РАДІОФІЗИКА

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RADIOPHYSICS

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THE DESIGN PROCEDURE OF SPECIFIED OPERATING LIFE OF FIBER-OPTIC CABLES

The task of prediction of fiber cable operating life for automating of design study of reliability of optical-fiber transmission system was solved in the paper. The paper offers generation method of mathematical models of complex coefficients, which brings out from the input models failure rates the coefficients, which considers the effects of regimes and conditions of usage of fiber cables on the durability indices.

The developed procedure does not require carrying out the experimental investigations and tests, based on the using of standardized models of failure rates and durability characteristics of fiber cables. Herewith for the prescribed modes and terms of usage of fiber cables automatically detected the right process of degradation, which determines values of operating life.

In contrast to the prediction technique of equipment operating life on the base of the probabilistic-physical failure patterns, the offered method operates with the dates, which are stated in the standard-technical documentation on the fiber cables, and allows to increase forecast precision of the operating life in comparison with the methods, which is recommended in the branch standards.

In the paper were developed software, which implements offered mathematical tool, by which were solved real-world forecasting problem of the operating live of the cable type ОК-ПН-01-5-60.

Keywords: optical-fiber transmission system, optical-fiber cable, reliability, durability, operating life, failure rate.

NOMENCLATURE

$d_{\max}$ is a maximal value of the damping constant in the fiber cable, by which provides operation of fiber-optic systems of information transmission;

I is a quantity of self-contained failure flows of the component parts of electro-radio elements;

I is a quantity of operating temperature (except the maximal allowed according to the technical requirements);

J_i is a quantity of factors, which is considered in i failure flow;

$L_к$ is a length of fiber cable;

N is a quantity of the bends (back winding, etc.) of the cable per time of its operation;

m is a quantity of the optic fibers in the cable;

t is a operating time of the cable;

$t(work)$ is a cable temperature in the operating mode, ^{0}C;

t_i is a total interval of operating time of the cable by the temperature T_i;

$t_{T\max}$ is a total interval of operating time of the cable by the maximal temperature according to the technical requirements;

$T_{\text{мах}}$ is a maximal allowed cable temperature according to the technical requirements;

λ_{b1} is a base failure rate of the optical fiber during the process of its operating time, referred to the 1m cable length;

λ_{b2} is a base sudden failure rate of the optical fiber composed of fiber cables during the process of its repeated back winding referred to the 1m cable length;

λ_{b3} is a base sudden failure rate of structure of cables during the process of its operating time, referred to the 1m cable length;

λ_{b4} is a base sudden failure rate of structure of cables during the process of its repeated back winding, referred to the 1m cable length;

λ_{b5} is a base gradual failure rate of fiber cables during the process of its operating time;

λ_{bi} is a base failure rates i failure flow;

λ_e is a failure rate of the fiber cable on the maximal regime and conditions of usage according to the technical requirements;

$\lambda_e(work)$ is a failure rate of the fiber cable on the operating mode;

ν is a constant variation of the resource; $\chi_\gamma = 95\%$, $\chi_\gamma = 99{,}9\%$ – fractile of the normalized normal distribution

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for the probability $\gamma = 95\%$ и $\gamma = 99,9\%$ accordingly;

$K^{*}_{r.y}$(work) is a value of the standardized coefficient for the operating mode of the cable;

$K_{i,j}$ is a coefficient, which considers j factor in i failure flow;

$K_{r.yi}$ is a coefficient, which depends on the mode and conditions of usage of cable;

K_{E} is a coefficient, which depends on energy of activation of degradation processes;

$K_{o.r}$ is a coefficient of cable operation rate in the regime of application of communication line;

CS_{1} is a serviceability criterion;

K_{cs1} is a coefficient of serviceability criterion of fiber cables by quantity of attenuation;

K_{c} is a cable capacity factor (by critical parameter);

$K_{av.b}$ is an average quantity of the bends (back winding, etc.) of the cable per time unit of its operating;

K_{T1} is a temperature coefficient of degradation speed of statical, mechanical strength of optical fiber;

K_{T2} is a temperature coefficient of change of dynamic, mechanical strength of optical fiber and cable sheath;

K_{T3} is a temperature coefficient of degradation speed of safety and reinforcing elements of structure of cable;

K_{T4} is a temperature coefficient of speed change of tensile strength of cable serving;

K_{T7} is a coefficient, which characterize maximal reversible changes of the damping constant in the fiber cable in over the range negative operating temperature;

K_{e} is a stiffness coefficient of operating conditions;

H(work) is a load of cable (by critical parameter) in the mode of operation;

$H(TR)$ is a maximum permissible load of the cable (by critical parameter) according to the technical requirements;

$T_{o.k}$ is a total operating time of the cable in a time $T_{o.1}$;

$T_{o.1}$ is a total operating time of the communication line during the year;

$T_{r.\gamma}$ is a gamma-percentile operating life before the writing of the cable in all regimes and terms of operation under the technical requirements;

T_{eq} is an operative temperature of components operation;

ε is a mean-root square error.

