The Study on the Dependence of Attenuation Coefficient from Crushing Force Parameters in Optical Fiber

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Abstract: The problem of reliability becomes decisively important when using optical fiber in telecommunication systems. This is because the transmission rate is very high. That is why the investigations connected with measurements of the parameters influencing the reliability of optical fiber (OF) are topical. This article contains the findings obtained by experimental investigations of the attenuation factor of multimode optical fiber caused by the magnitude and duration of crushing force applied along the full length.
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1. Introduction

The mechanical requirements on optical fiber structure are fulfilled if optical fiber used in it has a strength margin and does not collapse during the whole lifetime. That is why, in order to produce an optical fiber communication cable, it is necessary to analyze the strength properties of the light guide, to assess the short-time and long-term strength, and to estimate the reliability of optical fiber.

Such mechanical characteristics of optical fiber as short-time and long-term strength were studied in research papers [1-10]. In these papers, authors considered various kinds of mechanical strength distribution in optical fiber [5-8]. Besides, the authors put forward methods of assessing the long-term strength [1-4, 10]. The questions of optical fiber reliability were studied in paper [9]. Moreover, they proposed a method of reliability assessment for optical fiber on the basis of mechanical properties found out during the tests of short-time and long-term strength [11]. The tensile, bending and compressive strength of optical fiber were tested in paper [12]. Besides, they studied the mechanical, climatic and fire resistance of internal optical cable [13].

The ultimate strength characterizes the ability of the OF to resist tension and bending. The micro cracks on surface and interior defects are the main reasons for the fragility of the OF. Surface micro cracks play the significant role. They can grow under the effect of tensile load which occur during cabling. The slight increase of tensile and crushing force can lead to significant reduction of the lifetime. So the credible information about the load rate applied to the OF is necessary to assess the reliability of optical fiber communication lines.

Temperature changes, mechanical and chemical action, and aging of the OF can also cause defects.

Thus, the review of scientific papers showed the urgency of the findings obtained during the research of the attenuation of multimode optical fiber (MOF) by the magnitude and duration of crushing force in the framework of short-time strength.

2. Main part.

When operating in the field, mechanical force can act in different directions. The impact of differently directed mechanical force on the fiber-optic light guide can lead to different results. That is why, it is necessary to reproduce each kind of load separately in laboratory in order to estimate the impact of each one.

The research aimed at obtaining the attenuation coefficient of the MOF caused by lateral compression was conducted with the help of testing stand. Figure 1 shows the basic circuit of this testing stand. The circuit has the following notation conventions: 1 is the radiation source; 2 is the lens; 3 is the rotary table; 4 is the MOF; 5 is the photodetector; 6 is the electronic oscillograph.

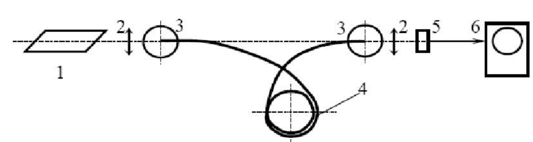

Figure 1: The measuring circuit for the coefficient of the attenuation of laser pulse in the MOF caused by crushing force

The MOF with length ~1500 m was in the self-supported coil with diameter 16 sm. The coil was spread out without crisscross (turn to turn), by the part of a turn, on the bottom base with wooden deck 1.0×0.1 m. The turn's part was at the bottom and underwent mechanical action. The same plate with wooden bearing was laid on top. This construction was put under pressure. The manometer of hydraulic press showed the value of crushing force. The crushing force acted within 20 min for each measuring. In 5 minutes after the force value was set, we installed the radiation source with specified wavelength and then measured the output signal change in the MOF. For the next measuring, the force was changed by increasing pressure from the previous value. The MOF was motionless all the time. The measuring was conducted at temperature 21-23°C without any special stabilization efforts.

Serial semiconductor and solid-state lasers were used as a source of monochromatic radiation. The wavelength was measured considering the availability of radiators and the necessity of using wavelength in wide spectral interval. In these conditions we can detect mechanical damages and their size by the transmission spectrum.

The focusing lens makes it possible to direct the major part of radiation into the MOF. The rotary table with its angle control system based on PC allowed us to match accurately the axes of laser radiation and the MOF. By rotation and lateral movements we placed the rotary table with light guide fixed to it so that the signal of the output photodetector was the maximum level. The coaxial photoelectric device FEK-09 with supply voltage 1 kV was used as a photodetector. The output pulse of FEK-09 was registered by electronic oscillograph LeCroy 440 WaveSurfer. The oscillograph had sensitivity of 2 V/div and sweep of 50 ns/div (the screen contains 500 ns or 1250 dots).

