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FEM simulation of laser shock processing on surface morphology and residual stress field of Ti-17 titanium alloy with different laser impact times

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ABSTRACT

Laser shock processing (LSP), an innovative surface treatment technique, imparts beneficial compressive residual stress on the surface of metallic components, improving their fatigue performance, wear resistance, and corrosion resistance. In our work, a short pulse (10 ns) 7J laser has been employed to modify mechanical properties of aeronautic titanium alloy: Ti–5Al–2Sn–2Zr–4Cr–4Mo (Ti-17). The influence of laser impact times on surface morphology, plastically affected depth, and residual stress has been investigated, and the process has been simulated by finite element modeling (FEM) method. Surface morphology and maximal plastic deformation were measured by White Light Interferometer (WLI) to verify the feasibility of LSP 3D finite element model. Afterwards, plastically affected depth and residual stress fields across surface and in depth direction after 1 to 3 laser impacts were simulated. Transmission electron microscope (TEM) was employed to observe the evolution of microstructure to analyze the mechanism of LSP-induced residual stress. Results showed that maximal depth of plastic deformations measured by experiment and FEM method had a high level of consistency. Plastically affected depth increased from 500 to 850 μm, which was consistent with microhardness change. Residual stresses of 1 to 3 laser shocks were 270.6, 325.4, and 352.1 MPa, respectively.

KEYWORDS: laser shock processing, finite element modeling, titanium alloy, surface morphology, residual stress