References

1. A.A. Bogorodickij and A.G. Ryzhevskij "Noniusnye analogovo-cifrovye preobrazovateli". Moscwo, Energija, 1975, 250 p.
2. M.K. Chmyh "Cifrovaja fazometrija", Moscow, Radio i Svjaz, 1993, 184 p.
3. K.L. Horiashchenko and I.V. Gula "Izmeritel' ugla fazovyh sdvigov za metodom koincidencii", Kyiv, Vesnik Nacional'nogo ttehnicheskogo universiteta Ukrainy «Kievskij politehnicheskij institut», Serija: Radiotehnika. Radioapparatostroenie, 2013, Volume 53, p. 74–81.
4. I.V. Gula "Issledovanie optimal'noj struktury avtomatizirovannogo izmeritelja fazy signalov na osnove principa koincidencii", Khmelnitksy, Herald of Khmelnitskiy national university, Technical sciecnes, 2013, Issue 4, p. 230-232.

Литература

1. Богородицкий А.А Нониусные аналогово-цифровые преобразователи / А.А Богородицкий, А.Г. Рыжевский. – М. : "Энергия", 1975. – 250 с.
2. Чмых М.К. Цифровая фазометрия / М.К. Чмых. – М.: Радио и Связь, 1993. – 184с.
3. Горященко, К. Л. Измеритель угла фазовых сдвигов за методом коинциденции / К. Л. Горященко, И. В. Гула // Весник Национального ттехнического университета Украины «Киевский политехнический институт». Серия: Радиотехника. Радиоаппаратостроение. – 2013. – Вип. 53. – С. 74–81.
4. Гула И.В. Исследование оптимальной структуры автоматизированного измерителя фазы сигналов на основе принципа коинциденции /И.В. Гула // Весник ХНУ. – Технические науки. – 2013. - №4. – С. 230-232.

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ESTIMATION OF TRANSMISSION PARAMETERS OF DIELECTRIC SELF-SUPPORTING OPTICAL CABLES IN THE EXPLOITATION CONDITIONS

Abstract. *In this paper, the estimation of transmission parameters of dielectric self-supporting optical cables, which operate in Odessa and Kiev climatic zones, defined and estimated the additional components of the transmission characteristics.*

Keywords: transmission parameters, dielectric self-supporting optical cables, climatic zone operation, physical and climatic loads.

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ОЦІНКА ПАРАМЕТРІВ ПЕРЕДАЧІ ДІЕЛЕКТРИЧНИХ САМОУТРИМНИХ ОПТИЧНИХ КАБЕЛІВ В УМОВАХ ЕКСПЛУАТАЦІЇ

В даній роботі проведено оцінку параметрів передачі діелектричних самоутримних оптичних кабелів в умовах експлуатації в Одеській та Київській кліматичній зонах та визначені й оцінені додаткові складові передавальних характеристик.

Ключові слова: параметри передачі, діелектричні самоутримні оптичні кабелі, кліматична зона експлуатації, фізико-кліматичні навантаження.

Introduction

Todays, advantages of application of self-supporting optical cables with different dielectric power elements (SSOCd) on the overhead fiber-optic communication lines (FOCL) on the transport telecommunication networks and networks of subscriber access cause no doubts [1 – 3].

Clearly, that for providing of transmission of high-quality optical signal for such SSOCd needs, that values of transmission characteristics of cables were expected and corresponded to the requirements of ITU–T recommendations.

In some works, for example, [4, 5] it is indicated that the module constructions of SSOCd are created thus, that to provide surplus of length of optical fiber (OF), placed in a cables core, with the purpose of exception of possibility by applying the mechanical tension to the optical fibers while occurrence of the tensile forces. It is provided the spiral laying of the optical modules with optical fibres round a central power element (CPE) with the certain radius R and step h (fig. 1). In addition, the optical fibers as a result of material thermocontracting of structural elements during SSOCd making, placed in a middle of OM by gelikoide, that creates additional surplus of OF length. Value of radius R, step h of spiral laying of OF and distances, between them and the internal surface of OM wall, which enables free movement fibers in the middle of tube of the module, determines the measure of the possible relative lengthening (longitudinal deformation) of cable ε_{pc}, which is the criterion of calculation of the maximall possible tensile loading F_c [5]. The maximall possible tensile loading of a cable is a basic parameter of longitudinal mechanical durability and that is why rationed for every type of a cable in its technical specifications.

