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PREDICTION METHODOLOGY OF DURABILITY OF LOCOMOTIVES DIESEL ENGINES

METODOLOGIA PROGNOZOWANIA TRWAŁOŚCI SILNIKÓW DIESLA W LOKOMOTYWACH

The article testifies that technical maintenance and repair terms as well as durability can be predicted accordingly to the maintenance parameters of the diesel locomotives. It is determined that fixing fuel consumption and capacity of diesel locomotives and taking in comparison with limit values allows to set a performance date for technical maintenance. Introduced suggested aspects of interrepair resource of the diesels dependent on comparable fuel consumption and evaluating their operating probability without failure for the durability prediction of diesel locomotives. Currently, the most common are three strategies: until failure, scheduled – premonitory and adaptive (diagnostic). When the quantity of necessary technical maintenances is known for the specific kind of diesel locomotives it is possible to determine interrepair resource depending on comparative and required per hour consumption of fuel and predict their durability taking into account probability of operating without failures.

Keywords: *durability, technical maintenance and repairs, locomotive engines, resources, reliability, prediction.*

W artykule wykazano, że częstotliwość przeglądów technicznych į remontów spalinowozów z silnikami diesla można prognozować analizując parametry eksploatacyjne. Obecnie najbardziej rozpowszechnione są trzy strategie: do awarii, planowo-wyprzedzająca i adaptacyjna (diagnostyczna). W konkretnych warunkach zarządzania gospodarczego na pierwsze miejsce wysuwa się specyfika użytkowania spalinowozów, o zaraz po niej – normatywne wymagania techniczne, reglamentujące eksploatację spalinowozów. Ustalono, że poprzez odnotowywanie zużycia paliwa oraz mocy spalinowozów można określić czas eksploatacji, po upływie którego konieczne będzie przeprowadzenie przeglądu technicznego. Przedłożona została teoretyczna zależność okresu międzyremontowego diesli od porównawczego zużycia paliwa, wykorzystywana do oceny prawdopodobieństwa bezawaryjnej pracy oraz zaproponowana metodyka prognozowania trwałości spalinowozów z silnikami diesla. Znając właściwą dla danej marki spalinowozu liczbę przeglądów technicznych, można oszacować okres międzyremontowy w zależności od godzinnego i porównawczego zużycia paliwa oraz uwzględniając ich prawdopodobieństwo bezawaryjnej pracy, w ten sposób prognozując ich trwałość.

Słowa kluczowe: *trwałość, przegląd techniczny į remont, silniki spalinowozów, okres międzyremontowy, niezawodność, prognozowanie.*

1. Introduction

Operating locomotives on the railroad leads to natural obsolescence of the engines as well as other components and details that consequently increases the number of failures. In order to increase operating reliability and durability of locomotive‘s diesel engines it is necessary to monitor their technical condition employing determined system of their technical maintenance and repairs which essence is to rebuilt nominal or approximate values of diesel state parameters while maintaining certain purposeful complex of implements as elimination of failures in operating conditions requires plenty of time and material resources. In that manner resource is rebuilt, high working probability of diesels without failures is retained.

Great influence on reliability and durability while operating diesels rationally plays technical maintenance and repairs operations. Accordingly, an opportunity to thoroughly analyze technical maintenance and repairs system implementation conditions and methods arises while periodically examining condition and equivalence to normative technical basis that regulate those processes particularly when more new enginery has been acquired.

The aim of this work – theoretical validation of technical maintenance and repairs as well as durability prediction of diesel locomotives according to exploitation parameters.

2. Research methodology and results

There exists a normative technical maintenance and repairs system of the locomotives that regulates technical maintenance and repairs of the machines [16, 17, 19]. However, improving enginery and its maintenance and repairs technologies there is an appreciable necessity to establish a corrected complex of new organizational technical means that, on one hand, settles united principles of technical maintenance and, on the other hand, various standards and regulations for the planning and management of technical services activities of railways locomotive depots.

With no doubt, a weighty influence on the diesel locomotives engines technical state maintenance has strategies of technical maintenance and repair systems. Currently, the most common are three strategies: until failure, scheduled – premonitory and adaptive (diagnostic). Within the given odds and outs [16, 17] all of them have a right to exist, yet a selection or creation of suitable strategy, furthermore, when selecting combinations of their elements, must be weight up well and, of course, reasoned by the appropriate manner. Particularity of the locomotives usage at specific property management conditions comes up in the foreground and only afterwards normative technical requirements that regulates operation of the locomotives [1–6, 10–13].

Certain algorithms with the attaining information about technical state changes as well as special technical state determination methods of the parts, as technical objects and their components are created and presented in the tasks [14–16, 18]. System of actions pointed to the management of diesel locomotives reliability and durability must base reliable and full information upon certain time limit. Being aware of the operating conditions, normative legal fundamentals, initial state (at the beginning of operating or after repair), chosen technical maintenance and repair system, material conditions of technical supplies allows to determine state of the object fairly precise. Logic says that maximum of information helps in choosing optimal unit of technical means and actions on certain manufacture conditions.

It is a pity that there is no settled constitutional attitude on the support of locomotives technical state. Diagnostics that should determine technical state of separate details and assemblies has a limited application possibility and cannot include a huge amount of factors that influence common technical state.

Guaranteed terms of necessary to perform tasks and moment when it is required to maintain correction actions of the technical state cannot be held if we follow planned – premonitory repair system of technical maintenance whereas applying adaptive strategy is possible only if we obtain very reliable information about technical state of an object. Until failure strategy does not give an opportunity to interpose into the management process.

There have been many trials to forecast resources and system of technical maintenances and repairs [14, 15, 18] taking into account operating rates until now, but this problem hasn‘t been solved yet.

Effective fuel capacity decreases depending on the technical state of diesel locomotives [7–9]. Evaluation of effective capacity that corresponds to the certain operating regime, according to the operating characteristics of the diesel locomotives it is possible to write expression of the fuel consumption per hour:

$$G_e = N_e \int_0^{P_{\max}} \int_0^{g_{\max}} P(g_e)\,dP\,dg_e \ , \qquad (1)$$

where N_e – effective diesel capacity, kW; $P(g_e)$ – probability function of operation without failure subjected to comparative fuel consumption (it is chosen according to the technical state and graphical interpretation of the diesel; P_{max} – maximal probability value of the diesel operation without failure; g_{max} – maximal comparative fuel consumption that are taken constant during the operating process, g /kW year.

If we trace an amount of used fuel of diesels during every hour while operating and compare those consumption with limit values, then time when we need to perform technical maintenance is expressed in such form:

$$t^{G}_{"M} = \frac{\sum_{i=1}^{n-1} G_{ei} t_i + \sum_{j}^{m} G_{ej}^{\lim} t_j}{\sum_{i=1}^{m} \bar{G}_{ei}} \ , \quad \begin{matrix} i = 1,2,3...n \\ j = n...m \end{matrix} \qquad (2)$$

where $\sum_{i=1}^{m} \bar{G}_{ei}$ – sum of diesel fuel consumption between the limit hours during the interval from j up to m, according to the operating conditions this interval has been chosen by the leadership (investigator) of the depot, with the difference not exceeding at any circumstances 8, kg/h; $\sum_{i=1}^{m} \bar{G}_{ei}$ – sum of average fuel consumption per hour without limited fuel consumption per hour, kg/h; *ti* – *i*-th run-in during limited fuel consumption per hour, h; t_j – *j*-th run-in during limited fuel consumption per hour from the fixed beginning, h.

Using expression (2), when we know values of minimal, maximal and limited fuel consumption per hour, it is possible to show times of technical maintenance performances graphically (Fig. 1).

