FUEL FEED TO DIESEL AT A START REGIME

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Abstract

Some factors defining starting properties of diesel engines are considered. Features of process of fuel feed on a starting mode are analyzed. Basic possibility of steering by processes of mixture forming and combustion is proved at a small speed of a crankshaft. Developed a design procedure of process of fuel feed in a diesel engine at a start regime. On the basis of the theory of transients in a fuel system, the reasons of deterioration of indicators of fuel feed process are explained at a start regime of diesel engine. Possibilities of a method of increase of initial pressure in a delivery highway by prostrating scrolling of a crankshaft with idle spray jets are investigated. The method of intensification of fuel feed process patented by authors used in diesel engine at a start regime. The results of numerical experiments confirming improvement of indicators of process of injection at high-speed speeding up of the pump of a high pressure are resulted: Increase maximum and an average pressure, cutting-down of duration of fuel feed process. The paper concentrates on possibility of improving fuel fed process at the starting regime by means of high speed forcing the fuel pump and the initial pressure rising by an earlier camshaft rotation with out of work injectors.

Keywords: *a starting duty, features of process of giving, nozzle valve lifting, an injection pressure, transients, cyclic fuel delivery*

Starting diesel properties characterized by the duration of a start regime depend on the parameters of a charge in a cylinder as well as on the character of fuel feed determining the quality of mixture forming and in the best case providing a save start with a minimum content of harmful compounds in the gaseous waste.

The peculiarities of charging the cylinder processes are connected with a small speed of the camshaft rotation at starting diesel.

We don't consider here a thermodynamic aspect of the pressure process for example the start at cold and heated walls of the cylinder. We'll only mark a noticeable leakage loss of the charge from a cylinder cavity due to a large "time-section" in conjunction with a piston-cylinder at a small speed of piston stroke rate.

At the diesel engine start the closure angle of the inlet valve turns out to be non optimal [1,2]. This also results in decreasing the quantity of the compressed charge and in lowering its pressure and temperature. If it is practically impossible to decrease the number of charge losses in modern design of the piston compressed arrangements, then the system of automatic phase changing of gas distribution easily allows improving charging cylinders at diesel start by decreasing the inlet valve closure angle of delay for the time of starting.

At the start regime a maximum and an average fuel injection pressure is significantly lowered due to decreasing the volume feed speed. However it is exactly due to the fuel feed system that a decisive role is assigned in the process of the mixture forming at the start regimes. As well as at the rest of regimes of diesel work, a detailed study of preceding the processes of mixture forming and combustion is an important task, with the main aim of investigation remaining research for methods of adjusting these processes. Here it is appropriate to mention that in spite of overcoming a lot of difficulties in building for example of economic diesels with an undivided combustion chambers, the task of adjusting the process of fuel feed has not been solved yet. Since the fuel injection period in high speed diesels completes before the beginning of the combustion process the fuel feed characteristics affect the combustion process proceeding only indirectly that is through the indices of the dispersion of fuel spraying, the form and the development of flame duration in time, as well as on the concentration flame structure. The availability of a relatively large period non-adjustable combustion process in diesel with indivisible chamber has essentially determined large speed of pressure growing and rising of the cycle maximum temperature, which accounts for a high level of diesel noise a great content of nitrogen oxides in the combustion waste.

The largest period of non-adjustable combustion process is characteristic for the high speed diesels with modern accumulator fuel systems providing an intensive short fuel injection. In this connection a start regime of diesel with a traditional system of fuel feed is remarkable for the least period of non-adjustable combustion process.

This is explained so. Even at significant increase of delayed ignition (in time) due to lowering the temperature and the charge pressure while compressing, the ignition delay measured, by the camshaft rotation angle, decreases. Therefore at an unchanged duration of fuel feed the period of non-adjustable combustion process is considerably less at start then at rest regimes.

However it does not mean that it is easier to control the heat output in the cylinder through the process of the fuel feed at the diesel start.