INTRODUCTION

In the period of intensive development of information and communication means the important place in our life plays systems of transfer, processing and storing of information. In spite of all-round introduction of wireless technologies, the most widespread has still the systems, which are constructed on the wire communication lines. In the systems of information transmission, where it is necessary to provide high speed of information exchange, quality and reliability, mainly will be applied the fiber-optic cables.

Obviously, by the design of such type communication lines the durability characteristics of fiber cables (minimal time between failures, gamma-percentile operating life, life time) will determine extensively indices of its durability. Consequently for increasing of the accuracy and validity of calculation value of durability characteristics of communication lines on the base of fiber cables it is necessary to use not only data, which is stated in the technical conditions for the cable, but also features of exploitation patterns composed of communication line, procedure and conditions of application.

The object of research is the forecasting method of optical cables resource in the reference data and the parameters of the modes and conditions of their application.

Calculated methods of operating life prediction [1, 2], usually, characterizes low self- descriptiveness [2], and also considerable time spent for the experimental investigation [1]. In the early design stage, the usage of such methods is difficult by the task solution of provision of the necessary level of durability indices. This situation brings about the necessity of models design, which does not demand carrying out of the tests and more fully considered the influence of conditions and terms of usage of fiber cables.

Subject of investigation are the methods and models, which is used for analysis of the design level of durability of fiber cables.

The goal of this work is design of methodology, which allows to increase the accuracy of prediction of durability indices of fiber cables and ensure the probability calculation of conditions of usage, in the frame of the approved at the present time calculation methodology of the operating life of electronic means.

1 PROBLEM STATEMENT

We consider characteristics of cable durability $T_{p.\gamma ТУ} = \{T_{p.\gamma 1ТУ}, T_{p.\gamma 2ТУ}, \ldots, T_{p.\gamma IТУ}\}$ – set I gamma-percentile operating in maximum and lite conditions under technical requirements and corresponding to its condition use $_{y} = \{R_{1ТУ}, R_{2ТУ}, \ldots, R_{IТУ}\}$ – set I vectors параметров parameter conditions, and also exploitation pattern optical-fiber transmission system $\boldsymbol{t} = \{t_1, t_2, \ldots, t_K\}$ – set K residence time of optical-fiber transmission system in different operation conditions, waiting and storing and respective application condition , waiting and storing $\boldsymbol{R} = \{R_1, R_2, \ldots, R_K\}$.

In that case forecasting problem of gamma-percentile operating life of fiber cables will be concerned with determination of relation $\boldsymbol{T}_{p.\gamma} = F(\Pi_1, \Pi_2, \ldots, \Pi_L)$ and parameter value (Π_l).

For quality rating of formed model can be used the criteria of mean-root square error [3]:

$$\varepsilon = \sum_{i-1}^{I}\left[T_{p.\gamma_i ТУ} - F\left(\Pi_{1_i}, \Pi_{2_i}, \ldots, \Pi_{L_i}\right)\right]^2 \to 0 \text{ при } L \to \max. \quad (1)$$

2 LITERATURE REVIEW

Calculated methods of forecasting of operating life can be divided into probabilistic and determinate.

Probabilistic methods [1, 4–5] assumes pilot researches of degradation process of electro-radio equipment, according to which forms the functions of distribution of accrued operating time and determines parameters. Yet even if prefer the hypothesis of one or other kind of cumulative distribution curve, then determination of its parameters according to the technical requirements will be nontrivial task, let alone about receiving of relations from the modes and operating conditions of electro-radio equipment[6]. Though, that the probabilistic methods found their way in a number of national standards of CIS countries (for example, [7]), in the engineering practical work still use determinate methods [2].

Basic data for calculation of durability indices of electro-radio equipment according to the methodology, stated in [2] are the normalized in technical requirements durability characteristics of electro-radio equipment and parameters of the model of communication line.

