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José María Pino Suárez 400-2 esq a Lerdo de Tejada. Toluca, Estado de México. 7223898475
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**TÍTULO:** Evaluación de la eficiencia de la Técnica del Dispositivo de Simplificación de Lanzamiento del motor frío del automóvil.

**AUTORES:**

1. Ilnar F. Suleimanov.
2. Damir A. Kharlyamov.
3. Aleksandr T. Kulakov.
4. Ruslan F. Kalimullin.
5. Alexander V. Kazakov.

**RESUMEN**. El artículo revela la contradicción entre el enfoque tradicional y el propuesto para la evaluación de la eficiencia de la técnica del dispositivo de simplificación de lanzamiento del motor frío (CCELSD), condicionado por la necesidad de tener en cuenta los procesos de desgaste del elemento en movimiento durante el arranque. Se propone un nuevo enfoque para evaluar la efectividad de CCELSD, basado en la capacidad de estos dispositivos para reducir el desgaste de los elementos móviles, presentándose una nueva metodología para la evaluación de la eficiencia de CCELSD, que tiene en cuenta los cambios en la tasa de desgaste del cojinete de cigüeñal en el modo de puesta en marcha por los indicadores del proceso de lubricación.

**PALABRAS CLAVES:** dispositivos de arranque, motor de automóvil, modo de arranque, tratamiento térmico, proceso de lubricación.

**TITLE:** Evaluation of the efficiency of the technique of the Launch Simplification Device of the automobile cold engine.

**AUTHORS**:

1. Ilnar F. Suleimanov.
2. Damir A. Kharlyamov.
3. Aleksandr T. Kulakov.
4. Ruslan F. Kalimullin.
5. Alexander V. Kazakov.

**ABSTRACT.** The article reveals the contradiction between the traditional approach and the one proposed for the evaluation of the efficiency of the cold engine launching simplification device (CCELSD) technique, conditioned by the need to take into account the wear processes of the moving element. during startup. A new approach is proposed to evaluate the effectiveness of CCELSD, based on the ability of these devices to reduce the wear of mobile elements, presenting a new methodology for evaluating the efficiency of CCELSD, which takes into account changes in the rate wear of the crankshaft bearing in the start-up mode by the indicators of the lubrication process.

**KEY WORDS:** start-up devices, car engine, start-up mode, heat treatment, lubrication process.

**INTRODUCTION.**

Winter operation is a rather severe test for the use of technology in any industry, including the automobile one [N.V. Semenov, 1993; G.S. Losavio, 1973].

Car manufacturers and traffic regulations recommend to drive immediately after the engine is started, which is primarily due to the requirements of harmful substance emission reduction from exhaust gases. The violation of the thermal regime and the lack of due attention to the process of preparing cars for load taking, causes the deterioration in the starting characteristics of engines, the accelerated wear of the units, increasing the risk of their failure. Thus, in the current problem situation, it is necessary to solve the tasks of pre-launch preparation of automobile engines before it starts. It is important not only to improve the performance of their starting qualities, but also to minimize the costs and the losses associated with the wear of the frictional surfaces [A.S. Denisov, A.T. Kulakov, 2007].

The use of different CCELSD is one of the solutions to this problem [V.S. Naiman. 2007; V.V. Robustov, N.G. Pevnev, S.G. Fomin, A.P. Zhigadlo, 1999]. The use of these devices should be cost-effective and take into account the parameters of the engine and the conditions of car operation. The existing methods and means of car thermal preparation are obsolete and have a number of shortcomings, and a rational choice of methods and devices to facilitate the start of a cold engine is difficult due to the lack of scientifically based methods for their selection.

## DEVELOPMENT.

In this regard, the study is aimed at the methodology development to evaluate the effectiveness of devices and to facilitate the start of a cold engine. The study is relevant and fits into the concept of road transport use efficiency improvement in modern conditions.

### Methods.

The main scientific statements and results presented in the article are based on previously developed theoretical positions and the results of experimental studies of car engine operational reliability, the use of tribodiagnostics methods and the study of change patterns in the technical condition of cars and units [P R.F. Kalimullin. 2016; K.V. Podmasteryev. 2012; N.N. Yakunin, R.F. Kalimullin, 2014; K. Holmberg, P. Andersson, N-O.Nylund, K. Mäkelä, A. Erdemir, 2014; Priest, M. and C.M. Taylor, "2000; Stachowiak, Gwidon W. and Andrew W. Batchelor, 2006; S.C. Tung, M.L. McMillan, 2004].

