L.5: Improvement of wear resistance of Inconel 718 by laser boriding process

Inconel 718 is widely used in gas turbines, rocket motors, spacecraft, nuclear reactors and pumps due to its high strength, outstanding weldability and favorable corrosion resistance. However, under the conditions of significant mechanical wear, the Inconel 718 has poor resistance against abrasion. To improve the wear resistance of Inconel alloys at high temperature, hard surface coating, case hardening, surface alloying, nitriding and boriding processes are carried out. Among these, boriding process is more suitable for Inconel alloys because it provides a hard surface that is stable up to about 850 °C due to formation of hard borides of Ni, Fe, and Cr elements. However, getting borided layer up to a depth more than 100 µm by conventional methods is not feasible due to change in microstructural stability of Inconel 718 alloy and limited diffusion of boron in the matrix. In view of this, in the present study, to achieve deeper depth of boriding in Inconel 718, laser boriding process is tried and its effect on microstructure and wear resistance is studied.

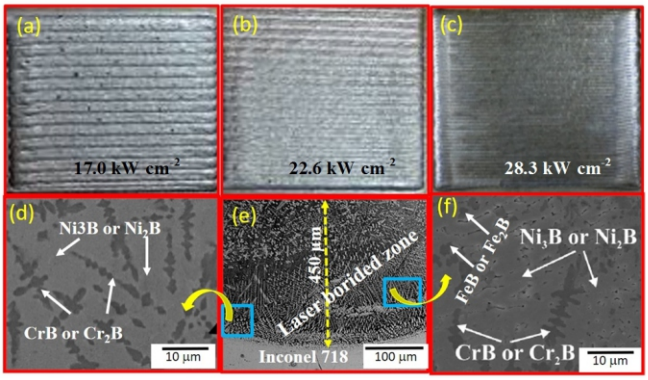

Fig. L.5.1: Parts (a)-(c) show photographs of borided surfaces at three different laser power densities, and part (d)-(f) show SEM micrographs across the borided layer.

The laser-boriding was carried out as the two-step process. First, the external surface of the substrate Inconel 718 is overlayed with a layer thickness of about 250 µm of amorphous boron in the form of paste blended with a diluted polyvinyl alcohol solution. The average particle size of boron powder is about 5 µm with a purity of 99.95%. The quantity of boron in the paste used for preplacing on the substrate was kept 0.5 g/cm^2. The preplaced layer together with small portion of substrate was melted by the continuous wave fiber laser beam during boriding process in the present study under protective environment of Argon gas. During the boriding process, the system is operated with the following parameters: the laser power densities (LPDs) are 17.0, 22.6 and 28.3 kW cm^{-2} and scanning rate is 3 m min^{-1}. The laser beam has multi-mode profile with close to hat top and beam diameter on substrate is kept as 2 mm. The lateral overlap of laser beam was maintained at 80%.

Figure L.5.1(a)-(c) presents the photographs of laser borided surface at three LPDs of 17.0, 22.6, and 28.3 kW cm^{-2}, respectively and it is observed that with increasing the LPD, the surface roughness is reduced significantly due to uniform melt pool formation. Further, the secondary electron micrographs taken across the cross-section of sample borided at LPD of 28 kW cm^{-2} are presented in Figure L.5.1(d)-(f). Figure L.5.1(e) shows that for LPD of 28 kW cm^{-2}, the laser boriding is feasible up to a depth of 450 µm, however, for lower LPDs, the depth of boriding was smaller. Further, with the help of energy dispersive spectroscopy setup attached in SEM, the different boride phases of Ni, Cr and Fe (Ni_3B/Ni_2B, CrB/Cr_2B, FeB/Fe_2B) are confirmed (Figure L.5.1(d) and (f)).

In addition, the presence of different boride phases is again confirmed with x-ray diffraction (XRD) and corresponding result is presented in Figure L.5.2.

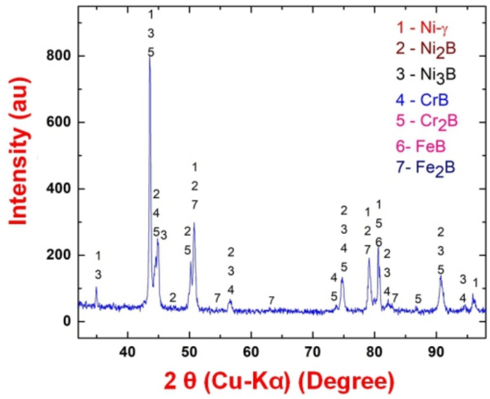

Fig. L.5.2: XRD spectrum of borided layer.

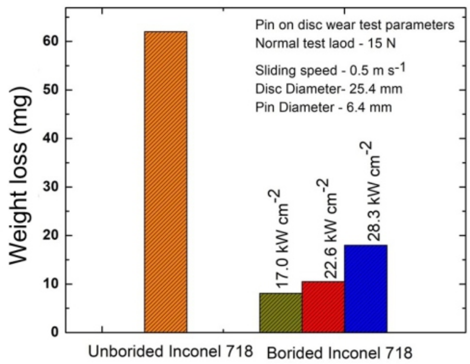

Fig. L.5.3: Weight loss measurement of borided and unborided Inconel 718 against wear test.

The weight loss data measured against wear test for borided and unborided Inconel 718 surfaces are provided in Fig. L.5.3. It is clear from this figure that the wear resistance is significantly improved in case of borided Inconel 718. Further, at higher LPD, the wear resistance is lower primarily due to formation of soft matrix (Ni-Fe-Cr) γ-phase as a result of increased dilution effect.

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