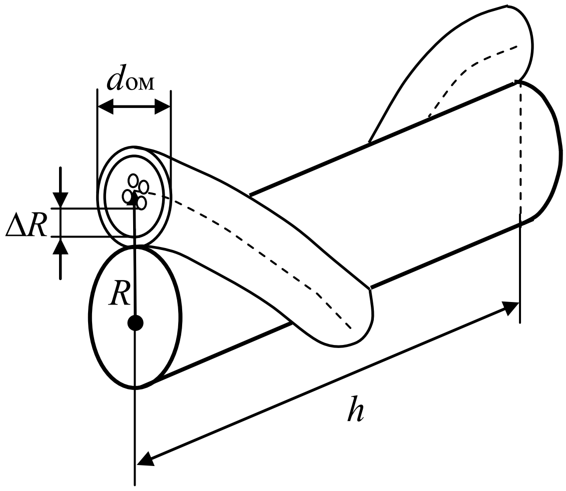

Fig. 1. Spiral laying of the optical modules round a central power element

Obviously, that, above all things, at presence of such spiral laying of fibers, their length will not equal length of SSOCd, which influences on the value of transmission parameters of OF and cables.

As known, to these transmission parameters of single-mode optical fibers behave: attenuation coefficient α, dispersion of signal τ and bandwidth ΔF, which is reciprocal to τ [7, 8].

As known, SSOCd are under the dynamic action of the mechanical, ice and wind loadings and temperature, that, above all things, cause it longitudinal deformation, the size of which can constantly vary, causing the permanent change of radius and step of spiral laying of OF at a core and transmission parameters of cables [6].

Goal of work

Today, the estimation of transmission parameters of SSOCd with power elements from different materials under the action of the mechanical, physical and climatic loadings of exploitation areas is not exposed to a full degree.

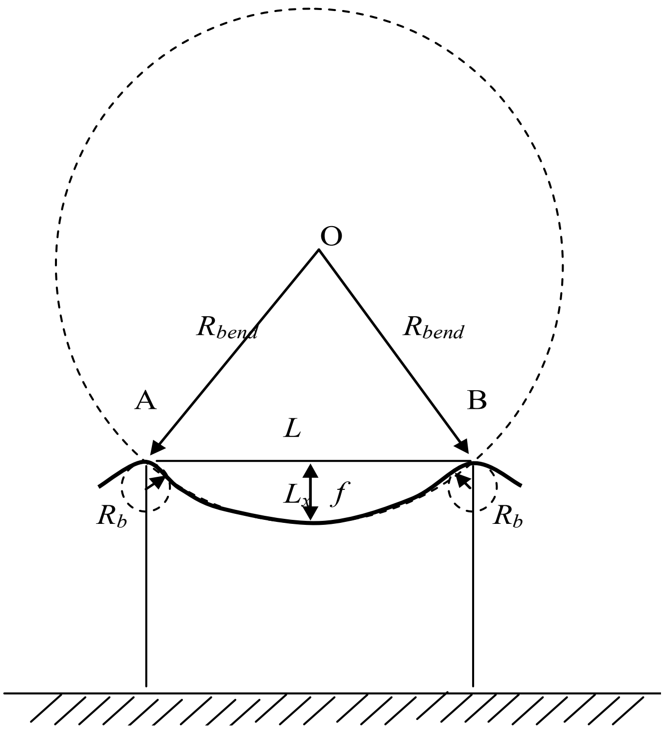

Fig. 2. Formation of imaginary circles with radiuses R_{bend} and R_b with sagging SSOCd in span of air FOCL

Calculation expressions for values of transmission parameters of optical fibers and SSOCd are widely presented in the literature, for example [7, 8].

For the estimation of change of transmission parameters of SSOCd during exploitation under the action of climatic factors it is necessary to expect the additional components of transmission characteristics, the values of which depend on, above all things, the structural features of cable: to the radius and step of spiral laying of OF in a cable and it bends during exploitation on poles of FOCL.

Accordingly to [9, 10] calculation expressions of additional components of attenuation coefficient, dispersion of signal and reason of their appearance are given in table 1.

For determination of component of signal attenuation coefficient α_{sl} it is necessary to know the change of parameters of spiral laying in the moment of action on SSOCd the external physical and climatic loads. Accordingly to [5, 6] change of the relative lengthening of a cable ε_c causes the change of parameters of spiral laying of OF *R* and *h*. However, the change of step of spiral laying at appearance of the longitudinal loadings on SSOCd can be not taken into account as a result of small meaningfulness [8].

