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MECHANICAL AND OPTICAL PROPERTIES OF OPTICAL FIBER JUMPER CORD (OJC) WITH COMPOSITE COIL SPRINGS

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SUMMARY: Recently, composites are widely applied to various parts, but rarely used for coil springs. Small diameter composite coil springs were made using a hot plated mold. The outer diameters of the springs were about 2mm and 3mm. These springs are inserted into the optical fiber jumper cord (OJC) to protect the damage of an optical fiber from the sudden load. Two types of composite coil springs are manufactured to compare the effectiveness for the damage protection. The experimental works were conducted to check the effect of the OJC with composite coil springs on the mechanical and optical properties. The experimental observations show a considerable effect on the flexural resistance, hence slowing down the deterioration of the optical power by the internal damage of the fiber. From these experimental results, it is revealed that the OJC covered with the composite coil spring has a possibility for a practical usage with full fruits.

KEYWORDS: Composite Coil Spring, Optical Fiber Jumper Cord (OJC), Mechanical Property, Optical Property, Optical Power

INTRODUCTION

The Ireland physicist John Tyndall demonstrated in 1870 that light can be guided in a stream of water. His experiments utilized the principle of total internal reflection, which is also applied in today's optical fiber. After the first laser was invented by Maiman, various efforts for the development of a beam-guiding medium started. In 1970 the first step-index fiber was manufactured and achieved attenuation values of less than 20dB/km at the wavelength of 633nm [1]. Optical fibers are manufactured in several production steps, making it possible to selectively optimize mechanical, geometric and optical properties of the fiber. With all of these techniques in use today a preform is produced. This is a glass rod consisting of core and cladding glass.

Metal springs have several advantages: they are very cheap to produce and can be produced in almost all kind of measures and in a very broad range of stiffness. On the other hand, they could become very heavy and have corrosion and insulation problems. However, in the cases where lightness and/or insulation and corrosion characteristics are more important than the price, a composite spring can be successfully used. Helical springs are important mechanical components in a wide variety of engineering applications. For compression or extension springs, which are loaded by axial forces along the helix axis, the primary stress produced in the cross section is shear stress. The increasing usage of lightweight materials of high strength in modern engineering structures encompasses applications in helical coil springs, and necessitates a thorough understanding of the mechanical behaviors of such springs [2,3].

In this paper, helical composite springs were manufactured to apply to optical fiber jumper cord (OJC) for preserving optical fiber from a sudden direct load or impact. Generally, OJC is very expensive and easily damaged from small loading and impact. If there is a defect in the equipment, whole OJC cannot be used for the line service. So helical composite springs are used as a protective wrapping layer, thereby reinforcing the OJC. The experiments were performed to find the suitable spring type for the OJC. Hence, the composite coil springs covered around OJC (CS-OJC) were manufactured to investigate the effect of the composite coil spring on the mechanical and optical properties of the OJC.

