VOL. 12, NO. 13, JULY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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FORMATION OF RECONDITIONING COMPLEXES DURING ON-CONDITION CENTRALIZED REPAIR OF AUTOMOBILE UNITS

V. N. Krasovsky, V. V. Poptsov, V. A. Korchagin and N. I. Krasovskaja
Industrial University of Tyumen, Volodarskogo Str., Tyumen, Russian Federation
E-Mail: atx.korchagin@gmail.com

ABSTRACT

The article covers the results of complex studies carried out with the purpose of enhancing technical services efficiency of motor transport and auto repair enterprises. When conducting experimental studies the production capacities of "Surgutneftegas" company were used. For the first time the theoretical and empirical dependences of control-diagnosis and technological operations for on-condition centralized repair of hoisting units on the basis of motor vehicles have been obtained. Using the methods of techno-economic modeling of technological processes and mathematical-statistical processing of empirical data as well as using the multidimensional taxonomy framework, the rational structure of reconditioning complexes has been formed. This allowed minimizing the probability of their erroneous assignments for a unit under repair, which saves costs of operational defects repair excluding unnecessary operations.

Keywords: on-condition repair, reconditioning complex, standard reconditioning combinations, pre-repair diagnosis.

1. INTRODUCTION

During the vehicle on-condition repair at a motor transport enterprise (MTE) the replacement of each vehicle unit and part is determined in the course of its dismantling by means of micrometry and subjective control methods. MTE small repair plans allow an assessment of vehicle technical condition in a similar way [1, 2].

The existence of standard reconditioning complexes (RC) during the centralized on-condition repair of automobile units (COCR) sometimes causes an excess of the required repair volume. However, it allows improving the production preparation by means of reconditioning formation and partial specialization of work places. During the COCR there is no need to determine all the vehicle failures, but it is sufficient to set a reconditioning complex, in which all possible combinations of unit defects are already taken into account [3, 4, 5]. Similar approach to the unit performance restoration is brought into being by a number of peculiarities of the pre-repair diagnosis subsystem, affecting the COCR technological system (Figure-1).

During the COCR the decision on repair of vehicles can be made according to the results of the diagnosis performed prior to maintenance No. 2 (D_2), or application diagnosis (D_{mp}), taking into account the remaining vehicle life and repair impacts during the operation [6, 7].

After the admittance of a vehicle to the COCR its technical condition is assessed by using pre-repair diagnosis. According to the results, a reconditioning complex required for the vehicle operability restoration is set. After the reconditioning, the vehicle is subjected to acceptance control, which assesses the quality of repair. In case of a wrong reconditioning complex applied, the automobile operability will not be restored. It will be revealed during the acceptance control (the generalized diagnostic parameters will be outside the tolerance). In this case, it will require further diagnosis and repeated repair to accomplish the required reconditioning [4, 5, 7].

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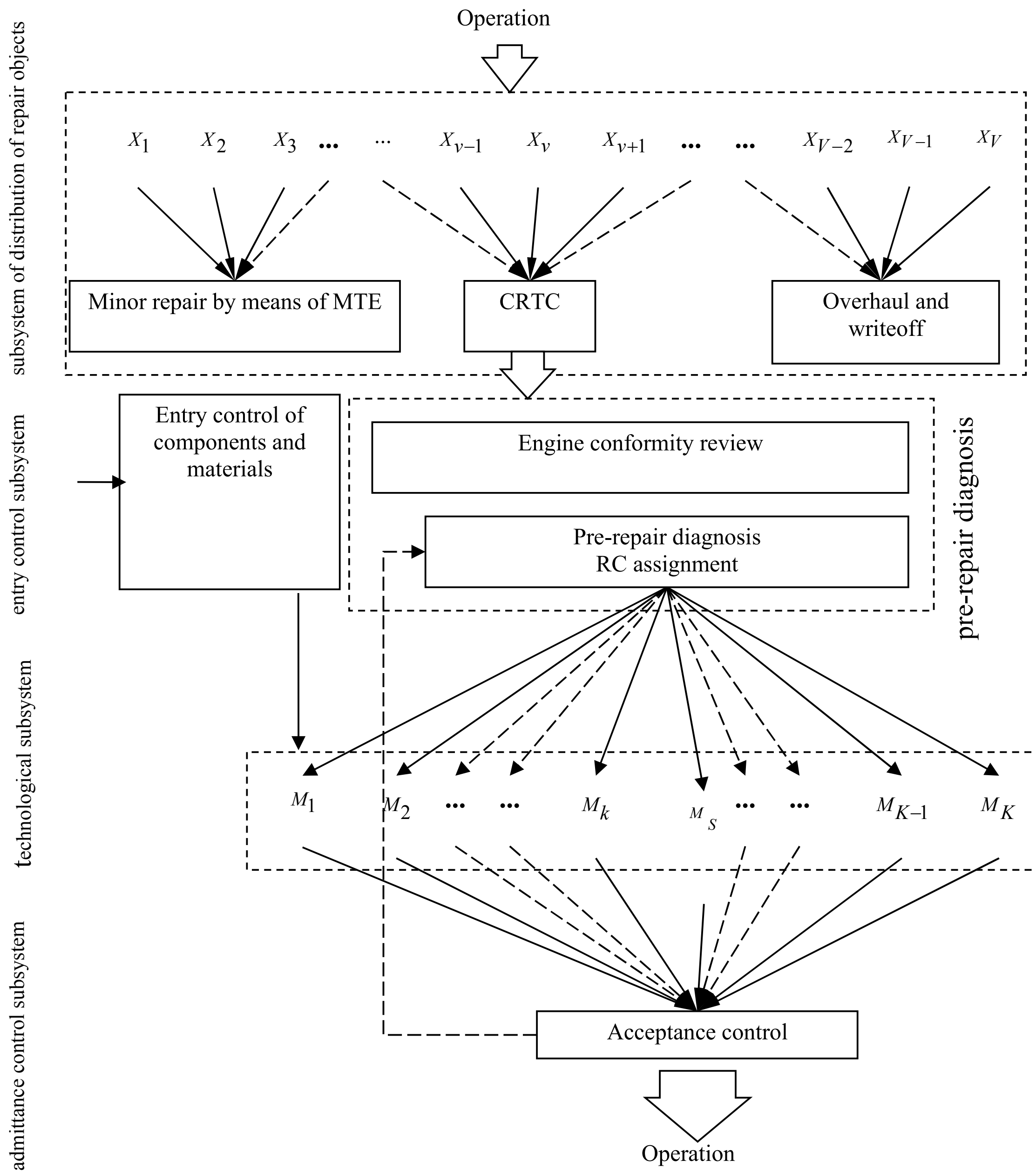