Yes, there are more possibilities to affect the process of combustion. But taking into account the complexity of the fuel feed process generally and its peculiarities at a small speed of camshaft rotation, one can state a search for adjusting methods can turn out to be not easier than at a charging regime.

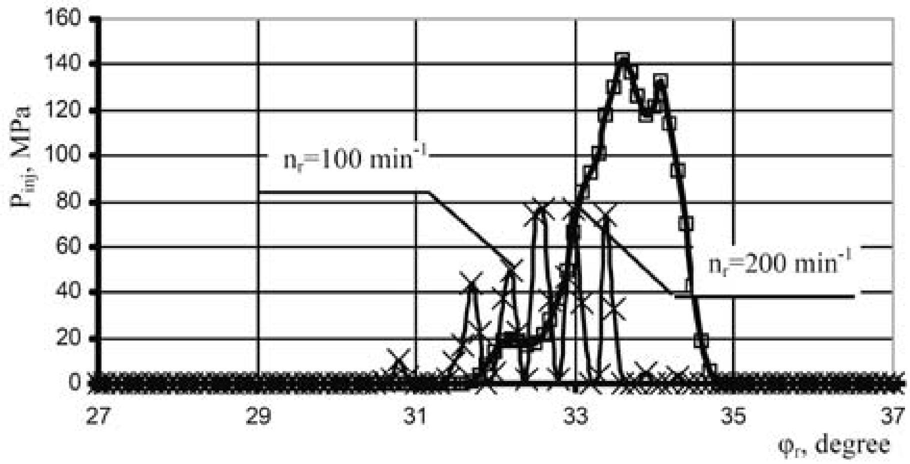

Fig. 1. The dependence of the injection pressure P_{inj} on the rotation angle of the pump φ_r: high pressure pump UTN-5; Q_c=72 mm^3

The peculiarities of the fuel feed process by the system with a high pressure pump UTN-5 are shown in Figure 1. At the starting rate with the camshaft rotation frequency of the pump n_r being 100 min^{-1}, sharp fluctuations of injection pressure have been noticed. A maximum pressure P_{inj} does not exceed 8 MPa.

The needle of the injector does not reach far the stop and performs vibrating motions (Fig. 2). The rising height of the needle H_n is approximately equal to that one under additional injections at the constant and transitional regimes of the charged diesel.

The analysis of the presented figures accounts for the reason of rapid going out of order the injectors at the frequent starts of diesels. Low speeds of large fuel leakage portions from the injector result in its overheating and coking nozzle holes. This also accounts for diesel smoking at the start.