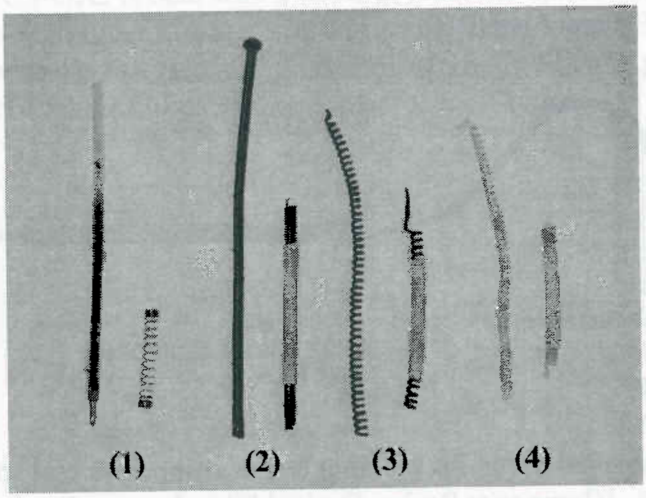
EXPERIMENTAL METHODS

Preparation of composite coil springs and test samples

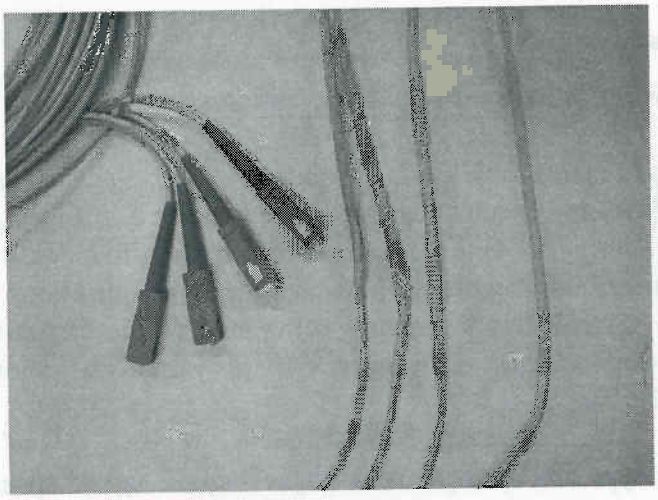
Carbon/epoxy (USN 125 B, Skyflex, SK Chemical, KOREA) and Spectra 900 (AlliedSignal, USA) were used for the materials of the helical composite spring. The method used for the production of the springs is a hot plated mould consisting of a helically grooved mandrel. The mandrel was coated so that the springs could be easily removable from the mould after the cure. The total curing time is 1 1/2 hours, 45 minutes at 80°C and followed by 50 minutes at 120°C. In the case of carbon/epoxy, two types of winding method were used. One is winding by the yarn and the other is by the band.

The shapes of the composite coil springs so manufactured are shown Fig. 1. In Fig. 1(a), longer ones are the naked composite springs after the cure, shorter ones are those of covered by a shrink PVC tube, while (1) shows a ballpoint pen and a small metal spring for a comparison. In Fig. 1 (a), spring (2) is a band type (B-type) carbon/epoxy, spring (3) is a yarn type (Y-type) carbon/epoxy, and spring (4) is a yarn type spectra (S-type). For the manufacture of the composite springs, a B-type spring is much easier than the Y-type spring. The Y-type springs need a pre-work to form a yarn, but the B-type springs can be wound directly to the heated mandrel without pre-works. Additionally, the B-type spring has a low material consumption, i.e., more economical compared with the Y-type spring. However, the Y-type spring is in better shape than the B-type springs.

And CS-OJC (Composite Spring-covered Optical fiber Jumper Cord), as shown in Fig. 1(b), was also prepared to compare with OJC during the bending test. The configurations of CS-OJC are similar to the actual OJC, which wraps up the optical fiber with aramid fibers and outer PVC layer. Instead, optical fiber is inserted into the composite coil spring, then wrapped by a shrink tube (SUMITUBE, Sumitomo, JAPAN) at 105°C for 3 min (pv-type).



(a)



(b)

Figure 1 Shapes of (a) the Composite springs and (b) CS-OJC (Composite Spring Optical Fiber Jumper Cord)

Experimental procedures

Three kinds of mechanical tests were executed; tensile to the axial direction, compression and bending at a right angle to the helical direction. For the tensile tests, epoxy resin was used to fix the spring to the grip. All the tests were done by the use of a universal testing machine (UTM, United STM-5-E, United Calibration Corp., USA). During the mechanical tests, applied load and displacement were recorded. From these tests, the tensile and the vertical compression strengths of the springs were measured.

To test the composite spring covered around the OJC, optical properties were measured during the bending test to compare the damage level in the optical fiber of OJC and CS-OJC, as shown in Fig. 2. To do that, two kinds of measuring instruments were used. One is OTDR analyzer (Optical Time Domain Reflectmetry) analyzer (HP E6000B, USA) and the other is

OPM (Optical Power Meters, OLP-6, Wavetek Wandel & Goltermann, Germany). The OTDR generates a laser source at –25dBm and the OPM perceives the optical signal variation.

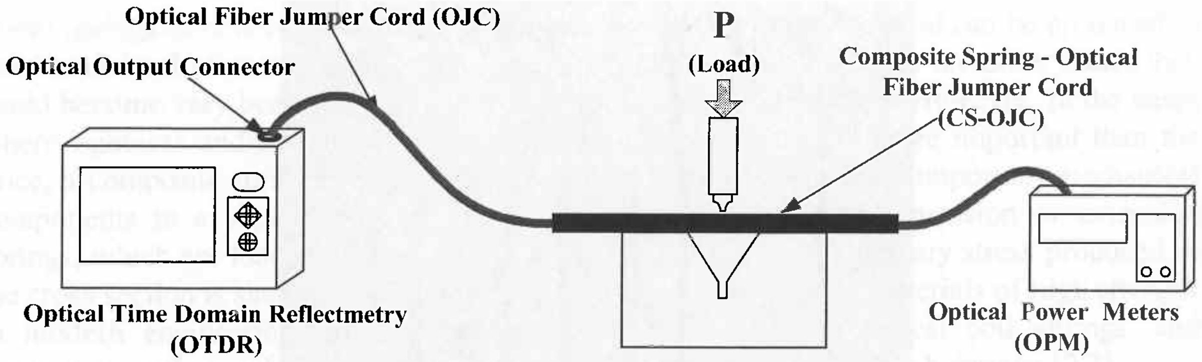


Figure 2 Experimental Setup for bending test of composite coil spring and CS-OJC (Composite Spring Optical Fiber Jumper Cord)

