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Model of conjoint fault detection at metrological service of electronics

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Abstract

Three types of conjoint fault detection are usually employed at the diagnostic of electronic systems, namely: independent conjoint fault detection, compatible conjoint fault detection, and zone conjoint fault detection. We have performed comparative consideration of the employment of these three types of conjoint fault detections for the troubleshooting of electronic systems. Expressions for quantitative assessment of quality indices (average recovery time, mathematical expectation of deviation of a diagnosis with one error in evaluation of the inspection result, the probability of correct diagnosis and the probability of correct evaluation of the result of the test) for all three types of conjoint fault detections are derived. Basing on these expressions a generalized model, which combines all three types of conjoint fault detection and performs a selection of the most appropriate type of conjoint fault detection, is developed. The model is capable of predicting quantitative parameters of the quality of diagnostic procedure with the account for the metrological reliability of measuring instruments. The latter allows for lowering of the labor expenses at repairing of the electronic systems. The model is also designed for the account of a possible diagnosis mistake for three types of conjoint fault detections. In the final stage of the model, a conditional diagnostic algorithm is developed and qualitative indicators are specified.

Keywords: metrological service of electronics; conjoint fault detection; metrological reliability of measuring instruments.

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1. Introduction

Nowadays when electronics deeply penetrates all spheres of human beings, its proper functionality in many cases is of survival importance. Development of techniques for control of the technical state, fault detection, and isolation, are, thus, among the priorities in modern technical progress, being of the importance, which is not lower than that of the invention of new technologies and devices. A generalized approach to the modeling of different approaches to the organization of fault detection in electronic systems with different degrees of damage, capable of taking into account the metrological reliability of the measuring instruments, is not available in the literature. The purpose of this paper is the development of a general model of the so-called *conjoint fault detection* (CFD) approach to the organization of the repairing of electronic systems. The paper is organized as follows. The classification of the approaches to the organization of the fault detection is given in section 2. The overview of the typical problems solved with different CFD models, considered in Refs. [1–11] is presented in section 3. In section 4, we develop a general model, which is capable of the combined consideration of the problems separately considered in Refs. [1–11]. Examples of the application of the model are presented in section 5. Section 6 concludes our results.

2. Classification of management approaches to the fault detection

Depending on the dimension of an electronic device (number of replaceable electronic elements) or system under repair, the detection of faults can be either *individual* or *conjoint*. The *individual fault detection* is performed by a single specialist. Traditionally the CFD is employed for small-dimension electronics with the countable number of replaceable electronic elements, but it appears to be insufficient for electronic systems (ES) of large-dimension with tens of thousands or more replaceable elements. A team of specialists should be involved in the fault diagnosis of large-dimension electronics. In such a case one says that the *conjoint fault detection* is employed. It is worth noticing, that the robotized fault detection (RFD), emerged in recent years should be added to this classification of the types of the organization of the process of fault detection. The distinct difference between the *individual fault detection*, on one side, and the CFD and RFD, on the other, is that the *individual fault detection* is based mainly on the intuition of the specialist, inspired by his own experience. Formalization of the detection process in the form of a written protocol for the *individual fault detection* is rarely needed, whereas the CFD requires, at least, redistribution of the duties between the repairing team members and management of their work, at least, by a head of the team.

Three types of CFDs are distinguished, namely: independent CFD (CFD_i), compatible CFD (CFD_c) and zone CFD (CFD_z) [1–3]. The CFD_i is employed for fault detection in complicate systems built of independent sections such as an engine, power station, security-alarming subsystems, *etc*. that work on essentially different principles and/or play roles, which are different from that of the main electronic part of the system. The CFD_c is performed for a system, parts of which are spatially dispersed on considerable distances. Common monitoring of the system as a whole by repairing specialists and exchange of information between them must be provided at the CFD_c. The CFD_z is employed for repair of ESs of modular construction or, if the electronic scheme allows for virtual, functionally justified division of the scheme into zones.

