$$N\text{диз} = \frac{N\text{тг}}{\eta\text{пер}} = \frac{\int_{\alpha}^{180°} Idt}{\eta\text{пер}} \qquad (5)$$

Итоговое значение удельного расхода сходным образом вычисляется как отношение значения расхода топлива к мощности с учётом поправочного коэффициента [4]:

$$Q\text{уд} = \frac{\frac{dV\text{топл}}{dt}}{N\text{диз}} = \frac{dV\text{топл}}{dt} * \frac{\eta\text{пер} * \eta}{\int_{\alpha}^{180°} Idt} \qquad (6)$$

Таким образом, приведенные примеры показывают, что диагностирование с помощью МСУ-Т сводится к подбору данных, необходимых для решения целевой задачи.

ПРОБЛЕМЫ С ДАННЫМИ

Несмотря на то, что в настоящий момент работы по проекту только начаты, уже было выявлено несколько значительных проблем разного уровня сложности, каждая из которых требует собственного, специфического подхода.

Первая – несовершенство программного обеспечения для анализа поступающих с локомотива данных. Точнее, необходимость приспособления под нужды диагностирования программ, изначально для этого не создававшихся. Эта проблема решается путем заключения с создателями программных продуктов договоров на их доработку.

Вторая проблема – отказы микропроцессорных систем. Для ведения учёта параметров работы оборудования локомотива требуется, чтобы надёжность слежения была заведомо выше, чем надёжность самого тепловоза, хотя на практике всё оказывается с точностью до наоборот. К примеру, сейчас исправно лишь порядка 20% АПК «Борт», ещё примерно 60% находится в работоспособном состоянии, а 20% систем неисправны полностью. Причинами тому служат не столько уровень надёжности узлов и агрегатов современных локомотивов, сколько низкая надёжность современных микропроцессорных систем (а зачастую и откровенный вандализм со стороны сотрудников депо и локомотивных бригад: вырванные блоки и перерезанные провода – реалии бортовых микропроцессоров). Решение этой проблемы тесно связано с наличием третьей проблемы.

Третья и, пожалуй, наиболее сложная в плане решения проблема – низкий уровень правовой проработки вопроса. Современная ситуация такова, что выявить неисправность значительно проще, чем вызвать какую-либо реакцию на неё со стороны локомотивного хозяйства. В настоящий момент сервисные компании прилагают значительные усилия, чтобы быть услышанными в депо, но до тех пор, пока на тревожные сообщения не будет ответа, не будет достигнута конечная цель – повышение надёжности парка.

Впрочем, и констатация существующего положения дел, и определенное совершенствование процесса мониторинга технического состояния тепловозов отражают растущее внимание к обозначенным в статье проблемам.

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DIAGNOSING LOCOMOTIVES ACCORDING TO ONBOARD MICROPROCESSOR SYSTEM DATA

Melnikov, Viktor A. *– Ph.D. student at the department of locomotives and locomotive facilities of Moscow State University of Railway Engineering (MIIT), Moscow, Russia.*

ABSTRACT

The article deals with the diagnostic process automation on the basis of software with the use of data received from microprocessor systems installed on locomotives. The peculiarity of the approach under review is the use of the results of monitoring of locomotives' technical condition for the accumulation of statics, which allows predicting the expected level of risks and planning corrective actions. The objective of the proposed project is, to provide timely prevention of faults, creating preconditions for objective analysis (operational control) and identifying certain trends.

ENGLISH SUMMARY

Background.

Within the framework of the conducted research as a prime condition should be regarded obtaining data, required for maintaining statistical records of locomotives. As the solution of this issue by traditional methods of manual data analysis is difficult because of the large volume of related work, it seems that the most appropriate method is full-fledged implementation of a complex system of electronic sensors and recording (or forward) information devices, however, this option is extremely expensive. And it is necessary to find a simple alternative.

Nowadays it is a targeted analytical use of data already available on locomotives of microprocessor control systems. The only thing that is required for them is the development of diagnostic algorithms that make it possible to get a report in a unified form on materials of onboard systems with a different set of recorded figures and facts. Such algorithms are consistent with the characteristic features of applied control means.

Objective.

