An Experimental and Modeling Study of Residual Stresses in Cold Spray Deposition Process

Chaitanya Vundru[1], Sohayb Batwa, Samuel Boese, Ozan Ozdemir, Sinan Müftü[1, *]

[1]Department of Mechanical and Industrial Engineering, Northeastern University, Boston, MA 02115, USA

[*]Corresponding author: c.vundru@northeastern.edu

The functional performance and the dimensional accuracy of the deposited components employing cold spray process could be adversely affected by thermomechanical distortion. Additionally, if tensile residual stresses are present in the deposited layer, the fatigue life of the restored portion could be compromised. The residual stresses in CS process originate due to coating and impact-induced temperatures, thermal mismatch of coat and substrate, heat transfer rate, and impact peening effect. A *sequentially coupled 3D thermomechanical model* (SC-3D-TMM) has been developed to capture the evolution of residual stresses in cold spray process. In the first step of the SC-3D-TMM, the temperature distribution for the domain is evaluated with the energy input to the process. Progressive *element activation* is used to simulate the powder deposition on the substrate. The hot gas impinging on the surface of the deposition is input as surface heat flux and the elements are activated at the temperature of the particles hitting the surface. In the second step, the thermo-mechanical stress analysis is performed by using the temperature history computed in thermal step. The Johnson-Cook model is used to model the plastic flow during the evolution of the residual stress. The aluminum base plate supporting the substrate is included to accurately represents the temperature and residual stress distribution. Numerical results are validated by experiments. In particular, the substrate temperatures and distortion due to thermomechanical mismatch are compared. The computational model developed predicts the temperature distribution, residual stress, and distortion with geometry evolution. Peak stresses are observed at the edges of the deposited material. At the interface of the deposit and the substrate the in-plane stress component in the direction of the nozzle motion (longitudinal stress) is tensile while the in-plane stress component in the transverse direction is compressive. It was also found that: increasing the number of layers increases the probability of failure at the interface; using thicker substrates can result in the decrease of distortion, but, may induce higher stress at the interface.