3. Review of the problems in the management of CFD

Increasing the efficiency of the work of the repair team can be achieved via the improvement of the repair and diagnostic support of the ES at the stages of their design and operation. Namely, the following components of the repair and diagnostic support: modular design, justification of the set of standard measuring instruments, rational embedding of diagnostic tools, proper completing of the repair kit for implementation of the repair by the modular method, *etc*., can be optimized during the design of the ES. In course of exploitation of the ES, the improvement can be achieved by enhancing the technical and technological documentation, by prompt and proper training of specialists, by the invention of modern achievements of technical diagnostics in practice of repair, *etc*. Such qualitative factors have to be quantitatively accounted for the description of the effectiveness of the repair procedure. Analysis of the available literature allows one to formulate general rules for their implementation with a purpose to increase the effectiveness of the joint activity of the repair team. Several particular problems have been considered in the current literature concerning the application of the CFD approach. Below we give a short survey of such studies aiming to set on a theoretical basis the process of management of diagnostics and repair of complicate electronic systems via CFD.

In Ref. [2] analytical expressions for quantitative evaluation of characteristics of the process of repairing of communication tools with accidental damage have been reported. In the study of the conjoint search for multiple defects, performed in Ref. [3], analytical expressions for quantitative estimation of the total number of inspections for localization of multiple defects with shortened search procedure for group algorithms as well as expressions for optimization of the form of group diagnostic algorithms for a given degree of damage to an object were derived; critical multiplicity of defects, exceeding of which requires application of group algorithms of the maximal form was established as well. Analytical expressions for quantitative evaluation of diagnostic errors for conjoint conditional algorithms of isolation of faults were derived in Ref. [4]. Functional dependences of the reliability indicators for diagnostics of electronic tools on controlled variables (repair conditions, quality of diagnostic and metrological support) were obtained in Refs. [5, 6] and investigated for their impact on the elimination of multiple faults of an ES with accidental damage to justify requirements for their metrological service. Formalization of the process of development of diagnostic support for maintenance and repair of communication tools with different degrees of damage was performed in Ref. [7] using the CFD approach. In Ref. [10] the application of compatible CFD is considered for current repair of ESs and quantitative indicators of its efficiency are given. Quantitative estimation of the metrological reliability of measuring instruments and of its impact on the calculated average recovery time of the ESs was performed in [11].

In summary, to the best of our knowledge, a generalized approach to the modeling of various types of CFDs during the troubleshooting of ESs with different degrees of damage, which takes into account the metrological reliability of measuring instruments, is not available in the literature. In the next section we develop a general model of the CFD process for repairing of ESs, which will be capable for the solution of the problems considered in Refs. [1–11], alluded to above. Namely, the aim of this paper is to develop a model for quantification of the probability of a correct diagnosis, the average recovery time, the effort needed to complete the work (man hours) and cost of repair taking into account the metrological reliability of measuring instruments and the probability of a correct assessment of the result of inspection.

4. Development of the Model

To build a model, capable of improvement of the repairing procedure one has to quantify its qualitative characteristics. The effectiveness of the repair activity of the team of specialists is characterized by the average time T_a needed for the restoration of an ES.

It should be noticed that the value of T_a includes the time for diagnostics of the object, such that up to 60–80% of T_a is spent for finding of defects, and only 40-20% for troubleshooting, checking performance in all available modes and, if necessary, for adjusting of the characteristics to their nominal values [1–9]. In the proposed model the quality of repair work is optimized via minimization of the time T_a, needed for the restoration of an ES. In terms of the theory of optimization we construct the loss function T_a $(L, S, R, t, t_{\text{trb}}, K, p)$, where L is the depth of fault search (dimension of the object); S is the degree of damage of the ES (the ratio of the number of faults to the dimension of the object); R is the total number of specialists in the mobile repairing team; t is the time needed for the inspection; t_{trb} is the average time of troubleshooting; K is the average number of inspections; p is the probability of correct evaluation of the result of inspection. The explicit expression for the loss function T_a $(L, S, R, t, t_{\text{trb}}, K, p)$ and other calculation ingredients are given in Table 1.

