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Review

A review of recent developed and applications of plastic fiber optic displacement sensors

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ABSTRACT

The recent developed and applications of plastic fiber optic displacement sensors (FODSs) based on intensity modulation technique are reviewed in this paper. In the evolvements of FODSs, the approaches to achieve high sensitivity and large linear range are normally categorized into two areas, namely the design of sensor probe and the target reflector. The applications of FODS are descried, which include the sensing of surface roughness, liquid refractive index, liquid level, vibration, the sensing of glucose concentrations, and temperature, etc. Recommendation for future work is summarized in conclusion.

Contents

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1. Introduction

In recent years, fiber optic sensors are received more considerable research efforts due to its potential sensitivity, detection speed and abilities to the widely assay conditions. Other main merits in favor of the use optical fiber sensors are high compactness, low cost fabrication process and the compatibility with other optical components make it an attractive instrument for sensing applications. The intensity-based fiber optic sensors are the earliest and most widely used technology to date because of its low cost, easy installation and high sensitivity [1]. Optical multimode plastic bundle fiber is typically used as a probe for intensity-based fiber sensors. They inherit many advantages, such as better signal coupling, larger core radii, receiving the maximum reflected light from target, and higher numerical aperture. As well as the bundled fibers are capable of providing larger dynamic range of sensing and this allows more accurate displacement measurement [2]. Based on the merits of the multimode fiber, it seems to be perfectly suitable for optical displacement sensor application.

Conventionally, FODSs can be classified into interferometry-based and intensity-based sensors. For interferometry-based FODSs [3,4], two optical waves with different optical paths are combined to generate interference fringes; one optical wave, the measurement wave, is modulated by the displacement to be measured and the other optical wave, the reference wave, is not. The change in the displacement, therefore, alters the optical path difference between the two waves resulting in a shift in the interference fringe pattern. As a result, the displacement change can be deduced from the measured fringe shift with ultra-high precision. This technique requires complicated instruments and is bandwidth limited. In comparison, an intensity-based FODS is simple to construct, using less expensive components, and can achieve very high bandwidth. The intensity modulation optical fiber sensors generally employ the mechanisms of misalignment losses in multimode optical fibers, absorption or scattering light losses. The amount of light collected by the bundle fiber is directly correlated to the displacement between the fiber and the reflective surface.

Meanwhile, FODSs are widely employed for the measurement of displacement, strain, pressure, vibration, temperature and liquid refractive index, etc., primarily due to their compactness, light weight, high sensitivity and immunity to hostile environments. FODSs inherit two primary advantages; which include ultra-accurate and non-contact sensing and flexibility in incorporating the optical sensors into compact and composite structures [5]. However, some demerits remain to be the challenges in the development of the displacement sensor. For instance, the random changes in the transitivity of optical path and variations of output power of the optical source depend on the light modulation principle which could directly affect the accuracy of the sensor [6]. Hence, the main goals of this work are to review the recent development of FODSs and its application areas.

2. Recent development of FODSs based on intensity modulation technique

2.1. Sensing principle

In general, a pair of fiber, which is bundled together, one being the transmitting fiber and another one the receiving fiber, is used as a sensor probe conjunction with a flat reflective target in a conventional FODS system. A basic configuration of FODS system is shown in Fig. 1. In Fig. 1(a), the sensor consists of a light source, a fiber optic probe, and a photodiode detector. The front view and side view of sensor probe is given also, in which two same plastic optical fibers (POFs) are parallel bundled as shown in Fig. 1(b). The typical output of this system is shown in Fig. 2.

As shown in Fig. 2, the curve exhibits a maximum with a steep linear front slope and back slope which follows an almost inverse square law relationship for the reflected light intensity versus distance of the mirror from transmitting fiber end. The signal is minimal at zero distance because the light cone does not reach the core of both receiving fibers. As the displacement increases, the size of cone of the reflected light at the plane of fiber also

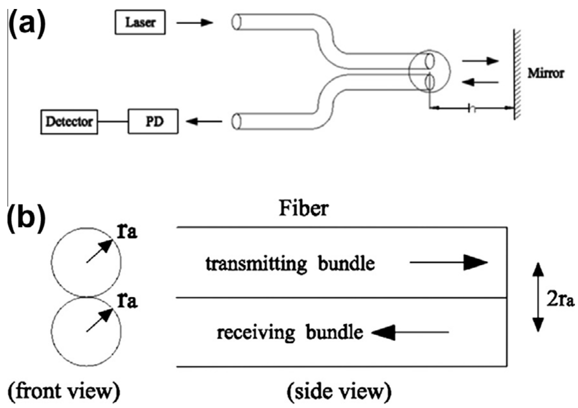

Fig. 1. A basic configuration of FODS system, (a) system configuration, (b) sensor probe front view and side view.

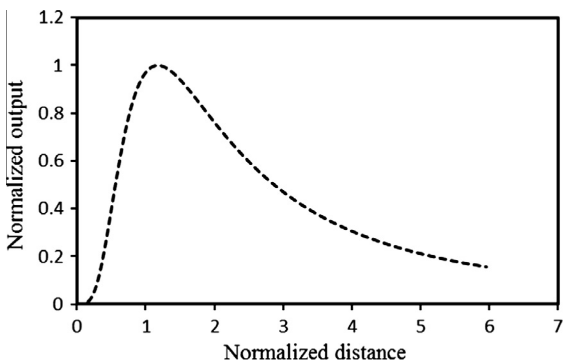

Fig. 2. FODS displacement response for the sensor probe with bundled configuration.