Results of experimental studies of cold running-in of a diesel engine D-240 with increased load-rate modes

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Abstract. Currently used diesel engine running-in methods are based mainly on typical technologies with the use of serial running-in and braking stands, which have limited speed and capacity for cold and hot running-in at idle and under load of all types of modern diesel engines, available in agricultural enterprises. In addition, typical running-in technologies have a number of technological, economic and environmental drawbacks. Taking into account high cost of up-to-date running-in equipment and low level of equipment of enterprises with serial running-in equipment, including those with long service life, the modernization of existing equipment is the urgent task, as well as the development of new technologies and means for their realization. The technology of cold running-in of diesels with increased load-rate modes using modernized running-in-brake stands and the developed system for increasing gas loads is proposed. The results of experimental studies show the possibility of creating higher load-rate modes during cold running-in of diesels and allow improving the typical technologies of running-in of diesels and means for their implementation.

1. Introduction

Most dealership centers for servicing and repair of domestic and foreign machinery, repair companies, service centres and workshops of agricultural enterprises and agricultural holdings engaged in current and overhaul repair of diesel tractors, combines and self-propelled machines do not have enough special equipment for running-in and testing of diesel engines, which is the final stage of the technological process of repair. At the same time running-in and braking stands such as KI-5540, KI-5543 and others based on electric machines with phasing rotors available at enterprises have limited capacity for cold and hot running-in under load [1,2,3,4], in this connection it is necessary to use several standard sizes of running-in and braking stands to run-in small, medium and large diesel engines and have several permanent running-in stations in repair shops equipped with fuel, air, ventilation, exhaust gas removal and cleaning systems, as well as powerful electric equipment. In view of high energy prices and the tightening of environmental legislation, most workshops are forced to overhaul diesel engines without a full running-in phase, thus reducing their remaining life after overhauls and servicing.

In this connection, an urgent task is to develop measures for modernization of existing equipment, as well as to develop resource-saving methods of technological running-in of diesel engines of any capacity and technical means for their implementation, which largely eliminate the drawbacks of typical running-in technologies of technological, economic and ecological nature.
2. Methods and Materials

An analysis of load-rate modes of cold running-in, hot running-in at idle and under load of diesel engines of domestic and foreign production shows that the most important are stages of cold running-in and hot running-in under load, the quality of running-in of friction surfaces, reduction of running-in wear and engine life during its operation depend on duration and load-rate modes [5,6,7].

Many researchers single out idle running-in stage as ineffective from the point of view of running-in quality, but necessary for warm-up of the running-in engine, check of fuel supply, lubrication and cooling systems and its preparation for the hot running-in stage under loading [1,2], which can be conducted either using stationary running-in and braking stands, provided a necessary capacity, or with the use of automated control systems that implement technologies of hot running-in with dynamic loading of diesels of any power.

The study of technologies of running-in, dynamics of change of running-in wear and intensity of running-in of engine pairs, temperatures of coolant and oil, power of mechanical losses, features of gas exchange and thermodynamic processes occurring in the cylinders of engines on stages of cold running-in and hot running-in under load shows [1,2,5], that the majority of repair enterprises and the manufacturers conduct cold running-in of diesel engines with maximum rotational speed of 1400-1450 min⁻¹, depending on the capabilities of the asynchronous AC motors used in running-in brake stands. At the same time, during cold running-in the load modes are also limited by gas loads on parts and junctions of diesels, depending on the air pressure in the end of compression in the diesel engine cylinders, which does not exceed, as a rule, 3...4 MPa, that does not allow to provide the necessary loading of diesel engine junctions, to reveal defects of production or repair and obtain the required quality of running-in.

As a result of the analysis of the running-in existing technologies, a technology of separate rolling was developed in Penza State Agrarian University. During its implementation at the factories-manufacturers of automotive equipment and repair enterprises that carry out overhaul and current repairs, after assembling diesel engines on conveyors or in the running-in sections, only their cold running-in with increased load-speed modes is carried out at additional, last, cold running-in stages, by increasing the crankshaft rotation frequencies up to nominal values and gas loads in the engine cylinders, identical to the gas loads at the hot running-in stages under load, while hot running-in at idle, under load and testing of repaired diesel engines is carried out after their installation on machines using the dynamic loading method.