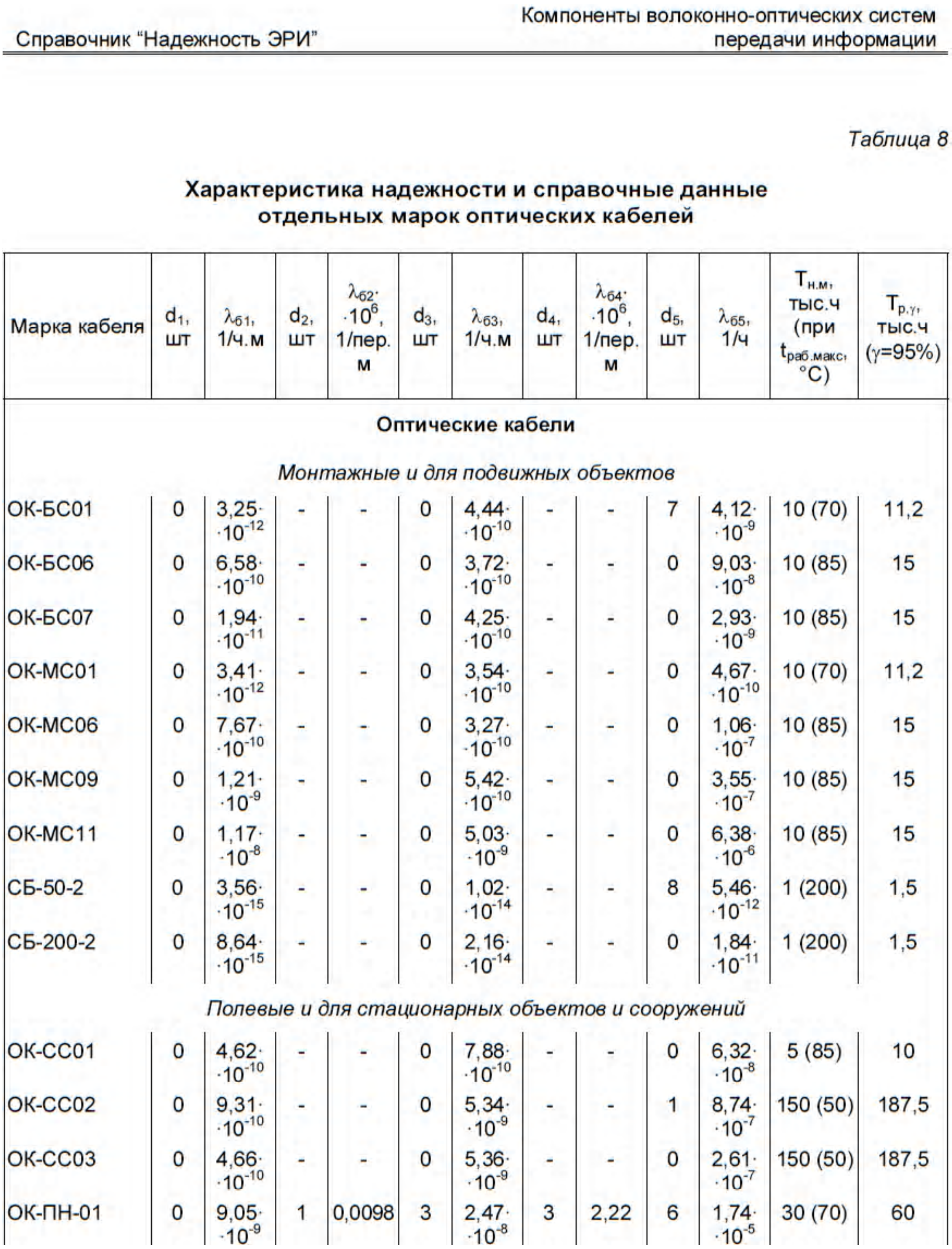
Value of gamma-percentile operating life of electro-radio equipment in operating mode is calculated under the mathematical model:

$$T_{r.\gamma}\left(\text{work}\right)=\frac{T_{r.\gamma}}{K_c\cdot K_{o.r}}, \tag{2}$$

where

$$K_{o.r}=\frac{T_{o.k}}{T_{o.l}},\; K_c=\frac{H\left(work\right)}{H\left(TR\right)}.$$

Values Tr.γ stated in the data book [8]. Fig. 1 shows a fragment with data of reliability characteristics of fiber cables.



