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DEFINITION OF SUFFICIENCY OF SPARE PARTS AT SERVICE OF DIESEL LOCOMOTIVES

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Summary. The technique of definition of sufficiency of spare parts is considered at service of diesel locomotives. Situations are classified and the basic structures of maintenance of service are offered by spare parts which most often are used in practice. Methods of quantitative definition of spare parts on each structure which include the nomenclature, intensity of a stream of applications, average time of restoration, and also separate price factors are offered. Sufficiency of spare parts for service maintenance service of diesel locomotives 2ТЭ116 is calculated.

Key words: sufficiency, spare parts, complete set, exchange collection, updating, repair body, service, supply, structure, diesel locomotive.

INTRODUCTION

During deep system transformations to a locomotive facilities of railways of Ukraine structural and functional interdependence promptly develop and go deep. It, on the one hand complicates, and with another strengthens economic relations without which modern locomotive depots which carry out service and repair of a traction rolling stock, cannot function and develop. In particular it concerns to material support when in conditions of transition to market attitudes{relations} development of modern methods of increase of efficiency of communications{connections} between suppliers and consumers is necessary at the organization of service of locomotives.

ANALYSIS OF LAST RESEARCHES AND PUBLICATIONS

Formation of the theory of storekeeping as scientific discipline has begun in the middle of 1950th years. Detailed development of this stage it is resulted in works [5,10,16]. There is a number of manuals [1,4,6,7,9,11,13,14,15,19] where from the mathematical point of view the essence of formation of volume of stocks reveals, and also the basic laws apply to various industries. In one of last works [16], on the basis of generalization as the main parameter the condition of maintenance of set reliability of supply is used. Algorithms offered in given work are developed by means of the device of the classical theory of management: modern methods of the theory of adaptation, mathematical programming, stochastic optimization, a principle of a maximum. At the same time it is necessary to note, that the majority of these development have the limited applicability because of impossibility in definition of costs as a result of loss of preference, strong-willed purpose of norms of stocks, and also absence of the complex approach to components of cumulative stocks on all way of their movement and to their distribution between parts of investigated systems. Proceeding from it, in given clause the complex technique of formation and an estimation of sufficiency of stocks of spare parts in view of the basic industrial parts is offered at the organization of service in a locomotive facilities.

MATERIALS AND RESULTS OF RESEARCHES

As is known updating of any stocks $Z_{s.p}$ always happens to some delay concerning the moment of delivery on it requirements [16]. These updating can be subdivided on:

- instant (delay in delivery is very small);
- with a delay for the fixed term;
- with a delay on a casual interval of time with known or unknown likelihood distribution;
- emergency updating.

Accepting, on features of a design, a diesel locomotive as the big difficult object, it is possible to allocate in him three basic structural subsystems of the organization of supply with spare elements:

- the single complete set $Z_{s.p}^{O}$ representing amount of spare elements which are given to directly given locomotive for maintenance of his working capacity;
- the complete set of spare elements of the repair body $Z_{s.p}^{RO}$, representing amount of spare elements which are given only to him, with the purpose of maintenance of his working capacity. Functioning of repair body (*RO*) consists in elimination of refusals in faulty sites or details of the locomotive which to him act for their restoration. Thus, the repair body is intended for restoration of the objects which have acted to them and should be provided by the stock $Z_{s.p}^{RO}$;
- the exchange collection of repair body $Z_{s.p}^{EC-RO}$ representing amount of finer spare elements which are given to repair body which can serve both the single complete set $Z_{s.p}^{O}$, and sites acting in repair body.

These structural subsystems can be combined among themselves in various variants. Proceeding from this 7 variants of structures of maintenance of service by spare elements (*SMSSE*) which most often are used in practice are offered. They are presented on fig. 1.

The first variant reflects the most widespread *SMSSE* in which has reserved $Z_{s.p}^{O}$ replenishes directly from an external source. This external source will be understood hereinafter as an external warehouse, base, a factory, etc. which limitation at updating elements in calculation is accepted will not be. In default at the locomotive what or an element in the complete set $Z_{s.p}^{O}$ the application which is immediately satisfied acts if the corresponding spare element there is available. At absence of a spare element the application becomes in "turn" and waits to not appear yet an opportunity her to satisfy. The length of turn of unsatisfied applications can be various and depends on main principles and conditions functioning of system of logistics.