If we write expression (2) taking into account formula (1), we get dependency of technical maintenance performances to their comparative fuel consumption per hour evaluating possibility of operation without failures:

$$t^{gP}_{"M} = \frac{\sum_{i=1}^{n-1} t_i P_{eV} \int_{\lim}^{P_{\max}} \int_0^{g_{\max}} P(g_{eV})\,dP\,dg_{eV} + \sum_{j}^{m} t_j P_{ej} \int_0^{P_{\lim}} \int_0^{g_{\max}} P(g_{ej}^{g})\,dP\,dg_{ej}}{\sum_{i=1}^{m} \frac{P_{eV}}{m} \int_{\lim}^{P_{\max}} \int_0^{g_{\max}} P(g_{eV})\,dP\,dg_{eV}} \qquad (3)$$

Graphical interpretation (3) is given in Fig. 2. There is also necessary to put minimal, maximal and limit values of the comparative fuel consumption per hour.

If we constantly (all the time) obtain information about variation of diesel capacitance during exploitation it is possible to draw graphs of operating probability without failures dependent on the effective capacitance (Fig. 3).

The graph shows that there exists point 2, 3, 5 that correspond to maximal values of probability working without failures during diesels exploitation. Points that are below show decrease of diesels reliability and demand renewal (improvement) of their technical state. As we can see from the graph, transitions from zones with minimal and maximal values of effective capacity can be of several types, i.e. interruption can be sudden in order to improve technical state of diesels, rise the probability of operating without failures or it can be performed

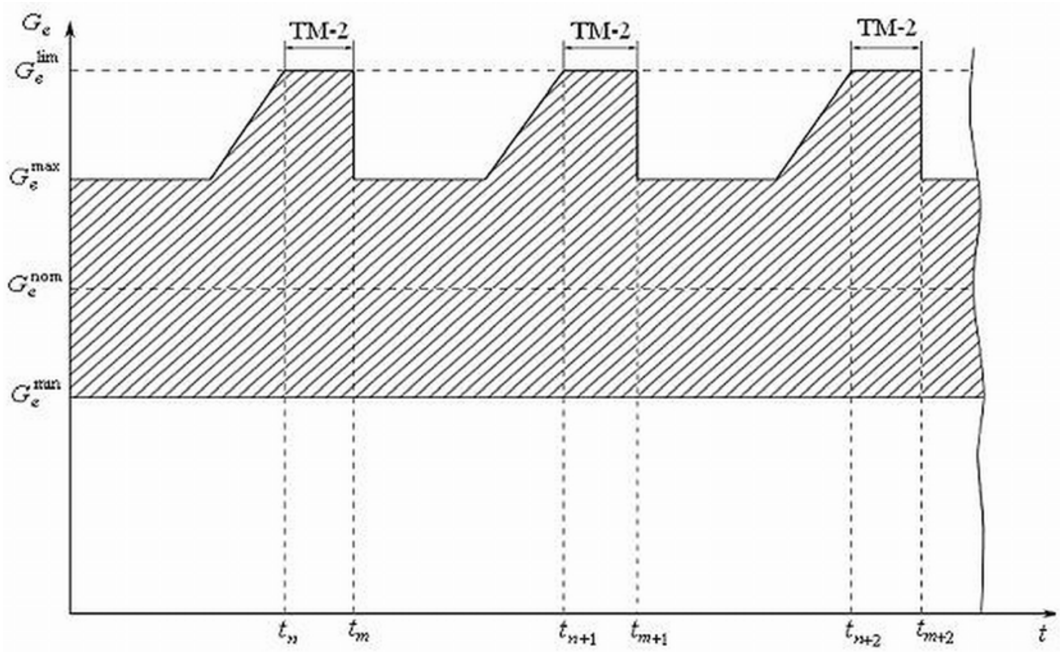

Fig. 1. Technical maintenance performance times according to fuel consumption per hour of the thermo diesels

