Eco-Friendly Remanufacturing of Metallic Surfaces via Advanced Laser Processing

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ABSTRACT

Remanufacturing technologies that can effectively remove surface corrosion and/or coatings while restoring surface integrity are essential for various metallic components, such as cylinder blocks, cylinder heads, and exhaust manifolds. However, the current corrosion and coating removal strategy, which relies on a two-step "burning + blasting" process, faces significant technical and economic barriers. These include 1) the energy- and time-intensive volumetric heating step, which burns fossil fuels and causes undesirable microstructural and property changes in the component's interior; and 2) the blasting step, which leads to material waste, surface wear, and contamination issues. Therefore, it remains a grand challenge to develop an energy-efficient and eco-friendly strategy to realize effective removal of corrosion and coatings for metallic surface remanufacturing. In this study, we explored the potential of laser surface ablation as an innovative surface remanufacturing technology for the removal of corrosion and coating layers, aiming to restore surface integrity. A laboratory-scale laser surface remanufacturing system was developed for the experiments. The cast iron samples were machined from a used engine cylinder head for laser remanufacturing experiments. The study examined the effects of key parameters, including laser intensity, scanning velocity, and scanning cycles. In addition, to provide a computational tool facilitating the design and optimization of laser remanufacturing, a physics-based computational model capable of predicting the removal efficiency in laser surface ablation was developed. In specific, the time-dependent temperature distribution along the depth was modeled, the ablation-induced recession velocity of the irradiated surface was calculated, and the ablation depth was computed by the time integration of the recession velocity. Based on the experimental data and modeling results, we established process design guidelines and baseline processing parameters for laser remanufacturing of cast iron surfaces. The proposed laser processing technology is expected to provide an eco-friendly, energy-efficient, highly controllable, and user-friendly solution for metallic surface remanufacturing. This REMADE project was conducted through collaboration among researchers from multiple universities and engineers from the industry partner Volvo.