Figure-1. COCR operation model.

As noted above, during the COCR operation there is a need for a reconditioning complex. This task is solved by means of entry control which is performed in two stages. At the first stage the conformity of the units to be repaired to particular requirements (Technical Conditions, GOST) is reviewed. The first stage does not differ greatly from the entry control of engines and repair stock parts during the overhaul and is performed in accordance with GOST 18322-78 [8]. The specific feature of the entry control during the COCR is the second stage - pre-repair diagnosis.

The pre-repair diagnosis system is a set of tools and the object of diagnosis and, if necessary, the performers prepared for the diagnosis or performing it in accordance with the regulations established by the appropriate documentation (GOST 20911-89) [9].

During the attribution of a repair object to one of the RC based on the results of the diagnosis an erroneous RC assignment can occur, which will lead to losses in the COCR system. The losses will be expressed by undue disassembly-assembly work, unreasonable replacement of parts and repeated diagnosis.

The development of an economically and technically sound pre-diagnosis system during the centralized on-condition engine repair allows reducing the losses arising because of the errors in the RC assignment.

VOL. 12, NO. 13, JULY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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An incorrect RC assignment causes losses in the COCR system. The probability of an erroneous RC assignment is characterized by a certain combination of type I and II error probabilities during the evaluation of structural parameters technical conditions. The RC formation determines in what way the structural parameters are grouped in the complexes relative to each other and, therefore, it affects the occurrence of type I and II errors during the diagnosis. Thus, the variants of RC grouping affect the probability of erroneous RC assignment [3, 7, 10, 11].

2. METHODS

Let's consider a few characteristic cases of RC formation [4, 5, 12]. The work analysis showed that one of the characteristic cases of RC formation is the combination (Figure 2, a), when the *s-th* RC includes *k-th* one:

$$M_k \in M_s (k = 1, K-1, s = \overline{k+1, K})$$

This implies that all the jobs, performed in complexes M_k are M_s, and all the spare parts, replaced in M_k, are replaced in M_s; but complex M_s includes the operations not contained in M_k, and accordingly, some of the parts, replaced in M_s, are not replaced in RC M_k. An example of this combination may be the complex of repair operations on the gas-distributing mechanism and the complex, where the gas-distributing and crank mechanisms and repaired jointly. The first RC corresponds to M_k, and the second one corresponds to M_s.

The second typical case of RC formation is the variant (Figure-2, b), when the combinations of $M_s$and M_k intersect ($M_s \cap M_k$, where $\cap$ is the symbol of intersection of sets), i.e. a part of jobs performed in the M_s coincides with those in M_k and some parts, replaced in M_s, are replaced in M_k. An example of similar case can be a complex of repair operations for the gas-distributing and crank mechanisms and a complex of repair operations for the gas-distributing mechanism and the cylinder group. They have the repair operations for the gas-distributing mechanism in common:

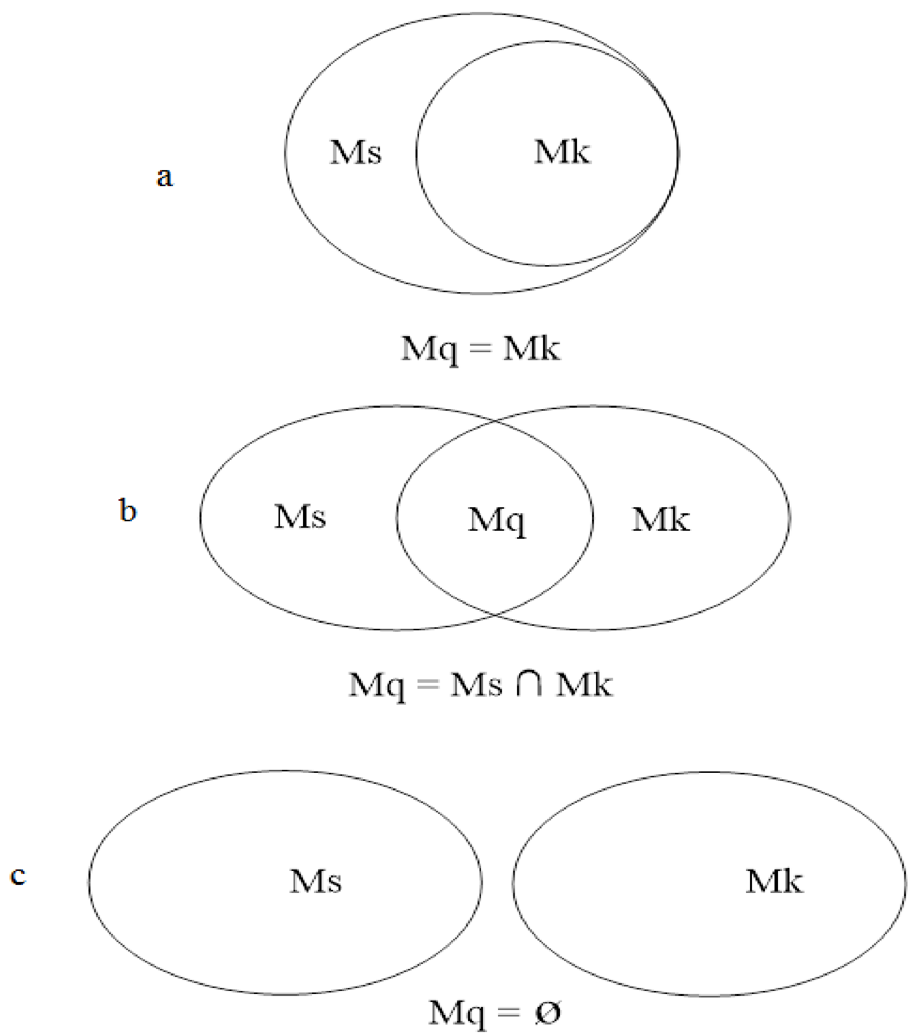

Figure-2. Possible combinations of recognized RC.

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The third typical case of RC formation is the combination (Figure-2, c) when the jobs, performed in RC M_s and RC M_k do not coincide, and the parts, replaced in RC M_s, are not replaced in RC M_k.

An example of the combination includes the combination of repair operations for the car engine gas-distributing mechanism (M_s) and repair of its crank mechanism (M_k).

To simplify the notation of each combination it is proposed to introduce a fictitious reconditioning complex M_q. It is a set, located at the intersection of sets M_s and M_k. In the first combination of RC formation set $M_q = M_k$ as $M_k \epsilon M_s$;in the second combination $M_q = M_s \cap M_k$; and in the third combination $M_q = ø$.

The first combination of RC formation is simpler than the second one. Let's consider the situation when the technical condition of a repair object determines the necessity of RC M_k; and according to the results of the pre-repair diagnosis the necessity of job combination M_s has been erroneously identified. This case is characterized by a type I error, according to at least one of the structural parameters from field $M_s / M_k = M_s / M_q$(symbol «/» means the exclusion of one set from the other). The probability of occurrence of at least one of the joint events is determined by the following formula:

$$P_{sk}^{I} = \sum_{U=1}^{U} \delta_{ue} P(A_{xu} \bar{B} ye) \Psi(\delta_{us} - \delta_{uk}) \quad (1)$$

where $\psi(\delta_{uk} - \delta_{us}) = \begin{cases} 1, if(\delta_{uk} - \delta_{us}) = 1; \\ 0, if(\delta_{uk} - \delta_{us}) < 1. \end{cases}$

In calculation of probability P_{sr}^{I} it is necessary to take into consideration the possibility of evaluation of one structural parameter with several diagnostic ones.

The erroneous evaluation of the *u-th* structural parameter occurs in the case, when during its evaluation by all … *l–1; l; l+1* … diagnostic parameters an error will occur; in the regarded case it is a type I error. Accordingly, the probability of erroneous evaluation of the *u-th* structural parameter equals the product probability of erroneous evaluations by each diagnostic one. This should be taken into account during the evaluation of the type II error probability.

