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Magnetoelastic softening in cold-sprayed polycrystalline nickel studied by resonant ultrasound spectroscopy

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Extended Abstract

Abstract

Cold spray is a cost-efficient and rapid additive manufacturing method for deposition of materials from feedstock powders. The powder particles are accelerated to supersonic velocities by a pressurized gas jet, and they undergo severe plastic deformation upon their impact onto the substrate or the preceding sprayed layers. Extreme-rate viscoplastic deformation ultimately leads to the formation of a very strong bond between the particles. Hence, the final deposits exhibit a unique, highly deformed microstructure and significant residual compressive stress. These stresses are not commonly assessed using ultrasonic methods, since the elasto-acoustic constants in metals are relatively low, making it difficult to distinguish the effects of residual stress on acoustic parameters from those originating from defects. Fortunately, in magnetostrictive ferromagnetic materials, residual stresses affect elasticity through magnetoelastic coupling, leading to an effective softening of the elastic response, also known as the ΔE effect. Hence, the suppression of this inelastic relaxation by residual stresses opens the possibility

of examining them using laser-ultrasonic. With contactless resonant ultrasound spectroscopy, we studied three polycrystalline nickel materials – two cold-sprayed deposits and a rolled sheet as a reference – with different levels of plasticity-induced grain refinement and substructuring hence, also of the residual stresses. The evolution of the shear modulus and the internal friction parameter with temperature was monitored during a heating-cooling cycle across the Curie point. The proposed methodology is also suitable for in situ observation of the recrystallization process in the vicinity of the Curie point, as well as inspecting the homogeneity of the residual stress level across the thickness of the cold-sprayed deposit. We show that the presence and intensity of residual stresses, as well as their mitigation through recrystallization, can be efficiently analyzed using laser-ultrasonic in ferromagnetic magnetostrictive materials via the ΔE effect.

Keywords:

Resonant ultrasound spectroscopy Cold-spray Phase transition Residual stresses Magnetoelastic coupling Elastic moduli Pollycrystalline nickel