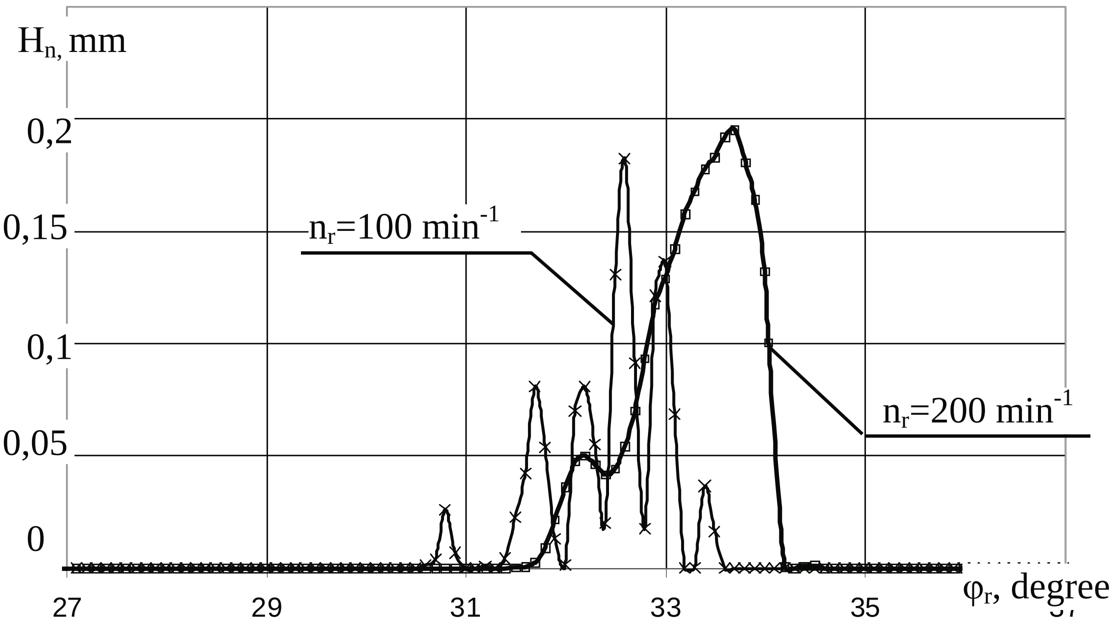

Fig. 2. The dependence of the injector needle height H_n on the camshaft rotation angle of the pump φ_r: high pressure pump UTN-5; Q_c = 72 mm^3

In the same figures one can see a change in injecting pressure P_{inj} and rising the needle H_n of the injector of the camshaft rotation frequency of the pump n_r = 200 min^{-1}. This is a high speed regime of the fuel pump at the diesel start with an experimental (patent) system. [3]. In this system the camshaft rotation velocity of fuel pump has been doubled with the aim of intensifying the fuel feed process.

The results of calculation show that the pressure P_{inj} in the experimental system has increased almost twice at the rate of start (Figure 1). The height of the injection needle H_n increased up to 0,25 mm at the height of stop – 0,26 mm (Figure 2).The character of changing these parameters has become the same one as at the regimes of engine loading. Consequently, when double increasing the pump camshaft rotation frequency at diesel start, the indices of the fuel feed process have remarkably improved.

The furl system with a high pressure pump 8NK-10 does not provide improving the indices of the fuel feed process at rapid forcing the fuel pump. Figure 3 shows the height change of the injector needle rise H_n in the function of the camshaft rotation angle of the pump φ_r at the camshaft rotation frequencies of the pump 100 and 200 min^{-1}. Only at the camshaft rotation frequency of the pump 350 min^{-1} the character of changing the pressure and the injection speed as well as the rise the height of the injector needle has become the same as the one at the rate of engine loading. In Figure 4 the law of the rise height change of the injector needle in the function of the camshaft rotation angle of the pump φ_r has been presented. The calculation process of fuel feed by the system with high pressure pump 8NK-10 was made by V. Maidgi.

Modern systems of diesel starts provide for the camshaft rotation frequency 200…220 min^{-1}. This allows as our calculations have shown to improve the indices of the fuel feed process by using the system with the doubled rotation speed of the pumpUTN-5 at the start regime (Figure 1,2). We fail to obtain this by using the fuel pump 8NK-10. It is hardly expedient to raise the diesel camshaft rotation frequency at the start rate 350 mm-1 and changing at that the indices of the start system, including energy expenditures on the camshaft rotation.

In the above mentioned cases the quantity of the cycle fuel feed at the experimental high speed regimes corresponded to the rate, recommended by the producing plant. Often in the process of maintaining the fuel system an insignificant wear of the plunger couples brings to decreasing the pump efficiency and lowering the injection pressure at the start regime. At the rest of high speed and changing regimes the fuel feed system functions normally. Especially the wear of the plunger couples becomes apparent at the start of heated diesel, when due to decreasing fuel viscosity increase its leakage through the gaps in conjunction with plunger-bushing.