During the assignment of M_s instead of M_k *($M_k \epsilon M_s$)* the volume of remedial work will be overstated. This will cause additional costs of disassembly-assembly and test operations C_{sk}^{1} as well as waste of spare parts C_{sk}^{2}. In general, the losses for this case can be represented as:

$$C_{sk} = P_{sk}^{I}(C_{sk}^{1} + C_{sk}^{2}) \quad (2)$$

The assignment of M_k instead of M_s for the first combination of RC formation (M_q=M_k) is possible in the case, when during the evaluation of all structural parameters in area Ms/M_k type II errors occur.

The probability of joint occurrence of several events can be represented as:

$$P_{sk}^{II} = \prod_{U=1}^{U} [1 - \delta_{ue} P(\bar{A} xu B_{ye}) \Psi(\delta_{uk} - \delta_{us})] \quad (3)$$

In this case, the number of remedial jobs will not be accomplished. Therefore, the operability of the unit will not be restored. During the acceptance control this will cause a deviation from the standards of the generalized diagnostic engine parameters (power, moments of scrolling, etc.). To restore the operability of this engine repeated diagnosis and repair would be required. The effect of the type II error could be estimated by the costs of the repeated diagnosis C_{ks}^{4} and losses from the repeated repair, which coincide in both complexes C_{ks}^{3}.

The losses for this case will be represented as:

$$C_{ks} = P_{ks}^{II}(C_{ks}^{3} + C_{ks}^{4}). \quad (4)$$

When regarding the cases of type I and II error occurrence for the first combination of RC formation we can define the general losses by formulas (2 and 4):

$$C_{1}^{//} = \sum_{k=1}^{K} \sum_{s=k+1}^{K} N(C_{sk} + C_{ks}) = \sum_{k=1}^{K} \sum_{s=k+1}^{K} N[P_{sk}^{I} k_{k}(C_{sk}^{1} + C_{sk}^{2}) + $$
$$+ P_{ks}^{II} k_{s}(C_{ks}^{3} + C_{ks}^{4})], \quad (5)$$

where N is a repair plan;

k_k, k_s are the repair coefficients for M_k or M_s.

For the second combination of RC formation assignment M_s instead of M_k is only possible during the joint occurrence of two events:

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event *D,* when the structural parameters' excess of the allowance in area M_s/M_q has been registered erroneously (this event is characterized by type I errors);

event *E,* when the structural parameters' excess of the allowance in area M_k/M_q has not been identified (this event is characterized by type II errors).

The erroneous assignment of M_s instead of M_k will take place when in area M_s/M_q a type I error occurs at least by one structural parameter; and during the evaluation of structural parameters in area M_k/M_q, type II errors will occur. The probability of the first event is evaluated by the following equation:

$$P_{sk}^{I} = \sum_{U=1}^{U} \delta_{ue} P(A_{xu} \overline{B} ye) \Psi(\delta_{us} - \delta_{uk}) \quad (6)$$

and the error probability of the second event is evaluated by the formula:

$$P_{sk}^{II} = \prod_{U=1}^{U} [1 - \delta_{ue} P(\overline{A}_{xu} B_{ye}) \Psi(\delta_{uk} - \delta_{us})] \quad (7)$$

Since the event of assignment of reconditioning complex M_s instead of M_k is characterized by joint occurrence of events *D* and *E,* the probability of this event will be represented as:

$$P(DE) = P_{sk} = 1 - (1 - P_{sk}^{I})(1 - P_{sk}^{II}) \quad (8)$$

In case of assignment of M_s instead of M_k for the second variant of RC formation a particular kind of losses will occur in the system. During the repair operation on the engine according to M_s instead of M_k part of the work will not be done (in area M_k/M_q). This leads to the fact that the engine will not pass the acceptance control, and repeated diagnosis will have to be performed. Therefore, the system will incur costs for the repeated diagnosis C_{sk}^{4}. During the repair work according to M_s "extra" work, such as disassembly-assembly and control in area M_s/M_q, will be done, the cost of which will amount C_{sk}^{1}. In this case the parts replaced during the work in area M_s/M_q will be replaced erroneously. Therefore, losses from excessive use of spare parts will occur. In this case, there is another cost component from the repeated execution of the works coinciding in RC M_s and M_k – C_{sk}^{3}.

The system losses which occur during the assignment M_s instead of M_k for the case of $M_s \cap M_k$ will be represented as:

$$C_{sk} = P_{sk}(C_{sk}^{1} + C_{sk}^{2} + C_{sk}^{3} + C_{sk}^{4}) \quad (9)$$

The assignment of reconditioning complex M_k instead of M_s for the second combination of RC formation may take place during the joint occurrence of two events:

- in area M_k/M_q an excess of the allowance by at least one structural parameter has been erroneously registered (the event is characterized by type I errors);
- in area M_s/M_q all structural parameters have been erroneously evaluated as occurring within the allowance (the event is characterized by type II errors).