Table 1

Parameters for the model of CFD

Parameter	Type of CFD		
	Independent	Zone	Compatible
$\{\mu, R, Z, K_Z\}$	$\{1, 1, 1, K\}$	$\{1, R, Z, K_Z\}$	$\{\mu, \mu, 1, K\}$
K	$\frac{1-S}{2SL(m-1)^2}\left(\frac{m-1}{1-S}-1\right)\times$ $\times\left(\frac{m-1}{1-S}+m\right)+2(SL-1)+$ $+SL\log_m\frac{1-S}{S(m-1)}$	$Z(1+K_Z)+SL/Z$	$SL\left(1+\log_{\mu+1}\frac{L}{n}\right)+$ $+\frac{n-\mu-1}{\mu}$
K_Z	–	$\frac{1-S}{2SL(m-1)^2}\left(\frac{m-1}{1-S}-1\right)\left(\frac{m-1}{1-S}+m\right)+$ $+2\left(\frac{SL}{Z}-1\right)+\frac{SL}{Z}\log_m\frac{1-S}{S(m-1)}$	–
n	$SL(m-1)/Z(1-S)$		$\mu SL/(1-S)1n(\mu+1)$
P	$p^{1+ZK_Z/SL}$		$p^{\mu\left(1+\log_{\mu+1}(L/n)\right)}$
T_a	$(\mu tK+SLt_{\text{trb}})/PR\,P_M$		
W	$T_aR=(\mu tK+SLt_{\text{trb}})/P\,P_M$		
C	$W\sum_{i=1}^{R}c_i=\left[(\mu tK+SLt_{\text{trb}})/PP_M\right]\sum_{i=1}^{R}c_i$		

Attempts of computer simulations of the repair process for an ES reported in Refs. [5–10] have been made with the application of particular types of CFDs. The model developed here covers all three types of CFDs. The idea of the model is the optimization of the choice of the most appropriate type of CFD by the criterion of minimum quality repair indicators for restoration of functionality of the ES, with the account for permissible limits of variation of the parameters of the conditional diagnostic algorithms as well as with the account of quantitative assessment of their probability characteristics [9, 12].

We perform the choice of the type of CFD with the following restrictions for the conditions of repair

$$CFD\{CFD_i, CFD_z, CFD_c\}\,at\begin{cases}T_a\le T_{a\,\text{perm}};\,C\le C_{\text{perm}};\,0.01<S<0.2;\\1\le\mu\le R;\,\rho_{\max}\le 1;\,\rho\le 0.5;0.6\le p<0.999,\end{cases}\tag{1}$$

where $T_{a\text{perm}}$ is the upper permissible limit for the recovery time; ρ is the mathematical expectation of a deviation of a diagnosis with a single error in the evaluation of the result of the test; $\rho_{\max}$ is the maximum possible value of ρ; C is the minimal cost of the repair; C_{perm} is the upper permissible limit for C;

W is the total number of hours for the repair. Input data are obtained from the following sources: L, Z, R, p from manuals of the ES or measuring instruments, and from the information on the qualifications of repairing specialists; K, n, m from the characteristics of the employed diagnostic procedures. When a repairing crew is distanced from the main team and its supply base, one uses the number μ of repairing specialists in the crew involved in the given CFD, instead of the total number R of specialists in the main repairing team, such that $1 \le \mu \le R$. The parameter Z is the number of search zones in the application of the CFD$_z$, n is the number of groups of elements in the algorithm of fault detection; m is the selection module of inspections. By definition, m is the number of possible outcomes of the inspection. Namely, $m = 2$ is for the possible outcomes in the form “norm/not-norm”, $m = 3$ for the outcomes “less-than-norm/norm/more-than-norm”, $m = 4$ for “no-signal/less-than-norm/norm/more-than-norm”, and so on. The higher is the selection module the lower is the number of inspections needed for detecting a fault. The possibility of increasing the selection module appeared with the use of digital measuring instruments of high accuracy, which allowed one to quantify gradations of possible outcomes. The latter was not possible for analog devices, and, thus, one had to use the binary algorithms with the module $m = 2$, which implies the presence or lack of control signal at a calibration point.

