Metallo-thermo-mechanical modeling of laser cladding for additive restoration of die steels

†Santanu Paul[1, 2], *Wenyi Yan[1], and Ramesh Singh[2]

[1]Department of Mechanical and Aerospace Engineering, Monash University, Clayton, VIC 3800, Australia
[2]Department of Mechanical Engineering, Indian Institute of Technology, Bombay, Mumbai, India

*Presenting author: wenyi.yan@monash.edu
†Corresponding author: santanupaul@iitb.ac.in

Abstract

Laser cladding is a coating technique, wherein several layers of clad materials are deposited over a substrate so as to enhance the physical properties of the work-piece such as wear resistance, corrosion resistance etc. Strong interfacial bond with minimum dilution between the material layers is a pre-requisite of the process. In addition, laser cladding has great significance in enhancement of surface properties, repair of components and rapid prototyping. As such the estimation of temperature distribution over the work-piece is used as input for prediction of microstructure and phase evolution, clad geometry prediction, melt pool shape over the substrate, the stress field estimation and subsequently the prediction of deformation and crack generation in the work-piece. Laser surface cladding in general has widespread application in repair and restoration of aerospace, naval, automobile components.

The clad quality and integrity are influenced by a number of physical phenomena thereby influencing the melt pool morphology, microstructure evolution and residual stress generation. The finite element models developed in this respect lack to capture certain aspects of the process such as strain evolution due to phase transformation and the subsequent volume dilation which are very important for predicting the final residual stress field. Therefore, in the present study effort has been devoted to develop a metallo-thermo-mechanical model using a uniform moving heat source for Gaussian powder distribution. The final residual stress is calculated by incorporating the effect of differential thermal expansion; and metallurgical transformations in the clad & substrate. The model is able to predict the transformed region and residual stress with reasonable accuracy with prediction errors lying within ~13%. Moreover, the model has highlighted the fact that the effect of the scanning velocity on the average residual stress on the clad layer is greater than that of the laser power. Additionally, the model predicts a threshold point beyond which the amount of incident thermal energy dictates the amount of residual stress developed in the clad layer.

Keywords: Laser cladding, repair, residual stress, metallo-thermo-mechanical finite element model.