This case regarded as analogous to the previous one, type I and II errors during the assignment $M_s$instead of M_k, are defined by the following equation:

$$P_{ks}^{I} = \Psi(\delta_{us} - \delta_{uk}) \sum_{U=1}^{U} [\delta_{ue} P(A_{xu} \overline{B} ye)] \quad (10)$$

$$P_{sk}^{II} = 1 - \prod_{U=1}^{U} [1 - \delta_{ue} P(A_{xu} \overline{B} ye) \Psi(\delta_{uk} - \delta_{us})] \quad (11)$$

$$P_{ks} = 1 - (1 - P_{ks}^{I})(1 - P_{ks}^{II}). \quad (12)$$

The losses occurring in the system in this case will be also analogous:

$$C_{ks} = P_{ks}(C_{ks}^{1} + C_{ks}^{2} + C_{ks}^{3} + C_{ks}^{4}). \quad (13)$$

In general case the losses occurring in the system because of the type I and II errors will be represented as follows for the second combination of RC formation:

$$C^{//} = \sum_{k=1}^{K} \sum_{s=k+1}^{K} N[P_{sk}^{I} k_k (C_{sk}^{1} + C_{sk}^{2} + C_{sk}^{3} + C_{sk}^{4}) + P_{ks}^{II} k_s (C_{ks}^{1} + C_{ks}^{2} + C_{ks}^{3} + C_{ks}^{4})] \quad (14)$$

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While observing the RC combinations represented in Figure-2, we can easily notice that the second combination (Figure-2, b) is a general case; and equation (14) allows evaluating the losses in the COCR system with any RC combination.

Let's analyze how equation (14) will change if it is regarded in terms of the RC first combination. In the first RC combination area M_k/M_q = Ø; therefore, an erroneous assignment of RC M_s instead of M_k will lead to accomplishment of all repair operations included in Rc M_k. Repeated diagnosis and repair are not necessary ($C^4_{sk} = 0, C^3_{sk} = 0$). The losses in the system will only occur with "extra" work on M_s (C^1_{sk}) RC and with additional consumption of spare parts (C^2_{sk}), Erroneous assignment of M_s instead of M_k for the first RC combination is only characterized by type I errors in evaluation of structural parameters; therefore in equation (3.8) $P^{II}_{ks} = 0$ and $P_{ks} = P^I_{ks}$. The first part of equation (14) for the first RC combination will be represented as:

$$P^I_{sk} k_s (C^1_{sk} + C^2_{sk}) \tag{15}$$

At an erroneous assignment of RC M_k instead of M_s for the first combination of RC (M_k/M_q = ø) a part of complex M_s repair work will not be accomplished which will require a repeated diagnosis (C^4_{sk}) and repair according to M_s (C^3_{sk}). There will be neither additional waste of spare parts nor reconditioning, which do not enter M_s ($P^I_{ks} = 0, P^{II}_{ks} = 0$). Erroneous assignment of $M_k$instead of M_s is characterized by type II errors in evaluation of structural parameters in area M_s/M_k. Type I errors in this case are an impossible event; therefore, in equation (12) $P^I_{ks} = 0$, and $P_{ks} = P^{II}_{ks}$. The second part of equation (14) for the first combination of RC formation will be represented as:

$$P^{II}_{ks} k_k (C^3_{ks} + C^4_{ks}) \tag{16}$$

Summing $P^I_{sk} k_s (C^1_{sk} + C^2_{sk})$ and $P^{II}_{ks} k_k (C^3_{ks} + C^4_{ks})$ for s and k we obtain an equation analogous to equation (5), which allows evaluating the losses in the COCR system for the first combination of RC formation. Accordingly, equation (14) is applicable for evaluation of the losses in the COCR system for the first combination of RC formation.

For the third combination of RC formation (Figure-2, c) the assignment of M_s instead of M_k is characterized by joint occurrence of two events:

- a type I error during the evaluation of at least one of structural parameters in area M_s;
- type II errors during the evaluation of all structural parameters in area M_k.

The probability of these events can be evaluated by equations (6), (7) and (8). The losses in the COCR system will be defined by the costs of disassembly-assembly and control jobs by combination of M_s C^1_{sk}, the unfounded waste of spare parts during the repair according to M_s (C^2_{sk}), and costs of the repeated diagnosis (C^4_{sk}). There will only be no losses caused by repeated work in RC M_s and M_k, because M_s/M_k= ø $C^3_{sk} = 0$. The loss constituents C^1_{sk}, C^2_{sk}, C^4_{sk} in the system, and the probability of erroneous assignment M_s instead of M_k enter the first part of equation (14).

The erroneous assignment of M_k instead of M_s in the third combination of RC formation (Figure 2, c) is characterized by joint occurrence of two events:

- a type I error during the evaluation of at least one structural parameter in area M_k;
- type II errors during the evaluation of all structural parameters in area M_s.

