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Experimental study of the use of optical cables with different types of fibers in monitoring systems

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Abstract. A comparative study of the sensitivity to point vibration of a single-fiber optical cable with standard single mode optical fiber (SSMF) and with bend loss insensitive optical fiber (BLIF) was carried out. The measurement was carried out for a single vibration action – the fall of a kettlebell, and harmonic acoustic effects. During the experimental study, the advantage of the used optical cable with the bend loss insensitive optical fiber was revealed.

Keywords: fiber-optic reflectometers, optical fiber, Rayleigh scattering, DAS, fiber-optic acoustic distributed sensor

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Экспериментальное исследование использования оптических кабелей с различными типами волокон в системах мониторинга

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Аннотация. Представлены результаты сравнительного экспериментального исследования чувствительности к локальному вибровоздействию одноволоконного оптического кабеля со стандартным волоконным световодом и световодом с уменьшенными потерями на изгибах. Исследование проводилось для единичного вибрационного воздействия – падения гири и гармонического акустического воздействия. В ходе экспериментального исследования выявлено преимущество использования оптического кабеля с волоконным световодом с уменьшенными потерями на изгибах.

Ключевые слова: волоконно-оптические рефлектометры, волоконный световод, рэлеевское рассеяние, DAS, волоконно-оптический акустический распределенный датчик

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Introduction

The distributed fiber-optic physical field sensors occupy a special place among sensor systems and represent the wide class of devices for the wide range of applications. The advantages of fiber-optic sensors over electrical ones are the possibility of the completely passive design, variety of shapes, immunity to electromagnetic interference and aggressive environments [1–5], small size and weight. As a result, they can be used in explosive atmospheres, flammable mixtures and strong electromagnetic fields [1–5]. Such fiber systems consist of the sensitive element - a conventional optical fiber - and the unit for generating an optical probing signal and analyzing the signal backscattered in the optical fiber. The operating principle is based on the time domain reflectometry technique (Optical Time Domain Reflectometer, OTDR). Local measurement of physical parameters using such sensors makes it possible to monitor in real time.

The purpose of this work is to study the influence of the choice of the optical fiber as part of the distributed sensor system on its parameters and the possibility of increasing spatial resolution when testing the object with the coherent reflectometer due to the optimal choice of the optical fiber.

Experimental study

At the test site, a trench was dug in the ground 120 cm deep, 30...40 cm wide, 30 m long. An optical cable was laid into the trench every 30 cm in height, starting from the bottom of the trench and covered with soil. After compacting the optical cable with soil, a period of 2 ... 3 weeks was maintained in the trench to stabilize the system parameters. The schematic block diagram of the measuring stand is shown in Fig. 1.

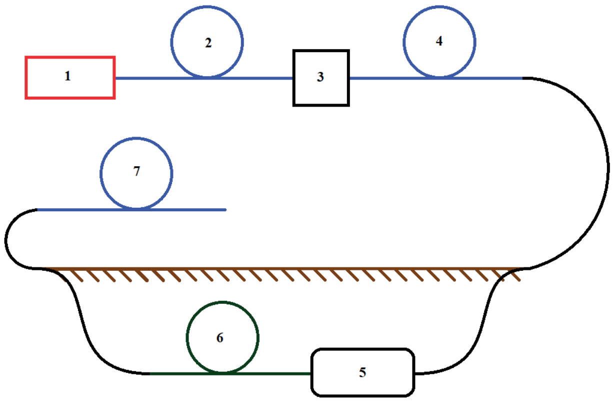

Fig. 1. Structural block diagram of the measuring stand: *1* – coherent optical reflectometer Danube, *2* – optical fiber, *3* – optical 19" cross-panel, *4* – multi-fiber optical cable, *5* – optical coupling for splicing a multi-fiber fiber-optic cable with test samples of optical cables in the trench, *6* – optical cable (segment) under test, *7* – optical fiber

The tested optical cable *6*, using an optical coupling *5*, was commutated with a multi-fiber trunk cable *4*, connected through a normalizing coil *3* to the coherent reflectometer *1*. An effect is made next to the cable: turning on sound at various frequencies from a reference frequency generator (Fig. 2).

