Plasma technology for increase of operating high pressure fuel pump diesel engines

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Abstract. This paper presents the results of a change in the service life of high pressure fuel pumps of diesel engines on the working surface of the plunger which a wear resistant dielectric plasma coatings based on silicon oxycarbonitride. Such coatings possess high wear resistance, chemical inertness and low friction.

1. Introduction.
In [1] it was proved that reliability and durability of the high pressure fuel pumps (pump) diesel engines, primarily depends on the resources of their plunger. Unfortunately, the quality of domestic manufacturing plunger such that their share is less than 3 thousand operating hours, while that of foreign analogues it reaches 12 thousand or more. As was shown in [2], the resource is determined to develop the plunger of the pressure and wear of mating parts. Developing a pair of plunger pressure is directly dependent on the clearance between the sleeve and the plunger. The smaller the gap, the higher the pressure developed by plunger pair, therefore the greater share of work. Backlash in domestic plunger pairs is about 1.5 - 2.0 microns, and a foreign - one micron or less. In addition, the wear resistance of domestic plunger is 1.5 - 2.0 times lower than the wear resistance of the foreign. Studies have shown [2 - 4] that the achievement of a resource foreign counterparts plunger able to produce sputter of titanium nitride on the working surface of the plunger.

2. Materials and methods of research.
This article examines the possibility of creating another type of coating on the working surface of the plunger via plasma technology [5-13]. The coating produced in the plasma unit UFPU-111, the development of Scientific and Production Company "Plasmatsentr". It provides a coating based on silicon oxycarbonitride [14]. These coatings are a class of diamond-like and have high abrasion resistance, chemical inertness and low friction. According to these parameters, they are slightly higher than the coating of titanium nitride [14, p. 376]. In addition, non-vacuum plasma thin-film coatings are dielectric. This eliminates the chance of setting precision of mobile connections at the point overheating the workpiece surface.

For the experiments were chosen 4 new models of pump plunger pairs 33-02 Engine KAMAZ 5320. As well pump elements can be restored. The parameter for measuring chosen gidro density plunger. Meters on the device CP-1640A. Increase the pressure on the plunger end depends on the weight of the cargo and its location on the lever device. In our case, the cargo and its location on the lever of the device have been chosen in such a way as to increase the pressure on the plunger end was 500 N.
3. Results and discussion.
Measurement results gidro density plunger before and after application of a plasma coating on the working surface of the plunger shown in Table 1. Here the plunger with the numbers 1 and 2, the coating thickness was about 0.5 microns, and with the numbers 3 and 4 of the order of 1.0 microns. However, we must bear in mind that the total elimination of the gap in the mating surface of the plunger assembly of parts by covering fraught with consequences. In particular, it became clear from the plunger rooms 3 and 4.

Table 1 – Gidro density plunger before and after plasma coating on the working surface of the plunger, second

| The surface condition of the plunger | Non plungers |
|-------------------------------------|--------------|
|                                     | 1    | 2    | 3    | 4    |
| Original                            | 15   | 18   | 20   | 16   |
| Plasma coating                      | 28   | 30   | 140  | 120  |

4. When an ambient temperature of 25 °C for the movement of plungers slidably sleeves occurred, and at a temperature of 10 °C occurred their jamming. Therefore, when developing the application of plasma coating technology must take into account this factor. The table above shows that the non-vacuum plasma thin-film coatings can increase gidro density plunger both new and refurbished.

There is a link between the size of the gap in the pump element and the fuel leak through the gap in the active course of the plunger. It can be expressed by formula [15]:

\[ Q = \frac{\pi D p l^3}{12 \mu L} \]  

where \( Q \) - momentary amount of fuel flowing into the annulus; \( D \) - the diameter of the plunger; \( p \) - pressure difference; \( l \) - Radial clearance in the pump element; \( \mu \) - the absolute viscosity of the fuel; \( L \) - length of the sealing surface.

