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Full-field temperature and strain measurements using synchronized optical and infrared imaging

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ABSTRACT

The progress in optical and imaging technology has made it possible to monitor the full-field strain and temperature in a wide range of conditions. The use of temporally and spatially synchronized measurements are a robust method for data acquisition which can be used for thermomechanical analysis of solids and fluids. The full-field measurements have been successfully carried out at a wide range of speeds and temperatures to investigate the mechanics and fracture of materials, providing new information which was previously inaccessible. There are several challenges for carrying out the measurements, as all imaging systems must acquire data synchronously, monitor the same region in space, data must be presented on a shared coordinate system in the same reference frame so that it is spatially synchronized. Temporal synchronization is generally obtained by using a single triggering source for either externally clocking the cameras or triggering each image acquisition. Although trivial at low speeds, it is essential for data acquisition to be properly synchronized when imaging fast moving objects. To represent the displacements and strain in the same coordinate system as temperature, the intrinsic parameters of the cameras and extrinsic parameters of the system have to be calibrated. This can be carried out by imaging a calibration target with known size and features simultaneously all cameras. After being represented on a global coordinate system, the full-field displacements obtained from the optical images can then used to deform the thermal images to represent the temperature data in the same reference frame as the full-field strain. There are additional challenges when using this method at elevated temperatures, as visible light starts to be emitted by matter, oxidation occurs at a higher rate, and a heat resistant random pattern must be applied to the target object. This has been dealt with by using a shortpass filter that only allows for blue-green radiation to be imaged, by minimizing the time which a target object is at high temperatures and using ceramic based paints. It is also noteworthy that radiometric measurements rely on the emissivity of the target. To obtain accurate surface temperature measurements, the infrared system needs to be calibrated for different wavelengths, temperatures, experimental setups, and environmental conditions. The data obtained with this method has been successfully used to investigate the thermomechanical behavior of metals under high strain rates and elevated temperatures, the damage initiation and evolution in composites, and the heat release of materials under plastic deformation. The prospects for full-field analysis in experimental mechanics are excellent and it can particularly excel in providing data for validating and improving numerical approaches which rely on inverse problem solution. This presentation focuses on highlighting the possibilities of the synchronized optical and infrared imaging in mechanics of materials, discusses the accuracy and measurement uncertainties, as well shows several examples of recent successful measurements.

Keywords: synchronized full-field measurements, high strain rate, digital image correlation, infrared imaging.