NEWS RELEASE

NTT

September 20, 2001

New "distributed fiber optic strain sensor" about half the cost and providing three times the measurement accuracy of a conventional sensor.

- Accelerated construction of various monitoring systems using optical fiber -

Nippon Telegraph and Telephone Corp. (NTT) has developed a new "distributed fiber optic strain sensor" that uses an optical fiber to monitor degradation or damage in concrete structures such as tunnels, river levees, and slopes. The newly developed sensor employs a novel scattered light detection system that makes it considerably less expensive and more accurate than a conventional sensor. It is expected that the new sensor will be widely used for various optical fiber based monitoring systems.

A monitoring system is needed that can diagnose degradation in structures such as buildings, tunnels, different forms of conveyance and road embankments. A monitoring system using a distributed fiber optic strain sensor has attracted particular attention because it has the advantage of permitting strain measurement not only one dimensionally along the fiber but also two dimensionally. In addition, fiber is easy to install. Research into ground surface failure monitoring systems using optical fiber is an important subject of concern to the Ministry of Land, Infrastructure and Transport (*1). However, since the sensor cost was high, it was impossible to respond to requests originating in various fields.

In 1997 NTT Access Network Service System Laboratories developed "a strain measurement technology for the ground and constructions using an optical fiber" (BOTDR *2, See Fig. 1). Since then, we have made an effort to establish monitoring technology using the BOTDR. The BOTDR is designed to measure the strain that occurs in optical fiber based on the change in the scattered light (Brillouin scattered light) produced by an incident light launched into the fiber. Our newly developed "distributed fiber optic strain sensor" uses the same measurement principle as the conventional sensor. However, our use of a new scattered light detection system reduces the cost by about half and triples the measurement accuracy. The new sensor can measure strain over a distance of approximately 10 km.
We believe that this sensor could be applied to systems designed to monitor such structures as buildings, tunnels, river levees, slopes, dams, ships, and airplanes. (See Fig. 2)

Our new sensor has the following advantages over the conventional sensor.
(1)It is about 50% less expensive
(2)It offers improved measurement accuracy: (an error of 0.003 % has been realized compared with 0.01 % for the conventional sensor).
(3)It reduces the required measurement time from approximately 10 minutes to approximately 5 minutes.

The above improvements had no detrimental effect on the measurable distance, which remains approximately 10 km, similar to that of the conventional sensor.
The regulations of the Japan Society of Civil Engineers state that the minimum allowable crack width in a concrete structure is approximately 0.1 mm. The new sensor can detect cracks at this level. This means that accidents can be prevented and maintenance costs reduced by detecting cracks at an early stage or by systematic observation with this new sensor.

A heterodyne detection(*3) system for measuring Brillouin scattered light is incorporated in the new sensor as a new technology. (See Fig. 3)

With the conventional sensor, Brillouin scattered light produced in a fiber is extracted through an optical heterodyne detection system. In the system, branched light from a laser light source is used as a standard signal. To make signal detection easier, the scattered light frequency must agree with the branched light frequency. So, we up-converted the frequency of the light launched into the optical fiber by approximately 11 GHz through a frequency-shifting device. In this device, the light is repeatedly frequency-shifted by ten and several MHz and amplified. However, this configuration has certain shortcomings, namely its cost is high, the measurement is unstable, and it requires a long measurement time.

With the new sensor, we employ a novel configuration for Brillouin scattered light detection that has no frequency-shifting device. There are two steps in the detection of the scattered light, namely, optical and electrical heterodyne detection. First, Brillouin scattered light is detected optically, in a way similar to the approach used with the conventional sensor. An electrical intermediate output is extracted that has a wide frequency range exceeding 10 GHz, because the frequency of the pulsed light launched into the fiber is not up-converted. Next, the intermediate output is heterodyne-detected electrically using a stable signal from an electric local oscillator. We can realize both cost reduction and stable measurement by adopting this configuration.

NTT has constructed tunnels for communications mainly in cities designated by ordinance. We plan to employ the new sensor in a "tunnel structure monitoring system" to monitor such damage as cracks and deformation, and systems will be gradually installed as required in the central areas of Nagoya, Osaka, and Tokyo from next spring. (See Fig. 4)

Terminology
*1Important topics of concern to the Ministry of Land, Infrastructure and Transport
Rock and slope failure risk management technology is an important research and development topic in the New 5-year Road Improvement and Management Program of the Ministry of Land, Infrastructure and Transport. Under this program, the Public Work Research Institute and fourteen private companies including NTT have been undertaking joint research on ground surface failure monitoring systems using optical fiber since 1999.

*2BOTDR : Brillouin Optical Time Domain Reflectometry
This is technology designed to measure the strain applied to an optical fiber by measuring and analyzing the power spectrum of the Brillouin scattered light that is produced when pulsed light is launched into the fiber.

*3Heterodyne detection

This is measurement technology utilizing interference (beat signal) and employed in the field of wireless communications. The addition of a standard signal to a received signal produces an intermediate signal with a frequency between the two values (generally, lower than the frequency of received signal). The signal to be received is extracted through this intermediate signal. This system has high sensitivity.

Attachment

- Fig. 1 Distributed fiber optic strain sensor (BOTDR)
- Fig. 2 Main applications of distributed fiber optic strain sensor
- Fig. 3 Technology introduction
- Fig. 4 Structure Monitoring System for Telecommunication Tunnels

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