It is proposed to evaluate the effectiveness of CCELSD in terms of efficiency evaluation, equal to the ratio of the economic effect value in operation and the engine durability increase (tribological effect) to the costs that ensured this effect. This indicator $K_{IQ}$ for a single start is determined by the following formula:

$$K_{IQ} = \frac{K_I - (K_Q + K_S)}{K_Q + K_S} = \frac{K_I}{K_Q + K_S} - 1, \qquad (1)$$

where $K_I$ is the cost savings resulting from increased engine durability, rub.; $K_Q$ - the costs of fuel (energy) for CCELSD operation, rub.; $K_S$ - the cost of the acquisition and installation of CCELSD, rub.

The values of dependence (1) components are determined by the formula (2) and (3):

$$K_I = R_L L_{\text{ПИ}} \left( 1 - \frac{I_i^{\text{ПП}}}{I_i^{\text{БС}}} \right), \qquad (2)$$

where $R_L$ is the value of the costs for engine restoration, per 1 km of the car drive, rubles/km; $L_{PI}$ - mileage equivalent for wear during a single start, km; $I_i^{\text{Ï Ï}}$ and $I_i^{\text{ÁÑ}}$ - the values of bearing wear intensity indicator in the start-up mode with the use of CCELSD and without it (in the base state);

$$K_Q = R_Q ( Q_T^{\text{Ï Ï}} - Q_{\text{Ò}}^{\text{ÁC}} ) + C_{1\text{åä.ý}} W_{\text{Ý}} , \qquad (3)$$

where $R_Q$ is the price of 1 l. of fuel, rub.; $Q_{\text{Ò}}^{\text{Ï Ï}}$ and $Q_{\text{Ò}}^{\text{ÁÑ}}$ - the amount of fuel consumed by the engine during warm-up to a predetermined temperature with the use of CCELSD (preheating) and without it, respectively, l; $C_{1\text{ед.э}}$- the price of 1 l. of consumable fuel (1 kW of network electric power) during the operation of CCELSD, rub./l (rub./kW); $W_{\text{э}}$- fuel consumption (electric power network) during CCELSD operation, l (kW).

The values of RL are determined from the statistical data on the cost of specific engine performance restoration, per 1 km of the car drive; $R_Q$ and $C_{1ед.э}$ are taken based on the cost of 1 liter of fuel and 1 kW of electrical energy, $W_Э$ is taken into account based on CCELSD power and the duration of work; $K_S$ is taken into account on the basis of CCELSD purchase and installation cost for the car, the period of operation.

To determine the $L_{PI}$, the formula proposed by G.S. Losavio can be used [2]:

$$L_{ПИ} = \frac{270}{T^0_{ДВ} + 40}, \quad (4)$$

where $\grave{O}^0_{\ddot{A}\hat{A}}$ is the initial temperature of the engine, °C.

To assess the wear rate of crankshaft bearing indirectly, it was introduced the new parameter Ii - "specific integrated wear rate of crankshaft bearings". The value of the parameter Ii shows the proportion of crankshaft bearing wear intensity at the current engine operation mode compared to the wear rate in the rated power mode with a constant contact interaction of the bearings. The parameter is dimensionless and takes the value from 0 to 1.

Its current value $I_{i.x}$ is determined by the following formula:

$$I_{i.x} = (1 - E_{g.x})\frac{N_{i.x}}{N_i^{max}}, \quad (5)$$

where $E_{g.x}$ is the current value of the parameter “the integral degree of the lubricant layer in the crankshaft bearings”; $N_i^{max}$ and $N_{i.x}$- is maximum and current indicator engine power, respectively, kW.

In the start-up mode, the engine is idling and, based on the theory of internal combustion engines, the indicator power is equal to the power of mechanical losses, and the formula (5) takes the following form:

$$I_{i.x} = (1 - E_{g.x})\frac{n_x(a_м + b_м S n_x / 30)}{n^{max}(p_e^{max} + a_м + b_м S n^{max} / 30)}, \qquad (6)$$

where $a_м$ and $b_м$ are the empirical coefficients, the values of which depend on the number of cylinders, the ratio of the piston stroke to the diameter of the cylinder and engine type; S – piston stroke, m; $n_x$ and $n_{max}$ - current and nominal crankshaft speed, $min^{-1}$; $\check{ð}_e^{max}$ - the average effective pressure at nominal frequency, MPa.