RESULTS AND DISCUSSIONS

Compression behaviors of composite coil springs

The compression test results of 3 kinds of composite springs, i.e. carbon/epoxy yarn type, carbon/epoxy band type, and spectra yarn type, are presented in Fig. 3. These tests follow the guideline of ASTM D 695-96 [4]. Fig. 3 shows the applied load vs. vertical displacement to the axial direction during the compression test. From the compression test results, naked coil springs are generally weaker than the metal spring, but Y-type carbon/epoxy shows a similar behavior to the metal springs. It means that a yarn type shows better mechanical characteristics than the band type.

And generally the pv-type coil springs are stronger than the naked springs. It means that there is an interactive complement between the composite coil spring and the PVC shrink tube, even if the spring has a defect during the manufacturing process. Among those composite springs, pv-Y-type carbon/epoxy spring has the best mechanical property. It shows two times higher stiffness and strength than the metal spring, resulting in considerable resistance to the damage by a vertical load.

Optical Characteristics of CS-OJC

Fig. 4 shows the reduction trends of the optical power in two types of CS-OJC and original OJC subjected to a flexural load. From this result, CS-OJC is more effective against a direct load perpendicular to the helical route. The resistance of CS-OJC is about quadruple than that of OJC. From these tests, it is revealed that there is a tremendous difference in the damage resistance between the CS-OJC and OJC. Comparing with Y-type and B-type carbon/epoxy CS-OJC, there is a little difference, but slightly better characteristics in yarn type.

It is also found from the tests that the optical power can be restored a certain amount even after the excessive loading. Though the optical power is not detected after the damage of the CS-OJC in the overload, it was recovered after the unloading. It means that the composite spring in the CS-OJC is bearing the flexural load and protecting the optical fiber from the external load directly, hence optical power can be recovered to the first situations afterwards. Therefore, even if the CS-OJC is bent with a flexural load, the optical fiber is in a situation of good preservation. Through these bend tests, it can be concluded that CS-OJC has much better durability compared with the OJC and there are lots of possibilities to the practical usage for the damage protection of optical fiber jumper cords.

