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Increasing Life Of Plunger Pairs Of Diesel Engines.

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ABSTRACT

Performing technological operations, diesel technology operates up to 90% of the total time in non-steady-state conditions. Vibrational loads lead to a change in the performance of fuel equipment. Failure of fuel equipment leads to an increase in fuel consumption and toxicity of exhaust gases. The main cause of failure of fuel equipment is the wear of the plunger pairs. If the condition of the plunger pairs is unsatisfactory, the unevenness of the fuel supply through the sections reaches up to 63%. Uneven fuel flow through the engine cylinders above 10% leads to an increase in the total fuel consumption. The efficiency of the fuel pump is provided by cyclic feeding of the plunger pairs. In turn, a significant effect on the cyclic fuel supply is the gap between the plunger and the bushing. The size of the gap in the plunger pair is estimated by hydraulic density and provides for their division into density groups. When examining the hydraulic density of the produced plunger pairs, it was found that 86% had an increased gap. The application of a thin film coating to the working surfaces of the plunger pairs has made it possible to reduce the existing gap. The bench studies of cyclic feeding of produced and experimental plunger pairs were carried out. As a result of the study, it was found that at a camshaft rotation speed in the range of 200 - 1000 min-1, the reduction in the delivery of the produced plunger pairs reached up to 53%, with uneven feeding in sections up to 36%. In the experimental plunger pairs, the fuel supply decreased to 37%, and the fuel unevenness did not exceed 5%. A model is obtained for the formation of the gradual rejection of produced and experimental plunger pairs. The wear resistance of precision parts having thin-film coating is 2.25 - 2.4 times larger.

Keywords: resource, working surfaces, wear resistance.

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INTRODUCTION

The increase in the efficiency of the operation of diesel equipment is primarily due not only to the increase in the reliability of its main units, aggregates, joints, and parts but also to a reduction in costs and fuel consumption in the performance of production processes. Reducing the cost of fuel can be provided in many ways, including various types of repair and recovery methods. The developed method for the restoration of precision parts [3], provides an increase in life and a decrease in fuel consumption during the operation of the plunger pairs of the high-pressure fuel pump (HP pump). But this method of increasing the longevity of precision parts is advisable to apply during the repair of fuel equipment.

At the same time, operational experience shows that a significant proportion of the operating time of the equipment is not fully loaded, often up to 40 ... 50% [4]. The resulting transient and unsteady regimes, as well as the design features of the fuel equipment of domestic-produced diesel equipment, lead to over-consumption of fuel and a significant increase in the unevenness of fuel delivery along engine cylinders to 26 ... 38% [5, 6]. Along with this, the intensity of wear of the main components of fuel equipment, especially precision ones, also increases. Therefore, studies aimed at improving the physicomechanical and tribological properties of surface layers of precision parts of fuel equipment that provide an increase in the efficiency of diesel technology are of practical interest and are relevant.

RESULTS AND DISCUSSION

Incomplete loading of engines and intermediate operating modes, which differ from the nominal, lead to a decrease in the speed of the plunger of the fuel pump of high pressure and increase the intensity of fuel flow into the annular gap.

The structural size of the gap in the plunger pair is estimated by the hydraulic density and provides for their division into density groups. The analysis of the technical state of the plunger pairs, supplied as spare parts by the hydrodensity indicator, showed that there is a sufficient reserve for improving the efficiency of diesel fuel equipment.

Studies of hydraulic density were carried out on produced, coming in as spare parts, and experimental plunger pairs. Experimental details were processed at the UVPU-111 installation of the laboratory of the educational research and production center "Restoration and hardening of machine parts" of the Technical Service, Standardization and Metrology Department of the Stavropol State Agrarian University. The results of the analysis are presented in Table 1 and Table 2.

