Improving the quality indicators fuel pump of plasma technology

S N Sharifullin, A S Pirogova
Kazan Federal University, 18 Kremlyovskaya Street, Kazan, 420008, Russian Federation

Saidchist@mail.ru

Abstract. It is shown that the product quality control is not only to control the process of its manufacture. To the product was in demand and the competitive need to search for new promising technologies for its production. One such technology is the plasma technology.

1. Introduction.
According to GOST R ISO 9000-2015 2.2.1 The quality of the products and services of the organization depends on the ability to meet consumers' intentional or unintentional influence on relevant stakeholders. Indeed, the quality is largely determined by the consumer and, therefore, the manufacturer must monitor the quality of work - namely, to follow the development of modern science. It is no secret that today, technologies such as plasma technology - a progressive trend in the field of engineering, which allows repeatedly and effectively improve the reliability and durability of machine parts. What does "progressive trend"? This means that there will always be those who are interested in the development of issues related to this field. So here rightly be competition. It was she who pushed the organization to maintain and enhance its position in the market. Usually this makes quality management.

Quality management is defined by a coordinated activity on all matters of organization management manual. Recall quality management principles: Customer focus, defining the interests and desires of buyers; Leadership that provides unity of purpose and direction of the state; The interaction of employees, ensuring the involvement and expertise in manufacturing processes; Process approach, implying the achievement of the goal through the relationship of all the elements; Continuous improvement, suggesting success; Decision making based on facts, which help to achieve the desired result; Management relations, which is the link between suppliers and the organization. All these factors must be met to obtain the expected, and most importantly - quality product (service) at the output. Multifaceted concept of quality, and therefore the characteristics of a particular object, it will be different. We say that the quality characteristics of the product parameter. In this aspect, usually takes into account the functional characteristics, reliability, durability, defect-free (free from defects), safety, design, sustainability, etc.

This material is considered a quality indicator as longevity or would be correct to say, life of the high pressure fuel pump (fuel pump) diesel internal combustion engines of transport and technological machines. Presumably, the more the life of the product, so it is more popular and competitive.

2. Materials and methods of research.
This article considers the possibility of increasing the service life of the high pressure fuel pump by creating a plasma coating of titanium nitride on the working surface of the plunger. For the base model of the fuel pump fuel pump is taken 33-02 model car engine KamAZ 5320 with factory plunger pairs. Application of titanium nitride on the plunger to produce magnetron installation UVN-4-2. Analysis of the results of research carried out with a theoretical model for the construction characteristics of the work pump. Construction characteristics of pump operation is based on the Lagrange polynomials.
3. Results and discussion.

In [1] it was proved that reliability and durability (high pressure pump) diesel engines, primarily depends on their resource plunger. Unfortunately, the quality of domestic manufacturing plunger such that their life is not more than 3 thousand operating hours, while that of foreign analogues it reaches 12 thousand or more. As was shown in [2], a resource plunger is determined by the pressure and wear of the developing mating parts. A pair of pressure developed by the plunger is directly dependent on the clearance between the sleeve and the plunger. The smaller the gap, the higher the pressure developed by plunger pair hence the greater its working life. 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 [2-18] that the achievement of their foreign counterparts resource plunger possibly producing ion-plasma deposition of titanium nitride on the working surface of the plunger.

In [2] we developed a theoretical model for the construction of resource characteristics of the high-pressure fuel pump works, or briefly pump. Fig. 1 is a block diagram of the developed model. The essence of this model is as follows: The circuit has two branches: the left and right. The left branch of the pump is seen with known parameters based on experimental data obtained in the course of the performance test. The right branch of the block diagram of the theoretical model refers to the pump with unknown parameters. It requires build characteristic of his work and to determine resource. Pump with known parameters is taken as the base fuel pump. For the base model pump define the cyclic fuel delivery \( q \), developed by a pair of plunger pressure \( p \) and the operating time \( t \) since the start of the pump up to the limit of his condition. Removing the data produce a certain period of duration of pump operation. Using one of the mathematical programs, using the Lagrange polynomial characteristic of building a working base model pump.

A theoretical model for the construction of resource characteristics of the work can not only build a characteristic pump works, but also to determine its service life. This was used by the resulting changes in the law developed by a pair of plunger pressure from developments [2]:

\[
A^{kt} = 0.1(p_o - p) + 1
\]  

where \( A \) - constant characterizing the influence of the initial developed by a pair of plunger pressure; \( k \) - coefficient taking into account the intensity of wear plunger; \( t \) - duration of the operation; \( p \) - to develop a pair of plunger pressure at operating time \( t \).
Going from the plunger assembly to the fuel pump and the fact that its operating time is determined by the service life plunger according to the formula (1) can be found and the service life of the pump:

$$t_r = \frac{\log(0.1(p_0-p_{lim})+1)}{k \log A}$$

(2)

where $t_r$ - the life of the fuel pump; $p_{lim}$ - the limit value developed by a pair of plunger pressure equal to the minimum pressure of the fuel injection through the nozzle.

Take for the base model fuel pump 33-02 model car engine KamAZ 5320 with factory plunger pairs. According to the experimental data (Fig. 2) of this resource injection pump 3000 hours at the initial developing a pair of plunger pressure of 70 MPa. Let the base model pump coefficient taking into account the wear plunger is unity, $k = 1$. If the resource limit injection pump 3000 hours developed by a pair of plunger pressure is the operating pressure of the injector. In this case $P_{lim} = 20$ MPa. Then, from the formula (2) we find the constant $A$: $A = 2.6 \cdot 10^{-4}$ or $A = 0.00026$.

