# Abstract

Cobalt-based Tribaloy$^{TM}$ T800 (T800) hardfacing alloy is widely used to extend the service life of components operating under high-stress abrasion, high-temperature wear, and oxidation. T800 microstructure contains nearly 60 vol.% of C14 $Co_3Mo_2Si$ Laves phase that provides its characteristic wear resistance but renders the alloy brittle. When T800 is deposited on steel substrates cold cracks tend to form after solidification due to residual stresses generated from difference in shrinkage between the clad and substrate. Conventional methods to reduce cold cracking, such as substrate preheating, laser remelting and process parameter optimization, have resulted in decline of the abrasive wear resistance of T800 clads. Hence, in this study, compositionally graded material design for the laser deposition of T800 has been adopted by introducing multiple intermediate layers between the T800 surface and stainless steel substrate, with an objective to reduce stiffness mismatch with the substrate, improve toughness of the clad, and preserve the wear-resistant properties of the clad. To investigate suitable intermediate layer compositions, arc-melted specimens were first produced by blending T800 with stainless steel (SS316L) at 10, 25, and 40 weight percentages. These blends resulted in the formation of three alloys, designated as T8S10, T8S25 and T8S40, respectively. The incorporation of SS316L reduced the proportion and size of the brittle primary Laves phase which led to substantial improvement in toughness, increasing three-point bending strength from 500 MPa to 1500 MPa and fracture strain from 2% to 5%. Although the reduction in hard phases resulted in a decline in hardness and wear resistance, it significantly enhanced oxidation resistance. The blended alloy exhibited 86% reduction in mass gain compared to T800 after 250 hours of exposure at 800 °C, due to the development of a finer microstructure that facilitates rapid $Cr_2O_3$ formation. To understand the influence of laser deposition parameters on geometrical characteristics, dilution, microstructure, hardness, and wear resistance, a systematic set of 20 single-layer single-overlapped T800 clads were deposited by varying laser power (600-1400 W) and cladding speed (5-20 mm/s). Fe intermixing from the substrate was found to influence Laves phase formation. The clad with the least geometric dilution (~6%) exhibited the lowest wear rate of $0.54 * 10^{-5}$ $mm^3$ $N^{-1}$ $m^{-1}$, increasing to $2.88 * 10^{-5}$ $mm^3$ $N^{-1}$ $m^{-1}$ as the dilution increased to 60%. Building on these findings, monolithic (M-T800) and compositionally graded (CG-T800) clad were fabricated, where M-T800 composed of pure T800 in all layers, while the CG-T800 was deposited sequentially with T8S40, T8S25, T8S10, and finally T800 on the surface. M-T800 exhibited both delamination-type and through-thickness cracks, which resulted in material decohesion after fabrication. Highest crack density occurred in the initially deposited layers of M-T800, where horizontal cracks preferentially propagated through metastable aggregates formed by rapid solidification, thereby rendering multilayer laser deposition of T800 infeasible. In contrast, CG-T800 exhibited no decohesion, which is attributed to the suppression of metastable phase aggregates in the initially deposited layer. A gradual reduction in intermetallic fraction, together with increased toughness and decreased modulus mismatch from the surface layer towards the substrate, enhanced structural integrity and reduced tensile residual stresses. Nevertheless, cracks were still observed in CG-T800 primarily due to unmelted powder particles and thermal stresses. Overall, the CG-T800 clad showed a reduced crack density while maintaining wear resistance comparable to M-T800, thereby demonstrating that compositionally graded material design provides a viable strategy to mitigate cold-cracking susceptibility in laser-deposited T800.

**Keywords: Laser material deposition, Tribaloy, Compositionally graded coating, Surface wear, Crack susceptibility, Cold crack, Hardfacing, High temperature oxidation, Laves phase, Residual stress**