Справочник “Надежность ЭРИ”

Компоненты волоконно-оптических систем передачи информации

Таблица 8

Характеристика надежности и справочные данные отдельных марок оптических кабелей

Марка кабеля	d_1, шт	λ_{61}, 1/ч.м	d_2, шт	$\lambda_{62}\cdot10^6$, 1/пер. м	d_3, шт	λ_{63}, 1/ч.м	d_4, шт	$\lambda_{64}\cdot10^6$, 1/пер. м	d_5, шт	λ_{65}, 1/ч	$T_{н.м}$, тыс.ч (при $t_{раб.макс}$, °С)	$T_{р.\gamma}$, тыс.ч (γ=95%)
Оптические кабели												
Монтажные и для подвижных объектов												
ОК-БС01	0	$3{,}25\cdot10^{-12}$	-	-	0	$4{,}44\cdot10^{-10}$	-	-	7	$4{,}12\cdot10^{-9}$	10 (70)	11,2
ОК-БС06	0	$6{,}58\cdot10^{-10}$	-	-	0	$3{,}72\cdot10^{-10}$	-	-	0	$9{,}03\cdot10^{-8}$	10 (85)	15
ОК-БС07	0	$1{,}94\cdot10^{-11}$	-	-	0	$4{,}25\cdot10^{-10}$	-	-	0	$2{,}93\cdot10^{-9}$	10 (85)	15
ОК-МС01	0	$3{,}41\cdot10^{-12}$	-	-	0	$3{,}54\cdot10^{-10}$	-	-	0	$4{,}67\cdot10^{-10}$	10 (70)	11,2
ОК-МС06	0	$7{,}67\cdot10^{-10}$	-	-	0	$3{,}27\cdot10^{-10}$	-	-	0	$1{,}06\cdot10^{-7}$	10 (85)	15
ОК-МС09	0	$1{,}21\cdot10^{-9}$	-	-	0	$5{,}42\cdot10^{-10}$	-	-	0	$3{,}55\cdot10^{-7}$	10 (85)	15
ОК-МС11	0	$1{,}17\cdot10^{-8}$	-	-	0	$5{,}03\cdot10^{-9}$	-	-	0	$6{,}38\cdot10^{-6}$	10 (85)	15
СБ-50-2	0	$3{,}56\cdot10^{-15}$	-	-	0	$1{,}02\cdot10^{-14}$	-	-	8	$5{,}46\cdot10^{-12}$	1 (200)	1,5
СБ-200-2	0	$8{,}64\cdot10^{-15}$	-	-	0	$2{,}16\cdot10^{-14}$	-	-	0	$1{,}84\cdot10^{-11}$	1 (200)	1,5
Полевые и для стационарных объектов и сооружений												
ОК-СС01	0	$4{,}62\cdot10^{-10}$	-	-	0	$7{,}88\cdot10^{-10}$	-	-	0	$6{,}32\cdot10^{-8}$	5 (85)	10
ОК-СС02	0	$9{,}31\cdot10^{-10}$	-	-	0	$5{,}34\cdot10^{-9}$	-	-	1	$8{,}74\cdot10^{-7}$	150 (50)	187,5
ОК-СС03	0	$4{,}66\cdot10^{-10}$	-	-	0	$5{,}36\cdot10^{-9}$	-	-	0	$2{,}61\cdot10^{-7}$	150 (50)	187,5
ОК-ПН-01	0	$9{,}05\cdot10^{-9}$	1	0,0098	3	$2{,}47\cdot10^{-8}$	3	2,22	6	$1{,}74\cdot10^{-5}$	30 (70)	60

Figure 1 – Table fragment from the data book “Reliability of electro-radio product”

As fig. 1 shows according to the classification of the data book [1] fiber cables are the electro-radio equipment, which are related to the group “Fiber cables” type “Components of optical fiber systems of information transmission”, for which standardized $T_{м.н}$ и $T_{p.\gamma}$.

Consider the value calculation $Tr.\gamma$ (work) by the example of fiber cable type ОК-ПН-01-5-60. The cable is intended for operating in the communication lines by conditions of stationary, nonstationary and air laying and operation in the field conditions with the repeated laying.

Construction of the cable consists of quartz optic fibers, longitudinal laid together with thread СВМ-К in cover made from the epoxyacrylate (fig. 2).

According to the technical requirements [9] are indicated following values of no failure operating time (minimal) of the cable for the application mode:

– to 35°C – 200000 h. (light mode);
– to 55°C – 100000 h. (light mode);
– 70°C – 30000 h (maximum mode).

As follows from the fig. 2 and [9] “critical” parameter for the cable type ОК-ПН-01 is the temperature. In that case

$$K_c = \frac{t(work)}{t_{work\_\max}}. \tag{3}$$

Find the values K_c by formula (1) by $K_{o.r} = 1$ and by formula (2). The results of calculation are shown in the table 1.

