

Fully coupled Discrete Element Model for integrated Thermal-Electrical-Mechanical Phenomena in Spark Plasma Sintering

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Spark Plasma Sintering (SPS) is an advanced manufacturing technique that leverages electric current and uniaxial pressure to achieve rapid consolidation of powder materials. The efficiency of SPS stems from intrinsic multiphysics coupling, where electrical, thermal, and mechanical phenomena are dynamically interdependent. However, this also makes the system complex to understand and model, particularly at microscopic level.

This work presents a novel, fully coupled microscopic thermal-electrical-mechanical model within the Discrete Element Method (DEM) framework. The model explicitly represents individual powder particles as discrete elements, enabling direct simulation of microstructural evolution. It integrates validated sub-models including thermal and electrical model for conduction and effective properties and mechanical model for viscoelastic deformation and densification. The coupled model incorporates Joule heat generation from current distribution, temperature dependent sintering kinetics and material properties and densification dependent effective electrical and thermal conductivity. This study provides a powerful computational tool to understand the multiphysics phenomena in SPS, offering insights for process optimization to achieve targeted microstructures and properties.

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