The consideration is performed with the following assumptions: the degree of damage S to the technical object is determined with a given probability as a result of defects identification in the range $0.01 \le S \le 0.2$ [4]; the worst of possible diagnostic scenarios of uniform distribution of defects in the inspected object is assumed; new defects do not occur during the diagnostic process; organizational time losses are not taken into account; technological equipment (power supplies, switchers, cables for connection of units under repair, specialized repairing tool) and spare parts kits are in good order; the qualification of repair specialists corresponds to their employment positions; repair equipment is provided with a proper set of documentation.

The following notions are defined as controllable variables at the development of a diagnostic tool for an ES: K is the total number of inspections to search for the defects at given values of L, S, R for chosen type and form of the conditional diagnostic algorithm; P is the probability of correct diagnosis; P_M is the metrological reliability of the measuring instrument [11]. The probability

$$P_M = 1 - 720\tau K_U K_M K_S^* / T^* \qquad (2)$$

of the preservation of the values of metrological characteristics in the specified limit range during the time interval τ (measured in months) between scheduled inspections is chosen as a degree of metrological reliability of the measuring instrument, where K_U is the coefficient of exploitation of a given measuring instrument ($0.1 \le K_U \le 0.3$); K_M is a fraction of metrological characteristics, which are not covered by the built-in control; K_S^* is the statistical estimation of the coefficient of hidden failures ($0.1 \le K_S^* \le 0.24$); T^* is the statistical estimation of the working time of the measuring instrument in approach to its failure [11]. For a working measuring instrument typically $0.85 \le P_M \le 0.9$ (compare to $0.9 \le P_M \le 0.99$ for a standard perfectly working measuring instrument). In the absence of real statistics on the metrological reliability of the measuring instrument at calculations, one can use an approximate value $P_M \approx 0.9$.

The loss function T_a, given in Table 1 has to be minimized with respect to the chosen variables to provide a value of T_a which is lower than the given value $T_{a\,\mathrm{perm}}$ at a minimum cost of repair C, depending on the operating conditions of the repairing team, either in stationary office conditions or at restrictions on resources in conditions of autonomous exploitation, when an ES is considerably distanced from the supply and repair bases (for example, on ships and aircraft, polar and space stations, expeditions and in many other similar cases) [11].

Minimization of the loss function with respect to the variable parameters such as the number of groups of elements in the algorithm, the total number of inspections in the search for all defects, the required number of specialists in the team, *etc.* [2–11] results in explicit analytical expressions for quantitative assessment of quality indicators of the diagnostic service via the CFD of the given type, which are summarized in Table 1. The definitions of the parameters presented in the Table are specified above in the text and their role in the model will be discussed below in this section; c_i is the cost of work of a specialist of i qualification per hour. Hints for the derivation of the expressions given in Table 1 can be found in Refs. [2–11]. Below we illustrate the derivation of the expression for one of the parameters, namely for the total number K of inspections by the repairing team under the compatible CFD by the conditional diagnostic algorithm of the minimum form, for example at $L=28$, $n=7$, $\mu=3$, $Q=4$, $S=0.143$ (depicted in Fig. 1) with the uniform distribution of defects (with elements # 3, 10, 17 and 24 being damaged).

