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DEVELOPMENT OF A FUEL PUMP CONTROL DEVICE FOR A DIESEL ENGINE

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Modern vehicle engines in operation, especially those in urban environments, have low load rate. Low loads and idling modes [1] are make up more than 50% of total performance. Therein fuel expenditure increases and environmental indicators deteriorate. The problem of operational economic and environmental performance increase is relevant. In the work [2] the electromechanical fuel supply control system of internal combustion engine on partial engine operating modes was considered.The studies of passenger traffic conducted in [3, 7-10] confirm incomplete vehicle engine load when operating in urban mode. The operational fuel efficiency of vehicle diesel engine is determined by the efficiency of partial load modes conducted by the studies [4, 5].

In traditional for vehicle diesel engines scheme of fuel equipment with fuel injection pump camshaft solid drive, two mechanical moderators are used: h_r which is automatic pump control rod position moderator and centrifugal coupling for automatic change of the Θ fuel injection advance angle. When switching to a new drive [5], which provides adjustable uneven camshaft rotation, in addition to these two parameters, the third parameter – the Δj uneven camshaft rotation degree should also be changed depending on diesel engine speed rate. All the new drive designs developed make it possible to simultaneously change the Δj and Θ parameters under the influence of one uneven rotation drive automatic moderatorwhich is common to them.

The principles of these values regulation are explained in [6]. If an all-mode moderator is used on the engine, then its speed rate is determined by the accelerator pedal position (fuel pump control lever). In this case, a special moderator for pump drive is not needed, since the regulating effect can be obtained from the same lever. At the same time, the constant values of the j_{max} maximum gearing ratio and the Θ injection advance angle, which are optimal for the full-load curve modes. These characteristics have rather high gradient, therefore, the discrepancy between the rotational rate values and the rotation unevenness rating, as well as the rotational rate and the injection advance angle, can be neglected.

When a fuel injection pump operates with a new drive, its camshaft rotates unevenly with a periodically varying (within each shaft rotation) rotational speed. Therefore, preserving the principle of governor flyweight connection to a camshaft adopted in the traditional fuel equipment scheme can lead to moderator malfunction associated with the occurrence of control rod high-amplitude oscillations, which can cause change in the fuel supply, and in some cases disrupt the entire pump sections operation. To eliminate these negative phenomena, the fuel equipment layout diagram must be changed so that smooth running is transmitted from diesel engine camshaft to load holder, bypassing the uneven rotating shafts of a new fuel injection pump drive.

The developed automatic uneven rotation drive moderator belongs to the class of moderators with an inertial sensitive element and is designed to control the fuel pump shaft uneven rotation rating and the fuel injection advance angle depending on the n frequency rotation of the diesel engine shaft. The specified regulation is made by a corresponding cam plates turn [5] at the δ_1 and

δ_2 angles while the Δj rotational unevenness rating is determined by the δ angle of the relative cam plates shift

$$\delta=(\delta_1-\delta_2)/2=0...6°, \quad (1)$$

and the Θ injection advance angle is determined by the Δ angle of their joint turn

$$\Delta=(\delta_1+\delta_2)/2+0...6°. \quad (2)$$

The analysis of this automatic controller operating conditions on the YaMZ and KamAZ diesel engines showed that the moderator output link will be affected by cam plates with a total alternating moment, the maximum value of which is estimated to be 30 ... 40 Nm at a constant injection advance angle ($\delta_2= -\delta_1$) and the level of 70 ... 100 Nm at a variable injection advance angle ($\delta_2\neq -\delta_1$). Furthermore, for all sections of plungers active stroke, this moment has one definite sign (here it seeks to reduce the δ and Δ angles). Consequently, designed moderator operating conditions are similar to the operating conditions of the automatic injection advance angle change coupling, and therefore the design of this coupling was taken as the basis for this mechanism design.