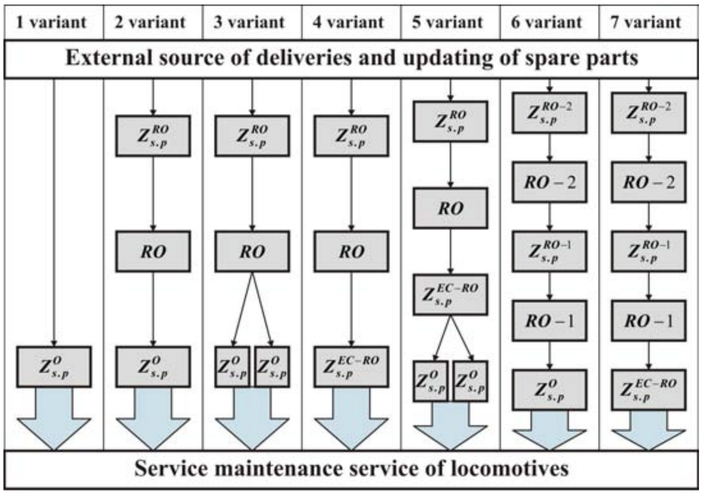

Fig. 1. Variants of service maintenance with spare elements

Thus, in the first variant the application for a spare element which has arrived from object in the complete set $Z_{s.p}^{O}$, can be satisfied or immediately, or with some delay.

In the second variant the complete set $Z_{s.p}^{O}$ replenishes from repair body *RO* which in turn has the complete set $Z_{s.p}^{RO}$ and filled up of an external source.

The third variant provides, that the complete set $Z_{s.p}^{O}$ is given to each type of the locomotive. These complete sets replenish also from repair body *RO* which in turn has the complete set $Z_{s.p}^{RO}$ and filled up of an external source (as well as in the second variant).

In the fourth variant for service the exchange complete set of elements $Z_{s.p}^{EC-RO}$ which directly replenishes from repair body *RO* is given.

For the fifth variant it is installed, that each complete set $Z_{s.p}^{O}$ for service replenishes from the exchange complete set of elements $Z_{s.p}^{EC-RO}$ which too directly replenishes from repair body *RO*.

In the sixth variant updating of the complete set $Z_{s.p}^{O}$ for service is provided directly from several repair bodies *RO*-1 and *RO*-2 in various combinations.

The seventh variant provides updating elements for service from the exchange complete set of elements $Z_{s.p}^{EC-RO}$ which too directly replenishes from repair bodies *RO*-1 and *RO*-2 in various combinations.

For an estimation of sufficiency of the concrete complete set $Z_{s.p}^{O}$, following data are necessary.

1. Quantity of types of replaceable elements N_0 in a product;

2. On each type of replaceable constructive elements the data card with initial data is made

i	Λ_{iO}	T_{iO}	n_{iO}	ρ_{iO}

(1)

where: i - number of type of elements under the nomenclature of the complete set $Z_{s.p}^{O}$; Λ_{iO} - intensity of a stream of applications for elements of *i*-th type from a product in the complete set $Z_{s.p}^{O}$; T_{iO} - average time of restoration of one element of *i*-th type in $Z_{s.p}^{O}$ (i.e. average time which passes between withdrawal of a spare element from the complete set $Z_{s.p}^{O}$ and receipt in this complete set of a similar serviceable element instead of withdrawn); n_{iO} - initial amount of spare elements of *i*-th type in the complete set $Z_{s.p}^{O}$; ρ_{iO} - the maximal possible length of turn of unsatisfied applications for elements of *i*-th type of century $Z_{s.p}^{O}$ (the whole positive value ρ_{iO} corresponds to cases of the limited turn of unsatisfied applications. At ρ_{iO} = 0 it is accepted, that the length of turn is unlimited).

Intensity Λ_{iO} is defined by a stream of replacements of elements of *i*-th type in products (not necessarily conterminous with a stream of refusals), and also a stream of refusals of elements of *i*-th type at storage in the complete set $Z_{s.p}^{O}$

$$\Lambda_{iO} = k_{iE}(m_i\lambda_i + l_i\lambda_i) + (1-k_{iE})\,(m_i + l_i)\lambda_{iSt} + n_i\lambda_{iSt}\,, \qquad (2)$$

where: m_i - quantity of basic elements of *i*-th type in a product; l_i - quantity of reserve elements of *i*-th type in a product; k_{iE} - factor of intensity of operation of a product; λ_i - failure rate of one basic element of *i*-th type; λ_{iSt} - failure rate of one basic element of *i*-th type at storage.

