Comparisons between strain gauges and digital image correlation in experimental testing of 3D printed PLA elements

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The widespread Fused Filament Fabrication (FFF) is an additive manufacturing technique based on polymers. Recently, lots of researchers studied how 3D printed parts behave under load to design functional components. Whether for characterization or validation, mechanical tests are the primary tools; proper measuring displacements or strains is essential. The contact transducers, such as Strain Gauges (SG) for deformations or Linear Variable Differential (Inductive) Transformers (LVD(I)T) for displacements, are established instruments. However, when the tests involve materials with a low modulus of elasticity, the interaction between the sensor and the specimen might alter their output. Non-contact transducers, such as the Digital Image Correlation (DIC), do not suffer from these effects. In this work, the authors experimentally and numerically compared SG and DIC in testing 3D printed PLA components. Two sets of tensile specimens formed the test bench of this work. During the tests, SGs monitored the first set; SGs and DIC monitored the second one. The authors quantified the effect using the apparent moduli of elasticity and detected a local reinforcing effect. Specimens with bonded strain gauges appeared stiffer in terms of strains derived from the SGs themselves. However, the same specimens appeared to be consistent with the non-instrumented ones in terms of DIC strains, which allowed a global reinforcing effect to be excluded. A 2D Finite Element (FE) model was used to simulate these effects: 2D shell elements discretized both the specimens and the strain gauge, bonded together in the hypothesis of perfect adhesion. The strain gauge internal microstructure, a metal grid into polymeric layers, was simplified as an isotropic constitutive model with equivalent elastic modulus and Poisson ratio. The authors proposed a digital procedure to evaluate the volume fraction of the metal grid based on a high-resolution image of the transducer; through it, they estimated both the above equivalent mechanical properties. The simulation agreed with the experimental results: it confirmed the local reinforcing effect and its magnitude. This effect was present, although the SGs were specifically designed for low-modulus material. The estimated and equivalent elastic modulus of the strain gauge had the same order of magnitude as the tested PLA; this feature advised that the stiffening effect

could worsen in even less-stiff materials. Strain gauges can still be necessary tools, mainly when the surfaces to be analyzed are not in sight and DIC tools are ineffective. In these circumstances, the authors' experimental and numerical methods allow the output correction when calibration curves are not available.