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On the Identification of Dissipative Phenomena in Fatigue-Loaded 2024 Aluminum by Means of Second Harmonic of Temperature Analysis

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ABSTRACT

This study explores the use of temperature harmonics to detect intrinsic dissipation during cyclic loading in aluminum alloys. Under sinusoidal loading, the temperature of a solid is modulated by thermomechanical heat sources. The primary source is the thermoelastic effect, which modulates the temperature at the load frequency and twice the load frequency (second harmonic). Thermoelastic stress analysis (TSA) signal processing is employed to extract the temperature harmonics and analyze their evolution when the stress amplitude increases. The detected second harmonic comprises three main contributions: a thermoelastic component, predicted by the second-order thermoelastic effect theory, a spurious contribution due to load components at twice the nominal frequency, and a dissipative second harmonic. The main aim of this work is to separate the thermoelastic and spurious contributions from the measured second harmonic to isolate and capture dissipation. AL 2024 alloy samples, which exhibits strong second-order thermoelastic response, are employed in the investigation. Aluminum has already been reported as a material where thermomechanical dissipation is difficult to quantify, or even qualitatively observe, with other more traditional thermographic methods. The results show interesting features of the second-harmonic decoupled components, providing insight into intrinsic dissipation of aluminum alloys under fatigue-loading conditions.

1 | Introduction

Evaluating changes in the structural health of materials and structures using infrared thermography (IRT) has become a concrete and appealing practice due to notable progress in infrared hardware and digital signal processing technologies. A critical factor in harnessing such technological potential is the capacity to correlate the mechanical behavior with the temperature field measurable on the structure's surface [1–3]. This requires a comprehensive understanding of the thermomechanical sources under various loading conditions and the associated energy dissipation and heat transfer. A particularly focused area of research pertains to the behavior of materials under cyclic loading characteristic of fatigue regimes. The objective of thermographic methods in this context is to correlate temperature-based metrics to the material irreversible changes induced by fatigue loading. During the last 25 years, considerable effort has been spent in the tentative development