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PIEZO ACTUATORS INJECTOR OF COMMON RAIL FUEL INJECTION SYSTEM

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S u m m a r y . The problem of determination of expedience of the use of piezoelectric sensors in piezo actuators, connected with the scheme of DD-TR, is considered. The transitional characteristics and amplitude of output signal also is determinate.
K e y w o r d s : common rail, piezoelectric valve, piezo actuator, piezoelectric sensor, piezoelectric transformer, domain-dissipative.

INTRODUCTION

Diesel engines with Common rail fuel injection system are most modern. This type of diesel engines is used not only in trucks but also in passenger cars because it has great advantages among other diesel engines. Reduction of noise of working engine, reduction of amount of harmful substance, thrown out to the atmosphere, power increase are the main advantages of diesel engines with Common rail fuel injection system. By its dynamic characteristics diesel engines with Common rail fuel injection system became common to petrol engines. The difference of Common rail fuel injection system is in big injection pressure (over 1000 bar). Structurally differs by the presence of general distribution pipe, situated in a direct adjacency to the injectors, in which the fuel is under constraint over 1000 bars. The injection of fuel in the cylinders of engine is carried out through the electric guided injectors [7, 8, 25].

Application of two types of injectors is possible in the systems of injection of Common Rail: with an electromagnetic valve and with a piezoelectric valve. The advantage of injectors with a piezoelectric valve is a speed and accuracy of injection. The lacks of injectors with a piezoelectric valve is a high price, lack of possibility of control of moving of valve in the process of exploitation. Injectors with an electromagnetic valve allow to conduct control of moving of valve on the size of resistance of spool inductance, however they possess large inertia, that influences on impairment of accuracy of injection [7, 9, 28].

For realization of possibility of control of moving of valve of piezo injectors in the process of exploitation it is suggested to use piezo actuator working as on reverse so on direct piezoelectric effect [1, 2, 5, 9].

The system of injection of Common Rail with piezo injectors, allowing to produce control of moving of valve of injectors, works as follows (fig. 1). Fuel, being in a tank 1, through a pumping pump 2 is given by fuel pipe through an electromagnetic valve 4 to the high pressure pump 3. The high pressure pump gives a fuel into general distribution pipe 5. Thus, the main function of high pressure pump is the maintenance of pressure of fuel to general distribution pipe.

Fuel, being in the distribution pipe, through electric controllable piezo injectors 6 is given to the engine cylinders 7. The signal from a pressure fuel sensor 15, set in general distribution pipe, and sensor of position of crankshaft enters to the electronic control unit (ECU) 16 [11, 15, 21, 25].

Electronic control unit of the injection of fuel consists of input amplifier 8, analog-digital converter 9, controller 10, digital-analog converter 11 and output amplifier 12.

