TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2010, 10A, 91-97

METHOD OF DIAGNOSTICS OF LOCOMOTIVE DIESEL ENGINE1

Oleg Dzetsina, Vitaliy Gladushin

Volodymyr Dal East-Ukrainian National University, Lugansk, Ukraine

Summary. The modern state of locomotive equipment of railway transport of Ukraine is considered in the article. The renewal of park of locomotives due to modernization supposes the change of the system of technical maintenance and introduction of facilities of the technical diagnostics for the estimation of their technical state.

Key words: main-line and yard diesel locomotives, modernization, systems of diagnostics, internal thermal balance

INTRODUCTION

The periodicity of technical maintenance and repair of traction rolling stock on the railways of Ukraine mainly depends on operating time from the beginning of exploitation or after overhaul [Grybinichenko 2007].

Resource of the locomotives produced in soviet time, will be finished in 2010 according to the prognosis of administration of Ukrzaliznytsa. Therefore the technical maintenances of UkrZaliznytsa had to correct the strategy of providing for transportations on the railways of Ukraine [Blokhin 2007, 3 2007].

Board of State Administration of Railway Transport of Ukraine (UkrZzaliznytsa)) in June, 1998 confirmed the Program of restructuring on the railway transport of Ukraine. The directions of perfection of management by a locomotive economy are ascertained in this program. Basic directions of this program are bringing the capital funds, labor and financial resources in correspondence to the requirements of needs of national economic complex and people in transportations, as well as reduction of expenses by introduction of resource-saving technologies.

In modern economical conditions the prospect of replacement of diesel locomotives on new ones and more economical is hardly probable. It remains to acknowledge that the most real way is the modernization of existing diesel locomotives, on which many repair enterprises got up already.

RESEARCH OBJECT

A considerable amount of main-line and yard locomotives of 70-80th is equipped by the four-stroke diesels of D49 type. Technical data of diesels of some yard locomotives is resulted in a table 1, data of main-line ones is given in a table 2.

Table 1. **Technical data of diesels of some yard locomotives**

Basic indexes	Series of diesel engines			
	TEM5	TGM6A	TEM12	TEM7
Type of diesel)	6Д49	3А— 6Д49	6Д49	2-2Д49
Rated effective horse-power, hp	1200	1200	1200	2000

Table 2. **Technical data of diesels of some main-line locomotives**

locomotive	Diesel-generator	Type of engine	RPM	Total power
-	-	-	rpm	kW
2TE10MK	1A-9DG	1A-5D49	850	2206
TE129,142	2-9 DG	2-5D49	1000	2942
2TE116	1A-9 DG	1A-5D49	1000	2250
2TE121	2B-9 DG	2B-5D49	1000	2942
TE136	1-20 DG	1D49	1000	4412
2TE116УП	11-EDG	11-5D49	1000	2650

The system of scheduled preventive-maintenance and repair of traction rolling stocks is applied for a railway transport. Conception of the system of technical maintenance and repair of traction rolling stock on the actual technical state is offered in the last years. This conception supposes the presence of the complex system of diagnostics of traction rolling stock

Strategy of technical maintenance and repair of rolling stock taking into account the technical state is based on the method of control of parameters level. Informative basis of this method is the technical diagnostics for which it is necessary to determine the composition of diagnostic parameters, proactive admittances on parameters, periodicity of control of the technical state.

A mean prime cost of repair of D49 diesel in relation to the total prime price of repair of locomotive makes 44%, and the unplanned repairs on a diesel group make approximately 46%. So decreasing of expenses on repair of diesels in locomotive equipment is one of actual tasks [Sergienko 1999, Pushkarev 1985].

In these terms the actuality of application of facilities of the technical diagnostics increases for the estimation of the technical state of diesel locomotives and, in the first turn, of its power set.

RESULTS OF EXPEREMENTAL RESEARCH

The analysis of methods of the technical diagnostics allowed select the parametric method [Nikitin 1987] as basic at the estimation of the technical state of power aggregate. The locomotive has a few parameters, characterizing quality of his functioning, such as: power at the set number of revolutions; economical operation; ecological characteristics

The diagnostics is beginning with control of these functional parameters. The determining parameters are the following: rated effective power **Ne**; specific effective consumption of fuel $\mathbf{g_e}$; pressure $\mathbf{P_s}$ and temperature $\mathbf{t_s}$ of supercharging air; temperature of exhaust gases on the cylinders $\mathbf{t_r}$; temperature of water on an outlet from the diesel $\mathbf{t_w}$; pressure $\mathbf{P_m}$ and temperature of oil on inlet into the diesel.