As follows from the table 1 by using formula (2) if in the technical requirements are not indicated data for the facilitated regimes, above considered method of standard [2] gives underestimation of durability characteristics of the fiber cables.

Consequently, for improving the accuracy of prediction of operating life of fiber cables it is necessary to find mathematical model, which adequate describes relation of operating life from the modes and conditions usage of cables, and determine parameters and coefficients.

3 MATERIALS AND METHODS

For receiving of calculation correlation of estimation of gamma-percentile operating life of fiber cables on the facilitated regimes we will take principle of duality [10], reasoning from we can state, that [11, 12]:

$$\frac{T_{r.\gamma}work}{T_{r.\gamma}} \sim \frac{\lambda_e}{\lambda_e(work)}. \tag{4}$$

Figure 2 – Sketch of construction cable type ОК-ПН-01-5-6/0

Table 1 – The results of calculation of capacity factor

№	t(work), ^{0}C	Capacity factor	
		Model (1)	Model (2)
1	2	3	4
1	35	0,15	0,5
2	55	0,3	0,786
3	70	1,0	1,0

Mathematical calculation modes of failure rates of fiber cables are stated in the data book [8]. As the fiber cables refers to the group of complex items, cumulative, which compounded of self-contained failure flows of its component parts, mathematical calculation mode of its failure rates has the following view:

$$\lambda_e = \sum_{i=1}^{I} \lambda_{e_i} = \sum_{i=1}^{I} \left[\lambda_{b_i} \cdot \prod_{j=1}^{J_i} \left(K_{i,j} \right) \right]. \tag{5}$$

Mathematical modes of the failure rates (λ_{ei}) has the following view:

$$\lambda_{e_1} = \lambda_{b_1} \cdot m \cdot K_{T1} \cdot L_K \cdot K_e; \tag{6}$$

$$\lambda_{e_2} = \lambda_{b_2} \cdot m \cdot K_{av.b} \cdot K_{T2} \cdot L_K \cdot K_e; \tag{7}$$

$$\lambda_{e_3} = \lambda_{b_3} \cdot K_{T3} \cdot L_K \cdot K_e; \tag{8}$$

$$\lambda_{e_4} = \lambda_{b_4} \cdot K_{av.b} \cdot K_{T4} \cdot L_K \cdot K_e; \tag{9}$$

$$\lambda_{e_5} = \lambda_{b5} \cdot m \cdot K_{T1} \cdot K_{cs1}. \tag{10}$$

Coefficient values K_{T1} and K_{T3} calculated by the formula:

$$K_T = e^{-K_E \cdot \left(\frac{1}{T_{eq}} - \frac{1}{298} \right)}. \tag{11}$$

Value T_{eq} determines by the formula:

$$T_{eq} = \left[\frac{1}{T_{\max}} + \frac{1}{K_E} \cdot \ln \left(\frac{t}{t_{T_{\max}} + \sum_{i=1}^{I} t_i^*} \right) \right]^{-1}. \tag{12}$$

Value t^*_i determines by the formula:

$$t_i^* = t_i \cdot e^{-K_E \cdot \left(\frac{1}{T_i} - \frac{1}{T_{\max}} \right)}, \tag{13}$$

where:

$$t = t_{T_{\max}} + \sum_{i=1}^{I} t_i.$$

Value $K_{av.b}$ determines by the formula:

$$K_{av.b} = \frac{N}{t}. \tag{14}$$

Value of the serviceability criterion CS_1, by which defines value of coefficient $K_{cs1,}$ determines by the formula:

$$CS_1 = \frac{d_{\max}}{K_{T7}}. \tag{15}$$

Since the negative temperature is the factor, which reduces the rate of chemical reaction, then in the calculation durability value models (7) and (9) can be disregarded. In addition, analysis of the formulas (6), (8) and (10)–(15) and the tables of the data book [1] shows, that the parameters of the modes and conditions of usage of fiber cables are K_e, N, t, $T_{\max}$, $t_{T\max}$, set of values T_i, set of values t_i and I. Remaining parameters and coefficients of the formulas (6), (8) and (10)–(15), determines in fact values λ_{bi}, as it depends on the features technological structure of the cable.