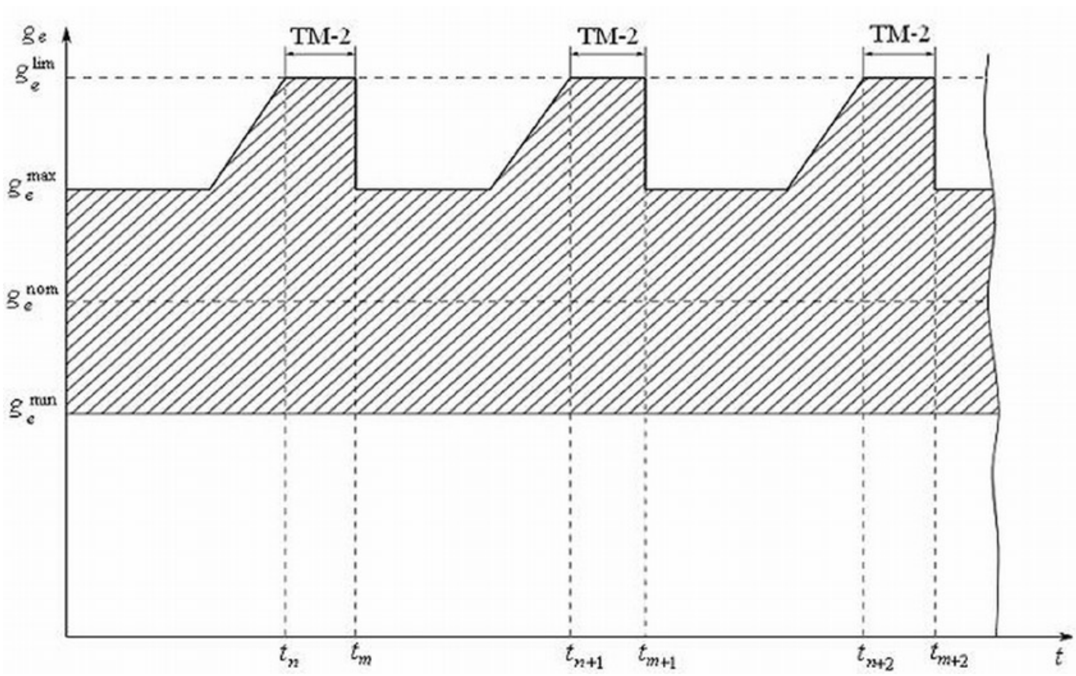

Fig. 2. Technical maintenance performance times according to comparative fuel consumption on the diesel locomotives

