ABSTRACT

The present study is aimed at a detailed investigation on the scope and mechanism of improving the surface dependent properties like resistance to corrosion, wear and erosion of a few commercially important systems by laser surface alloying (LSA). The model systems chosen are: AISI 304 stainless steel (304-SS) (to be alloyed with Mo) and Cu (to be alloyed with Cr). In addition, a one dimensional heat transfer model has been developed to correlate the process parameters with the thermal profile and in turn, with the microstructure of the alloyed zone (AZ) obtained by LSA of the above mentioned systems.

304-SS possesses excellent mechanical properties and corrosion resistance in oxidizing environment but shows a very poor pitting corrosion resistance in the presence of halide ions. Mo as an alloying element is known to improve the pitting corrosion resistance of stainless steel by stabilizing the passive film and preventing. The objective of the present study was to improve the pitting corrosion resistance of 304-SS by LSA with Mo. Mo was deposited by plasma spraying on sand blasted 304-SS samples with a thickness of 100 to 250 μm. Subsequently, the Mo deposited 304-SS samples were laser irradiated with the help of a continuous wave (CW) CO_2 laser (with 1 mm beam diameter). A detailed characterization of the AZ in terms of microstructure, phase and composition distribution was undertaken and the properties like microhardness, pitting corrosion and erosion corrosion were evaluated. Both the microstructure and chemistry of the AZ were found to be strong functions of laser power density and interaction time. The microhardness of the AZ was improved significantly by 2-3 times due to LSA. The optimum laser parameters were determined in terms of pre-deposit thickness, laser power density and laser-material interaction time. A detailed electrochemical study showed that the pitting corrosion resistance in terms of critical potential for pit formation and pit growth was significantly enhanced following LSA. The erosion-corrosion property in 20 wt.% sand + 3.56 wt.% NaCl solution was also improved due to LSA.

Cu and its alloys are extensively used as electrical and thermal conductors. However, the wear resistance of pure Cu is quite poor. Cr is known to improve the mechanical properties of Cu without significantly affecting the conductivity.

However, the poor solid solubility of Cr in Cu restricts the scope of conventional surface alloying or bulk alloying of Cu with Cr. In this regard, LSA may enable circumvention of the problem of restricted solid solubility. Thus, the present study aimed to improve the surface dependent mechanical properties of Cu by LSA with Cr. LSA of Cu with electrodeposited Cr (with thickness of 10 and 20 μm) was carried out with the help of a 2 kW CW-CO$_2$ laser. Subsequently, a detailed investigation of the microstructure, composition and phase distribution in the AZ and the extent and scope of improvement in the surface dependent mechanical properties was carried out. The mechanical properties evaluated here included microhardness, adhesive/abrasive wear in dry condition, localized friction/wear in terms of resistance against scratching, and erosive wear in a circulating fluid medium with 20 wt.% sand. The mechanical properties were correlated with the microstructure/composition of the AZ. Finally, an effort was made to construct a process map in terms of the major lasing parameters to predict the conditions for an optimum improvement in wear and erosion resistance of the substrate.

To predict the microstructural/compositional modulation, and subsequently, to correlate them with the surface properties of laser surface alloyed samples, a detailed knowledge of the thermal profile in the AZ is necessary. Several studies for the quantitative description of the heat flow during laser-assisted heat treatment, melting or semiconductor annealing were attempted in the past. However, melting/solidification of a bi-metallic region (*i.e.*, deposit and a part of the substrate), as required in LSA, was not considered in these models. Thus, an attempt was made to develop a one-dimensional unsteady-state heat transfer model to predict the distribution of temperature in the AZ during a CW laser irradiation as a function of time. Furthermore, unlike the previous attempts, temperature/phase dependence of the material properties was also taken into consideration. The model illustrated the effect of incident power density and interaction time on the temperature distribution, melt depth, and subsequently, determined the heating/cooling rates and thermal gradient experienced by the AZ. The model systems selected for validation of the present approach were 304-SS surface alloyed with Mo and Cu surface alloyed with Cr.