Abstract

Laser cladding with powder feed is one of the emerging surface modification technologies in which the substrate is locally melted and fused with the coating materials by an intense heat source. This creates a built-up geometry, called clad, and a good metallurgical bond between the substrate and the coating material. The metallurgical bond thus formed is strongly dependent on the thermal history near the solidification interface. But any measurement to obtain temperature and flow velocity inside the molten pool can not be done due to the small size of molten pool, opacity of the molten metal, and harsh high temperature environment. Development of numerical model of fluid flow and heat transfer during laser cladding processing will offer the opportunity to look at the transport processes inside the hot material.

In the present investigation, a fluid flow and heat transfer model has been developed to study laser deposition of metals with powder feed. Phenomena like absorption of laser energy by the powder stream as well as the substrate, formation of melt pool on the substrate, addition of powder in the melt pool, and convection due to the surface tension gradient and density gradient have been considered.

The governing equations are discretised by finite volume method in a multiblock non-orthogonal grid system with collocated variable arrangement. The discretised equations of flow field are solved using SIMPLE algorithm. Melt pool boundary is tracked iteratively and the free surface shape is modelled using appropriate force balance equation.

This research is mainly divided into three parts. The first part focuses on the development of theoretical process maps considering uniform melting of the powder particles inside the melt pool. These maps provide an operating range for a feasible laser cladding process. In the second part, a thorough investigation is carried out to study the heat transfer characteristics of melting of a metal spherical powder particle in its own liquid. The aim is to obtain the rate of melting under different hydrodynamic and thermal conditions to which the metal spherical powder particle is exposed during melting. In the last part, the more realistic condition of non-uniform melting of the powder particles inside the melt pool has been introduced into the model.

Keywords: laser processing, heat transfer, cladding, process map, melt pool convection, melting, superheat, numerical simulation