Design of Process-Material-Shielding Combinations for Hard Coatings Using Laser Surface Alloying

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Laser surface modifications are used to modify the surface properties of metals and ceramics. Surface modification is achieved by localized melting, the addition of a second material, followed by solidification of a new alloy and subsequent solid-state transformations.

A numerical heat-transfer model was coupled with computational thermodynamics and kinetics model to describe the dissolution of hard particles including titanium carbide (TiC), titanium nitride (TiN) and tungsten carbide (WC) in liquid metal during laser surface alloying. The heat-transfer model allowed for the prediction of thermal cycles at different regions of the molten pool. The computational thermodynamic model was used to predict phase stability in molten metal as a function of composition. In the next step, a diffusion controlled growth model was used to evaluate both dissolution and growth of WC in Fe-based and Ni-based molten metal. The predicted dissolution rate of tungsten carbide was rapid in Fe-based melts than in Ni-base melts. This observation is qualitatively supported by extensive dissolution of these carbides in a Fe-based melt during laser surface alloying. This methodology allowed for evaluating combinations of liquid metal and hard particle additions for various applications. During such calculations, the results indicated that higher fractions of TiC could be reatined during laser surface alloying of a 431 martensitic stainless steel mixed with TiC powders. Further calculations also indicated that by allowing for excess nitrogen in the liquid steel, copious precipitation of Ti(CN) can be promoted. Experimental evaluation of these predictions were performed by laser deposition of a mixture of commercially pure 431 steel powder 20% TiC powders using a Hobart Model HLP 3000 3.0 kW Nd-YAG laser. To allow for nitrogen dissolution, the laser surface alloying was performed in a 100% nitrogen-shielding atmosphere. Experimental microstructures showed extensive dendritic carbides and the hardness of the coatings were higher than the deposits made with argon shielding. Extension of this method to direct diode laser surface alloying is also evaluated.

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