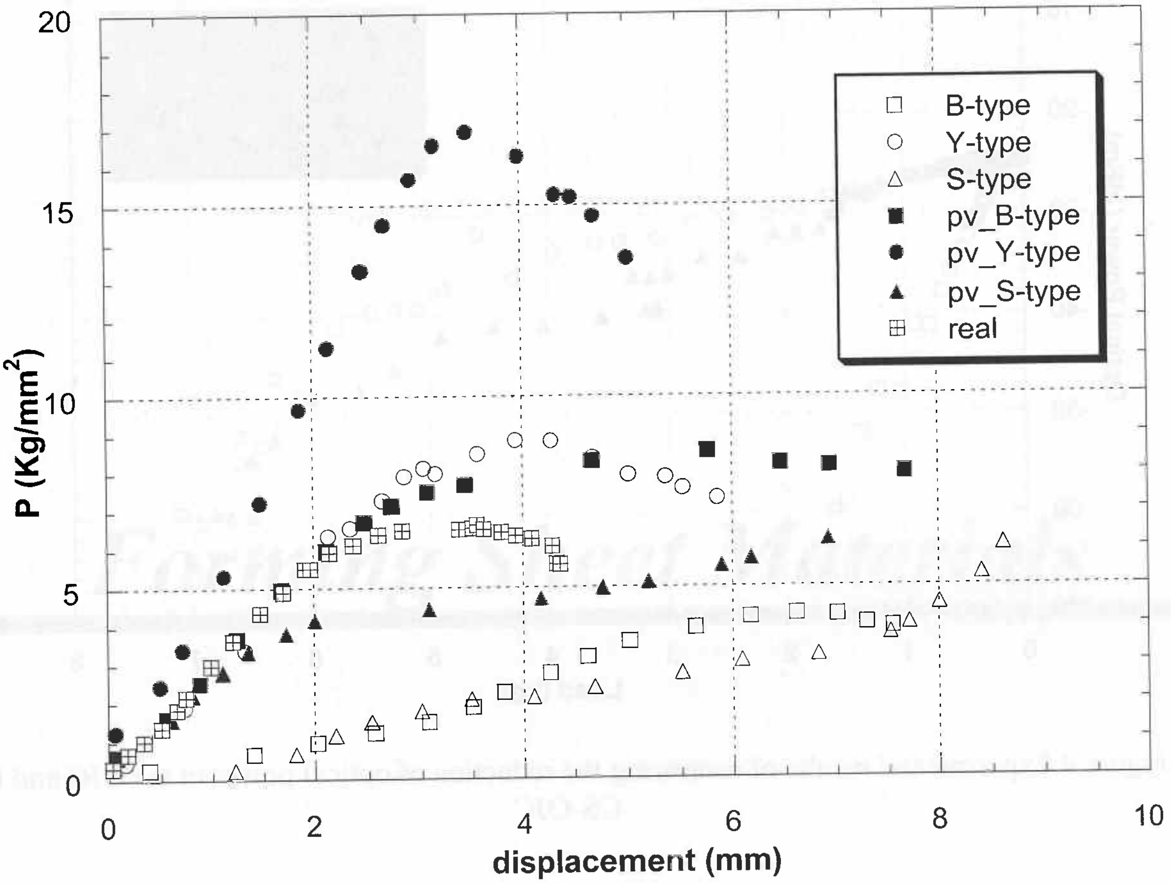


Figure 3 Experimental results of compression tests for the composite springs (CS)

CONCLUSIONS

Composite coil springs are manufactured to protect the optical fiber of OJC from the damage by the sudden loadings. And two types of composite springs are presented as helical composite springs for the OJC protection. One is a band type (B-type) spring and the other is a yarn type (Y-type) spring. From this research, it is revealed that the Y-type helical composite springs are more effective than the B-type spring in the compression characteristics, but shows a similar behavior for the protection of optical fiber inside the jumper cord. The composite coil spring covered OJC has much more efficient resistance to the flexural deformation than original OJC. At any rates, these types of composite coil springs can make up for the flexural weakness in the current OJC.

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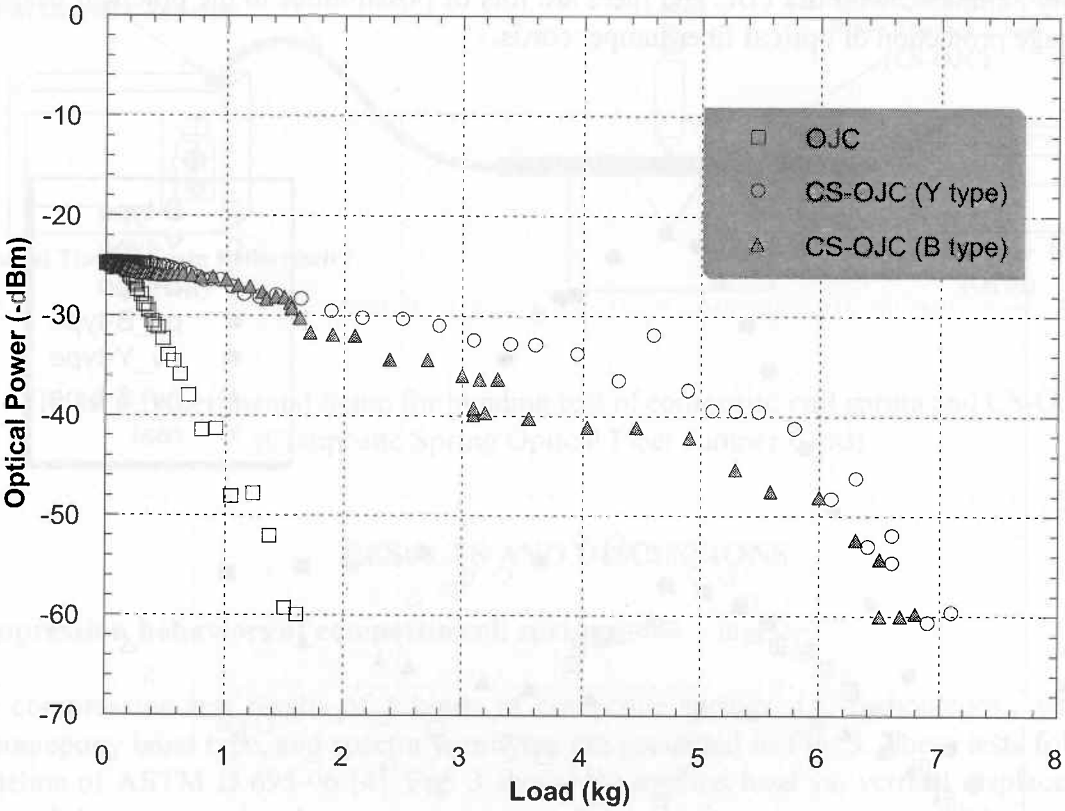

Figure 4 Experimental results of measuring the reduction of optical power in the OJC and the CS-OJC

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