The author aims at showing different aspects of two microprocessor systems› application, which can be used in locomotive sector to identify malfunctions and solve them.

Method.

The author uses mathematical methods and method of comparison.

Results.

Hardware-software complex (hereinafter-HSC) «Board» is created by experts as a means of accounting of fuel consumption, includes sensors covering diesel generator set of a locomotive and accessory equipment, as well as the microprocessor processing unit having access to a global positioning system (GPS).

The current version of HSC «Board» receives from a locomotive 21 parameters, all of which are available for viewing using the program «Kontrol» (program name starts with «K») in the form of graphs – time dependences [3].

The principal feature of the complex, in terms of monitoring, is its ability to transmit data to the server through the mobile communication system GPRS. From the server, in agreement with Research institute of technology, control and diagnostics, information can be obtained for use. Since the data transmission system was created with considerable reliability, data are duplicated twice – on the memory card, given to a machinist and built-in memory card of a locomotive.

Server of HSC «Board» has the access interface in its current version able to automatically detect a dozen different disorders that correspond to the tasks of monitoring at the level of operational locomotive depot [3].

The main disadvantage of this HSC is its focus on accounting of fuel consumption that for a small set of diagnostic parameters reduces the implementation of any diagnostic algorithm to the problem of obtaining the necessary input data. As an example, it makes sense to demonstrate two algorithms.

The first algorithm, proposed by the author of the article, is control of oil circulation at the launch of diesel. In this case, all the parameters required for the control (oil pressure and frequency of a crackled axle rotation) are already in the system and the process of diagnosis is reduced to detection of time periods when oil pressure is below the permissible value at nonzero diesel's rotation. Upon detection of irregularities the following message is fixed in the report: «The launch of diesel without oil circulation». Pic. 1 shows graphs of parameters illustrating the situations of oil pressure (1) and the frequency of engine crankshaft (2). Launch of diesel without oil circulation is obvious.

The second algorithm, already implemented in HSC «Board» is control algorithm of specific fuel consumption accounting.

Since this hardware-software complex has no information on either fuel consumption or of the shaft power of diesel, both parameters must be calculated. Consumption is determined by a known method for the average level of consumption ($h_{топл}$) (in the «Board» there is the average value of the left and right level detector; product of the length of the tank ($l_{бак}$) and its width ($b_{бак}$) is assumed constant). The principle of calculation is implemented in the formula (1).

As for a capacity of diesel the situation is somewhat different: in HSC parameter of generator power is used, calculated as the product of the current ($I_г$) of the generator and its voltage ($U_г$). Accordingly, the ratio of the power at the output of the generator to its nameplate efficiency (η) is the output power at the shaft of the diesel. Calculation of output power of the diesel is given in (2).

To assess the impact of devices receiving power directly from the engine crankshaft, a safety factor (η) is added to the formula. The final value of specific fuel consumption is obtained as the ratio of fuel consumption to the power at the shaft of the diesel engine with account of correction factor, as it is shown in formula (3).

Upon detection of irregularities the following message is fixed in the report: «The increased specific fuel consumption». [2] Pic. 2 shows that the rate of change of fuel level (1) changes proportionally to the position (2) of controller driver (4) and rotation of diesel (3).

Thus, «Board» is an example of a ready and simple self-contained diagnostic complex, which is required to be adjusted for the purpose of monitoring with minimal changes, which is a real task, although with a high degree of complexity due to the limited range of recorded data.

Fundamentally different is the situation with developed by specialists family of diagnostic microprocessor systems, referred to as MSU- T.

From the outset it had a significant by the standards of the rolling stock, number of sensors (in its current version the system supports up to 250 sensors in the actual number of about 150–200 depending on the series of locomotives), and they were installed only on new domestic locomotive (2TE25A (K), TEP70BS, 2TE116U). That latitude of diagnostic signals› range of this family of systems makes it an interesting device from the standpoint of not only the diagnosis, but also investigation of the processes occurring in the structures and mechanisms of the locomotive. At the same time an increasing amount of information is problematic for analysis, and holding even the simplest of checks is associated with a significant number of parameters [4].