Thus, the longitudinal lengthening of a cable, which creates under the action of the certain physical and climatic loadings on SSOCd, above all things, causes the change of radius of OF laying and, as a result, distances between fibers and internal surface of OM wall. This connection between the longitudinal relative lengthening of a cable and distance ΔR_c is possible to present as expression

$$\frac{\varepsilon_{pc}}{\Delta R_{pc}} = \frac{\varepsilon_c}{\Delta R_c}, \tag{1}$$

here ε_{pc}, ΔR_{pc} – the maximall possible relative lengthening of a cable and distance between OF and OM wall, that provides it; ε_c, ΔR_c – the relative lengthening of a cable and distance between OF and OM wall, that apperas here at the certain loadings.

Table 1

Calculation expressions of additional components of transmission parameters of SSOCd

Reasons of appearance of transmission parameters change of SSOCd	Expressions of calculation of additional component transmission parameters of SSOCd: attenuation coefficient of signal	Expressions of calculation of additional component transmission parameters of SSOCd: dispersion of signal
General expression	$\alpha_{ad} = \alpha_{sl} + \alpha_{bend} + \alpha_b$. (4) here α_{sl} – losses in OF due to their spiral laying in the core of SSOCd, dB/km; α_{bend} – losses on the bend of SSOCd due to sagging in air FOCL, dB/km; α_b – losses due to the bend of SSOCd in the places of binding on poles, dB/km.	$\tau_{ad} = \tau_{sl} + \tau_{bend} + \tau_b$, (8) here $\tau_{sl}, \tau_{bend}, \tau_b$ are componenets of polarization dispersion of signal in OF, that arise due to it's spiral laying in the core of SSOCd, bends of SSOCd due to sagging in air FOCL and in the places of binding on poles accordingly, s/km.
1. Presence of spiral laying of OF in the cable core	$\alpha_{sl} = ((\chi - 1) + 0{,}02)\alpha_{ownOF}$, (5) here χ – a coefficient of spiral laying; α_{ownOF} – own losses in OF, dB/km, 0,02 shows length increasing of OF in the core of cable due to it's laying by gelikoide. $\chi = \sqrt{1 + \left(\frac{\pi}{h}\right)^2 (d_{CPE} + 2R)^2}$, (6) here d_{CPE} – diameter of CPE, mm.	$\tau_{sl} = \frac{\lambda^2}{c n_1^3} \cdot \left[\frac{r}{R} G(A) + \frac{r^2}{2R^2} H(A)\right] \left[\sum_{i=1}^{3} \frac{A_i l_i^2}{(\lambda^2 - l_i^2)^2} - \frac{A_i}{\lambda^2 - l_i^2}\right]$, (9) here r – current coordinate of the circulating cylinder system, m; R – radius of spiral, on which OF is layed, m; $G(A)$ and $H(A)$ – functions, which depend on the geometrical parameters of spiral [9]; A – coefficient, which is determined after expression $A = \frac{h}{4\pi R}$; A_i, l_i – Selmeyer coefficients, which depend on chemical composition of OF.
2. Presence of bend of cable due to sagging in air FOCL	$\alpha_{bend} = \frac{33\Delta^{0,25}\lambda^{1,5} e^{-KR_{bend}}}{\sqrt{R_{bend}}\lambda^2}$, (7) here Δ – relative difference of refraction indexes of core and cladding of OF; λ – wave-length of radiation, nm; K – an intermediate coefficient; $K = 1{,}244\frac{\Delta^{1.5}}{\lambda}\left(2{,}748 - \frac{0{,}996\lambda}{\lambda_0}\right)^3$; λ_0 – cut-off wavelength of optical fiber, nm; R_{bend} – radius of bend of SSOCd between poles in FOCL, nm.	The same, but at the value of bend radius of cable R_{bend} between poles in FOCL.
3. Presence of bend of cable in the places of binding on poles	The same, but at the value of bend radius of SSOCd R_b in the place of binding on poles.	The same, but at the value of bend radius of cable R_b the place of binding on poles.