To create a vibration-acoustic effect, an acoustic system was used, to which a harmonic signal was supplied. Signal frequencies varied from 5 Hz to 200 Hz

Results and Discussion

The tested optical cable samples differed in the type of optical fiber. In the first case, a standard optical fiber (SSMF, Standard Singlemode Fiber) was used, in the second case, a optical fiber with reduced bending losses (BLIF, bending-loss insensitive single-mode optical fiber) was used (Fig. 3, 4). Fiber parameters: dispersion D = 16.67 ps/nm/km (β_2 = 20 ps^2/km), loss 0.2 dB/km at operating wavelength λ = 1550 nm.

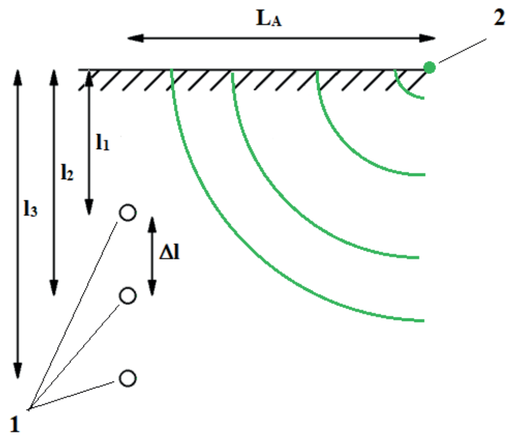

Fig. 2. Layout of the emitter and the optical cable under test: *1* – simplex optical cable, *2* – speaker

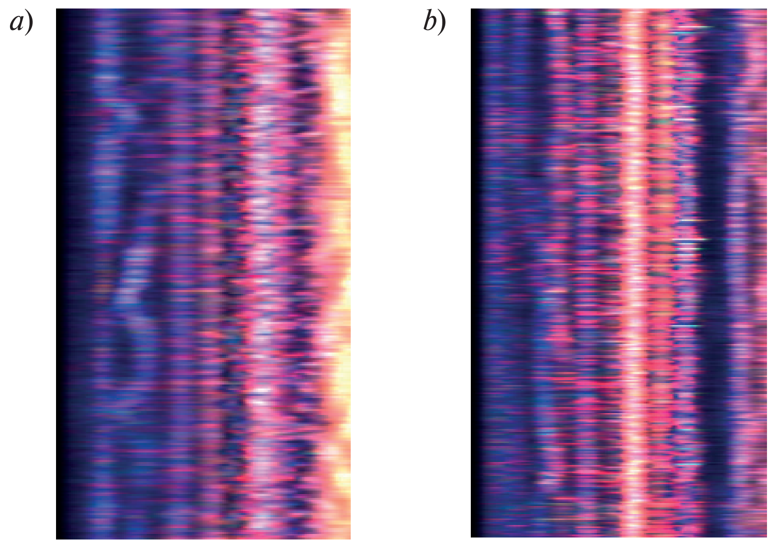

Fig. 3. "Waterfall" when recording vibration effects with an optical cable with a standard optical fiber (*a*) and with increased resistance to bending (*b*)

Table presents the results of measuring the response for the case of a weight (inert projectile) weighing 10 kg falling at a distance L_A = 10 m from the optical cable route.

Table

The effect of lens voltage on the structure size

Optical Fiber	Depth *l*, cm		
	l_1 =60 cm	l_2 = 90 cm	l_3 = 120 cm
SSMF	9.3	3.5	1.9
BLIF	9.4	7.0	5.6

The table shows that for the dumbbell weighing 10 kilograms, the signal energy is greater, therefore the effect is better discernible if the bend loss insensitive optical fiber is used as the sensor element.

The maximum permissible detection range is also longer for the optical cable with bend loss insensitive optical fiber.

Conclusion

The comparative study of the sensitivity to point vibration effects of a single-fiber optical cable with the standard optical fiber and bend loss insensitive optical fiber was carried out. The measurements were carried out for a single vibration impact - dropping the weight, and harmonic acoustic impact. An experimental study revealed the advantage of using an optical cable with the bend loss insensitive optical fiber.

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