The probability of these events can be evaluated by equations (10), (11), and (12). The losses incurred by the COCR system will be similar to those, regarded in the previous case, and consist of the cost of repair according to RC (C^1_{sk}), unjustified waste of spare parts (C^2_{sk}) and the cost of repeated diagnosis (C^4_{sk}). They all enter the second part of equation (14). Accordingly, equation (14), taking into account the losses for the second combination of RC formation, is applicable to the evaluation of the losses in the third RC combination.

The equation (14) analysis showed that it is universal and can be applied to the formation of rational RC composition for COCR of all vehicles and their component parts in the presence of the original composition of standard reconditioning combinations (SRC).

VOL. 12, NO. 13, JULY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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3. RESULTS

A number of theoretical and experimental studies on SRC formation for some items of special oil-and-gas machinery for maintenance and repair of oil-and-gas wells were carried out by the order of JSC "Surgutneftegas" [3, 11, 13]. This paper presents some results of the accomplished work on the example of a pervasive hoisting unit A-60/80 used during wells overhaul.

Despite the occurrence of a large number of companies that perform maintenance and repair of oil-and-gas machinery and special vehicles in the Surgut region, collecting the amount of experimental data sufficient for analyzing is quite complicated. There are no any records of the performed operations; or the whole process is recorded on paper media, which are usually destroyed after the expiry of the warranty period. JSC "SNG" explain their refusal to provide for the data by an internal confidentiality regulation or the lack of sufficient information because of a short period of work.

That is why, to collect data oil-and-gas production departments "Surgutneft" and "Bystrinskneft" of JSC "Surgutneftegas" have been selected as base enterprises. Their production facilities provide service to up to 60% of the A-60/80 hoisting unit park. The NGDU administration agreed to provide access to the archive orders, which necessarily reflect all the maintenance and repair operations performed.

The NGDU archive stores orders of the past two years, but some of them are handmade, often in illegible handwriting or in carbon copy, and thus, poorly readable. All the documents are stored in large boxes without any sorting, that is why the statistics on the performed work implies difficulties.

Since August 2010, the arrangement of all primary documents is made on the personal computer by means of specialized software "AvtoServis 7.10". This program made by "AvtoDiler", one of the Ekaterinburg companies, allows not only making out all necessary documents, scheduling the working time and monitoring the stock, but also creating some types of report, which facilitates the task of reconditioning base formation. So, it was decided not to carry out an analysis of the handwritten orders, but to create a database of the performed operations based on the reports generated by "AvtoServis 7.10". The data collection was limited to the period from 01 October 2014 to 01 March 2016. By the end of this period some 13,364 orders were in the database.

The client reports were exported to Microsoft Excel for further processing. Using a spreadsheet, sorting data on hoisters' run was performed. All the models, the number of orders for which does not exceed 0.5% of the total, were reduced into one group. Further on, the work completion reports were sorted according to the types of this work and its volume.

It should be noted that a large number of positions are occupied by daily maintenance, monitoring and diagnostic operations, as well as lighting and alarm systems installation. For our studies, these kinds of work did not present any practical value and were removed. Only the operations on replacement or repair of parts and units, the serviceability of which affect the performance of the hoisting unit, were preserved (brake parts, transmission, engine, steering and suspender, top elements). The total resulting sample, consisting of 2,853 repair operations for hoisting units A-60/80B was obtained.

The data, sorted in this way, were copied on separate sheets and distributed according to operation types. It should be noted that at this stage to facilitate the task there were admitted certain conventions to reduce the total number of operation types. For example, the operations on replacement of the clutch driven plate or clutch pressure plate, even if only one part was replaced, were combined into one group "Clutch Replacement". Regardless of the number of the replaced ball joints on one automobile we consider that only one ball joint was replaced. The same situation is with suspension struts, steering rods and brake hoses. The "Repair of generator" group includes both repair of electrical components of the generator (brushes, Rectifier Bridge, stator, etc.) and replacement of bearings. Replacement of the starter was considered in the similar way. Replacement operations are equal to repair operations, because they all record the fact of automobile element failure. In the case of A-60/80B it was decided not to combine into one group the operations on repair and replacement of the components of the tubing round trip electronic control system, but to study separately.

As a result of these actions a finite number of repair operation types for each automobile model A - 60/80 was obtained, which amounts to 36.

In order to simplify the task, during the study the maximum value of the run of the hoisting units under study is limited to 200 thousand kilometers. If the run is greater than the predetermined value, it is considered equal to 200 thousand kilometers.

When building frequency polygons the number of partition intervals for a specific sample is determined according to the rule of Sturges [13, 14]:

$$d \cong 1 + 3{,}32 \ln N \,, \qquad (17)$$

where d is a number of partition intervals,
N is a sample size.

$$d \cong 1 + 3{,}32 \ln 200 = 18{,}6$$

The number of intervals was adopted equal to 20. For easy sorting the odometer readings of the hoisters' run were rounded upward with a step of 10 km; and for each type of repair failure partition tables depending on the run were built by means of Microsoft Excel. The experimental data are grouped in the summary table for the hoister model under study (Table-1).