To calculate a parameter of sufficiency *EC-RO* following initial data is necessary.

1. N_{EC} - quantity of types of elements on which applications in *EC-RO* can come;

2. On each of N_{EC} types of elements to set the data card of initial data:

i	Λ_{iEC}	$\grave{O}_{iEC}$	n_{iEC}

(3)

where: Λ_{iEC} - intensity of a stream of applications for spare elements of *i*-th type, acting in *EC-RO* from served samples of object or the complete set $Z^{O}_{s.p}$, i.e. average quantity of applications for elements of *i*-th type in unit of time; $\grave{O}_{iEC}$ - average time of repair of one element of *i*-th type in *RO*; n_{iEC} - initial quantity of elements of *i*-th type in *EC-RO*.

To calculate value Λ_{iEC} it is necessary to summarizes on all samples of object in the group, intensity of streams of replacements of elements of *i*-th type served to data *RO* in object [19]

$$\Lambda_{iEC} = \sum_{K=1}^{S} \Lambda^{K}_{iEC} , \tag{4}$$

where: S - quantity of samples of objects in group; Λ^{K}_{iEC} - intensity of a stream of replacements of an element of *i*-th type in To-th the sample of object.

Intensity of a stream of replacements of an element of *i*-th type in *K*-th the sample of object Λ^{K}_{iEC} is defined as

$$\Lambda^{K}_{iEC} = k_{i\hat{a}}(m_i\lambda_i + l_i\lambda_i) + (1 - k_{i\hat{a}})\,(m_i + l_i)\lambda_{ixp} + n_i\lambda_{ixp} , \tag{5}$$

where: m_i - quantity of basic elements of *i*-th type in a product; l_i - quantity of reserve elements of *i*-th type in a product; $k_{i\hat{a}}$ - factor of intensity of operation of a product; λ_i - failure rate of one basic element of *i*-th type; λ_{ixp} - failure rate of one basic element of *i*-th type at storage.

To calculate value of a parameter of sufficiency $Z^{R\hat{I}}_{s.p}$ following initial data are required.

1. $N_{R\hat{I}}$, - quantity of types of completing elements which can be demanded for job *RO*;

2. On each type of completing elements to set the data card of initial data:

j	$\Lambda_{jR\hat{I}}$	$\alpha_{jR\hat{I}}$	$\grave{O}_{jR\hat{I}}$	$\tau_{jR\hat{I}}$	$n_{jR\hat{I}}$

(6)

where: j - number of type of elements under the nomenclature $Z^{R\hat{I}}_{s.p}$; $\Lambda_{jR\hat{I}}$ - intensity of a stream of applications for elements of *i*-th type, acting in $Z^{R\hat{I}}_{s.p}$, i.e. average quantity of applications for elements of *j*-th type in unit of time; $\alpha_{jR\hat{I}}$ - the type of strategy of updating of a stock of elements of *j*-th type of century $Z^{R\hat{I}}_{s.p}$. Value $\alpha_{jR\hat{I}}$ can accept values 1, 2, 3. At $\alpha_{jR\hat{I}}$ =1 stock of elements of *j*-th type replenishes periodically. At $\alpha_{jR\hat{I}}$ = 2 updating of a stock of elements of *j*-th type is made with emergency deliveries, i.e., besides scheduled periodic restoration of a stock, it is supposed also his off-schedule restoration up to an initial level if the element of *j*-th type is required for job *RO*, and the stock of elements of *j*-th type in $Z_{s.p}^{RÎ}$ is empty. At $\alpha_{jRÎ}$ = 3 stock of elements of *j*-th type in $Z_{s.p}^{RÎ}$ replenishes due to repair of the given up elements in special RO_s. (distinct from that *RO* to which it is given data $Z_{s.p}^{RÎ}$); $\grave{O}_{jRÎ}$ - key parameter of strategy of updating of a stock of elements of *j*-th type. At $\grave{O}_{jRÎ}$ = 1 or $\grave{O}_{jRÎ}$ = 2 value $\alpha_{jRÎ}$ is the period of updating of a stock of elements of *j*-th type. At $\grave{O}_{jRÎ}$ = 3 value $\alpha_{jRÎ}$ is average time of repair of one element of *j*-th type; $\tau_{jRÎ}$ - additional parameter of strategy of updating of a stock of elements. At $\tau_{jRÎ}$ = 1 or $\tau_{jRÎ}$ = 3 value $\alpha_{jRÎ}$ is equal to zero. At $\tau_{jRÎ}$ = 2 value $\alpha_{jRÎ}$ represents average duration of emergency delivery of elements from an external source of updating; $n_{jRÎ}$ - initial quantity of elements of *j*-th type of century $Z_{s.p}^{RÎ}$.

