Tech Science Press

ICCES, 2024, vol.32, no.3
DOI: 10.32604/icces.2024.011229

PROCEEDINGS

A Thermodynamically Consistent Phase-Field-Micromechanics Model of Solid-State Sintering with Coupled Diffusion and Diffusion-Induced Shrinkage

Qingcheng Yang[1,*] and Arkadz Kirshtein[2]

[1]School of Mechanics and Engineering Science, Shanghai Institute of Applied Mathematics and Mechanics, Shanghai University, Shanghai, 200072, China

[2]Department of Mathematics, Tufts University, Medford, MA 02155, USA

[*]Corresponding Author: Qingcheng Yang. Email: qyang@shu.edu.cn

ABSTRACT

Sintering is a pivotal technology for processing ceramic and metallic powders into solid objects. A profound understanding of microstructure evolution during sintering is essential for manufacturing products with tailored properties. While various phase-field models have been proposed to simulate microstructure evolution in solid-state sintering, correctly incorporating the densification assumption—where particles move toward each other by rigid body motion—remains a challenge. The fundamental obstacle lies in the ad hoc treatment of particle motion, where the thermodynamical driving force cannot be derived from the system's free energy. In this work, we present a novel phase-field micromechanics model for sintering. We relax the rigid body assumption, allowing powder particles to mechanically deform through surface and grain-boundary tensions. