Experimental Errors of Fiber Optic Sensors

Article Overview

Measurement errors in fiber optic sensors primarily arise from strain transfer inefficiencies, sensor packaging, host material properties, and spatial resolution limitations, which can be analyzed and mitigated through theoretical modeling and experimental calibration.

Sources of Experimental Error

Strain transfer loss is a major source of error in distributed fiber-optic (DFO) sensors. When strain is applied to the host structure, it must be transmitted through protective and adhesive layers to the fiber core. Any mismatch in mechanical properties, such as the Young's modulus of the protective layer relative to the fiber core, can reduce the strain transfer coefficient, leading to underestimation of the actual strain in the host material . Multi-layered sensor packaging, while necessary for durability, introduces additional interfaces where strain may be partially absorbed or delayed, further contributing to measurement error . Spatial resolution limitations in distributed sensing systems, such as Brillouin Optical Time Domain Analysis (BOTDA), can degrade reconstruction accuracy. Low spatial resolution may fail to capture sharp strain gradients or curvature discontinuities, resulting in errors in shape or deformation measurements . Host material effects also influence sensor accuracy. Nonuniform strain distributions, viscoelastic behavior, or localized stress concentrations in the monitored structure can cause deviations between the actual strain and the measured strain in the fiber core .

Theoretical Modeling for Error Analysis

Shear lag theory is commonly used to model strain transfer in fiber optic sensors. Early models, such as those by Cox, Ansari, and Yuan, provide analytical solutions for uniform or linear strain fields, allowing calculation of the strain transfer coefficient and identification of critical points where errors are likely to occur . Recent models extend this to multi-layered, surface-bonded sensors under bi-linear or nonuniform strain distributions, offering closed-form solutions for both single- and bi-linear strain profiles . These models enable parametric studies to evaluate how adhesive thickness, protective layer stiffness, and fiber geometry affect measurement accuracy.

Experimental Validation and Error Compensation

Experimental validation often involves high-resolution optical frequency-domain reflectometry or BOTDA systems. For example, a 28.91 m four-core shape sensing fiber was tested using forward and backward reconstructions, with polynomial or exponential weighting strategies to fuse trajectories and compensate for endpoint errors . Such error compensation algorithms can improve reconstruction accuracy by over 86% compared to classical methods without compensation. Calibration procedures, including radial-offset tuning and segment alignment using reference hotspots, are essential to minimize systematic errors and ensure reliable measurements in complex geometries . Laboratory tests also allow verification of theoretical strain transfer models and adjustment of sensor installation parameters to reduce measurement discrepancies.

Practical Implications

Understanding and mitigating experimental errors in fiber optic sensors is critical for structural health monitoring (SHM), geotechnical applications, and large-scale engineering projects. Proper sensor design, including selection of protective layers, adhesive materials, and calibration protocols, combined with theoretical modeling and error compensation algorithms, ensures high-accuracy strain and deformation measurements over long distances . In summary, experimental error analysis in fiber optic sensors integrates strain transfer theory, host material characterization, sensor design, and advanced calibration techniques to quantify and reduce measurement errors, enabling reliable monitoring of complex structures.

Fabry-Perot interferometers (FPIs) have found a multitude of scientific and industrial applications ranging from

Finally, we simulate and quantify nonreciprocal phase shift to be detected in fiber optic current sensor related with

As the basic application of fiber optic sensing technology, strain measurement accuracy as a key index needs to be

accuracy of embedded or surface-bonded fiber-optic sensors; however, the effect of fields in substrates has not been well elucidated.

Here, a theoretical model was proposed for the analysis of strain transfer mechanisms in surface-bonded distributed

Experimental system and optical path of fiber optic current sensor under different ambient temperatures is shown in Fig

In recent years, distributed fiber-optic sensing technology, due to distributed and long-distance advantages, was widely

Using fiber optics as a tool for different kinds of geotechnical monitoring can be highly

Abstract Fiber-optic shape sensing enables real-time monitoring of structural deformation across a wide range of applications.

Furthermore, Han et al. designed a new type of joint fiber-optic displacement sensor to address the problem of large

Aiming at solving this issue, a new joint fiber-optic displacement sensor which can achieve accurate displacement

The optical current transformers (OCTs) using silica optical fiber as Faraday sensor were manufactured and tested in

Optical fiber sensors offer attractive characteristics that make them very suitable and, in some cases, the only viable sensing

Fiber optic sensors are defined as devices that utilize optical fibers to measure a variety of stimuli, including mechanical, thermal,

Optical fiber sensors (OFSs) have emerged as essential tools in the monitoring of physical, chemical, and bio-medical

High-temperature measurements above 1000 °C are critical in harsh environments such as aerospace, metallurgy,

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