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Error Analysis of Fiber Optic Sensors



Overview

Error analysis and experimental research of joint fiber-optic. Aiming at solving this issue, a new joint fiber-optic displacement sensor which can achiev.

Key Takeaways

High-fiber optic sensors, such as Fiber Bragg Gratings (FBG) and OFDR-based distributed sensors, exhibit measurement errors primarily due to strain transfer inefficiencies, environmental factors, and sensor packaging, with typical strain test errors under 2–5% after calibration.Sources of Error



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Strain Transfer Errors: One of the main contributors to measurement inaccuracies in fiber-optic sensors is the imperfect transfer of strain from the host material to the fiber sensor. When sensors are bonded to a structure or embedded within it, the presence of intermediate layers—such as adhesives, cladding, or protective coatings—can reduce the effective strain measured by the fiber compared to the actual strain in the host material. Local debonding or modulus mismatch between layers further exacerbates this error, requiring theoretical correction functions to improve accuracy (Wang et al., 2014) . Environmental Influences: Fiber-optic sensors are generally resistant to electromagnetic interference and corrosion, but temperature fluctuations, humidity, and mechanical vibrations can still introduce errors. FBG sensors, for instance, are sensitive to both strain and temperature, necessitating compensation techniques to isolate the desired measurement (MDPI, 2024) . Sensor Architecture and Signal Processing: In fiber-optic gyroscopes (FOGs) and other interferometric sensors, errors can arise from thermal and mechanical drifts, optical noise, and signal processing limitations. Advanced filtering, noise suppression, and machine learning-based compensation algorithms are often employed to mitigate these effects (MDPI, 2023) .

Calibration and Accuracy

Calibration experiments using standard beams and resistive strain gauges have shown that FBG and OFDR sensors can achieve strain measurement errors below 2%, with good linearity ($R^2 > 0.998$) and repeatability after multiple loading cycles. Finite element analysis is often used alongside experimental data to validate sensor performance and quantify residual errors (MDPI, 2024) .

Mitigation Strategies
• Optimized Bonding and Packaging: Ensuring uniform adhesive layers and minimizing debonding improves strain transfer efficiency. Protective coatings should balance durability with minimal mechanical damping.

• Temperature Compensation: Dual FBGs or reference fibers can be used to separate thermal effects from mechanical strain.

• Signal Processing Enhancements: Filtering, drift compensation, and advanced algorithms reduce noise and improve long-term stability.

• Distributed Sensing Techniques: OFDR-based sensors allow high-resolution, point-to-point measurements over large areas, reducing localized error impact and enabling more accurate structural health monitoring.
Applications

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High-fiber optic sensors are widely used in civil engineering, aerospace, ocean platforms, and oil pipelines for long-term monitoring due to their durability, corrosion resistance, and immunity to electromagnetic interference. Accurate error analysis and compensation are critical for ensuring reliable measurements in these demanding environments (Wang et al., 2014; MDPI, 2024) . In summary, error analysis in high-fiber optic sensors involves understanding strain transfer inefficiencies, environmental effects, and sensor-specific limitations, with calibration and advanced signal processing being key to achieving high-precision measurements.

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Bias error, along with scale factor, is a key factor that affects the measurement accuracy of the fiber-optic current

Review of Optical Fiber Sensors: Principles, Classifications and

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

Error Analysis and Measurement Uncertainty for a Fiber Grating Strain ...

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Thus, fiber optic sensors are ideal for the applications in potential smart structures and materials. Fiber Bragg gratings (FBGs) have

Optical Fibre-Based Sensors—An Assessment of Current Innovations

The paper is organized in the following manner: Section 2 presents the market and implications for fibre optic-based sensors. The

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Fiber Optic Sensor

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Linear Deformation Sensing and Error Self Correction Method Based

In view of the problem that the distributed optical fiber-based deformation reconstruction method can produce serious

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Brief theory of sensing principle, fabrication method, applications, advantages and disadvantages of the different

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Using fiber optics as a tool for different kinds of geotechnical monitoring can be highly attractive and cost-effective

The Nonreciprocal Errors in Fiber Optic Current Sensors

Fiber-optic current sensors have the significant advantages that they are non-conductive and lightweight, which can

Optical fiber sensors in infrastructure monitoring: a comprehensive ...

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