Effective power of the diesel-generator set **Ne** is determined on strength of current and voltage, which are produced by a generator:

$$Ne = 1{,}314 \cdot U \cdot (J_1 + J_2 + J_3),$$

where: U - voltage, produced by a generator, V; J_1, J_2, J_3 is strength of current in the first, second, third windings of generator, A; 1,314 is a conversion factor.

The fuel consumption per hour $\mathbf{G_T}$ is measured by means of flowmeter and is calculated on dependence as follows:

$$G_T = 3600 \cdot \frac{\Delta G_T}{\Delta \tau}$$

where: ΔG_T - fuel consumption for certain period of time $\Delta\tau$;.

Knowing the fuel consumption per hour it is possible to determine the specific effective consumption of fuel $\mathbf{g_e}$ on dependence:

$$g_e = \frac{10^3 \cdot G_T}{Ne}$$

Thus, determining basic parameters and comparing them to the factory values we draw a conclusion about the technical state of diesel on the whole. For a new diesel the specific fuel consumption at rated effective power and normal terms makes $\mathbf{g_e}$ = 151+5% g/hp.hr [Pushkarev 1985].

If even one of parameters falls short of a standard value, it is necessary to establish the reason of this disparity. For this purpose it is necessary to pass to the next level of diagnostics – diagnostics of separate working cylinder of diesel.

The parametric method envisages the periodic and continuous measuring of one or a few diagnostic parameters of diesel, resulted in a table. 3. Except for measuring of these parameters, at diagnostics of diesel we take into account the row of other operating factors (atmospheric conditions, mode of loading, heat of combustion of fuel and so on).

In the parametric method the indicator indexes of working process are basic part of diagnostics parameters, characterizing the heat-engineering state of diesel [Vibe 1962, Gonchar 1968, Razleytcev 1980].

For this purpose it is necessary to measure pressure of gases in a combustion chamber on cylinders with scanning on the turning angle of crankshaft and pressure of injection of fuel to the section-by-section of fuel pump with scanning on time.

Table 3. **Diagnostic parameters of diesel**

Parameters of diagnostics	Measuring limits
Pressure of gases in a combustion chamber on cylinders with scanning on the turning angle of crankshaft, MPa	0—15,0
Temperature of exhaust gases on cylinders, °C	0—600
Consumption of fuel to the section-by-section of fuel pump, kg/hr	0—500
Pressure of injection of fuel to the section-by-section of fuel pump with scanning on time, MPa	0—30,0
mean indicated pressure on the cylinders of engine, MPa	0—2,0
Temperature of supercharging air on cylinders, °C	0—100

A basic index at diagnostics of cylinder is mean indicator pressure. Traditionally it is determined by sensors, set in the combustion chamber. Then the indicator diagram is recorded and processed.

There are alternative methods of estimation of value of mean indicator pressure. One of them supposes the use of the results of analysis of working exhaust gases.

For determination of mean indicator pressure it will be required to measure pressure **Ps** and temperature of air **Ts** on inlet in the cylinder and the coefficient of surplus of air outside a cylinder. Thus the special attention must be taken the question of uniformity of work of separate cylinders.

Value of mean indicator pressure for every cylinder of diesel we can get from dependence of indicator efficiency coefficient as follows:

$$\eta_i = 8314 \cdot \frac{\alpha \cdot L_o \cdot T_S \cdot p_i}{\eta_{v_s} \cdot Q_H \cdot p_S}$$

where: **α** - a coefficient of surplus of air in cylinder; $\mathbf{L_o}$ – theoretical necessary amount of air for combustion of 1 kg of fuel; $\mathbf{T_s}$ - temperature of air before the inlet valves of diesel; $\mathbf{P_s}$ - pressure of air before the inlet valves of cylinder; $\mathbf{P_i}$ - mean indicator pressure; $\boldsymbol{\eta_{Vs}}$ - coefficient of filling; $\mathbf{Q_н}$ - lower calorific value of fuel.

$$p_i = \frac{\eta_i \cdot \eta_{V_s} \cdot Q_н \cdot P_s}{8314 \cdot \alpha \cdot L_o \cdot T_s}$$

The alternative method of estimation of the technical state of every separate cylinder can be a method of determination of mean indicator pressure on the basis of internal thermal balance.

For this purpose the heat-engineering tests of module of D49 diesel were conducted. Methodology of determination of indicator indexes was based on recording the indicator diagram of working cylinder and measuring of necessary parameters at the tests of internal combustion engine.