For the decision of a problem of calculation $Z_{s.p}^{RÎ}$ following initial data are required.

1. $N_{ÐÎ}$ - quantity of types of completing elements which can be demanded for $Z_{s.p}^{RÎ}$.

2. On each type of spare elements the data card of initial data is made

j	$\Lambda_{jRÎ}$	$\alpha_{jRÎ}$	$\grave{O}_{jRÎ}$	$\tau_{jRÎ}$	$\tilde{N}_{jRÎ}$

(7)

where: parameters j , $\Lambda_{jRÎ}$, $\alpha_{jRÎ}$, $\grave{O}_{jRÎ}$, $\tau_{jRÎ}$ have the same sense, as in the data card (6), and $\tilde{N}_{jRÎ}$ - expenses for 1 element of j -th type $Z_{s.p}^{RÎ}$.

Calculation of a parameter of sufficiency $Z_{s.p}^{RÎ}$ is made under the formula

$$\Delta t_{RO}^{D} = \frac{\sum_{j=1}^{N_{RO}} \Lambda_{jRO}\ \Delta t_{jRO}}{\Lambda_{RO}} \ , \qquad (8)$$

where: Δt_{RO}^{D} - a parameter of sufficiency of a stock of elements of *j*-th type of century $Z_{s.p}^{RÎ}$.

Depending on strategy of updating of a stock of elements of *j*-th type in $Z_{s.p}^{RÎ}$ (i.e. depending on a preset value $\alpha_{jRÎ}$ =1, 2, 3) the parameter of sufficiency of elements of *j*-th type in $Z_{s.p}^{RÎ}$ can be certain under following formulas.

1. In case of $\alpha_{jRÎ}$ =1 (when updating of a stock of elements of *j*-th type in $Z_{s.p}^{RÎ}$ occurs periodically) the parameter of sufficiency is defined from expression

$$\Lambda_{jRO}\Delta t_{jRO} = \frac{1}{a_j} e^{-a_j} \sum_{k=1}^{\infty} K \sum_{i=n_{jRO}+K+1}^{\infty} \frac{a_j^i}{i!} \ , \qquad (9)$$

where:

$$a_j = \Lambda_{jRO} T_{jRO} \ . \qquad (10)$$

Calculations under the given formula it is made as follows. The size originally pays off

$$\varepsilon_j = \frac{a_j \varepsilon_{RO} \Lambda_{RO}}{2N_{RO}} \ , \tag{11}$$

where: ε_{RO} - the set accuracy of calculation of a parameter of sufficiency.

Under tables of distribution Puasson [18]

$$F(n,a) = e^{-a} \sum_{K=n}^{\infty} \frac{a^K}{K!} \ , \tag{12}$$

Values $F(n_{jRO}+2, a_j)$, $F(n_{jRO}+3, a_j)$ …. until the inequality for the first time will not be executed are found

$$F(n_{jRO}+K^*+1, a_j) \le \frac{\varepsilon_j}{K^*} \ . \tag{13}$$

In conformity with the found values $F(n_{jRO}+K^*+1, a_j)$, $K = 1, 2, \ .... K^*$ the size is defined

$$\Lambda_{jRO} \Delta t_{jRO} = \frac{1}{a_j} \sum_{K=1}^{K^*} K \cdot F(n_{jRO}+K, a_j) \ . \tag{14}$$