According to the methodology of the standard [2], by the calculation of the durability values of the equipment, by which total failure flow rate consists of self-contained failure flows of its component parts, the value of the resource determines in the following way:

$$T_{r.\gamma} = \min_{i=1,3}\left\{T_{r.\gamma_1}, T_{r.\gamma_3}, T_{r.\gamma_5}\right\}. \quad (16)$$

Hence, using (4) find the formula for calculation of the coefficients, which depends on the mode and conditions of usage of cable, for each self-contained failure flow:

$$K_{H1} = \frac{\lambda_{e_1}(work)}{\lambda_{e_1}} = \frac{K_{T1}(work)\cdot K_e(work)}{K_{T1}\cdot K_e}; \quad (17)$$

$$K_{H3} = \frac{\lambda_{e_3}(work)}{\lambda_{e_3}} = \frac{K_{T3}(work)\cdot K_e(work)}{K_{T3}\cdot K_e}; \quad (18)$$

$$K_{H5} = \frac{\lambda_{e_5}(work)}{\lambda_{e_5}} = K_{T1}(work). \quad (19)$$

In formulas (17)–(19) indicate:

$$\prod_{j-1}^{J_i} K_{i,j} = K_{r.y_i}.$$

4 EXPERIMENTS

To verify the proposed method find the value $K_{r.yi}$ for maximal the mode and conditions of usage of cable type ОК-ПН-01-5-6/0 according to the data, indicated in the data book [8] and technical requirement [9]. Table 2 shows the results of calculation.

In a similar way calculate the value $K_{r.yi}$ for the temperature $T_{\text{мах}}$ = 35°C and $\text{T}_{\text{мах}}$ = 55°C and divide it into the limit value from the table 2. Table 3 shows the results of calculation.

Data, which is stated in the table can be considered as functions $T_{o.m}(K^*_{r.y})$, defined of its values. Besides, as the table 3 shows, functions $T_{o.m}(K^*_{r.y1})$ and $T_{o.м}(K^*_{r.y5})$ are congruent. So the form (16) has the following view:

$$T_{r.\gamma} = \min\left\{T_{r.\gamma_1}, T_{r.\gamma_3}\right\}.$$

Find the value 95% of the cable resource for the temperature 35°C and 55°C. For that using the formula, which is stated in the standard [2]:

$$T_{r.\gamma} = \frac{1-\nu\cdot\chi_{\gamma=95\%}}{1-\nu\cdot\chi_{\gamma=99,9\%}}\cdot T_{o.m}. \quad (20)$$

Find the value of the constant variation, solve (20) relatibely н by values $T_{o.m}$ and $T_{r.\gamma}$, stated on the picture 2:

$$\nu = \frac{T_{r.\gamma} - T_{o.m}}{\chi_{\gamma=99,9\%}\cdot T_{r.\gamma} - \chi_{\gamma=95\%}\cdot T_{o.m}} = 0,22.$$

By that value constant variation 95% cable resource by the temperature 35°C is 400000 h., by temperature 55°C – 200000 h.

5 RESULTS

For the approximation of the relationship $T_{r.\gamma}$ $(K^*_{r.y})$ can be used piecewise linear function. Besides, in the technical requirements [3] values $T_{o.m}$, and for normal temperature (25°C) are not stated, let take, in the temperature range 25–35°C value is constant and equal to 400000 h.

Table 2 – Values of the coefficient $K_{p.yi}$

№	Design formula	Value	Reference
1	2	3	4
1	$K_{r.y_1} = K_{T1}\cdot K_e$	371.3	$I = 0$; $t_i = 0$; $t_{T\max} - t$; $t = 30000\ h$ – minimal operating time according to the technical requirements [3]; T_{Max} = 70°C (343°K) – according to the technical requirements [3]; $K_{E1} = 13.44\cdot10^3$ – according to the table in the data book [2]; $K_e = 1$ (group 1.1) – according to the table in the data book [2]
2	$K_{r.y_3} = K_{T3}\cdot K_e$	34.6	$I = 0$; $t_i = 0$; $t_{T\max} - t$; $t = 30000\ h$ – minimal operating time according to the technical requirements [3]; T_{Max} = 70°C (343°K) – ccording to the technical requirements [3]; $K_{E3} = 8.05\cdot10^3$ – according to the table in the data book [2]; $K_e = 1$ (group 1.1) – according to the table in the data book [2]
3	$K_{r.y_5} = K_{T1}$	371.3	$I = 0$; $t_i = 0$; $t_{T\max} - t$; $t = 30000\ h$ – minimal operating time according to the technical requirements [3]; T_{Max} = 70°C (343°K) – according to the technical requirements [3]; $K_{E1} = 13.44\cdot10^3$ – according to the table in the data book [2]

Table 3 – Value of the standardized coefficients $K^*_{r.yi}$

№	Temperature	$\text{K}^*_{\text{r.y1}}$	$K^*_{r.y3}$	$K^*_{r.y5}$	$T_{o.m}$, thousand. h.
1	2	3	4	5	6
1	35°C	$1{,}16\cdot10^{-2}$	$6{,}94\cdot10^{-2}$	$1{,}16\cdot10^{-2}$	200,0
2	55°C	0,167	0,341	0,167	100,0
3	70°C	1,0	1,0	1,0	30,0