The essence of cold running-in with increased load-rate modes consists in the fact that on its last stages the speed modes and maximum pressure in cylinders are provided, corresponding to the hot running-in of diesels of the given brand under load. In order to obtain the required speed ratings both commercially available and upgraded, test benches are used, as well as various stationary and autonomous drive stations. To obtain the required gas loads on the details of the crank mechanism and piston-cylinder group the air compression pressure in the cylinders is increased by increasing the pressure at the inlet, by air recirculation from the exhaust to the diesel inlet, with the supply of additional air into the recirculation loop from an external compressor or a pneumatic system. Air recirculation reduces the required compressor capacity which is mainly spent on compensating for air leaks through diesel piston rings and increases the air temperature.

In order to implement the method of cold running-in with increased load-rate modes, the existing running-in and braking stands must be equipped with step-up gears to enable cranking of engine crankshafts with speeds up to 2800-2900 min⁻¹, and the system for increasing gas loads in diesel cylinders at additional stages of cold running-in.

The experimental set for investigation of cold running-in regimes of the diesel engine D-240 includes a modernized running-in-brake stand KI-5543, a device for increasing gas loads and a measuring-recording complex.

Figure 1 shows the system of air compression end pressure increase in the cylinders of the diesel engine D-240. The system includes a receiver 1, connected to the air supply line under overpressure from an external source (compressor), which is connected to the exhaust 2 and intake 3 manifolds of...
the engine, a pressure gauge 4 to control pressure in the receiver, an inlet flap 5 and a bypass flap 6, as well as a valve 7 to control pressure in the receiver 1. The bypass flap 6 controls air flow from the exhaust manifold 2, through the receiver 1, into the intake manifold 3, and the inlet flap 5 closes the air outlet from the receiver into the air cleaner, when additional cold running-in stages are implemented.

![Figure 1. System for increasing the compression end pressure: 1 - receiver; 2, 3 - exhaust and intake manifolds, accordingly; 4 - pressure gauge; 5 and 6 - inlet and bypass flaps; 7 - control valve.](image)

During cold running-in with increased load modes at the first stages of the cold running-in typical modes are implemented with the rotation speed of up to 1450 min⁻¹ and compression end pressures of up to 3...4 MPa, with the inlet flap 5 open, the bypass flap 6 closed, and the control valve 7 set to zero operating pressure. On additional, final stages of the cold running-in the inlet flap 5 is closed, an excessed air pressure in the receiver 1 is supplied from the compressor, the control valve 7 is set to the required for this stage of running-in pressure in the receiver (up to 0.2 MPa), and respectively in the engine inlet manifold, which is controlled by the pressure gauge 4. Then running-in is conducted either at the maximum speed provided by the commercial stand (1300-1450 min⁻¹), or at the speed of the stages of hot running-in under load (2200...2300 min⁻¹), provided by the modernized (with the step-up gear) stand.

3. Results

Experimental studies of cold running-in regimes of diesel engine D-240 to determine the effect of crankshaft RPM, pressure in the receiver and the angle of bypass damper rotation on the value of compression end pressure and mechanical loss moment, were conducted using methods of planning experiments [8].While carrying out a three-factor experiment the factors were varied at three levels: diesel engine crankshaft rotation frequency \( n = 600; 950; 1300 \) \( \text{min}^{-1} \), the receiver pressure \( P_r = 0.1; 0.14; 0.18 \) MPa; degree of recirculation - the angle of the by-pass flap rotation = 30; 50; 70 deg. The compression end pressure \( P_c \) and the mechanical loss moment \( M_{ml} \) were taken as response functions.

To process the experimental data, Microsoft Excel, Statistika and Mathcad programs were used, with the help of which Fisher's F-criterion was calculated and regression coefficients were calculated to check the adequacy of the obtained model.