During measurements, all lasers equipped with mechanical shutters generated the continuous pulse sequence. Radiation wave used for measuring the signal changed its length by installing a light guide into the clip of relevant changeable radiator. After installing the light guide, the shutter opened.

The total time of testing the MOF by increasing pressure did not exceed two hours. The results are presented in Figure 2.

The test was conducted for three different MOF of the same grade. The signal was measured for the 1 m long section of light guide in order to assess the radiation power of lasers placed into the MOF. The electric signal for the radiation coming out of the light guide section was taken as a signal for laser radiation.

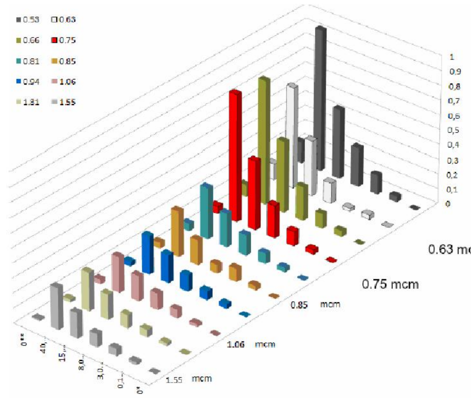

Figure 2: The average spectra of MOF attenuation coefficients (α, dB/km) from the magnitude of crushing force at room temperature on specified wavelength (* - before the test, ** - after the test)

The coefficient of the MOF attenuation from the crushing force duration was found out at the similar stand which basic circuit is shown in Figure 1. We used the same technology of laying the MOF ~1500 m long under pressure. During the whole test, we used one and the same MOF lying immovably under pressure.

Constant crushing force acted continuously during the whole test. Measuring time was 15-20 min. The changes of the wavelength are described above. The difference consists in the fact that all radiators switched up simultaneously directly before measurement after specified testing time. Then they generated pulses up to the end of the test. Then lasers switched off until the next test.

The tests were conducted at room temperature. Attenuation coefficient was found out in specified moments of time count off from the moment of putting the MOF under pressure and setting the specified pressure of 40 MPa. The results of tests are presented in Figure 3.

3 Findings

The increasing short-time mechanical effect on the MOF leads to the growth of attenuation coefficient synchronously at all wavelengths. At the same time, the comparative increase of attenuation coefficient is more intensive in long-wave area. The comparative value of residual attenuation after short-time crushing force is also higher in long-wave area. Although, the absolute values of the attenuation of optical radiation measured by external induced force in the MOF are higher in short-wave area. This allows us to suppose that changes in the MOF caused by mechanical effect have smaller characteristic size than 0.5 mcm (minimal wavelength), taking into account the theory of interaction between optical radiation and medium's heterogeneity. The absolute value of induced attenuation is not proportional to the value of initial attenuation at different wavelength. This makes us suppose that the natural attenuation and the induced one have different nature. After taking off the crushing force the induced changes in the MOF partially remain the same.

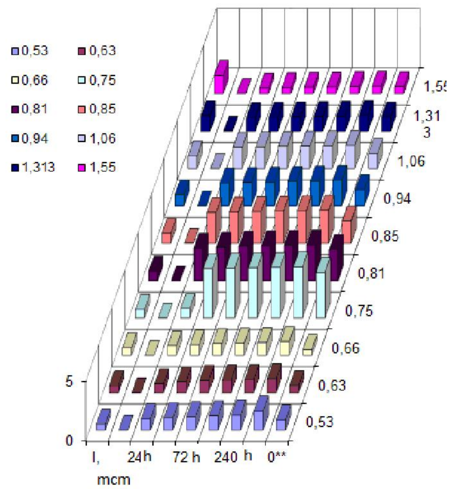

Figure 3: The spectrum of coefficients of the MOF attenuation (α, dB/km) from crushing force duration of 40 MPa for different wavelengths of radiator (** - after the test).

When the action is durable, one can see the significant increase of the MOF attenuation during the first twenty-four hours. In further 18 days, the attenuation coefficients monotonically increase at different wavelengths. Besides, there is a significant residual attenuation most probably caused by residual values of the MOF parameters. The absolute values of additional attenuation are higher in short-wave area. This allows us to suppose that short-time and long-term mechanical efforts generate the cases of heterogeneity of the same nature, for example micropores in the core of the MOF. It follows from Figures 1 and 2 that long-term effect causes the accumulation of attenuating centres but not the change of their parameters, such as the size.

4 Conclusions

1. Even a short-time crushing force can lead to the increase of attenuation coefficient of the MOF radiation in the spectrum range 0.53-1.55 mcm.

2. The residual value of attenuation coefficients increases as a result of positive action of crushing force proportional to effect time.

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