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Table-1. Failure distribution of A-60/80B hoister elements by run (fragment).

	Operation types	Automobile run, thous. km										
		10	20	30	40	50	…	160	170	180	190	200
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Replacement of the rear shock strut	0	1	1	2	7	…	5	3	4	3	1
2	Replacement of the front shock strut	0	0	4	3	1	…	1	5	3	3	2
3	Repair of the high pressure fuel pump	0	0	0	0	2	…	1	0	1	0	0
4	Replacement of the vacuum servo	0	0	0	0	0	…	0	0	0	0	0
5	Repair of the cylinder head	0	0	0	0	2	…	1	1	2	0	0
6	Repair of the generator	0	1	4	8	3	…	0	0	0	2	0
7	Replacement of the clutch master cylinder	0	0	0	0	4	…	3	2	2	2	0
8	Replacement of the master brake valve	0	0	0	2	1	…	1	0	5	3	3
9	Repair of the gas distribution mechanism	0	0	0	0	1	…	0	1	0	0	0
10	Replacement of rear brake blocks	0	0	0	2	2	…	2	6	3	2	2
11	Replacement of rear brake chamber	0	0	1	0	1	…	3	4	4	5	4
12	Repair of electrical equipment elements	0	0	0	0	0	…	0	1	0	0	0
13	Replacement of injectors	0	0	0	2	2	…	1	1	5	5	3
14	Repair of checkout equipment	0	1	1	9	12	…	2	2	1	2	0
17	Replacement of the cardan drive joint	0	0	1	0	1	…	1	0	2	0	1
18	…	…	…	…	…	…	...	…	…	…	…	…
19	Replacement of the axle bearing	0	0	1	1	1	…	1	0	1	0	0
20	Replacement of the hub bearing	0	1	6	6	6	…	2	2	1	2	3
21	Replacement of the water pump	0	2	7	3	5	…	0	2	0	1	1
22	Replacement of the clutch operating cylinder	0	0	1	0	2	…	0	2	0	1	1
23	Repair of the transfer gearbox	0	0	0	1	1	…	0	1	0	0	2
24	Replacement of spring U-bolts	0	0	1	3	5	…	0	0	2	1	1
25	Replacement of the rear axle gear box	0	0	0	0	0	…	0	0	0	0	0
26	Replacement of the front axle gear box	0	0	0	0	0	…	1	1	0	2	0
27	Replacement of the steering rod end	0	0	1	6	8	…	2	1	3	0	0
28	Replacement of the pivot	0	0	0	0	3	…	1	5	5	3	7
29	Repair of the starter	0	0	0	5	4	…	1	0	0	0	0
30	Replacement of the clutch	0	0	0	9	2	…	2	1	2	5	4
31	Replacement of the thermostat	0	0	1	0	4	…	1	0	2	0	0
32	Replacement of the brake chamber air drive	0	0	0	0	0	…	0	0	0	0	0
33	Total	0	14	45	92	110	…	42	49	58	58	50

To calculate the main characteristics of the distribution the built-in capabilities of Microsoft Excel were used. Figure-3 shows a histogram of the A-60/80B unit elements failure rates distribution, a graph of the approximating function and its equation. The reliability value of approximation R^2 has been calculated.

During the determination of the main characteristics of the distribution the standard expressions of mathematical statistics were used [13]:

- mean distribution value

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$$\bar{x} = \sum \frac{x_i}{N}, \qquad (18)$$