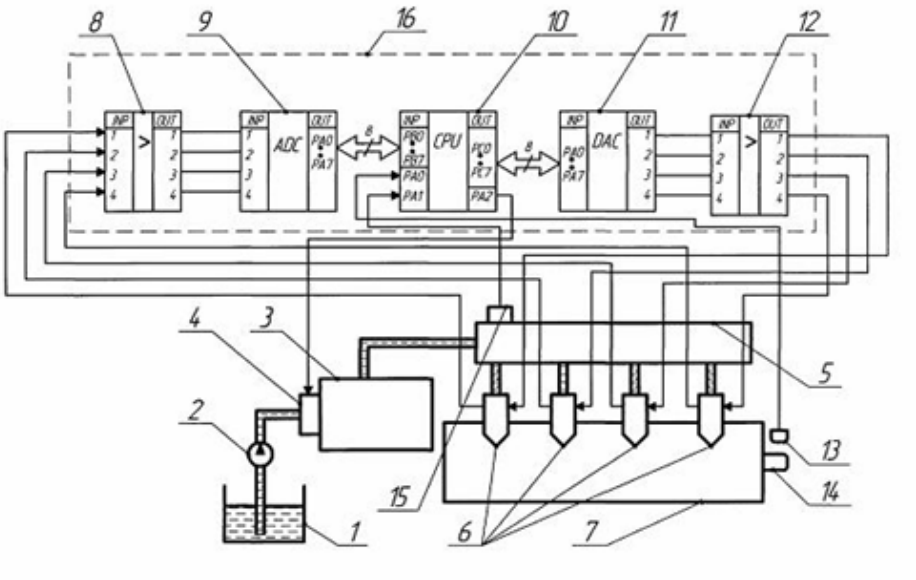

Fig. 1. Common rail fuel injection system

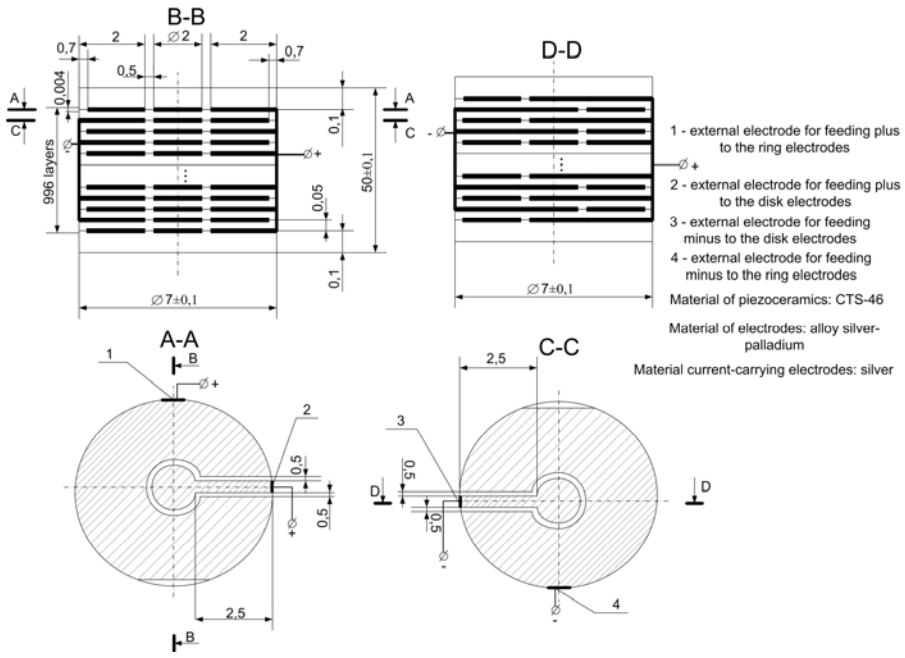

Fig. 2. Piezo actuators injector

The process of injection of fuel control is realized through an electric signal amplitude of $U_{inp} = 110$, given to input electrodes 1, 4 of piezo actuators of injector (fig. 2). While giving the electric voltage the change of sizes of piezo actuators injector and moving of nozzle valve occurs. After a voltage removing piezo injector returns its sizes to the initial ones. For diminishing of time of return of piezo actuator to the initial sizes a reinforcing spring is provided with effort of bridle of the order of 5 kgf.

Control of moving of piezo actuators injector is realized by a signal, which is weighted from the output terminal of piezo actuator 2, 3 (fig.2). Proceeding from the phenomenon of reverse piezo sensor, the formation of signal occurs while moving of piezo actuators injector, herewith on output electrodes 2, 3 a charge occurs, the size of which is proportional to the size of moving of piezo actuators injector ΔX [3, 4, 5, 12, 22]. Thus, control the size of moving of piezo actuators injector ΔX is realized with the amplitude of signal is measured from the output terminal of piezo actuator [1, 2, 15, 17].

THE ANALYSIS OF PUBLICATIONS AND MATERIALS

Piezo actuator consists of 996 piezoelectric sensors, which electrodes are parallel connected between it selves. On the fig. 3 one piezoelectric sensor of piezo actuator is schematically represented.

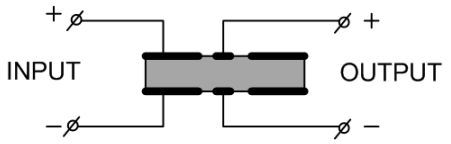

Fig. 3. Piezoelectric sensor of piezo actuator

The most approximate analogue of piezoelectric sensor of piezo actuator is a piezoelectric transformer [3, 4, 5, 24]. A piezoelectric transformer is the piezoelectric sensor with two systems of electrodes – input and output, to one of which the source of electric vibrations (for example, generator) is connected, and to the second - electric demand (for example, measuring device). On a construction and mutual location of electrodes piezoelectric sensor of piezo actuator is analogical to a disk piezoelectric transformer. The basic parameter of piezoelectric transformers is a coefficient of transformation of K [3, 4, 5, 23]. When using piezoelectric sensors in piezo actuators this coefficient is also the most important, so far as it influences on accuracy of determination of size of moving of piezo actuator ΔX. The less is the coefficient of transformation K, the more precisely possible is to define the size of moving of piezoelectric sensor of ΔX.

The coefficient of transformation is determined by the formula:

$$K=Uinp\backslash Uout, \qquad (1)$$

where: *Uinp* is the amplitude of electric signal, weighted from input electrodes, *Uout* is amplitude of electric signal, taken from output electrodes.

