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RESEARCH PAPER

Speckle Pattern Inversion in High Temperature DIC Measurement

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Abstract

During hot fire rocket engine testing, non-contacting measurements are superior to bonded gauges because they are immune to burning, shaking loose, or damage due to the harsh testing conditions. Additionally, when compared to instruments which register at single points, Digital Image Correlation (DIC) has the added benefit in that it collects full-field displacement and strain maps over the duration of the test. However, for certain materials and paints under some circumstances of temperature and camera sensitivity, portions of the speckle pattern which were darker at room temperature may emit more light compared to the initially lighter portions of the pattern, resulting in a high temperature pattern which is inverted in comparison with that at room temperature. To address this inversion, a post-processing method is introduced wherein an inverted image containing only emitted light is subtracted from an image containing both emitted and reflected light, thereby generating an un-inverted image. The artificial high temperature image is subsequently correlated against the room temperature image to obtain full-field strains. The subtraction technique is then validated using optical bandpass filters to prevent significant amounts of emitted light from reaching the camera sensor. The two methods are mapped onto common coordinates and shown to produce comparable results. The subtraction method sufficiently mitigates speckle pattern inversion, but its key drawback is that it only works when there is negligible displacement between the subtracted images (i.e. quasi-static loading). It is therefore preferable to eliminate inversion from reaching the camera in the first place by using optical bandpass filters.

Keywords DIC · High temperature · Inversion · Ultraviolet light · Graphite · Gleeble

Introduction

High temperature applications create an extremely danding environment for which engineered components must survive [1]. One such application is for liquid rocket engine combustion device components, such as nozzles, nozzle extensions, and combustion chambers [2, 3]. As components are developed for these applications, validated test data is required to understand performance and predict lifespan in these extremely challenging environments. Strain gauges are a common traditional technique to obtain the response to surface stresses and attached with an adhesive or through spot welding [4]. There are a few challenges with strain gauges in these high temperature environments. The first challenge with this contact instrumentation method is the durability in the environment and rarely survives more than a few seconds. The second challenge is that strain gauges measure only a discrete and local response. A third challenge is the selection of orientation through uniaxial, biaxial, or triaxial applications. This limits the directional response of the strain measurement and could also result in inaccurate predictions.

One such solution to resolve the issues with strain gauges is the use of non-contact methods, such as Digital Image Correlation (DIC) [5]. DIC offers a two-dimensional or three-dimensional, line of sight, non-contact measurement technique to obtain surface full-field displacements and strains. DIC uses a single camera for 2D or a pair of digital cameras for 3D along with a stochastic speckle pattern on the surface being measured to obtain full surface strain measurements and deflections of the surface [6, 7]. This provides significantly more data than traditional methods using contact instrumentation.

DIC techniques have been successfully demonstrated through a host of aerospace applications. For example, the

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