In this mechanism, the half coupling shift by a certain angle causes a proportional gear 11 rotation and a corresponding cam plates turn on the δ_1, δ_2 angle. By combining the stiffnesses and initiation of spacer springs installed in the centrifugal coupling, one can obtain the required $\delta(n)$ and $\Delta(n)$ characteristics of moderator operating. The method for determining the δ and Δ angles, providing the specified values of the Δj speed rotation unevenity rating and the Θ injection advance angle, was described in [5].

A constructive scheme for the automatic moderator of fuel injection pump camshaft uneven rotation drive has been developed.

At the rotation rating of n=300 min^{-1}, on the control rod shift oscillogram, there were visible areas of sharp change in the nature of the movement, indicating breaks in the kinematic chain. In the n=500…600 min^{-1} frequency range, a significant (resonant) oscillations amplitude increase is observed.

Besides control rod oscillations, the experiment demonstrated significant "demolition" of the all-regime moderator at frequency, which is revealed in shifting of control rod average position due to governor flyweight uneven rotation. Moreover, at frequencies of smaller and larger resonant, this shift occurrs in different directions.

The presence of such a shift is a sign that the system under study has parametric resonance point in the frequency range n=500…600 min^{-1}. To explain the cause of this resonance, let us consider simultaneous equations (3–4) describing the operation of all-regime controller at the ω_{sr} constant average pump shaft rotation rating;

$$(J(y)\cdot\omega)''=Z_u\cdot(\omega_v(t)-\omega), \quad (3)$$

where $J(y) = J_0 + m_{gr}\cdot y^2$ is conversion load inertia of parts rotating along with moderator driven half-coupling; $\omega = \omega_r'$ is instantaneous half-coupling angular rate (the sign " $'$ " denotes t time differentiation); Z_u is spring stiffness; $\omega_v(t) = = \omega_{sr}\cdot(1 + \Delta\omega\cdot\cos(8\cdot\omega_{sr}\cdot t))$ is camshaft angular spin rate;

here m_{gr} is weight; $y = i_r\cdot h_r$ is the deviation of weight mass center from spinning axis; $\Delta\omega \approx 8\cdot\Delta\Phi$ is the degree of shaft uneven rotation;

at the same time, i_r is the gearing ratio between the h_r control rod movements and load mass center; $\Delta\Phi$ is camshaft oscillations amplitude; number 8 corresponds to the number of pump plungers;

$$m_r\cdot h_r''+ (j_{pr}\cdot Z_{pr} - \alpha\cdot m_{gr}\cdot\omega^2)\cdot h_r = j_{pr}\cdot F_{pr0}, \quad (4)$$

where m_r is parts reduced mass moving along with the control rod (including weight); j_{pr} is gearing ratio between the change in spring length and control rod movement; Z_{pr}, F_{pr0} are stiffness coefficient and moderator spring pretension; $\alpha = i_r\cdot j_r^2$; here j_r is the gearing ratio between moderator shaft and pump camshaft.

Simultaneous equations solving (3 – 4) can be found as the sum of the Fourier series

$$h_r(t) = a_0 + \Sigma a_1\cdot\cos(j\cdot 8\cdot\omega_{sr}\cdot t), \quad (5)$$

whereas the a_0 coefficient, which determines the $h_{r.sr}$ control rod average position over oscillation period, and the a_1 coefficient, which determines the Δh_r fundamental component amplitude, at small $\delta\cdot\omega$ values the following formulas correspond:

$$h_{r.sr} = f_0 / \omega_0^2 \cdot (1 - 0.5\cdot(\delta\cdot\omega)^2 / (A - 1)); \quad (6)$$

$$\Delta h_r = \delta\cdot\omega\cdot f_0 / \omega_0^2 \cdot (1 - A), \quad (7)$$

where $A = (\omega_0 / (8\cdot\omega_{sr}))^2$.

In the following formulas:

$$\omega_0^2 = (j_{pr}\cdot Z_{pr} - \alpha\cdot m_{gr}\cdot\omega_{sr}^2) / m_r; \quad (8)$$

$$f_0 = j_{pr}\cdot F_{pr.0} / m_r; \quad (9)$$

$$\delta\cdot\omega = (1/32)\cdot\alpha\cdot k\cdot(m_{gr} / m_r)\cdot\Delta\omega, \quad (10)$$

where $k = (Z_u / J(y_0)) / (8\cdot\omega_{sr})^2$.

