Lock-in thermography of compressed metal powder metallurgy in pre-sintered state as flaw preventive non-destructive evaluation modality

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The concept of preventive non-destructive evaluation (P-NDE) is introduced as an important new inspection approach which hinges on the premise of developing adequate analytical and measurement tools to investigate material integrity deficit factors during manufacturing that may lead to catastrophic flaws / cracks before the emergence of such flaws.

Introduction – Automotive industry utilization of powder metallurgy (PM) technology is increasing in popularity due to requirements for intricate and dimensionally accurate neat-shaped components which can be produced at competitive cost. The primary disadvantage of PM technology involves the possibility of seeding both surface and subsurface cracks at high-stress locations due to the powdered materials and non-isotropic pressure issues resulting from multi-ton press equipment adjustment. Therefore, non-destructive evaluation is an important inspection approach.

Methodology – Pre-sintered ("green") compressed metal powder components with known crack locations were studied using lock-in thermography imaging (LITI) which exhibited high crack detection efficiency [1, 2]. Thermal waves were excited by an 808-nm spread and spatially homogenized CW laser modulated beam, and were detected with a high-frame-rate mid-infrared (MIR) camera. 1 Hz modulation frequency was found to be optimal.

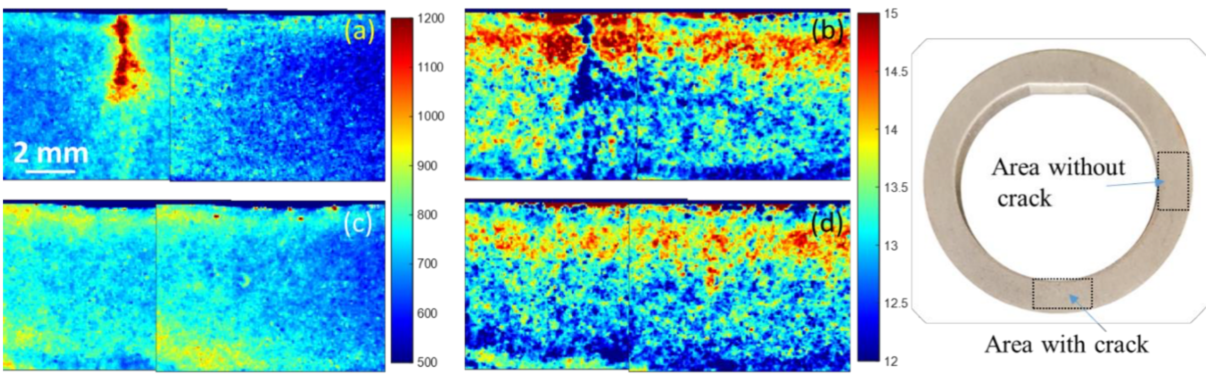

Fig. 1. (a, c) 1-Hz LIT amplitude and **(b, d)** phase of sample area with crack **(a, b)** and without crack **(c, d)**. **(e)** Photograph of a pre-sintered compressed metal powder automotive part. Dashed areas correspond to images (a-d).

Results – Local regions of interest with varying amplitude and phase lags were identified (Fig. 1). The local thermal diffusivity computed from a one-dimensional theoretical model implemented in this study exhibited strong correlation with the local pixel phase outside the immediate crack location. A proportionality relation was also found between phase lag and independently estimated local sample porosity. Fig. 2 shows the optical image of the polished surface area near the crack that confirms that higher porosity corresponds to larger phase lag.

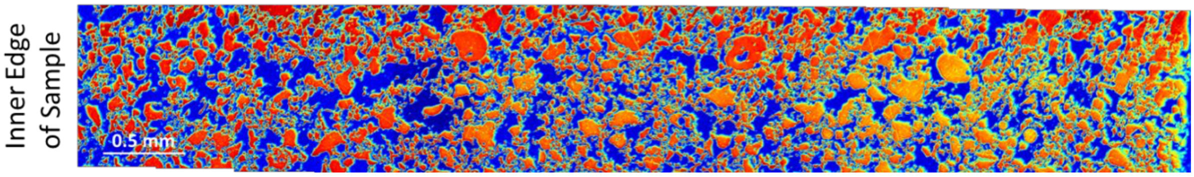

Fig. 2. Optical image of polished surface near the crack shown in Figs. 1a,b.

Discussion – The phase images of the area with the crack clearly confirm that the large lateral amplitude and phase gradients in the vicinity of, and across, the cracks coincided with radial amplitude and phase discontinuities. These produced multi-directional material inhomogeneities at their intersections acting as crack generators. They may be indicators that the metal powder was pressed under non-uniform radial and lateral pressure conditions around the circular sample. The bizonal character of the LIT phases is indicative of radial stresses in the inspected components resulting from density gradients. Under this condition, when radial stress coincides with lateral density gradients, it becomes a multi-directional stress source that is highly likely to generate cracks along the radial direction defined by the lateral density gradient.

Conclusions – This study introduces the concept of preventive non-destructive evaluation (P-NDE) as an early feedback tool for mechanical press corrections during the pre-sintering manufacturing process of metal powder compacts to anticipate and avoid potential cracks in post-sintered manufactured PM components.

References

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