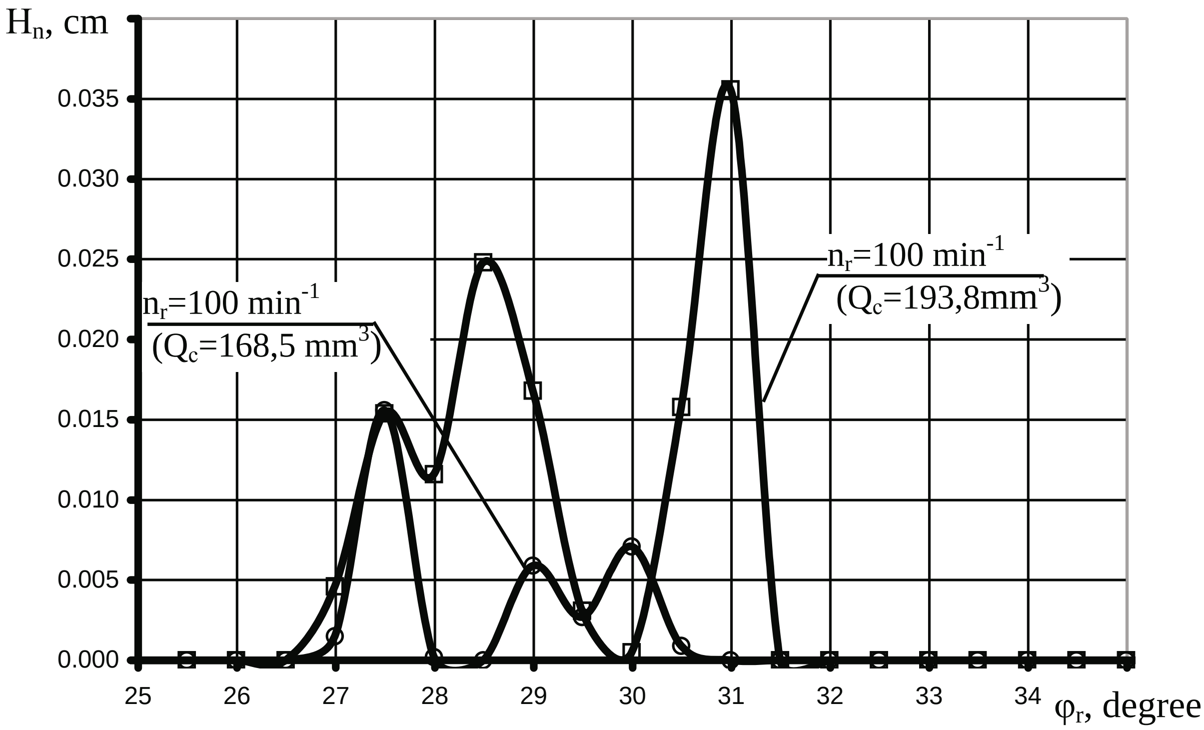

Fig. 3. The dependence of the injector needle rise H_n on the camshaft rotation angle of the pump φ_r: high pressure pump 8NK-10