Connection between the radius of spiral laying of OF in the core of SSOCd and distance ΔR_c between fibers and internal surface of OM wall shows expression, which is got in [8]

$$R = \frac{1}{2} d_{\text{CPE}} + \Delta t_{\text{OM}} + \Delta R_{\text{c}} + \frac{1}{2} d_{\text{OF}}, \qquad (2)$$

here d_{CPE} – diameter of CPE, mm; Δt_{OM} – a radial thickness of OM wall, mm; ΔR_c – distance between OF and internal surface of OM wall, mm; d_{OF} – diameter of OF with shell, mm.

Bend radius of SSOCd in span R_{bend}, which is got in expression (7), is a radius of imaginary circle, part of which coincides with the arc of sagging of SSOCd in span (fig. 2). The radius of bend of SSOCd in the places of binding on poles depends on the size of arrow of sagging of SSOCd and limited to the value minimum of possible bend radius of a cable, which is rationed in its technical specifications.

From fig. 2 evidently, that radius of imaginary circle of sagging of SSOCd in span it is possible to define by Pythagoras theorem

$$R_{bend} = \frac{1}{2f}\left(\frac{L_s^2}{4} + f^2\right), \qquad (3)$$

here f – sag of SSOCd in span at the certain loads; m; L_s – length of span of FOCL, m.

As you can see from fig. 2 an arc of sagging of a cable in span is part of imaginary circle by a radius, and in the places of binding to poles – R_b.

Temperature dependence of sag of SSOCd, certainly, creates the change of radiuses of bend R_{bend} and R_b during exploitation. It creates a necessity for research of change of transmission parameters of dielectric self-supporting optical cables dependently on the terms of hanging and action of temperature.

The additional component of signal dispersion, which can appears only in the case of lengthening of SSOCd on the size of the maximal possible relative lengthening ε_{pc} and which depends on the parameters of spiral laying of optical fiber in the core of cables, is polarization mode dispersion τ_{sl} [11].

During the calculations of value of component signal dispersion τ_{sl} as the parameter *R* in expression (9) can understand the radius of spiral laying of OF in the core of SSOCd, at calculations τ_{bend} – radius of bend of cable R_{bend} in span, and at calculations τ_b – radius of bend of cable R_b in the place of binding on poles.

Using the expressions (1) – (9) the calculations of additional components of transmission characteristics of SSOCd and estimation of their transmission parameters at appearance of loads of two climatic areas of exploitation were performed. Calculations were performed for: SSOCd of types ОКЛ-3-Д2А14-3×4Е, ОКЛ-3-Д3А14-3×4Е, ОКЛ-3-Д4А14-3×4Е, that exploitate in the conditions of Odessa and Kiev climatic areas, length of span of air FOCL L_s = 50 m (the network of railway transport, line of electro-transmission, electrified with tension to 1 kV), wavelengths of the second (1310 nm), third (1550 nm) and fourth (1595 nm) transparancy windows, wavelengths of cutt-off of 1260 nm regions, 1450 nm and 1530 nm accordingly, at three chemical compositions of OF core – 3,1% GeO_2, 96,9 % SiO_2; 7 % GeO_2, 93 % SiO_2; 13,5 % GeO_2, 86,5 % SiO_2, relative difference of refraction indexes of the core and the cladding of OF Δ = 0,005, the step of spiral laying h = 100 mm, the radius of bend R_b equals 20 diameters of SSOCd, the diameter of CPE d_{CPE} = 2,7 mm, the OM diameter d_{OM} = 2,5 mm, the thickness of OM wall Δt_{OM} = (0,15…0,2) d_{OM}, the diameter of the fibers with protective and painted covers d_{OF} = 250 microns, possible relative lengthening of SSOCd in range (0...0,368) %, which defined in [6, 8]. Characteristics conditions:

- Odessa climatic area: high speed of wind in default of ice-storm V_0 = 28,3 m/s; high speed of wind at ice-storm V_{is} = 23,6 m/s; a maximal thickness of ice wall on a cable Δt_{ice} = 28 mm; average annual temperature – 10,3 ºC [12].
- Kiev climatic area: high speed of wind in default of ice-storm V_0 = 25,3 m/s; high speed of wind at ice-storm V_{is} = 18 m/s; a maximal thickness of ice wall on a cable Δt_{ice} = 16 mm; average annual temperature – 8 ºC [12].

Such suppositions were accepted in the calculations of additional component of transmission parameters of SSOCd:

1. The change of bend radius of SSOCd in the places of binding on poles from a temperature was not taken into account, and accepted even minimum to the allowable value.