As a result we have the relationship of the following kind:

$$\eta_i = 1 - q_{yx} - W_{OГ} - \Delta_{HC} \pm \Delta_{HП} - W_{OK}. \qquad (1)$$

where $\mathbf{q_{yx}}$- losses of heat with exhaust gases; $W_{OГ}$ - losses of heat through the wall of cylinder and the cooled collector W_{OK}, incompleteness of combustion Δ_{HC} and pumping losses $\Delta_{HП}$.

In addition, as a result of conducted experiments the relationship of the mode and structural parameters was received as follows:

$$\eta_i = a_0 + at_S + a_1\alpha + a_2\alpha^2 + a_3P_S + \cdots \quad (2)$$

where α - a coefficient of surplus of air in a cylinder at combustion; P_S - pressure of supercharging; a_0, a, a_1, a_2, a_3 - constant values.

The value of η_i is changed during wear of engine. For example, with worsening of the technical state of supercharging air cooler t_S will be changed. Then the change of the technical state of turbo-compressor entails worsening of the following parameters of t_S, P_S, α.

For the standard state of D49 diesel and at its nominal mode at n=1000min^{-1} the equations of regression take the following kind:

$$T_T = a_0 + a_1P_e - a_2P_e^{\,2} - a_3B_C + a_4B_C^{\,2} - a_5\alpha + a_6\alpha^2 - a_7T_S + a_8T_S^{\,2} \quad (3)$$

The equations allow calculate the temperature of working exhaust gases with high accuracy. The accuracy is saved within the varied parameters:

mean effective pressure **P**$_e$=[0,815-1,504] MPa;

coefficient of surplus of air at combustion α =[1,76 3,02];

temperature of supercharging air **Ts**=[322 368] K;

a cycle supply of fuel **B**c=[0,78 1,39] g/cycle.

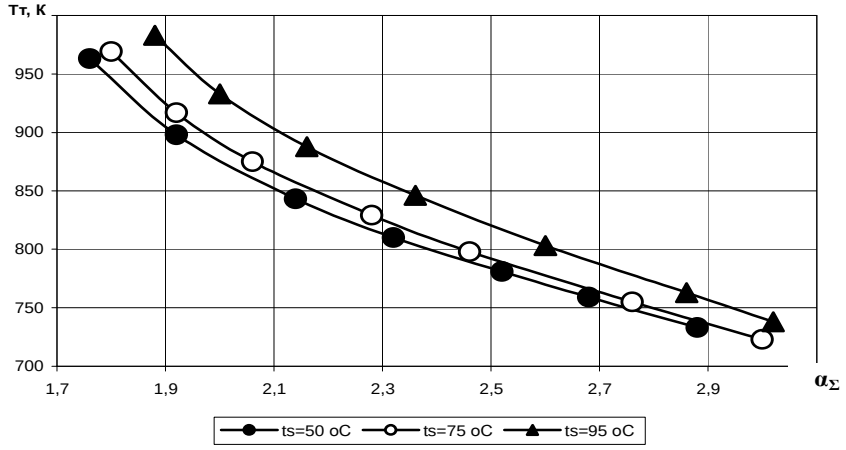

Fig. 1. Dependence of temperature of workings gases from
the total coefficient of surplus of air and the temperature of supercharging air

The equations (3) enable to calculate the standard magnitude of indicator efficiency coefficient and at the varied parameters of t_S, P_S, α, B_C. Difference of values η_i and $\eta_{i\Im}$ is the result of worsening of the technical state of fuel apparatus.

So, the relationships (1), (2), (3).can be taken as diagnostics parameters. Results of experimental research of dependence of temperature of workings gases, mean effective pressure and indicator к.п.д. from the total coefficient of surplus of air presented on pictures 1, 2, 3.

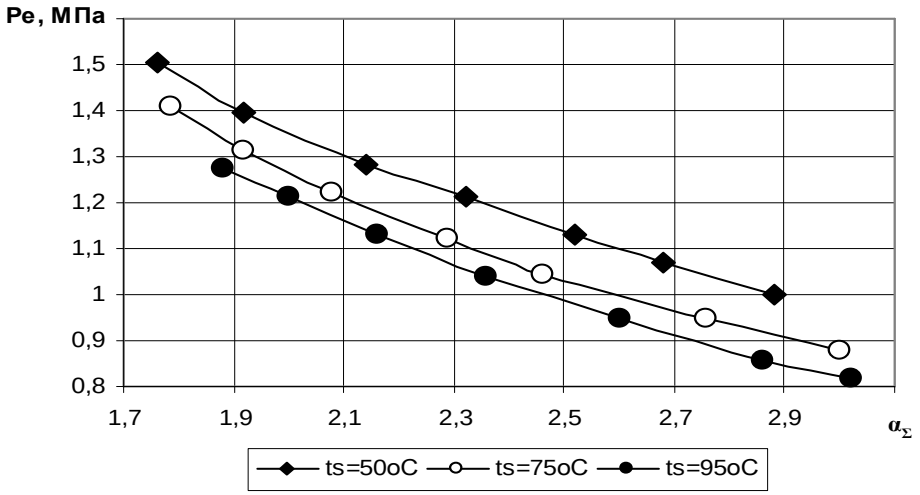

Fig. 2. Dependence of mean effective pressure from the temperature of supercharging air and coefficient of surplus of air