Based on the results of processing experimental data using the application program STATISTIKA, response functions (Figure 2) and regression equations were obtained in decoded form:

\[
P_c = -0.775 + 0.000433n + 54.01307 P_r - 0.01799 \beta - 0.000000038n^2 - 72.1922P_r^2 - 0.000026\beta^2 - 0.00202n P_r + 0.000012n\beta + 0.0322690P_r\beta; \quad (1)
\]

\[
M_{ml} = 21.59703 + 0.00213n + 385.3436 P_r - 0.33884\beta + 0.000006n^2 - 949.96752 P_r^2 + 0.00270\beta^2 + 0.01186n P_r - 0.000001n\beta + 0.51122 P_r \beta. \quad (2)
\]
The results of calculations according to the equations 1 and 2 for RPM show, that with increase of pressure in the receiver from 0.1 MPa to 0.18 MPa at constant values of crankshaft rotational speed, equal to 950 min\(^{-1}\), and the angle of throttle, equal to 50 deg, the engine compression pressure \(P_c\) increases from 4.0 MPa to 6.6 MPa (by 65.2 %), and the moment of mechanical losses \(M_{ml}\) increases from 51.5 N·m to 64.0 N·m (by 24.3 %).

With increase in crankshaft rotational speed from 600 min\(^{-1}\) up to 1300 min\(^{-1}\) at constant pressure in the receiver, equal to 0.14 MPa, and the turn angle of the bypass valve, equal to 50 deg, the engine compression pressure increases from 5.1 MPa up to 5.8 MPa (by 13.8 %), and the moment of mechanical losses increases from 64.7 N·m up to 65.3 N·m (by 0.9 %).

The analysis of two-dimensional cross-sections of response surfaces (Figure 2) shows that they have no centre of experiment and illustrate correlation of factors of the investigated process. Thus, for example, at \(\beta=500\) and \(n=600\) min\(^{-1}\), with an increase of pressure in the receiver from 0.10 to 0.17 MPa, the compression end pressure increases from 3.6 to 6.1 MPa, and the moment of mechanical losses increases from 47.6 to 58.2 N·m. The received mathematical models adequately describe changes of compression end pressure and the moment of mechanical losses depending on running-in speed conditions and parameters of control actions - an angle of a turn of the bypass flap and adjustment of the control valve (defining pressure in the receiver).

The obtained results of the research allowed to substantiate the methodology of calculation of increased load-rate modes of cold running-in of internal combustion engines and develop the technology of its implementation.

![Figure 2](image-url)  
**Figure 2.** Two-dimensional cross sections of the response surface: a) compression pressure; b) moment of mechanical losses (at \(\beta=50^0\)).

The results of comparative experimental studies of the typical and separate running-in of diesel engine D-240 show the identity of technical and economic parameters and indicators characterizing the quality of running-in of interfaces, with the total area of running-in surfaces of the first compression piston rings after the running-in period reaches 31...38%, and with a separate running-in - 35...50%, and the second and third, respectively - 12...20% and 15...27% of the total surface. The analysis of running-in surface roughness showed that the value of arithmetic mean profile deviation (Ra) of crank pin liners after cold and hot running-in has somewhat better results with separate running-in (0.36-0.38 \(\mu\)m and 0.26-0.28 \(\mu\)m) compared with the typical running-in (0.40-0.43 \(\mu\)m and 0.30-0.39 \(\mu\)m). Total fuel consumption during separate running-in was 5.1 kg, which was 2.6 times (61%) less than during type running-in, which was 13.5 kg.

4. Conclusion

The results of the conducted experimental studies show the principal possibility of creating, regulating and controlling increased load-rate modes during cold running-in of diesel engines, potential
possibility of improving the quality of running-in processes, as well as implementation of new energy-saving technology of separate running-in using the developed tools for their implementation.

The comparative studies of typical and separate running-in of diesel engine D-240 indicate the identity of technical and economic indicators, characterizing the quality of running-in of couplings. At the same time, additional cold running-in stages with rotation speed up to nominal and loads identical to those of hot running-in will reduce the number of hot running-in stages under load or even take them out of the running-in process, reduce fuel consumption for the running-in process and, consequently, reduce harmful emissions into the atmosphere, thus significantly improving the environmental situation at stationary sections of the running-in diesel engines.

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