At excitation of piezoelectric transformer on the radial mode of vibrations the stream of energy through a cylindrical surface remains unchanging for any radius and, consequently, the concentration of energy takes place in the center of a disk there. If to install the generator section of transformer in the center of the disk, the increase of coefficient of transformation occurs due to the concentration of energy. The reduction of thickness of piezoelectric transformer causes the increase of coefficient of transformation.

A mutual location and size of electrodes also influences on the size of coefficient of transformation, thus, the more is the correlation of areas of input and output electrodes of S_{inp}/S_{out}, the less is the coefficient of transformation and more is the moving of Piezoelectric sensor. Thus, to achieve the maximal moving and realization of opportunity of control of moving feature the construction of piezo actuator must provide the presence of input, output electrodes, and the area of input electrodes must be as big as possible, and the area of output electrodes must be as small as possible.

Piezoelement, is represented on a fig. 3, by its method of location of electrodes on the surface and connecting is the analogue of traditional piezoelectric transformer (Tr). The traditional transformer are called piezoelectric transformers, at which the angle of α between the vector of input and output vectors of the electric field and vector of polarization is equal to zero. Piezoelectric transformer at which the angle $0 < \alpha \leq 90^{o}$ is domain-dissipative (DD-DD) (fig. 4) [3, 4, 5, 11, 13, 14].

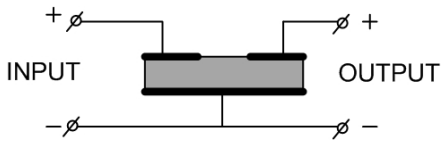

Fig. 4. Piezoelectric sensor connected with the scheme of DD-DD

When powering the input electrodes of piezoelectric sensor of signal is represented on a fig. 5, transitional characteristic of piezoelectric sensor, connected with the scheme of TR-TR (fig. 3), is represented in fig. 5. Transitional description of piezoelectric sensor, connected with the scheme of DD-DD (fig.4), is represented on a fig. 6.

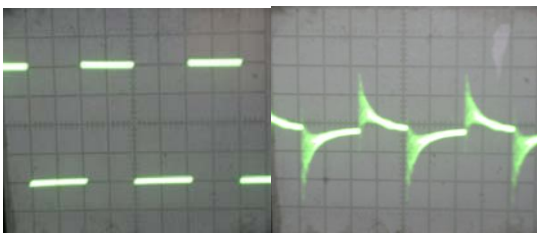

Fig. 5. The input signal and transitional characteristic of piezoelectric sensor, connected with the scheme of TR-TR

The advantage of piezoelectric sensors, connected with the scheme of DD-DD possessing

properties of differentiating element is a presence of linear characteristic in wider range, than traditional piezoelectric sensors have. The disadvantage of such piezoelectric sensors is the unsteady moving of piezoelectric sensor in relation to the axis of rotation. As a size of moving of ΔX depends on correlation of input and output electrodes, so the placement of electrodes on the surface of piezoelectric sensor by such method reduces the size of moving of piezoelectric sensor, that is the substantial disadvantage.

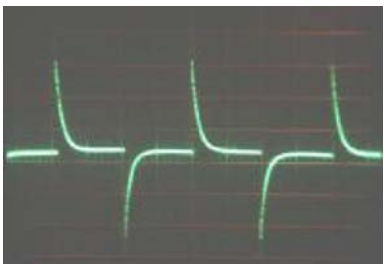

Fig. 6. The transitional characteristic of piezoelectric sensor, connected with the scheme of DD-DD

The advantage of piezoelectric sensors, connected with the scheme of TR-TR, is the steady moving of Piezoelectric sensor along the axis of rotation and large size of moving. The disadvantage is the presence of not linear characteristic [3, 4, 5, 21, 22, 24].

For the reliable functioning of piezo actuator piezo ceramic materials, from which piezoelectric sensors of piezo actuator are made, must have the followings parameters:

-high value of piezo modulus *d33*;

-to have high temperature stability in a range from -60 to +70;

-to have high strength.

The most suitable materials for making piezoelectric sensors of piezo actuator are: CTS-46 and CTBS-8.

PROBLEM STATEMENT AND RESEARCH

Two variants of connecting, considered before (Fig.3, 4), are basic, and every scheme has its advantages and disadvantages. For generation of piezo actuator, which fulfils the requirements of the large moving, availability of control function and characteristics linearity the use of fair quantities of combinations of basic variants of schemes is possible. Their main requirements are characteristics linearity in a wide range and as less as possible value of angle between the vector of input and output vectors of the electric field and vector of polarization.