Having absorbed the disclaimers of the relationship $T_{r.\gamma}$ from $K^{*}_{r.y}$ can be represented in the form:

$$T_{r.\gamma}\left(work\right)=\begin{cases}400000 \text{ при } 0\le K^{*}{}_{r.y}\left(work\right)\le K^{*}{}_{r.y_1}\\ T_{r.\gamma_n}+\dfrac{T_{r.\gamma_{n+1}}-T_{r.\gamma_n}}{K^{*}{}_{r.y_{n+1}}-K^{*}{}_{r.y_n}}\cdot\left[K^{*}{}_{r.y}\left(work\right)-K^{*}{}_{r.y_n}\right] \text{ для } K^{*}{}_{r.y_n}<K^{*}{}_{r.y}\left(work\right)\le K^{*}{}_{r.y_{n+1}}.\end{cases}$$

Diagrams of relationship $T_{r.\gamma}$ (work) from $K^{*}_{r.y1}$(work) and $K^{*}_{r.y3}$(work) are stated on the fig. 3.

Fig. 4 shows relation $K^{*}_{r.y1}$(work) from the temperature T_i and $(\frac{\Delta t}{t})K_i$, i.e. interval size of cable operation by the temperature T_i to the total hours of service t, which was received with the help of designed software in the MathCad programming language [13].

Calculation of the values $T_{r.\gamma}$(work.g) for the group of equipment, which uses cable, distinct from the group 1.1 calculated by the formula [5]:

$$T_{r.\gamma}\left(work.g\right)=\frac{T_{r\gamma}\left(work\right)}{K_e}.$$

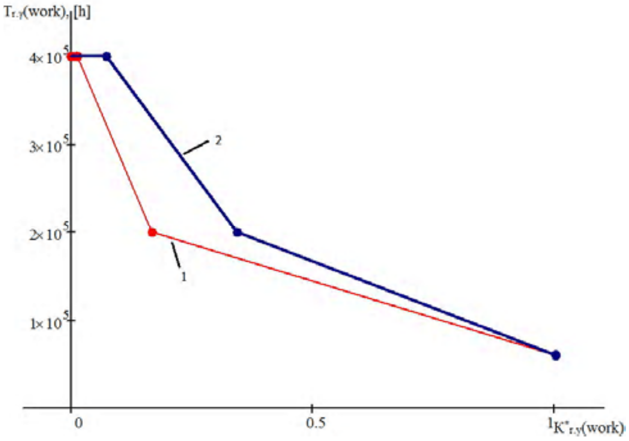


Figure 3 – Relationship of gamma-percentile operating life from the standardized coefficient : 1 – from $K^{*}_{r.y1}$(work); 2 – $K^{*}_{r.y3}$(work)

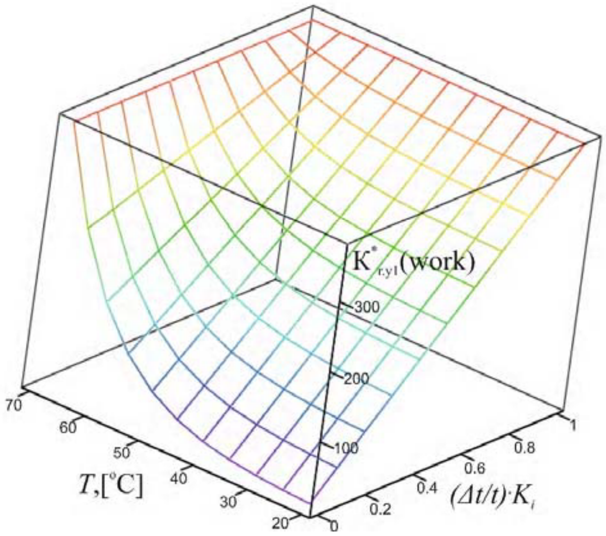


Figure 4 – Relation $K^{*}_{r.y1}$(work) from the temperature T_i and interval size of cable operation by the temperature T_i to the total hours of service t

Moreover, it should also be noted, that in this methodology value $K_{o.r}$ is not used, as the parameters of the exploitation pattern explicitly enters into the formula (11). Therefore the received value will be numerically equal the service life of the cable.