2. In case of $\alpha_{jR\hat{I}}$ = 2 (when updating of a stock of elements of *j*-th type in $Z_{s.p}^{R\hat{I}}$ occurs periodically to emergency deliveries) the parameter of sufficiency is defined from expression

$$\Lambda_{jRO} \Delta t_{jRO} = (\frac{\tau_{jRO}}{T_{jRO}}) \, \omega(n_{jRO}, a_j) \, (\frac{1+\Lambda_{jRO}\tau_{jRO}}{2}) \ , \tag{15}$$

where:

$$\omega(n_{jRO}, a_j) = e^{-a} \sum_{K=1}^{\infty} \sum_{i=K(n_{jRO}+1)}^{\infty} \frac{a_j^i}{i!} \ , \tag{16}$$

and

$$a_j = \Lambda_{jRO} T_{jRO} \ . \tag{17}$$

To calculate values of the function $\omega(n_{jRO}, a_j)$ set by the sum infinite of some (16), we act as follows. Under tables of distribution Puasson we define values $F(n_{jRO}+1, a_j)$, $F(2n_{jRO}+2, a_j)$ … until first time the inequality will not be executed

$$F(K^* \cdot n + K^*, a) \le \frac{\varepsilon_{RO}}{N_{RO}} \Lambda_{RO} \ , \tag{18}$$

where: ε_{RO} - the set accuracy of calculation of a parameter of sufficiency.

On the found values $F(K^* n + K^*, a)$ it is defined

$$\omega(n, a) = \sum_{K=1}^{K^*} F(K \cdot n + K, a) \ . \tag{19}$$

3. In case of $\alpha_{jR\hat{I}}$ = 3 (when elements of *j*-th type in $Z^{R\hat{I}}_{s.p}$ can be repaired) the parameter of sufficiency of a stock of elements is defined as

$$\Lambda_{jRO}\Delta t_{jRO} = e^{-a_j} \sum_{\hat{E}=n_{jRO}+1}^{\infty} (K - n_{jRO}) \frac{a_j^K}{K!}\,, \qquad (20)$$

and

$$a_j = \Lambda_{jRO} T_{jRO}\,. \qquad (21)$$

On the basis of calculations by the given technique sufficiency of quantity of spare parts by each variant of their formation for diesel locomotives 2TE116 has been certain. These data are resulted in table.

Table 1. **The list of spare parts for service TO-2 of diesel locomotives**

The name	Unit of measure	Quantity
1	2	3
1. Atomizer of a diesel engine	un.	4
2. Cover of the viewing hatch	- " -	2
3. The fuel pump of a high pressure	- " -	4
4. Pneumatic screen wiper	- " -	5
5. Regulator of a voltage PHT-6	- " -	2
6. The block of management БА-520 У3	- " -	1
7. The block of slipping ББ-320А	- " -	1
8. The panel of rectifiers	- " -	1
9. The force relay	- " -	2
10. The gate BB-1	- " -	2
11. The gate BB-1111	- " -	2
12. Section of the storage battery	- " -	1
13. The crane of machinist	- " -	1
14. The crane of an auxiliary brake	- " -	2
15. The valve of the compressor KT7	- " -	2
16. The trailer crane	- " -	2
17. Trailer sleeve	- " -	4
18. Reducer of a measuring instrument of speed	- " -	1
19. Match for the bearing	- " -	4
20. The platen of brake transfer	- " -	12

CONCLUSIONS

Seven basic variants of formation of stocks in view of their updating from external sources, and also the corresponding repair divisions which are carrying out restoration of units and details of locomotives are certain. The technique of definition of sufficiency of the generated variant of a stock which considers quantitative and qualitative characteristics of applications from a place of replacement, intensity of a stream of replacements of details, the nomenclature of details for concrete type of the locomotive, and also technical equipment of repair-regenerative bodies is offered. On the basis of the given technique sufficiency of spare parts for service of locomotives is certain.

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ОПРЕДЕЛЕНИЕ ДОСТАТОЧНОСТИ ЗАПАСНЫХ ЧАСТЕЙ ПРИ СЕРВИСНОМ ОБСЛУЖИВАНИИ ТЕПЛОВОЗОВ

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Аннотация. Рассмотрена методика определения достаточности запасных частей при сервисном обслуживании тепловозов. Классифицированы ситуации и предложены основные структуры обеспечения сервисного обслуживания запасными частями, которые наиболее часто используются на практике. Предложены методы количественного определения запасных частей по каждой структуре, которые включают номенклатуру, интенсивность потока заявок, среднее время восстановления, а также отдельные ценовые факторы. Рассчитана достаточность запасных частей для сервисного технического обслуживания тепловозов 2ТЭ116.

Ключевые слова: достаточность, запасные части, комплект, обменный фонд, пополнение, ремонтный орган, сервис, снабжение, структура, тепловоз..