As $\delta\omega \sim \Delta\omega \sim \Delta\Phi$, then while $A < 1$ with $\Delta\omega$ camshaft uneven rotation increase, the fuel supply should decrease, thus while $A > 1$ it should increase, which is confirmed in the experimental study course (Table 1 and Fig. 4).

When $A \approx 1$, an unlimited control rod oscillation amplitude increase can occur (parametric resonance). It should be noted that resonance phenomena are observed in these modes with oscillation amplitude usual for a camshaft $\Delta\Phi \leq 0.5°$, but in this case they are much more marked and their influence zone is expanded.

The principal and structural scheme of the automatic moderator for uneven rotation drive is developed and new layout schemes of fuel equipment fitted with uneven rotation drive of fuel pump camshaft are proposed.

In the course of engineless testing, the efficiency of the new moderator as well as the drive and all fuel equipment assemblies under the conditions of camshaft pump controlled uneven rotation was confirmed. At the same time, in a number of idling modes, a significant control rod oscillation amplitude increase was revealed, which is associated with resonance phenomena in the fuel injection pump mechanical moderator. The ways to eliminate these negative phenomena are outlined.

References

1. N. N. Patrakhalcev, S. V. Strashnov, I. S. Melnik, B. A. Kornev, "Izminenie chisla rabotayushchikh cilindrov dizelya – variant povysheniya ekonomichnosti ego rezhymov malyh nagruzok", Avtomobilnaya promishlennost, Moskva, № 2, pp. 11 – 13, 2012.
2. Perdulak, J., Kovac, D., Kovacova, I., Ocilka, M., Gladyr, A., Mamchur, D., Zachepa, I., Vince, T., Molnar, J. Effective utilization of photovoltaic energy using multiphase boost converter in comparison with single phase boost converter (2013) Komunikacie, 15 (3), pp. 32-38.
3. M. M. Moroz, S. O. Korol, Y. O. Boiko, "Social traffic monitoring in the city of Kremenchuk", Actual Problems of Economics, № 1 (175), pp. 385 – 398, 2016.
4. N. N. Patrahalcev, "Neustanovivshyesya regymy raboty dvigatelei vnutrennego sgoraniya: Monografiya, M., RUDN, 380p., 2009.
5. S. O. Korol, M. M. Moroz, S. S. Korol, S.A. Serhiienko, "Method and device for increase of weight charging of four-stroke engine cylinders", Scientific Bulletin of NMU, № 5 (161), pp. 56 –61, 2017.
6. M. M. Moroz, S. O. Korol, S. M. Chernenko, Y. O. Boiko, O. M. Vasylkovskyi, "Driven camshaft power mechanism of the vehicle diesel engine fuel pump", International Journal of Engineering and Technology (UAE), №7 (4), pp. 135 – 139, 2018.
7. N. Shramenko, D. Muzylyov, M. Karnaukh, "The principles of the choice of management decisions based on fuzzy logic for cargo delivery of grain to the seaport", International Journal of Engineering and Technology (UAE), №7 (4.3 Special Issue 3), pp. 211–216, 2018.
8. N. Y. Shramenko, "Methodology for evaluation of synergy effect in terminal cargo delivery system", Actual Problems of Economics, № 182(8), pp. 439–444, 2016.

I. M. Trunina, V. G. Zahorianskyi, O. L. Zahorianska, D. V. Moloshtan. Ensuring Competitiveness of Logistics Service by Selecting the Type of Storing Single-Piece Cargoes. International Journal of Engeneering and Technology. Vol. 7, No. 4.3 (2018). Special Issue 3. P. 537–544.

9. Moroz, Mykola M. Defining the term and the volume of investments on reduction to necessary structure of rolling stock of passenger public transport (Kremenchuk city case study) / Moroz, Mykola M. // Actual Problems of Economics / Aktual'ni Problemi Ekonomiki. – 2015, Vol. 166 Issue 4, p235–243.