In this case, all experts perform the test simultaneously, and therefore it is considered as one action. Then, the total number of inspections is equal

$$K = SL\left(1 + \log_{\mu+1}\frac{L}{n}\right) + \frac{n-\mu-1}{\mu}, \qquad (3)$$

where the last term in Eq. (3) takes into account the repeated execution of inspections. For the considered example one has

$$K = \sum_{i=1}^{Q} K_i = 2 + 2 + 3 + 2 = 9,$$

which is in agreement with that obtained using Eq. (3), namely

$$K = 0.143 \cdot 28\left(1 + \log_4\left(28/7\right)\right) + \left(\left(7 - 3 - 1\right)/3\right) = 9.$$

Diagnosis is performed with a truncated search procedure without re-checking the working part of the product, after eliminating defects.

In this paragraph, we continue the discussion of the parameters given in the Table. The parameter K_z is defined specifically for the zone CFD and for this reason is not calculated for the CFD$_i$ and CFD$_c$. The parameter n which is the number of groups of elements in the algorithm of fault detection depends on the number of specialists (μ), involved in the fault detection as well as on the degree of damage of the object (S). Since $\mu = 1$ for both the independent and the zone CFDs, the optimal value of n is calculated for them by the same expression, whereas for the compatible CFD, $\mu \neq 1$ and, consequently, n is calculated differently, as it is specified in the Table.

The similar situation is for the parameter P, which is the probability of correct diagnosis and which also depends on μ. Consequently, P is calculated by the same expression for the CFD$_i$ and CFD$_z$, which is different from that for the CFD$_c$. The loss function T_a was discussed at length above in this section. It is specified by the same expression for all three types of the CFD, but substituting the values of μ, K and P, which are specific for the given type of CFD. The parameter c_i is the cost of work of a specialist of i qualification per hour. Other remaining variables (t, S, L, t_{trb}, P_M) are common for all types of CFD.

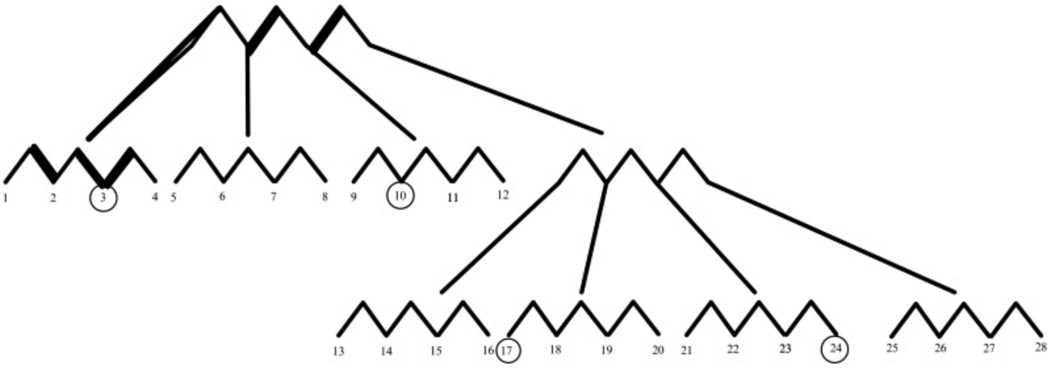


Fig. 1. An example of a compatible CFD with the exchange of information on the conditional diagnostic algorithm of the minimum form

The structure of the model is shown in Fig. 2. The model is designed to determine the type of CFD to reduce labor costs for restoration of the functionality of ESs and the satisfaction of requirements for their repair feasibility. Taking into account the above considerations, the general model of the CFD process (independent, compatible, zone) is a set of conditional diagnostic algorithms, which are used by a team of specialists, together with the functional dependencies of their parameters and constraints for controlled variables. The developed CFD model allows for quantitative assessment and maximization of the production capacity of the repair body at given conditions of operation.