where N is a total number of partition intervals

x_i is the value of a random variable

$$\bar{x} = \frac{3461}{20} = 173.05$$

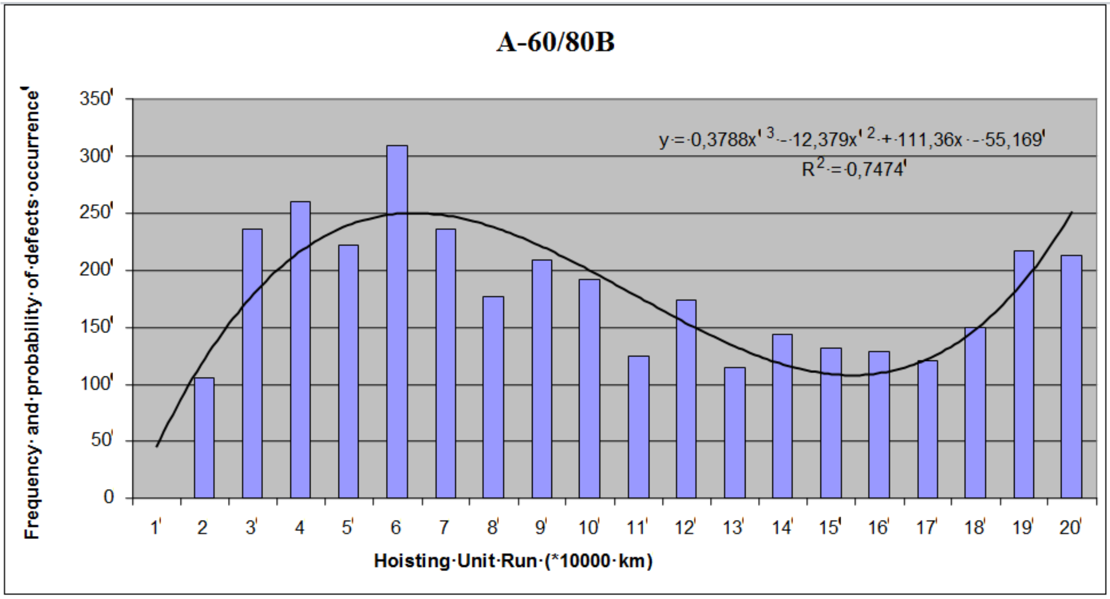

Figure-3. Parameter structuring of experimental data for A-60/80B units.

- variance of random variable:

$$D_x = \frac{1}{N-1} \sum (x_i - \bar{x})^2 \qquad (19)$$

$$D_x = \frac{1}{20-1} \times 89844.95 = 4728.68$$

- mean-square deviation:

$$S_x = \sqrt{D_x} \qquad (20)$$

$$S_x = \sqrt{4728.68} = 68.77$$

- coefficient of variation:

$$v_x = \frac{S_x}{\bar{x}} \qquad (21)$$

$$v_x = \frac{68.77}{173.05} = 0.4$$

The formation of standard reconditioning combinations in each interval of the hoister run was performed by means of the above methodologies in terms of technological compatibility [6, 12].

The results of the SRC formation for the A-60/80B hoisting unit are partially presented in Table-2.

VOL. 12, NO. 13, JULY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-2. Standard reconditioning combinations for the A-60/80B hoisting unit (fragment).

	Run, thous. km	**60**										**80**								
	Operation types	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**…**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Replacement of the front shock strut		X				X				…				X					
2	Replacement of the clutch operating cylinder				X						…					X				
3	Replacement of the front axle gear box										…								X	
4	Replacement of the rear axle gear box										…			X						
5	Replacement of the master brake valve					X					…							X		
6	Replacement of the clutch master cylinder				X						…					X				
7	Replacement of the rear shock strut										…				X					
8	Replacement of rear brake blocks	X	X	X						X	…						X			X
9	Replacement of the cardan shaft yoke		X				X				…				X					
10	Replacement of the steering lever		X						X		…				X		X			
11	Replacement of the pivot																		X	
12	Replacement of front brake blocks	X	X	X							…				X		X			
13	Replacement of the cardan drive joint									X	…									
14	Replacement of the axle bearing			X			X				…				X		X			
17	Replacement of the brake chamber air drive										…							X		
18	Replacement of the steering rod end		X						X		…						X		X	
19	Replacement of spring U-bolts		X						X		…				X					
20	Replacement of the clutch	X			X		X			X	…		X			X				X
21	Replacement of the thermostat					X					…		X							
22	Replacement of the vacuum servo		X			X		X			…							X	X	
23	Replacement of brake drums			X							…							X		
24	Replacement of rear brake chamber			X							…							X		
25	Replacement of injectors							X			…		X							X
26	Repair of the transfer gearbox					X					…			X						
27	Repair of the generator						X	X			…		X							
28	Repair of electrical equipment elements	X		X		X		X			…	X	X			X				
29	Repair of the starter	X				X					…	X				X				X
30	Repair of checkout equipment				X						…					X				
31	Repair of the high pressure fuel pump	X		X		X		X			…	X	X							
32	Repair of the gas distribution mechanism					X	X				…		X	X						
33	Repair of the cylinder head								X		…						X			

Later the obtained SRC were used for the formation of the RC rational number and composition for the A-60/80B hoisting unit.

4. CONCLUSIONS

The results of the research allow drawing the following conclusions.

a) During the COCR there is no need to determine all the vehicle failures; it is sufficient to assign a reconditioning complex (RC), in which all possible combinations of defects of this unit are already taken into account.

b) During the attribution of a repair object to one of the RC based on the results of the diagnosis an erroneous RC assignment can occur, which will lead to losses in the COCR system. The losses will be expressed by undue disassembly-assembly work, unreasonable replacement of parts and re-diagnosis.

c) The probability of an erroneous RC assignment is characterized by a certain combination of type I and II error probabilities during the evaluation of structural parameters technical conditions. Thus, the variants of RC grouping affect the probability of erroneous RC assignment.

d) A set of standard reconditioning combinations in the adopted interval of the automobile run (unit operating time) can be used as original population to form rational RC structure for an automobile unit under repair.

e) As a result of empirical data collecting and processing ordered by JSC "Surgutneftegas" reconditioning standard combinations for A-60/80B hoisters have been obtained. Their structure is partially given in the tables.

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