The main task of experimental research is determination of transitional characteristic of piezoelectric sensor made by the combined scheme of DD-TR (fig.7), and also determination of expedience of the use of such piezoelectric sensors in piezo actuators.

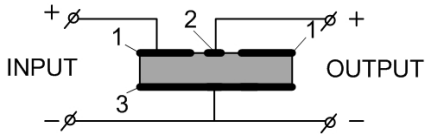

Fig. 7. Piezoelectric sensor connected with the scheme of DD-TR

Taking into account that all piezoelectric sensors of piezo actuator are equal, and the moving rate of piezo actuator is determined with a formula:

$$X_{\Sigma} = \Delta X \times n, \qquad (2)$$

where: X_{Σ} is a moving rate of piezo actuators, X_{Σ} is a moving rate of one piezoelectric sensor of piezo actuator, n - is the amount of piezo elements in piezo actuator, for determination of characteristics of piezoelectric sensor, made by the combined scheme of DD-TR, it is enough to conduct an experiment with one piezo actuator.

Moving of piezo actuator is realized under the action of electric voltage, attached to the electrodes 1, 3. Simultaneously the signal, which amplitude is proportional to the moving rate, is measured from electrodes 2, 3.

MAIN PART

For conduction of experimental researches piezo element is connected according to the scheme, represented on a fig. 8. As a device of voltage the generator G5-54 is used. The signal, taken down from output electrodes, is measured with the help of the oscillograph of S1-65A.

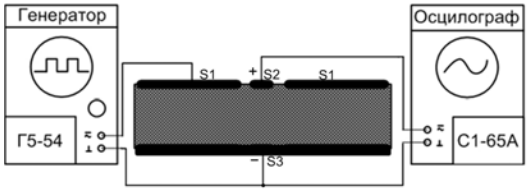

Fig. 8. The scheme of piezoelectric sensor is connected

On the input electrodes of piezoelectric sensor electric voltage with amplitudes 20, 30, 40, 50 volts is given by turns.

Table 1. Parameter of piezo sensor

Material	Diameter D, mm	Height L, mm	$S1$, mm^2	$S2$, mm^2	$S3$, mm^2
CTBS-8	30	2	678	24	706

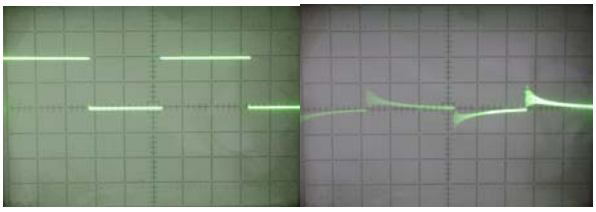

Fig. 9. The form of input electric voltage by amplitudes 20 volts and transitional characteristics

CONCLUSIONS

Information about the size of output voltage of piezoelectric sensor, connected by the scheme of TR-TR, are represented in the table 2 and taken from [6, 7, 8, 11, 26]. On diagrams, represented in fig.10-13, and measuring results, represented in the table 2, it is possible to make a conclusion, that the use of piezo elements in piezo actuator, made according to the combined scheme of DD-TR, allows to control moving with smaller distortions without the considerable diminishing of amplitude of output signal.

The increase of measuring accuracy is conditioned by the fact that at the increase of angle α between the vector of polarization and vector of voltage of the electric field of output signal there is the degeneration of vibration properties of transformer into an aperiodic differencing circuit. When increasing of angle α also sensitiveness is increased and the working range of frequencies broadens is extended.

Table 2. **The size of output voltage of piezoelectric sensor**

Inp.voltage	20	30	40	50
DD-TR. Out. voltage	8	14	18	22
TR -TR. Out. voltage	10	17	21	25

The outlook of further researches is determination by influence of parameters of environment, electromagnetic radiations on amplitude of output signal and moving rate of piezo actuator.

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ПЬЕЗОАКТУАТОР ФОРСУНКИ СИСТЕМЫ ВПРЫСКА COMMON RAIL

Ирина Кириченко, Александр Стрелец, Николай Кошевой

Аннтотация. В статье рассматриваются вопросы целесообразности применения в пьезоэлектрических актуаторах пьезоэлементов, выполненных по схеме ДД-ТР. Определена переходная характеристика и амплитуда выходного сигнала.

Ключевые слова. Common Rail, пьезоэлектрический клапан, пьезоэлектрический актуатор, пьезоэлемент, пьезоэлектрический трансформатор, доменно-диссипативная схема.