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A. Application Of Computational Thermodynamic And Kinetic Models To Laser Surface Alloying

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Introduction

Surface physical and mechanical properties can be tailored to different needs by the laser surface alloying process. These property modifications are made by localized melting of substrate material by laser beams with addition of alloying elements as well as hard particles. Through selection of proper hard particles, modification of underlying microstructure through rapid cooling and controlled alloying addition, one can tailor these surfaces for required properties. However, these processes are developed through extensive experimental trial-and-error methodology. This research shows an alternate design methodology by which these processes can be designed through computational thermodynamic and kinetic models.

Procedure

The phase stability of various particles including titanium carbide, titanium nitride, and tungsten carbide in liquid iron were calculated using thermodynamic software at different temperatures. The dissolution and growth of these particles were calculated using diffusion controlled growth models. The calculations indicated that phase stability of Ti(CN) can be improved by dissolving excess nitrogen in the liquid steel. To allow for this, the laser surface processing was performed with different levels of nitrogen in the shielding gas. A commercially pure 431 steel powder (80 wt.%) was mixed with TiC powder (20 wt.%) and preplaced to a thickness of 2 mm on a 1020-mild steel substrate. The laser deposition was made using a Hobart Model HLP 3000 3.0 kW Nd-YAG laser with a laser power of 2430 W.

Results and Discussion

The deposits made with a mixture of 20-wt.% TiC and 80-wt.% 431 steel powders with nitrogen shielding were shallower and smaller than the deposits made under identical conditions with argon shielding. The microstructure in the laser deposits the presence of a fine distribution of carbide particles with or without nitrogen shielding. The shape of these carbides in all the samples varied from faceted, well rounded, and small dendritic. The microstructure showed that the carbide morphology was predominantly dendritic. These carbides were distributed homogeneously, often showing different symmetry, which depended upon the intersection of the metallographic surface with the dendrites. These dendritic carbides showed no preferential alignment confirming that these carbides formed before the onset of ferrite solidification. Laser surface alloying with addition of TiC to 431-steel under argon shielding exhibited a hardness of 574 HV. Addition of 10-vol.% nitrogen to argon increased the hardness to 621 HV. Without any intentional shielding, under air, laser processing led to a hardness of 637 HV. With complete nitrogen shielding the hardness increased to 724 HV. Thermodynamic calculations indicate that TiC will form from the liquid first for steel with no nitrogen and TiCN will form for steel with nitrogen. In the case of steel without nitrogen, TiC forms at 2357 K and the TiCN forms at 2396 K. The above results are in qualitative agreement with experimentally observed dendritic

carbides. Further extensions of nitrogen shielding to other particle systems (TiN and WC) have been performed. The results will be presented at the convention.

Conclusions

A methodology to produce hard surface coatings by the laser surface alloying process with a mixture of 80-wt.% 431 martensitic steel and 20-wt.% titanium carbide (TiC) under nitrogen shielding, used as a reactive gas, has been developed. The use of nitrogen was found to produce a shallower deposit, and a microstructure exhibiting a homogeneous distribution of fine carbide particles, and a 65% increase (724 HV) in hardness compared to a deposit made with only 431 stainless steel powders (438 HV). Thermodynamic calculations showed the increased probability for the formation of Ti(CN) in the liquid steel at high temperatures due to dissolution of nitrogen.

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