Table 1: Values of the differential and integral functions of the produced plunger pairs

t	40,1…41,5	41,5…42,9	42,9…44,3	44,3…45,7	45,7…47,1	47,1…48,5	48,5…49,9
m_i	11	15	10	7	2	3	2
P_i	0,22	0,30	0,20	0,14	0,04	0,06	0,04
$\sum P_i$	0,22	0,52	0,72	0,86	0,9	0,96	1
$f(t)$	0,25	0,28	0,21	0,13	0,07	0,03	0,02
$F(t)$	0,23	0,52	0,73	0,86	0,93	0,96	0,99

Table 2: Values of the differential and integral functions of experimental plunger pairs

t	45,8…46,5	46,5…47,2	47,2…47,9	47,9…48,6	48,6…49,3	49,6…50,0
m_i	10	16	11	7	3	1
P_i	0,2	0,32	0,22	0,14	0,06	0,02
$\sum P_i$	0,2	0,52	0,74	0,88	0,94	0,96
$f(t)$	0,23	0,3	0,24	0,14	0,06	0,03
$F(t)$	0,21	0,5	0,74	0,88	0,94	0,98

It can be seen of Figure 1 that 86% of the investigated plunger pairs produced have a hydraulic density not exceeding t = 45.7 s, with an average value of 43.4 s and an average quadratic deviation σ = 2.29 s.

This distribution of parts indicates the possibility of increasing the resource and ensuring the stability of fuel supply in all operating modes due to an increase in the hydraulic density of the plunger pairs and the shift of the distribution center to the upper limit in the group.

After deposition of the thin film coating on the working surfaces of the new plunger pairs, the distribution of the hydraulic density has changed so that 82% of the experimental plunger pairs (Figure 1) have a hydraulic density greater than t = 45.7 s with an average value t = 46.7c with an average quadratic deviation σ = 1.05 s.