6 DISCUSSION

Suggested methodology of forecasting of operating life of fiber cables in comparison with methodology [2] provides substantially larger calculation accuracy. However suggested methodology demands high volume of basic data and higher labor-intensiveness of calculation, than methodology [2].

In comparison with methodologies, which are based on the probabilistic methods [1, 4–5] suggested methodology doe not requires experimental researches and tests, at the same time provides comparable accuracies of forecasting of durability indices.

Weakness of the suggested methodology is using piecewise-linear approximation, thus complicating carrying out of calculation.

Efficient use of the developed methodology will be higher with large quantity of operating life values stated in the technical requirements for the fiber cable. In case in the technical requirements is stated only one value, the effect from the developed methodology will be insignificant.

CONCLUSIONS

In the paper were solved the task of forecasting of operating life of fiber cables according to the reference data and characteristics of the modes and its conditions of usage.

Scientific novelty of the results, which were received in the article is that for the first time were suggested the methodology of forecasting of durability indices of fiber cables, which allows automatically select from the totality of failure rate the right failure rate, which determines the value of its durability indices, and also making the registration of influence of the modes and conditions usage on is, which allows to increase calculation accuracy and also detect the causes, which has an influence upon the level of calculated values.

Practical significance of the received results is that were developed software, which realizes the suggested method, on the base of which was solved practical task of forecasting of operating life of cable type ОК-ПН-01-5-6/0.

Prospects of further investigations are to research performance capability of the suggested methodology for forecasting of durability indices for other groups of components of fiber optic systems of information transmission, such as fiber connectors, fiber switchers, fiber couplers and splitters and optic-electronic modules.

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МЕТОДИКА РАСЧЕТА УТОЧНЕННОГО РЕСУРСА ОПТИЧЕСКИХ КАБЕЛЕЙ

Решена задача прогнозирования ресурса оптических кабелей для автоматизации проектных исследований надежности волоконно-оптических систем передачи информации. Предложена методика формирования математических моделей комплексных коэффициентов, которая позволяет выделить из исходных моделей интенсивностей отказов коэффициенты, учитывающие влияние режимов и условий применения оптических кабелей на их показатели долговечности.

Разработанная методика не требует проведения экспериментальных исследований и испытаний, базируясь на использовании стандартизованных моделей интенсивностей отказов и нормированных характеристиках долговечности оптических кабелей. При этом для заданных режимов и условий применения оптических кабелей автоматически выявляется тот процесс деградации, который определяет значения их ресурса.

В отличие от методик прогнозирования ресурса изделий на основе вероятностно-физических моделей отказов предложенный метод оперирует только с данными, приведенными в нормативно-технической документации на оптические кабели, и позволяет повысить точность прогнозирования ресурса по сравнению с методиками, рекомендованными в отраслевых стандартах.

Разработано программное обеспечение, реализующее предложенный математический аппарат, с помощь которого решена практическая задача прогнозирования ресурса кабеля марки ОК-ПН-01-5-60.

Ключевые слова: волоконно-оптическая система передачи информации, оптоволоконный кабель, надежность, долговечность, ресурс, интенсивность отказов.

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МЕТОДИКА РОЗРАХУНКУ УТОЧНЕНОГО РЕСУРСУ ОПТИЧНИХ КАБЕЛІВ

Вирішено задачу прогнозування ресурсу оптичних кабелів для автоматизації проектних досліджень надійності волоконно-оптичних систем передачі інформації. Запропоновано методику формування математичних моделей комплексних коефіцієнтів, яка дозволяє виділити з вихідних моделей інтенсивностей відмов коефіцієнти, що враховують вплив режимів і умов застосування оптичних кабелів на їх показники довговічності.

Розроблена методика не вимагає проведення експериментальних досліджень і випробувань, базуючись на використанні стандартизованих моделей інтенсивностей відмов і нормованих характеристик довговічності оптичних кабелів. При цьому для заданих режимів і умов застосування оптичних кабелів автоматично виявляється той процес деградації, який визначає значення їх ресурсу.

На відміну від методик прогнозування ресурсу виробів на основі імовірнісно-фізичних моделей відмов запропонований метод оперує тільки з даними, наведеними в нормативно-технічній документації на оптичні кабелі, і дозволяє підвищити точність прогнозування ресурсу порівняно з методиками, рекомендованими в галузевих стандартах.

Розроблено програмне забезпечення, що реалізує запропонований математичний апарат, з допомогою якого вирішена практична задача прогнозування ресурсу кабелю марки ОК-ПН-01-5-60.

Ключові слова: волоконно-оптична система передачі інформації, оптоволоконний кабель, надійність, довговічність, ресурс, інтенсивність відмов.

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