2. Through the small radius of spiral laying of OF in the core of SSOCd comparatively with the radius of bend of cable in span of air FOCL, an optical fiber during the calculation of value was examined as such which is laying on an arc.

Calculation of total attenuation coefficient of SSOCd, got by expressions (1) – (7) and recognition [7, 8] allowed to get dependence of SSOCd on the relative lengthening of cable ε_{pc} %, that appears under the action of loads on SSOCd of different external environments. On fig. 3 dependence of the total attenuation coefficient of SSOCd type ОКЛ-3-Д2А14-3×4Е α_{SSOCd} on λ = 1550 nm from the relative lengthening of cables ε_{pc}, % is shown.

On fig 4 the graph of spectral dependence of total linear dispersion of SSOCd is shown recognition and without by the account of additional component dispersion of signal.

On fig. 5 spectral dependence of bandwith of SSOCd is shown for chemical compositions of OF core 7 % GeO_2, 93 % SiO_2; 13,5 % GeO_2, 86,5 % SiO_2 at presence and absence of additional componenet ΔF .

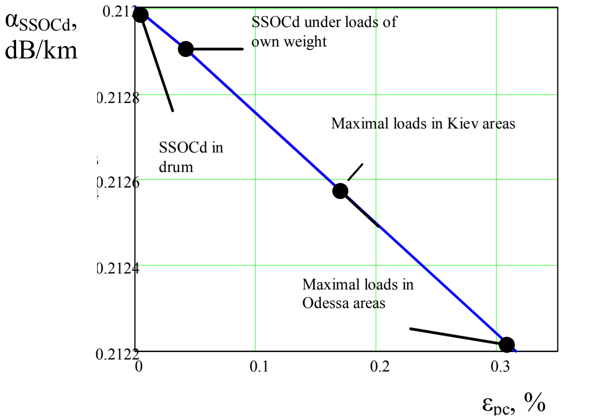

Fig. 3. The dependence of the total attenuation coefficient SSOCd α_{SSOCd} at λ= 1550 nm from lengthening of cables ε_{pc}, %

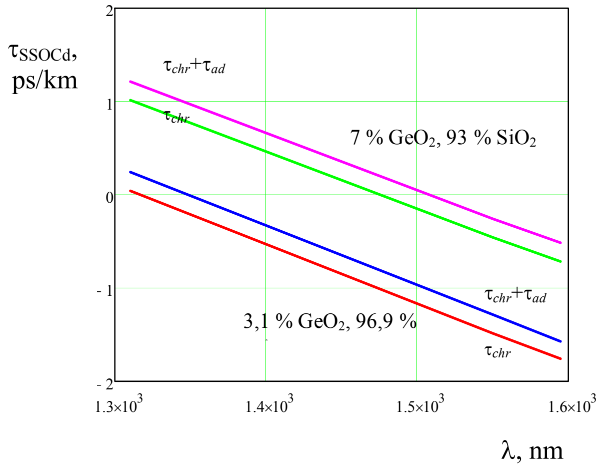

Fig. 4. Graph spectral dependence of the total linear dispersion of SSOCd with and without additional component

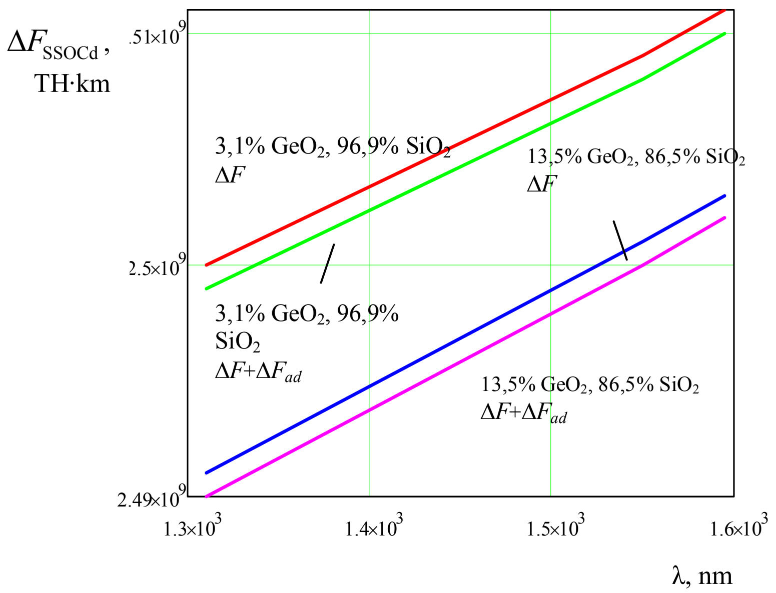

Fig.5. Graph of bandwidth from wavelength

Estimation of transmission parameters of SSOCd in the conditions of exploitation in Odessa and Kiev climatic areas allowed to set that:

- the transmission parameters of OF and SSOCd differ due to surplus length of fibers in the core of cables, which is conditioned it by a spiral laying with a certain step and radius.
- change of value of attenuation coefficient (α_{ad}) on wavelengths λ 1310 nm, 1550 nm, 1595 nm, conditioned by the spiral laying of OF in a core. It has the most value in default of loads of cables on a drum and does not exceed 2,1 % from the own losses of optical fiber and proportionally diminishes under the action of the longitudinal loadings. Under the action of loads, that relative lengthening of SSOCd, and temperatures of exploitation α_{ad} diminishes, mostly, due to straightening of spiral of OF on 0,23 % in the conditions of the Odessa

climatic area and on 0,12 % in the conditions of the Kiev area on supporting lengths of waves of the second, third and fourth transparancy windows. Additional losses due to the bends of different types of SSOCd in span of FOCL are 0 %, and due to minimum possible bends in the places of binding – does not exceed 0,1 % at all wavelengths;

- the spiral laying of optical fiber in the core of SSOCd and lengthening of cable to the maximal allowable value results in appearance of additional positive polarization dispersion, and bends of cables in span of FOCL and in the places of binding – to negative polarization dispersion;
- the additional component of signal dispersion makes from the value of the rationed linear chromatic dispersion in accordingly to recommendations of ITU-T: for the second transparancy window region – 5,7 %, for the third – 1,1 %, for the fourth – 5 %.
- bandwith ΔF_{SSOCd} it is a reciprocal to linear signal dispersion and can change in a range $\pm$ 0,1 % at all of the considered chemical compositions of OF and wavelengths.

Summary

In this work performed research in relation to the estimation of transmission parameters of SSOCd in the conditions of exploitation allowed to do such conclusions:

1. In this work the estimation of transmission parameters of dielectric self-supporting optical cables is performed in the conditions of exploitation in Odessa and Kiev climatic areas and the additional components of transmission characteristics are defind, that conditioned the spiral laying of OF in the core of SSOCd, by the bends of cables during sagging in span and in the places of binding to poles.
2. Results of calculations and researches of parameters it was allowed to set the transmissions of SSOCd, which are exploited in the conditions of Odessa and Kiev climatic areas, that:

- a change of value of attenuation coefficient of SSOCd on wavelengths 1310 nm, 1550 nm, 1595 nm, mostly, conditioned the spiral laying of OF in the core of cable. Attenuation coefficient of SSOCd has a most value in default of loads of cables on a drum and does not exceed 2,1% from the own losses of optical fibre;
- the additional constituent of signal dispersion appears only in the case of the relative lengthening of SSOCd to the allowable value and makes from the value of the rationed linear chromatic dispersion in accordingly to recommendations of ITU-T: for the second transparancy window region – 5,7%, for the third – 1,1%, for the fourth – 5%, that matters very much at the use of DWDM technologies of FOTS.
- bandwith ΔF_{SSOCd} depends on linear dispersion of signal and can change in a range $\pm$ 0,1% at all of the considered chemical compositions of OF and lengths of waves.

3. The estimation of transmission parameters of dielectric self-supporting optical cables in the conditions of Odessa and Kiev climatic areas can be made to order to the use in cable industry on the stage of planning of optimum constructions of SSOCd for application in the concrete terms of exploitation.