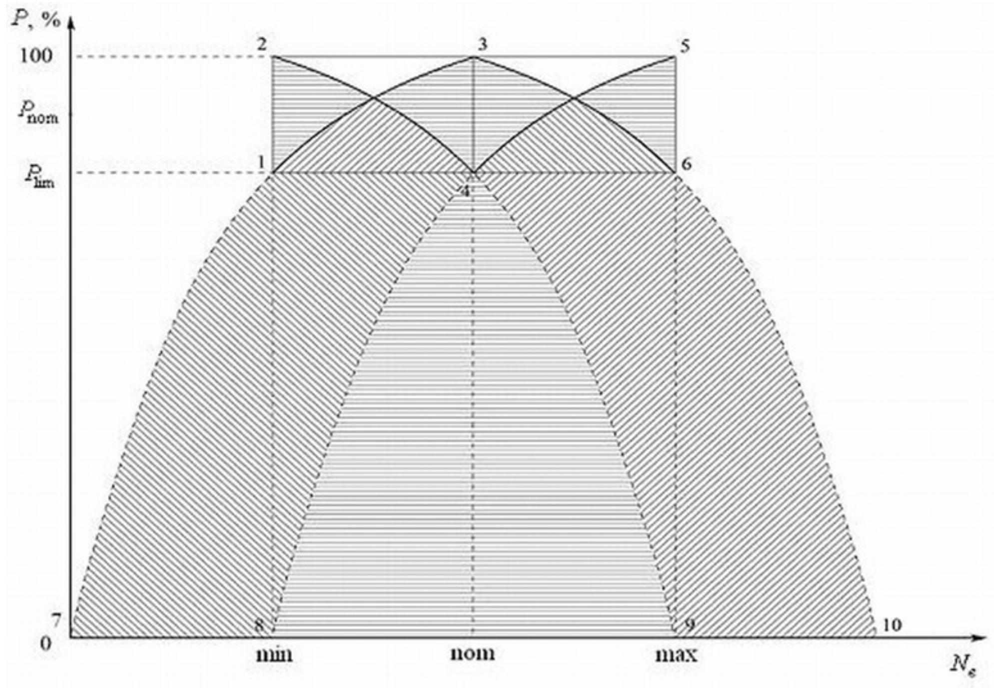

Fig. 3. Dependency of probability working without failures on the effective capacitance of diesel locomotives

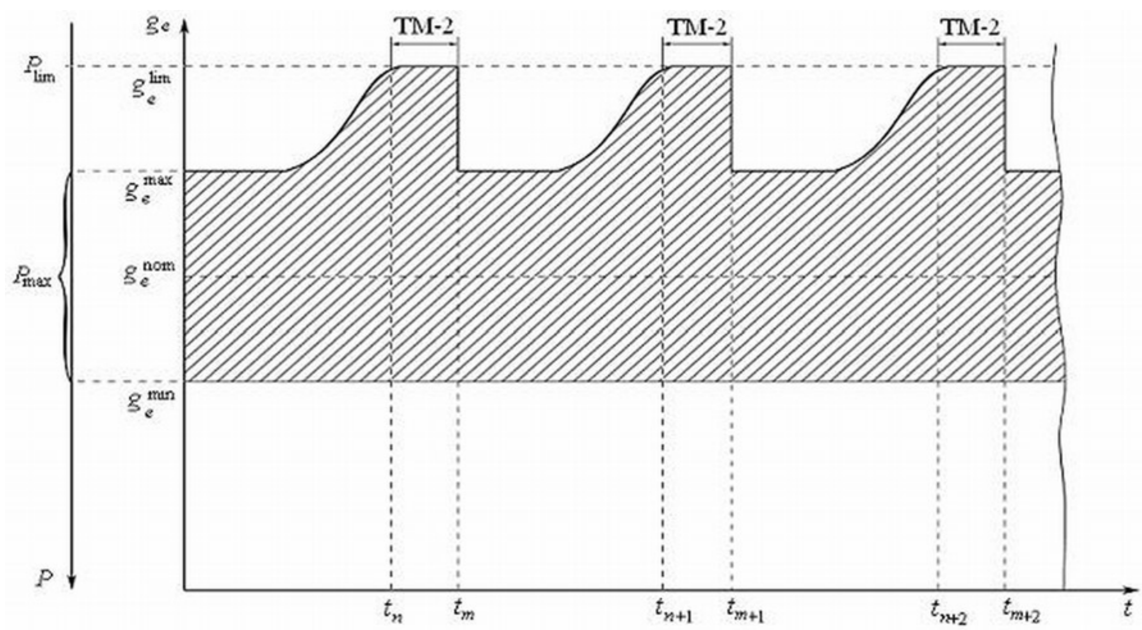

Fig. 4. Dependency of technical maintenance performance dates of diesel locomotives on comparative consumption of fuel and operating without failures probability

during planned technical maintenances that also guarantees high operating probability without failures.