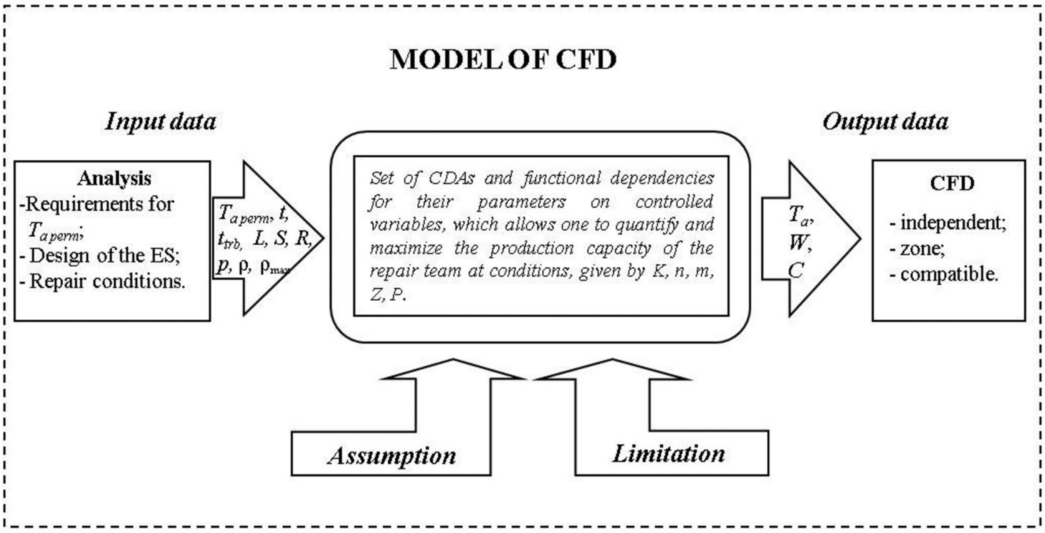
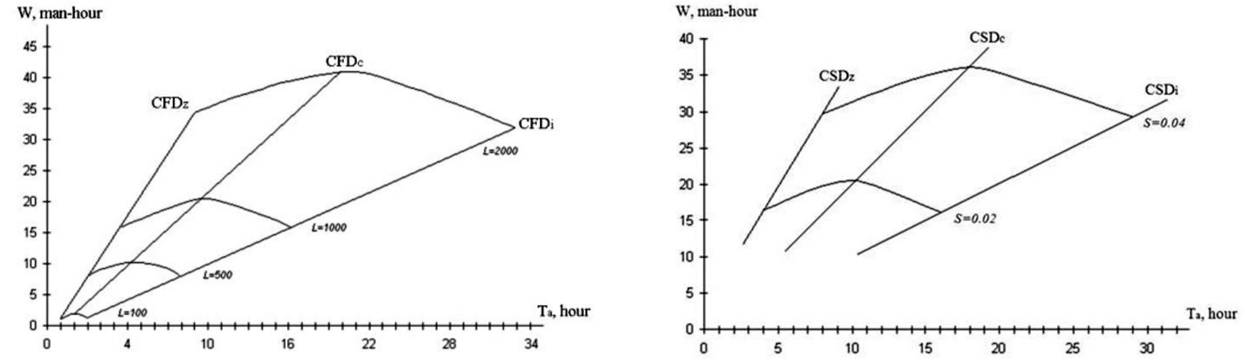