References

1. Bondarenko O.V. Vybor konstrukcii samonesushhego opticheskogo kabelja po rastjagivajushhim nagruzkam / O.V. Bondarenko, D.V. Iorgachev, L.L. Murad'jan // Tehnologija i konstruirovanie v jelektronnoj apparature. – 2001. – Vyp. № 1. – S. 18 – 21.
2. Bondarenko O.V. Rozrobka metodu rozrahunku stijkosti dielektrichnih optichnih kabeliv do roztjagujuchih navantazhen' / O.V. Bondarenko // Naukovi praci Donec'kogo nacional'nogo tehnichnogo universitetu. – Serija: "Obchisljuval'na tehnika ta avtomatizacija". – Donec'k, 2009. – Vip. 17(148). – S. 64 – 68.
3. Murad'jan L.L. Aprobacija metodiki rascheta konstrukcii SOK po rastjagivajushhim usilijam / Murad'jan L.A. // Naukovi praci ONAZ im. O.S. Popova. – Odesa, 2007. – Vip. № 1. – S. 158 – 160.
4. Bondarenko O.V. Metodika rozrahunku modul'noї konstrukciї optichnogo kabelju po roztjagujuchomu zusillju / O.V. Bondarenko // Modelirovanie i informacionnye tehnologi: sb. nauch. trudov / Institut problem modelirovanija v jenergetike im. G.E. Puhova NAN Ukrainy. – 2009. – Vyp. 54. – S. 31 – 34.
5. Bondarenko O.V. / Technique of determination of modules tube diameter and possible lengthening of optical cables construction / O.V. Bondarenko, D.M. Stepanov, O.M. Stastchuk // Fotoelektronika. – 2011. – Vyp. 20. – S. 76 – 80.
6. Bondarenko O.V. Doslidzhennja strili provisannja samoutrimnih optichnih kabeliv z periferijnim silovim elementom iz aramidnih nitok / Bondarenko O.V., Stepanov D.M. // Zbirnik naukovih prac' Donec'kogo institutu zaliznichnogo transportu. – Donec'k, 2013. – Vip. №33. – S. 86 – 92.
7. Volokonno-opticheskie kabeli. Teoreticheskie osnovy, konstruirovanie i raschet, tehnologija proizvodstva i jekspluatacija: [monografija] / [Iorgachev D.V., Bondarenko O.V., Dashhenko A.F., Usov A.V.]. – Odessa: Astroprint, 2000. – 536 s. – ISBN 966-549-542-9.
8. Stepanov D.M. Ocinka parametriv peredachi dielektrichnih samonesuchih optichnih kabeliv v umovah ekspluatacії: dis. kandidata tehnichnih nauk: 05.12.20 / Stepanov Dmitro Mikolajovich. – Odesa, 2012. – 272 s.
9. Bondarenko O.V. Viznachennja parametriv spiral'no-vignutogo odnomodovogo optichnogo volokna dlja kompensacії pogonnoї hromatichnoї dispersiї signalu / O.V. Bondarenko, O.M. Vlasov, O.M. Stashhuk,
10. D.M. Stepanov // Sensorna elektronika ta mikrosistemni tehnologiї / zb. nauk. prac'. – Odesa, 2011, Vip. № 3. – S. 95 – 98.

11. Kornejchuk V.I. Proektirovanie volokonno-opticheskih sistem peredachi / Kornejchuk V.I., Makarov T.V., Panfilov I.P. – Odesa, 1996. – 118 s.

12. Odincov N.N. Issledovanie poljarizacionnoj dispersii volokonnyh svetovodov, izognutyh po spirali / N.N. Odincov, O.M. Stashhuk // Naukovi praci ONAZ im O.S. Popova. – Odesa, 2009. – S. 36 – 40.

13. R 45-010-2002. Rekomendacії z pidvishuvannja optichnih kabeliv na oporah povitrjanih linij zv'jazku, LEP, kontaktnoї merezhi zaliznic'. – K.: Derzhavnij komitet zv'jazku ta informatizacії Ukraїni, 2004. – 95 s. (Vvedeno v diju 27.03.2003 r.).

Література

1. Бондаренко О.В. Выбор конструкции самонесущего оптического кабеля по растягивающим нагрузкам / О.В. Бондаренко, Д.В. Иоргачев, Л.Л. Мурадьян // Технология и конструирование в электронной аппаратуре. – 2001. – Вып. № 1. – С. 18 – 21.

2. Бондаренко О.В. Розробка методу розрахунку стійкості діелектричних оптичних кабелів до розтягуючих навантажень / О.В. Бондаренко // Наукові праці Донецького національного технічного університету. – Серія: "Обчислювальна техніка та автоматизація". – Донецьк, 2009. – Вип. 17(148). – С. 64 – 68.

3. Мурадьян Л.Л. Апробация методики расчета конструкции СОК по растягивающим усилиям / Мурадьян Л.А. // Наукові праці ОНАЗ ім. О.С. Попова. – Одеса, 2007. – Вип. № 1. – С. 158 – 160.