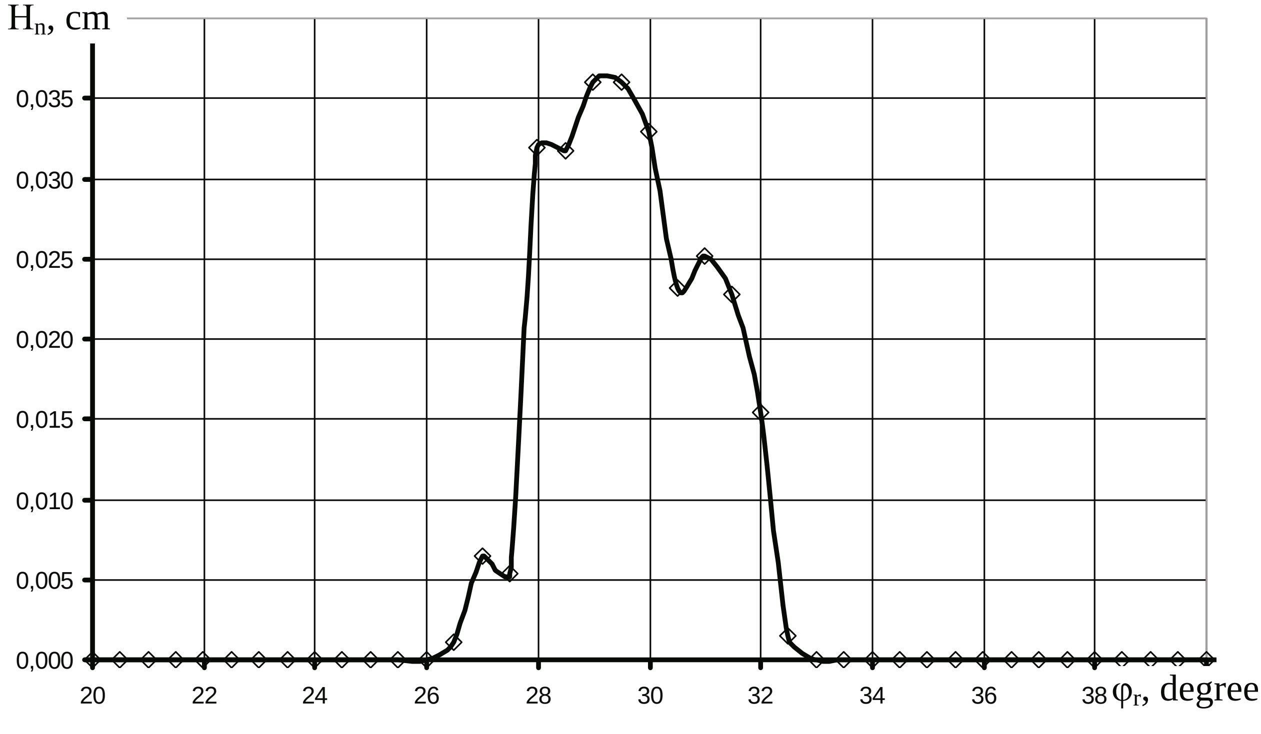

Fig. 4. The dependence of the injector needle height H_n on the camshaft rotation angle of the pump φ_r: high pressure pump 8NK-10; n_r = 350 mm^{-1}; Q_c = 190 mm^3

When changing the high speed regime or the position of the fuel pump rod in the fuel equipment of diesel there begins a transitional process accounted for changing the initial pressure in force main of the system.

It is established that injection pressure and the cycle fuel feed as well as the character of their change in the course of the cycle are accounted for a considerable degree by the initial pressure in the force main [4].

The peculiarities of the transitional process in the diesel fuel systems are such that under different combinations of the pump rod position and its high speed regime the initial pressure in force main either rises or lowers and the cycle fuel feed correspondingly changes for example at the diesel start.

Let us prove this, using the theory of the transitional process by applying the method of small inclinations at that [5].

Before starting the diesel it is proposed to realize some quantities of fuel cycles the regime of revolving the camshaft with out of work injectors.

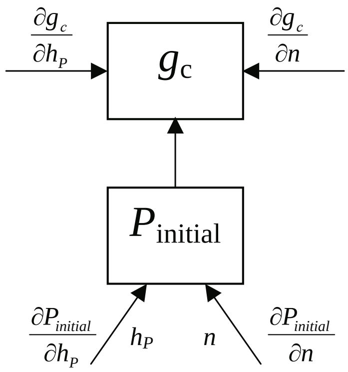

Fig. 5. The structural scheme of interconnection parameters of the fuel feed process for functional dependencies:

$$g_c = f(n, h_p, P_{initial}), \tag{1}$$

$$P_{initial} = f(n, h_p). \tag{2}$$

Here g_c, n, h_p, $P_{initial}$ – the cycle fuel feed camshaft rotation frequency of the fuel pump, the position of the fuel pump rod and the initial pressure in the force main correspondingly.