Fig. 2. Structure of the model of the CFD

Depending on the characteristics of the circuit design of the technical object and on the degree of damage, the set of conditional diagnostic algorithms, used in the development of diagnostic service with the given CFD can be of one of the forms: incomplete ($K_{\min} < K < K_{\max}$); perfect ($K_{\min} = K = K_{\max}$); minimal ($K_{\max} - K_{\min} = 1$); maximal ($K_{\min} = 1$; $K_{\max} = L - 1$). Depending on used measuring instrument, qualifications of specialists, implemented diagnostic procedures, the conditional diagnostic algorithms are of the type: binary ($m = 2$); homogeneous ($m = \mathrm{const}$); heterogeneous ($m = \mathrm{var}$) or group ($m = \mu+1$) [10]. Values μ, R, Z are selected based on the conditions of repair and design of the ES. When eliminating multiple defects, randomly distributed in the object, via CFD$_z$ in each of Z zones there are SL/Z defects among the L/Z elements. To minimize the total number of inspections in the zone K_z when constructing the conditional diagnostic algorithm, the elements are divided into $n \approx SL/Z$ groups, each of which contains no more than one defect, which is detected by the optimal form algorithm, after the execution of $k = \log_2\left(L/Zn\right) \approx -\log_2 S$ inspections. For K_z value, determined according to Table 1 one has $K_Z = (k+2)SL/Z$, where $k = K_Z/n - 2$.

5. Application of the model

The developed model allows one to compare the effectiveness of the implementation of different types of CFDs. Fig. 3*a* shows the dependence of the total number of hours W (calculated from the equation presented in Table 1) for the restoration of an ESs for the depth of the fault detection L with different used conditional diagnostic algorithms for $S = 0.02$; $m = 2$; $p = 0.995$. The advantage of the zone CFD$_z$, which minimizes both time and labor expenses of repairs, is evident.



a *b*

Fig. 3. Dependence of labor costs for the repair of one set of REM for different (*a*) depths of defect search using different algorithms at $S = 0.02$; $m = 2$; $p = 0.995$ (*b*) degrees of damage employing different types of CFDs

Similar results are obtained when studying the dependence of labor costs for repairing the same ES for different degrees of damage S using different type CFDs for $L = 1000$, $m = 2$, $p = 0.995$ (Fig. 3*b*). As it can be expected, our analysis shows that the increase of the professional level of the repair specialists results in the reduction of the time of recovery via increase of the intensity of labor, when the most effective conditional diagnostic algorithm (heterogeneous with the module of choice of more than two) is employed.

The adequacy of the model is verified on the example of the development of the diagnostic support of the station of tropospheric communication station [10] for the CFD by two specialists with the following input data: $L = 51$, $S = 0.01$; $p = 0.995$; $T_{a\,\mathrm{perm}} \leq 20$ min; $t = 3$ min, $t_{\mathrm{trb}} = 5$ min; $m = 2$; $\mu = 2$. To be explicit we recall that the adequacy of the model is the capability of the model to predict the output parameters [12] with a relative error, which is not higher than a certain nominal value. The error of diagnosis is specified by the condition of finding and isolation of a faulty element in a given part of the electronic system in the assumption of one error of the specialist in the evaluation of the result of the test. Namely, it is accepted that the average value of ρ is not higher than 0.5 and its maximum value is not higher than 1.0.

The results of testing the adequacy of the model are summarized in Table. 2. Analysis of Table 2 shows that the relative error of the results of calculations of the average recovery time $\delta T_a \leq 3.35\%$, and for the labor costs $\delta W \leq 5.0\%$, which confirms the feasibility of the model.

Analysis of the results of Table 2 shows that the highest probability of correct diagnosis (P) is provided by the independent and zone CFDs. However, they do not meet the requirements for an average recovery time, which according to the restriction alluded to above should not be longer than 20 minutes. Moreover, in the considered case, the construction of the tropospheric communication station [10] does not allow for the zone CFD. The lowest value of P for the compatible CFD is explained by the fact that in this case, the two specialists work at the same time and the probability of an erroneous assessment of the result of the inspection is higher than that for one involved

Table 2

Results of verification of the adequacy of the CFD model

Type of search		P	T_a, min	W, man-hour
CFD$_j$ [9]		0.931	17.9	0.6
Simulation results	CFD$_i$	0.944	24.0	0.4
	CFD$_z$	0.944	20.3	0.67
	CFD$_c$	0.911	17.3	0.57

specialist. Due to the teamwork of the two specialists at CFD$_c$, the recovery time reaches its minimum value of $T_a = 17.3$ minutes. However, it should be noted that the latter is accompanied by an increase in the amount of work up to 0.57 person-hours. Therefore, in the considered case, it is advisable to use the CFD$_c$, which allows one to achieve the required value of the average recovery time.