Constant maintenance of diesels high technical state ensures increase in durability of diesel locomotives. Graphical interpretation of obtained formula (3), i.e. dependency of diesels operating probability without failures on effective capacity P (Ne), results in possibility to specify formula (3) and write it in such a form:

$$t_{M}^{gP}=\frac{\sum_{i=1}^{n-1} t_i P_{eV}\int_{\lim}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})dPdg_{eV}+\sum_{j}^{m} t_j P_{ej}\int_{0}^{P_{\lim}}\int_{0}^{g_{\max}} P(g_{ej}^{g})dPdg_{ej}}{\sum_{i=1}^{m}\frac{P_{eV}}{m}\int_{\lim}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})dPdg_{eV}} \quad (4)$$

This expression describes terms of technical maintenances with higher probability that can be shown graphically (Fig. 4).

In this case it is necessary to determine limits of the diesels operating without failures probability additionally. Those limits are chosen according to which accurateness technical state diagnosis must be reached. When we know amount of corresponding technical maintenances for the certain kind of diesel locomotives, we can estimate interrepair resource depending on the comparative consumption of fuel evaluating probability of operation without failures:

$$t_{M}^{gN_eP}=\frac{\sum_{i=1}^{n-1} t_i \int_{\lim}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})P(N_{ei})dPdg_{eV}+\sum_{j}^{m} t_j \int_{0}^{P_{\lim}}\int_{0}^{g_{\max}} P(g_{ej}^{g})P(N_{ej})dPdg_{ej}}{\sum_{i=1}^{m}\frac{1}{m}\int_{\lim}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})P(N_{ei})dPdg_{eV}} \quad (5)$$

where A_{TM-1}, A_{TM-2} – amount TM-1 and TM-2 respectively.

In accordance to (2) and (3), durability of diesel locomotives can be expressed as follows.

Dependent on:

– fuel consumption per hour:

$$L^{G}=(A_{TR}+1)(A_{TM-1}+A_{TM-2})\frac{\sum_{i=1}^{n-1} G_{ei}t_i+\sum_{j}^{m} G_{ej}^{g}t_j}{\sum_{i=1}^{m}\bar{G}_{ei}} \quad (6)$$

– comparative fuel consumption evaluating probability of diesels operating without failures: (7)

$$L^{gP}=\frac{\sum_{i=1}^{n-1} t_i N_{eV}\int_{g}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})dPdg_{eV}+\sum_{j}^{m} t_j P_{ej}\int_{0}^{P_g}\int_{0}^{g_{\max}} P(g_{ej}^{g})dPdg_{ej}}{\sum_{i=1}^{m}\frac{N_{eV}}{m}\int_{g}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})dPdg_{eV}}\times (A_{TR}+1)(A_{TM-1}+A_{TM-2})$$

where ATR – total amount of overhauls of the diesel locomotives.

Using (5), durability of diesel locomotives can be expressed in such shape: (8)

$$L^{gN_eP}=\frac{\sum_{i=1}^{n-1} t_i \int_{g}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})P(N_{ei})dPdg_{eV}+\sum_{j}^{m} t_j \int_{0}^{P_g}\int_{0}^{g_{\max}} P(g_{ej}^{g})P(N_{ej})dPdg_{ej}}{\sum_{i=1}^{m}\frac{1}{m}\int_{g}^{P_{\max}}\int_{0}^{g_{\max}} P(g_{eV})P(N_{ei})dPdg_{eV}}\times (A_{TR}+1)(A_{TM-1}+A_{TM-2})$$

Prediction of life in economic activities is very important moment, because the object is expensive.

3. Conclusions

Performed theoretical investigations on the durability and dates of technical maintenance and repair performance estimation of diesel locomotives depending on exploitation parameters have shown that:

1. Fuel consumption per hour can be described as graphical interpretation depending on the probability of operating without failures and effective capacity.
2. It is possible to determine necessary date for technical maintenance performance depending on the state of exploitation parameters if we fix fuel consumption of the diesel locomotives during its operating hours and compare them to limit values.
3. When the quantity of necessary technical maintenances is known for the specific kind of diesel locomotives it is possible to determine interrepair resource depending on comparative and required per hour consumption of fuel and predict their durability taking into account probability of operating without failures.

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