4. Бондаренко О.В. Методика розрахунку модульної конструкції оптичного кабелю по розтягуючому зусиллю / О.В. Бондаренко // Моделирование и информационные технологи: сб. науч. трудов / Институт проблем моделирования в энергетике им. Г.Е. Пухова НАН Украины. – 2009. – Вып. 54. – С. 31 – 34.

5. Bondarenko O.V. / Technique of determination of modules tube diameter and possible lengthening of optical cables construction / O.V. Bondarenko, D.M. Stepanov, O.M. Stastchuk // Фотоелектроніка. – 2011. – Вып. 20. – С. 76 – 80.

6. Бондаренко О.В. Дослідження стріли провисання самоутримних оптичних кабелів з периферійним силовим елементом із арамідних ниток / Бондаренко О.В., Степанов Д.М. // Збірник наукових праць Донецького інституту залізничного транспорту. – Донецьк, 2013. – Вип. №33. – С. 86 – 92.

7. Волоконно-оптические кабели. Теоретические основы, конструирование и расчет, технология производства и эксплуатация: [монография] / [Иоргачев Д.В., Бондаренко О.В., Дащенко А.Ф., Усов А.В.]. – Одесса: Астропринт, 2000. – 536 с. – ISBN 966-549-542-9.

8. Степанов Д.М. Оцінка параметрів передачі діелектричних самонесучих оптичних кабелів в умовах експлуатації: дис. кандидата технічних наук: 05.12.20 / Степанов Дмитро Миколайович. – Одеса, 2012. – 272 с.

9. Бондаренко О.В. Визначення параметрів спірально-вигнутого одномодового оптичного волокна для компенсації погонної хроматичної дисперсії сигналу / О.В. Бондаренко, О.М. Власов, О.М. Стащук, Д.М. Степанов // Сенсорна електроніка та мікросистемні технології / зб. наук. праць. – Одеса, 2011, Вип. № 3. – С. 95 – 98.

10. Корнейчук В.И. Проектирование волоконно-оптических систем передачи / Корнейчук В.И., Макаров Т.В., Панфилов И.П. – Одеса, 1996. – 118 с.

11. Одинцов Н.Н. Исследование поляризационной дисперсии волоконных световодов, изогнутых по спирали / Н.Н. Одинцов, О.М. Стащук // Наукові праці ОНАЗ ім О.С. Попова. – Одеса, 2009. – С. 36 – 40.

12. Р 45-010-2002. Рекомендації з підвішування оптичних кабелів на опорах повітряних ліній зв'язку, ЛЕП, контактної мережі залізниць. – К.: Державний комітет зв'язку та інформатизації України, 2004. – 95 с. (Введено в дію 27.03.2003 р.).

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СИСТЕМА ДЛЯ ВИМІРЮВАННЯ І КОНТРОЛЮ ВОЛОГОСТІ НАФТОПРОДУКТІВ

Розроблено мікропроцесорну систему для вимірювання і контролю вологості нафтопродуктів, що може бути використана на нафтопереробних підприємствах, а також у вимірювальних лабораторіях під час видобутку нафти. Отримано залежності функції перетворення та визначено чутливість. Розбіжність теоретичних та експериментальних результатів не перевищує 3%.

Ключові слова: вологість, нафтопродукт, ємнісний сенсор, від'ємний опір

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THE SYSTEM FOR MEASURING AND CONTROL OF PETROLEUM PRODUCTS HUMIDITY

Abstract – The system for measuring and control the petroleum products humidity is developed and can be used in the oil industry and in test labs during oil production. The dependences of functions of transformation and sensitivity of petroleum products humidity are obtained. The divergence of theoretical and experimental results is 3 %.

Keywords: humidity, petroleum product, capacitive sensor, negative resistance

Вступ

Визначення вологості в нафті та маслах завжди було однією з головних проблем для фахівців. Вода, яка присутня в гідравлічних і мастильних рідинах, може викликати значні пошкодження технологічних вузлів, які потребують змащування деталей. Без відповідних пристроїв та засобів контролю важко помітити їхнє поточне руйнування. Вода наявна у нафті сприяє корозії, при її транспортуванні може спотворювати покази витратомірів, а також призводить до передчасного зношення обладнання та виникнення аварійних