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Research on the Stress Field Measurement Method Based on Terahertz Time-Domain Spectroscopy

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ABSTRACT

Terahertz time-domain spectroscopy (THz-TDS) can be utilized to probe internal parameters of dielectric materials, such as the refractive index. Based on the stress-optic law, stress-induced variations in the refractive index enable the calculation of applied stress through measured changes in the refractive index. This paper introduces a THz-TDS-based methodology for stress field measurement. First, a THz-TDS stress field scanning and imaging system was developed, incorporating an amplitude-field imaging method that maps stress distributions using variations in the amplitude of THz pulses. Second, two analytical algorithms were established: a planar stress analysis algorithm based on THz pulse amplitude data and a phase-informed stress separation algorithm utilizing THz signal phase information to decouple principal stress components.

Experimental validation was performed on a diametrically compressed disk specimen made of a typical elastic material. Through THz-TDS imaging experiments, the material's stress-optic coefficient was calibrated, and the stress field distribution on the disk under compression was measured, with the measurement accuracy in the elastic regime quantified. Furthermore, strategies to enhance stress field measurement precision were proposed. The study systematically elucidates the influence of elastic and plastic strain on the refractive index during elastic-plastic deformation, supported by experimental verification. By integrating theoretical principles, imaging techniques, and algorithmic innovations, this work provides a comprehensive framework for non-destructive, high-resolution stress field characterization in both elastic and elastic-plastic regimes, advancing applications in material science and structural mechanics.

KEYWORDS

Internal stress measurement; terahertz time-domain spectroscopy; stress field measurement; plane stress separation algorithm

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