![Figure 2](image)

**Figure 2** - Schedule features laws pump model 33-02 with factory pair of plunger. 1 - the experimental curve (base) at $P_0 = 70$ MPa; 2 - for polynomial curve at $P_0 = 110$ MPa; 3 - curve for the model when $P_0 = 110$ MPa

This constant $A$ will not change its value, since the initial value of the injection pump setting does not depend on the state of the plunger assembly. Original developed by a pair of plunger pressure will influence only the operating time. This pattern of change of the characteristics of the work of the pump operating time is also saved.

Determine the probability of life of the fuel pump at an initial base model to develop a pair of plunger pressure of 110 MPa. From the formula (2) that the resource will then be equal to 3900 hours.

To validate the calculation in the polynomial matrix for $y = 70$ MPa to change the ratio of fixed values $q$ of $x$ for the resource 3900 hours and plotted the cycle of fuel supply by operating time (curve 2 in Fig. 2). Fig. 2 curve 3 obtained according to the base curve at 1 time between the plunger assembly with a source to develop a pressure $P_0 = 110$ MPa. As can be seen, the curve 2 by the polynomial at $P_0 = 110$ MPa is fully integrated into the resulting curve. That means having the basic experimental data pump and conducting additional experiments can plot its basic parameters from the achievements and define the life of any source to a pair of pressure developed by plunger. It also follows from the graphs that the pattern of changes of the parameters of the pump operating time is stored in any source developed by a pair of plunger pressures. The difference will be only in the operating time.

Similarly, calculations are made for the injection pump having a plunger covering the plunger assembly of titanium nitride. Determine the probability of life of the fuel pump plunger with said cover when the original pair to develop plunger pressure of 110 MPa. According to the experimental data of the wear resistance of the titanium nitride coating is 2.4 times higher than the wear resistance...
of the material of the plunger the plunger assembly factory. Based on the above calculations for the
value of the coefficient k assumed to be 1/2.4. Then the formula (2) determine the probable life of the
pump plunger plunger coated pair of titanium nitride in the initial developing a pair of plunger
pressure of 110 MPa: t = 9230 hours. To validate the calculation in the polynomial matrix for pump
base model at y = 70 MPa to change the ratio of fixed values of x for the resource 9230 hours and
plotted the cycle of use of the fuel supply (Fig. 3).

Figure 3 - Charts laws work performance pump models 33-02 coated plunger plunger pair of titanium
nitride. 1- The experimental curve (base) at P0 = 70 MPa; 2 for polynomial curve at P0 = 110 MPa; 3-
curve for the model when F0 = 110 MPa.

Analysis of the curves in Fig. 3 gives the same results as the analysis from the curves in Fig. 2.
Then, we can conclude that the model works for the high pressure pump with a different state of
plunger. As can be seen from the graphs in Fig. 1, a coating of titanium nitride on the plunger allows a
three-fold increase in life of the diesel injection pump.

4. Conclusions
1. Plasma thin-film coatings can increase service life of the pump. For coating of titanium nitride may
increase the service life of the fuel pump in 2 - 3 times.

References
[1] Adigamov N R, Sharifullin S N 2009 The complete solution recovery problems fuel equipment
of diesel engines Tractors and farm machinery (3) 38 - 40
[2] Sharifullin S N 2009 Increase of operational reliability of automotive diesel engine high
pressure fuel pumps. - Diss. Doctor. tehn. Sciences. (Moscow: GOSNITI)
[3] Solovev R Y, Sharifullin S N, Adigamov N R 2016 Plasma technology for increase of operating
high pressure fuel pump diesel engines J. Phys.: Conf. Ser 669 012050
[4] Kashapov L, Kashapov N and Kashapov R 2013 J. Phys.: Conf. Ser. 479 012005
[5] Gavrilova V A, Fazlyyyakhmatov M G and Kashapov N F 2013 J. Phys.: Conf. Ser. 479
012010
[6] Fay Rushin I, Kashapov N and Dautov I 2014 J. Phys.: Conf. Ser. 567 012009
[7] Kashapov L N, Kashapov N F and Kashapov R N 2013 J. Phys.: Conf. Ser. 479 012011
[8] Kashapov L N, Kashapov N F and Kashapov R N 2014 J. Phys.: Conf. Ser. 567 012025
[9] Zaripov R G, Kashapov N F, Tkachenko L A and Shaydullin L R 2016 J. Phys.: Conf. Ser. 669
012053
[10] Denisov D G, Kashapov N F and Kashapov R N 2015 IOP Conference Series: Materials
Science and Engineering 86 012005
[11] Israfilov Z K and Kashapov N F 1991 Journal of Engineering Physics 60 364–368
[12] Galyautdinov R T, Kasparov N F and Luchkin G S 2002 Inzhenerno-Fizicheskii Zhurnal 75 170–173
[13] Saifutdinov A I, Fairushin I I and Kashapov N F 2016 JETP Lett. 104 180–185
[14] Galyautdinov R T and Kashapov N F 2003 Svarochnoe Proizvodstvo (3) 27–31
[15] Azarov A I, Kashapov N F and Osipova O P 2003 Litejnoe Proizvodstvo (11) 30–31
[16] Abdullin I Sh, Galyautdinov R T and Kashapov N F 2001 Inzhenerno-Fizicheskii Zhurnal 74 104–107
[17] Luchkin A G, Kashapov N F and Luchkin G S 2013 J. Phys.: Conf. Series 479 012019
[18] Kornienko E E, Lapushkina E J, Kuzmin, V I, Vaschenko S P, Gulyaev I P, Kartaev E V, Sergachev D S, Kashapov N, Sharifullin S, Fayrushin I 2014 Journal of Physics: Conf. Series 567 012010