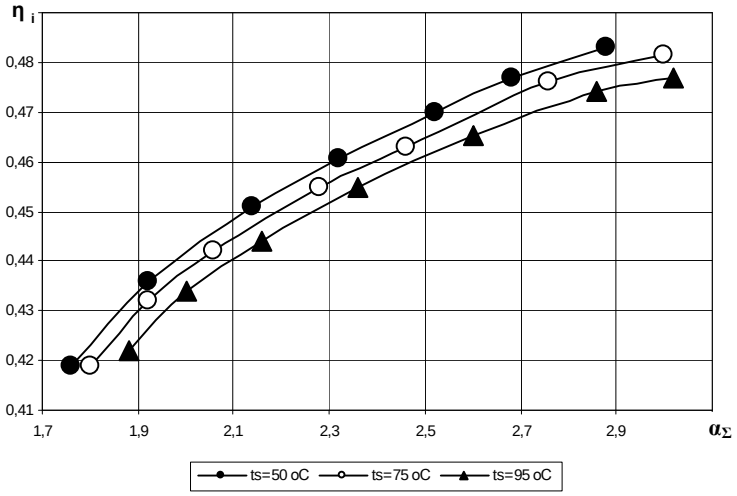

Fig. 3. Dependence of indicated efficiency from the temperature of supercharging air and the total coefficient of surplus of air

CONCLUSION

According to the prognosis of administration of Ukrzaliznytsa service life of the locomotives produced in soviet time, will be finished in 2010.

Presently the basic direction of perfection of the system of scheduled preventive-maintenance and repair of locomotives is their modernization with an introduction of the technical checking and diagnostics systems.

As a result of the conducted researches for the diesels of D49 type, the received relationships of temperature of exhaust gases, mean effective pressure and indicator efficiency from the total coefficient of surplus of air will be used as diagnostics dependences.

Further processing of results of tests allowed to get equation of regression of type of T_t=f (P_e, B_c, α_Σ , T_s), which can be used for the estimation of fuel consumption in every separate cylinder.

Integral estimation of the technical state of every separate cylinder is possible on the value of mean indicator pressure with usage of dependence η_i =f (α).

REFERENCES

1. Grybinichenko M.V., Dzetcina O.P., 2007. Technical maintenance and repair of the transport means of industrial transport. Lugansk, EUNU named after V.Dahl .
2. Blokhin A.S., 2007. About tendencies in development of park of main-line locomotives in 2006—2010th //Zaliznichniy transport of Ukraine. №1. 9-19
3. Complex Program of renewal of railway mobile rolling stock of Ukraine on 2006—2010th, Kyiv, 2006. —27 p.
4. Sergienko N.I., 1999. Ways of cutting of operational costs in the locomotive economy of railways of Ukraine // Zaliznichniy transport of Ukraine, № 4, 28-30.
5. Pushkarev I.F.,Pakhomov E.A.,1985. Control and estimation of the technical state of diesel locomotives.M. Transport.
6. Nikitin E.A. and oth. Diagnostics of diesels.1987. -M.:Mashinostroeniye.
7. Vibe I. I.,1962. New about the working cycle of engines.M.; Sverdlovsk. Mashgiz.
8. Gonchar B. M., 1968. Numerical modeling of working process of diesels. Energomashinostroenie. № 7, 34—35.
9. Razleytcev N. F., 1980. Modeling and optimization of process of combustion in diesels. Kharkov. Higher school.

МЕТОД ДИАГНОСТИРОВАНИЯ ТЕПЛОВОЗНОГО ДИЗЕЛЯ

Дзецина О.П., Гладушин В.В.

Аннотация. В статье рассмотрено современное состояние локомотивного хозяйства железнодорожного транспорта Украины. Обновление парка локомотивов за счет модернизации предполагает изменение системы технического содержания и внедрения средств технического диагностирования для оценки их технического состояния.

Ключевые слова: модернизация, магистральные и маневровые тепловозы, системы диагностики, индицирование, внутренний тепловой баланс.