The parameter Eg "the integral degree of the lubricant layer in the crankshaft bearings" is known [6] and is used for a generalized assessment of the lubrication process quality in the crankshaft bearing system. During operation, the value of the parameter Eg takes the values from 0 to 1 and depends on a large number of factors:

$$E_g = f(M, n, \Delta, \mu(T_M), T_{MП}, p_П), \qquad (7)$$

where M is the crankshaft torque, Н·м; n - crankshaft rotational speed, min-1; $\Delta$ - the diametral clearance in the bearing, m; $\mu(\grave{O}_{\hat{I}})$- the dependence of the dynamic viscosity of oil (Pa x s) on the oil temperature $\grave{O}_{\hat{I}}$ (°C); $T_{MП}$ - oil temperature at the bearing inlet, °C; $p_П$ - oil pressure at the bearing inlet, Pa.

When the engine is operating in the start-up mode, the values of the parameters Δ and $\mu(\grave{O}_{\hat{I}})$ are constant in the model (7), and the parameters n, $T_{MП}$ and $p_П$ depend on mode duration τ; therefore, during the start-up mode, the study of the lubrication process regularity is carried out according to the model $E_g$ ($T_{MП}$, n, τ).

When the engine is idling and heated, the values of the parameter $E_{g.x}$ depend on the current values of the crankshaft rotation speed $n_x$, the initial engine temperature $\grave{O}^0_{\ddot{A}\hat{A}}$, the warm-up time $t_x$ and the engine thermal state $T_S$ before starting:

$$I_{i.x} = f(E_{g.x}, \grave{O}^0_{\ddot{A}\hat{A}}, n_x, \grave{O}S, t_x). \qquad (8)$$

The parameters included in the formula (8), $I_i^{\text{Ï Ï}}$ , $I_i^{\text{ÁÑ}}$, $Q_{\text{Ò}}^{\text{Ï Ï}}$ and $Q_{\text{Ò}}^{\text{ÁÑ}}$ are the functions of $\text{Ò}^0_{\text{ÄÂ}}$.

With this in mind, $\hat{E}_{IQ} = f(\text{Ò}^0_{\text{ÄÂ}})$.

The use of CCELSD is effective at $\hat{E}_{IQ} > 0$, and ineffective at $\hat{E}_{IQ} \leq 0$.

The technique has been developed for CCELSD selection taking into account the specifics of car operating conditions [13].

The technique contains the following steps:

Stage 1 - the selection of test objects. The selection of the j-th automobile engine (ADj) for testing and the determination of costs by the statistical data to restore its working capacity per 1 km of run ($R_{Lj}$). The selection of the i-th CCELSD for testing and the determination of the costs for its acquisition and installation $K_{Sij}$.

Stage 2 - the testing of objects in the start mode. The testing of ADj (according to GOST R 53840-2010) in the range of ambient temperatures $T_{\text{ос}} \in [T_{\text{ос.min}}; T_{\text{ос.max}}]$ and the experimental determination of the dependences $I_{ij}$ ($T_{\text{дв}}$), $Q_{Tij}$($T_{\text{дв}}$) in two variants of AD configuration: in the base one and with CCELSD.

Stage 3 - the calculation of the conditions for the rational use of CCELSD. The calculation and the development of the dependences $K_{Iij}$ ($T_{\text{дв}}$); $K_{Qij}$ ($T_{\text{дв}}$). The development of the dependence $K_{IQij}$ ($T_{\text{дв}}$) = $K_{Iij}$ ($T_{\text{дв}}$)/($K_{Qij}$ ($T_{\text{дв}}$)+$K_{Sij}$)-1 and the finding of the range [$T_{\text{двijmin}}$; $T_{\text{двijmax}}$] at which $K_{IQij}$>0.

