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Characteristic Material Loading of Coupled Thermal and Dynamic Effects Generated by High-Intensity Pulsed Ion Beam

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High-intensity pulsed ion beam (HIPIB) technology has been developed as a unique approach for surface modification of components, utilizing the significant thermal and dynamic effects under typical parameters with an energy density of several J/cm^2 at pulse duration of tens to hundreds ns order. Under the HIPIB irradiation, notable surface remelting and ablation, and thermal stresses and stress waves propagating inwards can improve the surface integrity of components with formation of non-equilibrium microstructure and new phases, and plastic deformation layer with high density defects, and associated high hardness and low friction etc., finally leading to a high performance of wear, oxidation, and/or fatigue resistance. In practice, it is still difficult to select HIPIB process parameters in advance for generating the desired surface integrity for high performance, even though the thermal and dynamic processes have been intensively explored by numerically calculating temperature and stress fields evolutions, i.e. material loading in the irradiated components. A transient heat transfer model incorporated with constitutive equation is constructed to elucidate the surface integrity formation mechanism with varying irradiation parameters/conditions including energy density, pulse duration, and pre-heating temperature etc., by which characteristic parameters of the material loading are proposed and discussed taking into account the transition from thermal energy to mechanical energy, to establish a characteristic correlation between the surface integrity and HIPIB process parameters for design and optimization of the processes.

Keywords
High-intensity pulsed ion beam
Material loading
Thermal energy
Mechanical energy
Residual stress