moment of the MND:

$$MK = MND = \varepsilon p \; ID, \qquad (2)$$

where ID is the moment of inertia of moving parts reduced to the crankshaft of the internal combustion engine (the average value of ID = const for the kinematic cycle of the operation of the crank mechanism of the internal combustion engine).

According to equation 2, the dynamic load on the engine during running-in can be controlled by the amount of acceleration εr, determined, for example, by electronic differentiation of the USSKV signal in time, that is:

$$\varepsilon p = d\omega/dt \qquad (3)$$

The amount of acceleration during run-in is determined by the current value of the moment of mechanical losses of the internal combustion engine Mmp, and reflects break-in rate of mates

$$\varepsilon w = Mmp/Id \qquad (4)$$

The complex of sequential acceleration and run-out cycles form a dynamic loading cycle (DCS) of the internal combustion engine interfaces.

Multiple repetition of the CPM in a given interval of change in the USCV from ω1 to ω2 with the required values of the load dynamic moment at the stages of running in under load and during the required time of the stages, ensures the running-in of the internal combustion engine interfaces and is the essence of the considered method of running in with the DN.

The control of the central pressure pump is reduced to a cyclic effect on the fuel supply controls with the control of the magnitude of the dynamic load by the magnitude of the angular acceleration of acceleration. The limited range of changes in the USCV and the rapidity of the dynamic loading processes necessitate the automation of control and monitoring processes.

In the process of research, a number of automated control systems for running-in (ACS) and testing of diesel engines with DP have been developed, which implement various ways of controlling the central pressure pump with the impact on the lever of the speed regulator (RFV) or the rail of the high-pressure fuel pump (USSR patent, 1987). Figure 4 shows one of the variants of the automated control system for running-in diesel engines with dynamic loading. It includes an electric machine actuator mechanism 1, acting on the diesel speed control lever, control and monitoring unit 2, power supply unit 3, as well as a crankshaft speed sensor (Figure 4).

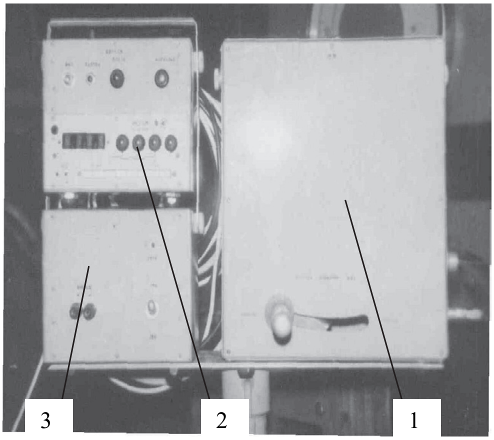

Figure 4. General view of the automated control system for running-in diesel engines with dynamic loading:
1 - actuator; 2 - control unit; 3 - power supply

The small dimensions and weight of the ACS elements make it possible to effectively run in and test the internal combustion engines installed on the machines with minimal cost and labor intensity. In addition, ACS can be a good addition to stationary run-in stands, in terms of expanding the range of speeds and power of run-in internal combustion engines and implement an alternative standard run-in technology with hot run-in under load and dynamic loading tests.

A significant difference between the running-in method with DN from the brake one is that the mechanical energy generated by the internal combustion engine during the non-brake acceleration stroke is spent on the implementation of running-in and necessary accompanying processes, and is also stored in the form of the kinetic energy of the system. At the run-out stroke, the kinetic energy is also spent on running-in processes, which in total determines the high value of the energy efficiency factor Ke of the DN mode and the running-in method with its use.

This coefficient is equal to the ratio of the energy spent on the implementation of the running-in APR and the necessary accompanying APW processes to the total mechanical energy (indicator work) Ai generated in the ICE cylinders, that is:

$$\text{æ}_{\acute{y}} = \frac{\grave{A}_{\eth} + \grave{A}}{\grave{A}_i} = \frac{A_i}{A_i} @ 1. \tag{5}$$

Analysis of expression 5 shows that the value of the energy efficiency coefficient of this method is close to 1. When implementing typical technologies of brake running-in, the value of Ke does not exceed 0.3 ... 0.4, since 60 ... 70% of the mechanical energy generated by the internal combustion engine is absorbed by the brake.

During running-in with DN, almost all energy is spent on running-in and accompanying processes, while providing the potential for saving up to 60 ... 70% of fuel compared to brake running.

Operational running-in of an internal combustion engine as part of machines with limited load-speed modes of their operation is important for the final running-in of interfaces and is recommended for both new and repaired internal combustion engines. Its implementation in the initial period of machine operation is subject to the negative influence of both production and subjective factors. The additional running-in of the internal combustion engine, carried out in stationary conditions before the start of operation, makes it possible to carry out the program of operational running-in in accordance with the optimal conditions and to ensure the possibility of subsequent operation of the machines with full load.

Reducing fuel consumption during running-in and testing of internal combustion engines with dynamic loading provides a corresponding reduction in harmful emissions into the atmosphere (Höniga, 2014).

In accordance with GOST R 56163-2014, emissions of harmful substances into the atmosphere were determined during the running-in of 100 D-240 diesel engines, presented in Table 1, which decreases when implementing an alternative typical and separate running-in 2.2 and 2.5 times, respectively, in comparison with typical running-in.

Table 1. Emission of harmful substances into the atmosphere

Gross emission of substances, kg	Typical running in	Alternative run-in with DN	Separate Running in
CO	48.60	21.50	19.44
NO2	55.35	24.49	22.14
CH	25.38	11.23	10.15
C	5.06	2.24	2.03
SO2	6.21	2.75	2.48
CH2O	0.95	0.42	0.38

RESULTS AND DISCUSSIONS

As a result of the research of the automated control system for the implementation of the developed technologies of tractor diesel engines D-240, D-65N, D-245, D-160, D-144, it was found that they allow realizing the established regularities of control actions and the required load-speed modes of running in with the DN, while the range of smooth adjustment of the load dynamic moment is from 10 to 100% of its nominal value in the operating range of the crankshaft rotation frequency. comparative studies of the technical and economic indicators of the internal combustion engine and the quality indicators of the running-in interfaces show their identity, while the total area of the running-in surfaces of the first compression piston rings during running-in with DN is 5 ... 15% more than with brake, and the total fuel consumption for the period run-in is reduced by 2.2 ... 2.3 times, depending on the model of the run-in engine.

Comparative studies of typical and separate running-in of the D-240 diesel engine showed approximately the same results, both in terms of running-in quality indicators and in terms of its output diesel indicators. It was found that the total area of the running-in cylindrical surfaces of the first compression rings after typical running-in reached 31.. 38%, with separate running-in 35...50%, and the second and third 12...20% and 15...29% respectively. Reducing the number and time of hot running-in stages with separate running-in reduced fuel consumption by 2.5-2.6 times compared to the standard one.

Comparative studies of a typical cold run-in and cold run-in from a D-144 tractor diesel engine with SDV showed that the area of the running-in surfaces of the crankshaft liners during running-in with SDV is 2 ... 5 times larger, and the power consumption is 4 ... 5 times less than with a typical one, in this case, the scrolling moment and the total length of the gaps between the piston rings and the cylinder liner also have smaller values.

CONCLUSIONS

As a result of the theoretical and experimental studies of the developed technologies and means of running-in, a high quality of running-in of ICE interfaces was established, with a significant reduction in capital costs for the acquisition and placement of equipment, the labor intensity of the process, fuel consumption, electricity and emissions of harmful components in exhaust gases compared to standard run-in technologies.

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