Unlike HSC «Board» MSU- T family initially did not have its own system of data transmission from the onboard computer of the locomotive to the workplace of a diagnostician, as its creators put the main focus on embedded diagnostic functions (which, however,

are very simple), and the ability to have online access to the data on the work of the plurality of nodes and aggregates of a locomotive. However, in the process of debugging of onboard systems and structures of the locomotive the function of recording data from on-board sensors was provided on removable storage device and further analysis was conducted using a special program «Oscilloscope» (which, like «Board» displays information of the sensors as time dependencies).

Implementation of algorithms for the diagnosis according to data of MSU-T is not hindered by a search for a source of information (in fact, often data provided are a source of inspiration for the construction of algorithms), so it has much wider possibilities. Below there are examples of algorithms by means of diagnostic complex «Oscilloscope-2», developed with the participation of the author.

Control of oil circulation at launch of the diesel: after t_1 *after turning-on of a relay actuator of the engine at speeds equal to zero, contactor of oil-priming pump must be closed. After* t_2 *after oil pressure reaches the allowable value contactor of oil pressure relay actuator comes into action. After* t_3 *rotation of diesel should not be equal to zero [4]. Pic. 3 shows how the relay actuator comes into action (steps 1 and 6–8) and graphics of oil pressure (steps 3 and 4) for normal launch of the diesel. In this case a much greater amount of information is controlled, but in order to standardize the report only one message will be fixed: «The launch of diesel without oil circulation». All other information is supplied to the operator to decide on further action (in the form TU –28 and TU –152, or as a footnote to the report).*

Control of specific fuel consumption: since in the systems MSU-T ratemeter is designed as a separate stand-alone subsystem, its involvement is checked additionally – an indicator of the fuel mass must not be zero. To solve the problem, it is proposed to apply the calculation method, similar to that used in the HSC «Board» – the time derivative is taken with the opposite sign, but depending on the changes in amount of fuel in the tank ($m_{топл}$*), as shown in formula (4).*

Parameter of electric power of traction transmission is also present in the system, but since all locomotives are equipped with MSU- T have traction synchronous generator, the total diesel power is now determined as the ratio of the traction transmission power ($N_{тг}$*) to the product of nameplate efficiency of the generator and the rectifier unit (in (5) identified as a transmission efficiency,* $\eta_{пер}$*). And at the thyristor rectifier of the locomotive 2TE116U this value varies depending on the opening angle of the thyristors (*η*), which leads to the need to consider the angle, which, however, appears in the MSU-T data. See (5).*

Final value of specific fuel consumption is calculated similarly as the ratio of the fuel consumption to power, with the correction factor [4]. See formula (6).

Thus, these examples show that the diagnosis via MSU-T reduces to the selection of data needed to solve the target.

Conclusion.

Despite the fact that work on the project has started, several significant problems of varying complexity have been revealed, each of which requires its own specific approach.

First of all there is imperfection of the software to analyze data coming from the locomotive. More precisely, it is required to adapt to the needs of diagnosis programs, initially not designed for it. This problem is solved by the conclusion with the creators of software contracts for their completion.

The second problem is failures of microprocessor systems. For accounting parameters of locomotive equipment it is required for the reliability to be obviously higher than the reliability of the locomotive, although in practice it turns out to be exactly the opposite. For example, now only about 20% of HSC «Board» function properly, still about 60% are in good working condition, and 20% of the systems are completely defective. The reasons for this are not only level of reliability of components and assemblies of modern locomotives, but also low reliability of modern microprocessor systems (and often outspoken vandalism on the part of the depot and locomotive crews: broken blocks and cut wires are reality for onboard microprocessors). Solving this problem is closely related to the presence of the third problem.

The third problem, and perhaps the most complicated in terms of addressing it, is low level of legal development of the issue. The current situation is that it is much easier to identify a malfunction than to cause any reaction to it from the locomotive department. Currently, utility companies are making significant efforts to be heard at the depot, but until the alarming messages are not being answered, the ultimate goal – improving the reliability of the park will not be achieved.

However, and a statement of the status quo, and a definite improvement of monitoring process of locomotives technical state reflect the growing attention to the problems outlined in the article.

Keywords: railway, locomotive, technical condition, monitoring, on-board microprocessors, prognosis, prevention.

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Координаты автора (contact information): Мельников В. А. (Melnikov V. A.) – lordson@inbox.ru.

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