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Fibre optic sensors for the structural health monitoring of building structures

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Abstract

In this work different fibre optic sensors for the structural health monitoring of civil engineering structures are reported. A fibre optic crack sensor and two different fibre optic moisture sensors have been designed to detect the moisture ingress in concrete based building structures. Moreover, the degeneration of the mechanical properties of optical glass fibre sensors and hence their long-term stability and reliability due to the mechanical and chemical impact of the concrete environment is discussed as well as the advantage of applying a fibre optic sensor system for the structural health monitoring of sewerage tunnels is demonstrated.

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Keywords: SHM; fibre optic sensor; humidity sensor; crack sensor

1. Introduction

Fibre optic sensors are well suited for the structural health monitoring (SHM) of civil engineering structures. In contrast to conventional measuring instruments, e.g. electrical sensors, fibre optic sensors are resistant to electromagnetic interference and are robust so that they can withstand harsh environments. Moreover, due to the low light attenuation of optical glass fibres they can be multiplexed and interrogated over several kilometres. In the past

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different fibre optic sensors have been developed in order to measure several physical and chemical parameters. For instance, different fibre optic strain and temperature sensors have been applied for the SHM of civil engineering structures such as dams [1], bridges [2] and sewerage tunnels [3].

In this work fibre optic sensors for the SHM of concrete based building structure are presented. Since the formation of cracks and the resulting moisture ingress is critical for concrete based civil engineering structures a fibre optic crack sensor and two different fibre optic moisture sensors are reported. Moreover, the degeneration of fibre optic sensors due the chemical and mechanical impact of the concrete environment is discussed. The advantage of a fibre optic SHM sensor system is demonstrated based on monitoring the structural health of a sewerage tunnel system.

2. Fibre optic moisture sensors

In order to detect the moisture ingress into building structures two different fibre optic humidity sensors have been developed. A swellable polymeric fibre optic sensor has been designed for the distributed moisture monitoring. This sensor allows in combination with an OTDR (optical time domain reflectometer) the spatial determination of the failure position and hence the position of the moisture ingress by measuring the attenuation. Furthermore, a single-point relative humidity (RH) fibre optic sensor based on a polyimide coated Fibre Bragg Grating (FBG) sensor has been created. Due to the wavelength encoded RH readings several polyimide coated FBG sensors can be easily multiplexed and interrogated simultaneously.

2.1. Distributed moisture sensing

A schematic of the fibre optic swellable polymeric sensor developed is shown in Fig. 1a [3]. The sensor consists of a polyvinyl alcohol hydrogel rod, an optical single-mode (SM) fibre, a device to cause micro bending of the fibre and a protective felt wick. The hydrogel swells in the present of water without dissolution and presses the SM optical fibre against the 'micro bending' device that causes an attenuation of the light transmitted through the optical fibre. The 'micro bender' device developed was realized by using a helically twisted thread, which covers both the polyvinyl alcohol hydrogel and the optical SM fibre. The hydrogel rod was fabricated from polyvinyl alcohol by dissolving polyvinyl alcohol granulate in deionized water with a subsequent freeze-thaw cycle polymerization and drying at room temperature for one week. Following this, the optical SM fibre SMF-28e+ form Corning was helically-twisted around the polyvinyl alcohol rod and tied to the polyvinyl alcohol rod by applying a helically-twisted thread. Finally, the whole sensor was covered by using a felt wick, which acts as a protective cover, as well as extending the water-exposure area of the polyvinyl alcohol rod. A picture of the fabricated fibre optic swellable polymeric sensor is illustrated in Fig. 1b.

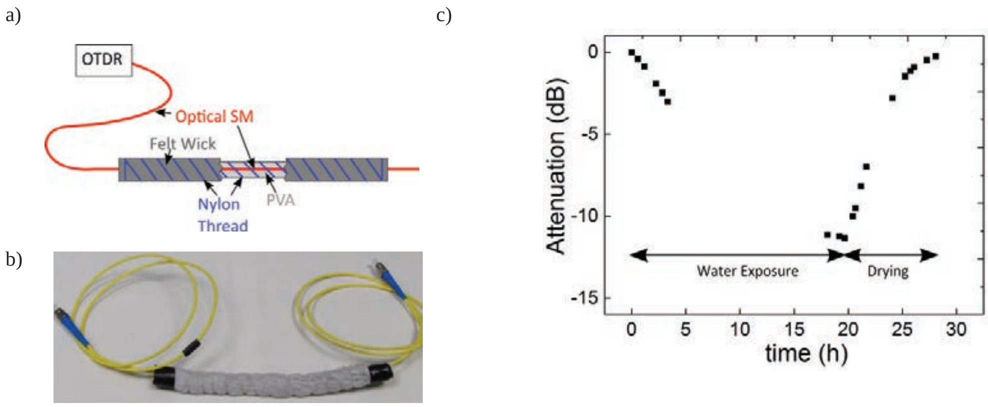

Fig. 1. Schematic (a) and picture (b) of the developed fibre optic swellable polymeric sensor for the distributed moisture monitoring. Response of the sensor when exposure to water and dried at room temperature (c).