$$\Delta g_ц = \left(\frac{\partial g_{initial}}{\partial n}\right)_{n=n_0} \cdot \Delta n + \left(\frac{\partial g_{initial}}{\partial h_P}\right)_{h_P=h_{P0}} \cdot \Delta h_P + \left(\frac{\partial g_c}{\partial P_{initial}}\right)_{P_{initial}=P_{initial0}} \cdot \Delta P_{initial}\ , \tag{3}$$

$$\Delta P_{нач} = \left(\frac{\partial P_{initial}}{\partial n}\right)_{n=n_0} \cdot \Delta n + \left(\frac{\partial P_{initial}}{\partial h_P}\right)_{h_P=h_{P0}} \cdot \Delta h_P\,. \tag{4}$$

After transformations:

$$\Delta g_ц = \left(\frac{\partial g_c}{\partial n} + \frac{\partial g_c}{\partial P_{initial}} \cdot \frac{\partial P_{initial}}{\partial n}\right) \cdot \Delta n + \left(\frac{\partial g_c}{\partial h_P} + \frac{\partial g_c}{\partial P_{initial}} \cdot \frac{\partial P_{initial}}{\partial h_P}\right) \cdot \Delta h_P\,. \tag{5}$$

After introduction the influence function (factors) N_{ng} and N_{hg} of the independent variables n and h_p on the function g_c.

$$g_ц = N_{ng} \cdot \Delta n + N_{hg} \cdot \Delta h_p\ , \tag{6}$$

$$N_{ng} = \frac{\partial g_c}{\partial n} + \frac{\partial g_c}{\partial P_{initial}} \cdot \frac{\partial P_{initial}}{\partial n}, \tag{7}$$

$$N_{hg} = \frac{\partial g_c}{\partial h_P} + \frac{\partial g_c}{\partial P_{initial}} \cdot \frac{\partial P_{initial}}{\partial h_P} \cdot \quad (8)$$

The factor of the direct influence on g_c of the independent variables n and h_p:

The particular factors of influence (Figure 5):

$$K_{ng} = \frac{\partial g_c}{\partial n}, \quad K_{hg} = \frac{\partial g_c}{\partial h_P}, \quad (9)$$

$$K_{nPg} = K_{nP} \cdot K_{Pg} = \frac{\partial P_{initial}}{\partial n} \cdot \frac{\partial g_c}{\partial P_{initial}}, \quad (10)$$

$$K_{hPg} = K_{hP} \cdot K_{Pg} = \frac{\partial P_{initial}}{\partial h_P} \cdot \frac{\partial g_c}{\partial P_{initial}}, \quad (11)$$

$$N_{ng} = K_{ng} + K_{nPg}, \quad N_{hg} = K_{hg} + K_{hPg}. \quad (12)$$

The factors $K_n p_g$ and $K_h p_g$ characterize a dynamic sensibility of the fuel system to the change of the high speed and load regimes. The indices K_{ng} and K_{hg} correspondingly reflect the form of high speed and load characteristics of the fuel system at the steady regime (SR).

Starting regimes:

$\Delta g_c'' = -N_{hg} \cdot \Delta h_p$ (decreasing the pump efficiency),

$\Delta g_c' = K_h p_g \cdot \Delta h_p$ (is expending on the rise of $P_{initial}$),

The cycle feed change under simultaneous changing n and h_p

$$\Delta g_c^{HYP} = N_{hg} \cdot \Delta n + N_{hg} \cdot \Delta h_p. \quad 13).$$

Depending on chosen range of star frequency on the area of the rod motion, the camshaft rotation before diesel starting can result in loading the force main up to rises $P_{initial}$ (increasing the cycle feed) or to its (force main) unloading still before the start injections (the absence of start feed).

Conclusions

1. As a result of numerical experiments some peculiarities of the fuel feed process have been revealed at the diesel start regime.
2. The possibility of improving the indices of the fuel feed process at the starting regime by means of high speed forcing the fuel pump.
3. It is offered fuel feed to raise the initial pressure in the force main of the fuel system by an earlier camshaft rotation with out of work injectors (before start camshaft rotation).

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