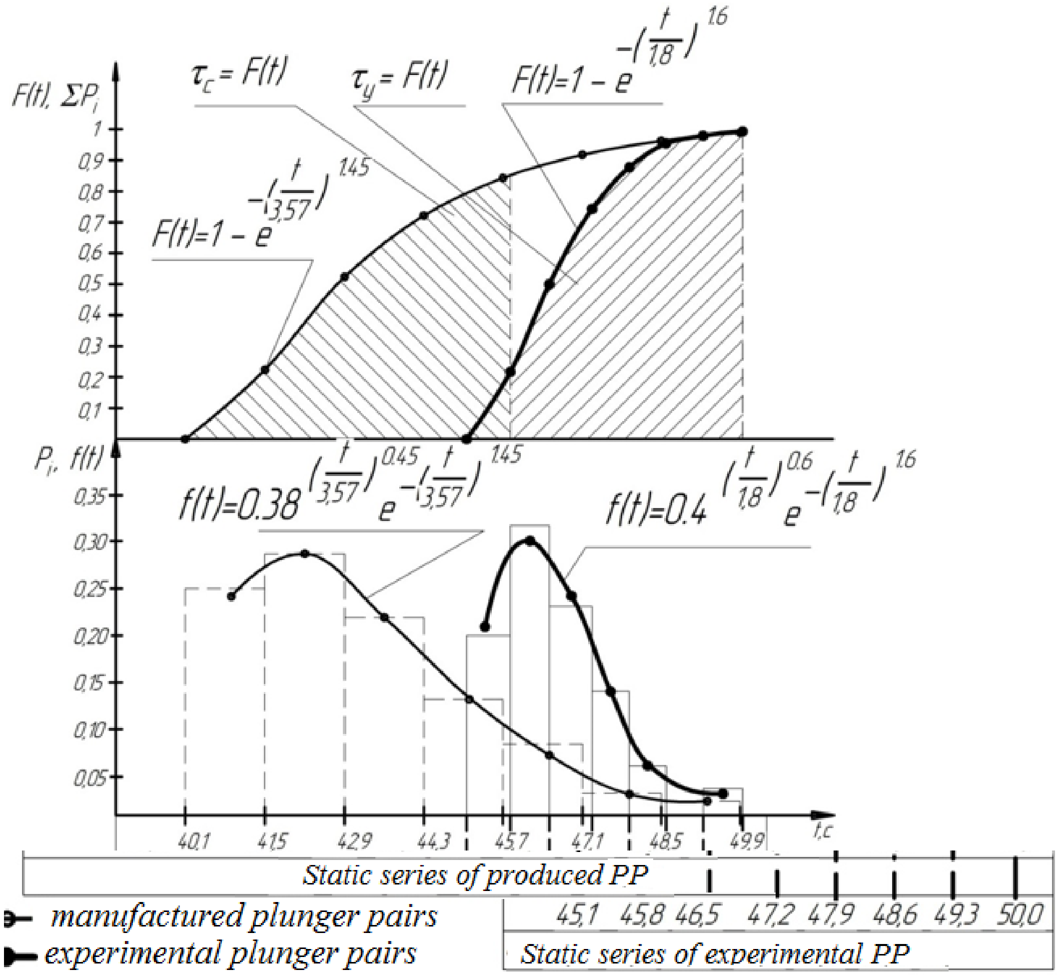

Figure 1: Experimental and theoretical distribution of the hydraulic density of produced and experimental plunger pairs

Analysis of the distribution of the hydraulic density of produced and experimental plunger pairs shows that all plunger pairs having a thin film coating have a hydraulic density greater than t = 45.1 s. Only 18% of the experimental plunger pairs have a hydrodensity less than t = 45.7 s, while 86% of the new pairs have this value up to this value. The data obtained during the experiment indicate an increased gap between the plunger and the bush for new parts coming in as spare parts. After the formation of a thin film coating on the working surfaces of the new plunger pairs, an increase in the hydraulic density is observed, which indicates a decrease in the initial clearance in the plunger pairs.

When carrying out comparative studies of the cyclic delivery of produced and experimental plunger pairs, depending on the speed of the camshaft of the fuel pump and the position of the rail, it was established that at a camshaft speed in the range 200 ... 1000 min-1 at L = 0 mm, which corresponds to the maximum fuel delivery was 115 ... 145 ml or 26.1%, with L = 2 mm, L = 4 mm and L = 6 mm, the decrease in the cyclic feed rate was 57.1%, 54.5% and 53%, respectively. And with the position of the rail L = 6 mm in the range of the rotation speed of the camshaft 200 ... 300 min-1, no fuel was supplied. Studies of cyclic feeding of experimental plunger pairs at different positions of the rail showed that when the position of the rail was L = 0 mm there was no decrease in fuel supply, at L = 2 mm, L = 4 mm and L = 6 mm, the reduction in the cyclic feed rate was 35.2% 37.7% and 26.1% respectively.

The results of the fuel unevenness test showed that the uneven fuel supply of the produced plunger pairs, with the speed of rotation of the camshaft in the range 200 ... 1000 min-1 and the position of the rail L = 0, L = 2 mm, L = 4 mm and L = 6 mm, is 25 ... 36%, while the experimental ones do not exceed 5%. Comparative tests of plunger pairs of a high-pressure fuel pump 4UTNM were carried out at the stand SDM 12-01. The conducted investigations made it possible to establish the dependence of the cyclic feed rate on the operating time and the rotational speed of the camshaft:

$Q_{cepp} = 0{,}18 \cdot n - 0{,}0011 \cdot t - 9{,}05 \cdot 10^{-5} \cdot n^2 - 20{,}6$
$q_{cspp} = 0{,}23 \cdot n - 0{,}0006 \cdot t - 0{,}0001 \cdot n^2 - 44{,}9$
q_{cepp} and q_{cspp} – cyclic feeding of experimental and serial plunger pairs, ml;
t – working hours of plunger pairs, moto-h;
n – rotational speed of the cam shaft of the fuel pump, min^{-1}.