From the above formula it is seen that the presence on the working surface of the plunger plasma non-vacuum thin film coating allows the 1.5 - 2.0 times to reduce the radial clearance in the pump element. This corresponds to approximately 5-fold increase in gidro density plunger assembly by non-vacuum plasma thin-film coating. In [2] determined to develop an empirical relationship between a pair of plunger pressure \( p \) and its gidro density \( \tau \)

\[ \frac{\tau_0 - \tau}{\tau} = 0.1(p_0 - p) \]  

where \( \tau_0 \) - the original density; \( p_0 \) - initial pressure (developed by a pair of pressure at the plunger \( \tau_0 \)); \( p \) - developed by a pair of pressure at the plunger \( \tau \).

From (2) it follows that at 6-fold increase in the difference gidro density plunger \( (p_0 - p) \) assembly is 50 MPa. In our case, \( \tau_0 \) and \( p_0 \) gidro density meet and develop a pair of plunger pressure plasma coating on the plunger, and \( p \) and \( \tau \) – gidro density and develop a pair of pressure plunger without coating on the plunger (factory plunger pair). Normally developing pressure plunger assembly factory is about 110 MPa. Then a pair of pressure developed by plunger Plasma coating on the plunger will have a pressure of 160 MPa.

In [2] and obtained a law change promoted by a pair of pressure on the plunger of use

\[ A^{th} = 0.1(p_0 - p) + 1 \]  

where \( A \) - constant characterizing the effect of initial density; \( k \) - coefficient, which takes into account the wear plunger; \( t \) - duration of the operation.
Going from a plunger pump and a pair given that his time between working life is determined plunger by the formula (3) can be found, and life of the pump

\[ t_n = \frac{l_q \{0.1(p_0 - p_{lim}) + 1\}}{\kappa * l_q A} \]  \hspace{1cm} (4)

where \( p_{lim} \) is the maximum allowable operating pressure in the plunger assembly.

For high pressure fuel pumps \( p_{lim} = 20 \text{ MPa} \). In [2] it has been shown that the pattern of change of the operational characteristics of the pump operating time is saved and his life depends on the plunger developed by a pair of pressure and intensity of its wear. Using developed in [2] for the construction of a theoretical model of the operational characteristics of the pump with non-vacuum plasma thin-film coating the working surface of the plunger and the plunger to develop a pair of pressure of 160 MPa. Consider the basic model fuel pump Model 33-02 Engine KAMAZ 5320 with factory plunger pairs. The experimental data resource of the high pressure pump 3000 Moto hours at the initial developing a pair of plunger pressure of 70 MPa. Let the base model pump coefficient taking into account the wear rate of plunger is equal to one, \( k = 1 \). From (4) we find the constant \( A \): \( l_q A = 2.6 \times 10^{-4} \) or \( A = 10^{0.00026} \). This constant \( A \) will not change its value, since initial value is independent of the pump plunger assembly state (it is set by the operator). Details considered plunger assembly made of a material ShKh15. [4, p. 373] that the ratio of the wear rate of the material ShKh15 non-vacuum plasma and thin-film coating is 2.0. Then, using the formula (4) we find the life of the pump with the new plasma coating. It is equal to 9000 Moto hours. Next, using a theoretical model, we construct a characteristic pump plunger pairs, which have a plunger non-vacuum plasma thin film coating (Figure 1).

As seen from the graphs of Figure 1, plasma non-vacuum thin film coating on the plunger allows a 3-fold increase in service life of the fuel injection pump diesel engines.
Figure 1 - Characteristics of the laws governing working pump plunger from the factory with a pair of $P_0 = 70 \text{ MPa}$ (1) and a pair of plunger non-vacuum plasma thin-film coated plunger with $P_0 = 160 \text{ Pa}$ (2)

4. Conclusions.

1. Plasma non-vacuum thin-film coatings based on silicon oxycarbonitride allow increased gidro plunger both new and refurbished.
2. With the use of vacuum-free plasma thin-film coatings based on silicon oxycarbonitride possible in 2 - 3-fold increase in service life of the fuel pump of domestic production.

Acknowledgments
The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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