Computational analysis of temperature profile and residual stresses generated during wire arc additive manufacturing of AlSi10Mg alloy

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is an emerging technology in the field of the additive manufacturing, categorized under the Direct Energy Deposition (DED) technique, where an electric arc is used to melt and deposit wire feedstock material to build large and complex metallic parts. WAAM has a wide variety of applications in automobile, aerospace sectors due to its high deposition rate; however, certain challenges are posed due to the high residual stresses generated, porosity and distortions of the built parts. These defects primarily stem from the high heat input and repetitive thermal cycles thus affecting the dimensional accuracy and structural reliability of the parts. The prediction and mitigation of these defects are necessary but challenging by conducting trial and error experiments. Thus, in the present study, a coupled thermo-mechanical model is developed to predict the temperature profile and residual stress distribution during WAAM of AlSi10Mg alloy. AlSi10Mg alloy has a wide variety of applications in automobile and aerospace sectors due to its high strength-to-weight ratio, good castability, and corrosion resistance. The computational model is developed by employing the finite element method with the Goldak double-ellipsoidal heat source to estimate the thermal profile and residual stresses generated during the deposition of a single layer AlSi10Mg alloy on an Al6061substrate of 200 mm x 100mm x 10 mm dimensions. The length of the deposited bead is considered to be 165 mm. The numerically predicted results show that the steep temperature gradients and tensile residual stresses are formed along the bead deposition direction, which have been well validated with literature. The influence of important process parameters like wire feed rate and printing travel speed are also studied on the temperature and residual stress profiles generated. The current study is envisaged to facilitate the prediction and have a comprehensive understanding of the thermo-mechanical behaviour of wire arc additively manufactured AlSi10Mg components.

Keywords— Wire arc additive manufacturing, Numerical modelling, Thermomechanical analysis, Finite element, Goldak heat source model, Residual stress