The results obtained during the tests showed that at the nominal speed of the camshaft the cyclic delivery of the produced plunger pairs decreased by 2.8%, while in the experimental ones the reduction in fuel supply was 1.3%, the unevenness of the fuel supply in both cases did not exceed 2%.

With a decrease in the rotational speed of the injection pump camshaft to 800 min^{-1}, the reduction in the cyclic feed of the experimental and factory plunger pairs was 1.8% and 5.5%, and the unevenness of the fuel supply in the sections increased to 2.3% and 6.7%, respectively.

At a camshaft speed of up to 500 min^{-1}, the reduction in the cyclic feed of the experimental plunger pairs was 4.9%, with unevenness in the sections of 2.8%, and in the factory 9.3% and 24.6%, respectively.

During the experiment, it was found that for serial and experimental plunger pairs, the wear rate is maximum at the maximum pressure in the contact zone and the maximum relative displacement speed, so the calculation of the resource was made with respect to these data. Based on the obtained calculations, a model for the formation of a gradual failure (Fig. 2) of serial and experimental plunger pairs was obtained.

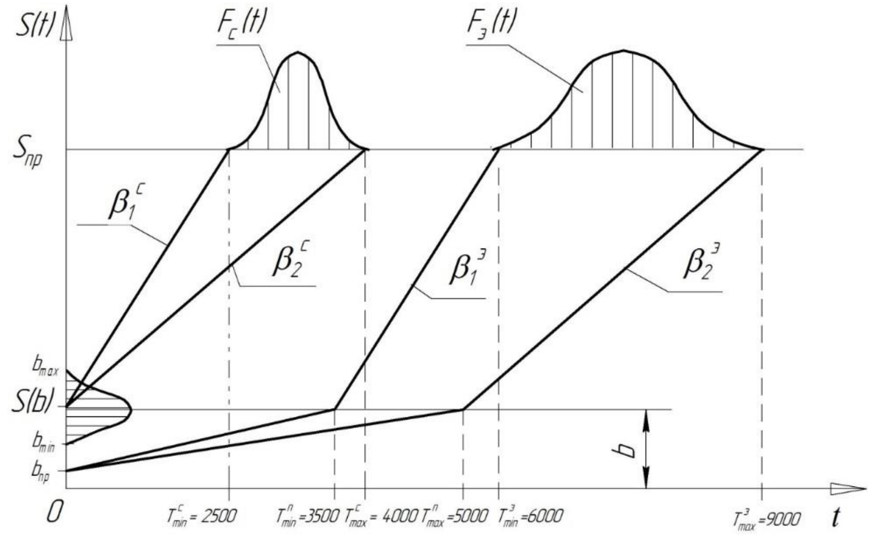

Figure 2: Model to formation the gradual failure of serial and experimental plunger pairs

At the maximum values of the pressure in the contact zone and the speed of relative displacement, the wear process of the working surfaces of the serial and experimental plunger pairs will occur at a rate of β_1^c = 9 µm and β_1^e = 0.85 µm per 1000 h, respectively. With this wear rate, the predicted resource of serial plunger pairs is T_{min}^c = 2500h, which is 2.4 times less than the experimental resource. With the minimum values of pressure in the contact zone and the speed of relative displacement, the wear rate of the working surfaces of the serial and experimental plunger pairs is β_2^c = 5.5 µm and β_2^e = 0.57 µm per 1000 h, respectively. With such indicators, the resource of the experimental plunger pairs will be T_{max}^e = 9000h, which is 2.25 times the service life of the serial plunger pairs.

CONCLUSION

Thus, the formation of thin-film wear-resistant coatings on the working surfaces of the plunger pairs provides not only an increase in the resource of 2.25 to 2.4 times but also an increase in the efficiency of diesel energy facilities in the MTA due to a decrease in fuel consumption by 15 ... 17%.

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