6. Conclusions

We have performed comparative consideration of the employment of three types of CFD (independent CFD$_i$, compatible CFD$_c$ and zone CFD$_z$) for the troubleshooting of ESs. Expressions for quantitative assessment of quality indices (average recovery time, mathematical expectation of deviation of a diagnosis with one error in evaluation of the inspection result, the probability of correct diagnosis and the probability of correct evaluation of the result of the test) for all three types of CFDs, are derived. Basing on these expressions a generalized model, which combines all three types of CFD and performs a selection of the most appropriate type of CFD, is developed. The model is capable of prediction of quantitative parameters of the quality of diagnostic procedure with the account for metrological reliability of measuring instruments. The latter allows for lowering the labor expenses at repairing of the ESs [13]. On the next stage of the model, a conditional diagnostic algorithm is developed and qualitative indicators are specified.

Модель групового пошуку дефектів при метрологічному обслуговуванні радіоелектронних засобів

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Анотація

Розроблено узагальнену модель групового пошуку дефектів для розрахунку кількісних параметрів процесу діагностування радіоелектронних засобів. Її використання зменшує трудові та часові затрати на пошук дефектів. Модель ґрунтується на аналітичних виразах для різних типів пошуку дефектів, які визначають показники якості діагностування, такі як: загальна кількість перевірок; ймовірність правильної постановки діагнозу; метрологічна надійність вимірювального приладу; загальна кількість годин на відновлення радіоелектронних засобів; мінімальна вартість ремонту та ін.

На практиці для ремонту радіоелектронних засобів застосовують три типи групового пошуку дефектів, а саме: незалежний, спільний та зонний. Виведено вирази для кількісної оцінки середнього часу відновлення, математичного сподівання відхилення діагнозу з однією помилкою в оцінці результату обстеження, ймовірності правильного діагнозу та ймовірності коректної оцінки результату перевірки для всіх типів групового пошуку дефектів.

Розроблено модель, яка поєднує в собі всі три типи групового пошуку дефектів і обґрунтовано дозволяє обрати найбільш ефективний із них. Модель призначено для прогнозування якості процедури діагностування з урахуванням метрологічної надійності вимірювальних приладів і оцінки помилкової постановки діагнозу при ремонті агрегатним методом. На завершальному етапі розробляється умовний алгоритм діагностування та уточнюються показники якості відновлення радіоелектронних засобів з урахуванням особливостей метрологічного забезпечення цього процесу.

Запропонована модель є універсальним засобом, який можна застосовувати для технічного обслуговування та ремонту комплексних об'єктів, що включають механічні, електронні та електричні складові.

Ключові слова: метрологічне обслуговування радіоелектронних засобів; груповий пошук дефектів; метрологічна надійність засобів вимірювання.

Модель группового поиска дефектов при метрологическом обслуживании радиоэлектронных средств

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Аннотация

Для ремонта радиоэлектронных средств применяют групповой поиск дефектов, а именно: независимый, совместный и зонный. Для них получены выражения по количественной оценке среднего времени восстановления, математического ожидания отклонения диагноза, вероятности правильного диагноза. Разработана модель, которая сочетает все типы группового поиска дефектов и обоснованно позволяет выбрать наиболее эффективный из них. Модель предназначена для прогнозирования параметров процедуры диагностирования с учетом метрологической надежности измерительных приборов при реализации ремонта агрегатным методом. На завершающем этапе разрабатывается условный алгоритм диагностирования и уточняются показатели качества восстановления радиоэлектронных средств с учетом особенностей метрологического обеспечения этого процесса.

Ключевые слова: метрологическое обслуживание радиоэлектронных средств; групповой поиск дефектов; метрологическая надежность средств измерения.

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