Stage 4 - the choice of rational CCELSD for AD. According to the model $K_{IQij}$ ($T_{\text{дв.доп}}$) the average value of the parameter $(m\hat{E}_{IQ}{}^{ij})^{\text{Ò}^{ij}_{\text{äâ.max}}}_{\text{Ò}^{ij}_{\text{äâ.min}}}$ is determined and CCELSD is selected according to the condition of maximum efficiency $(m\hat{E}_{IQ}{}^{ij})^{\text{Ò}^{ij}_{\text{äâ.max}}}_{\text{Ò}^{ij}_{\text{äâ.min}}} \rightarrow (m\hat{E}_{IQ}{}^{ij})_{\max}$. At this stage, the problem of choosing a rational CCELSD from a certain set of CCELSD and AD is solved.

Stage 5 - the calculation of CCELSD use economic effect. The regularities of the number of AD starts per day are determined from the temperature $T_{дв}$: at the beginning of the working day $S_{t.1}(T_{дв})$ and at the end $S_{t.2}(T_{дв})$. They depend on the mode of start (forcedly by a driver or automatically) and the number of cold starts per day (for example, in the morning and in the evening or an automatic start during parking).

From the data of the third stage, they determine the economic effect $\Delta К_{tij}=К_{Iij}-(К_{Qij}+К_{Sij})$ and the values of this effect at each launch $К_{t.1ij}=\Delta К_{t.1\ ijSt.1}$ and $К_{t.2ij}=\Delta К_{t.2\ ij}S_{t.2}$ at the temperature $\grave{O}^{0}_{\ddot{A}\hat{A}}$ .

Stage 6 - the determination of the start temperature conditions. According to the weather archive data, an array of data on the negative ambient temperature $T_{ос}<0$ is formed at given hours of the day $t_k$ and calendar days Дн: $T_{ос}(t_k,$ Дн$) <0$ in a specific k-th climatic region. The distribution $N_t.Дн_k(T_{ос})$ of the number of days in the year $N_t.Дн_k$ is performed by the ambient temperature $T_{ос}$.

Stage 7 - the choice of rational CCELSD taking into account the temperature characteristics of car operation. The annual economic effect $К_{годijk}=\Sigma К_{t.1ij}N_{t.1}Дн_k+\Sigma К_{t.2ij}\ N_{t.2}Дн_k$ is calculate. According to the sample of settlements for the k-th climatic region, the ranked distribution of $К_{годij}$ values is performed in descending order. This distribution allows you to select specific localities in which the efficiency of car operation is increased through the use of CCELSD, which provides the maximum values of $К_{годij}\rightarrow max$. At this stage, the problem of choosing a rational CCELSD for DA is solved, taking into account the temperature characteristics of car operation in a particular locality and the method of launch [I.T. Kovrikov, A.V. Kazakov, R.F. Kalimullin, 2018].

**Results and Discussion.**

The developed method makes it possible to establish climatic areas for CCELSD to operate motor vehicles by the criterion of the greatest economic efficiency from their use, taking into account temperature conditions.

In summary, the value of research for science lies in the development of methods and practical recommendations concerning the evaluation of existing and prospective CCELSD performance, which allow their selection for specific vehicles taking into account the climatic region of operation. A systematic approach was used, aimed at car operation efficiency improvement by starting quality performance increase, and also by the reduction of costs and losses associated with the wear of frictional pairs during CCELSD use.

Based on the analysis of existing, as well as on the conduct of own theoretical studies, they proposed the analytical dependencies of the lubrication process in the crankshaft bearing of an automobile engine in the start mode.

## CONCLUSIONS.

The practical significance of scientific research is in the fact that the developed theoretical concepts, computational and experimental methods and programs can be used to solve a wide range of urgent problems related to vehicle technical operation efficiency improvement through the effective use of CCELSD.

Theoretical and experimental results of the study can be used in the practice of motor transport enterprises, as well as by the manufacturers of CCELSD at the stages of their design and manufacture.

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**DATA OF THE AUTHORS.**

**1. Ilnar F. Suleimanov.** Kazan Federal University. Email: info@ores.su

**2. Damir A. Kharlyamov.** Kazan Federal University. Email: kharlyamov@gmail.com

**3. Aleksandr T. Kulakov.** Kazan Federal University. Email: global@ores.su

**4. Ruslan F. Kalimullin**. Orenburg State University. Email: info@prescopus.com

**5. Alexander V. Kazakov.** Orenburg State University. Email: global@prescopus.com

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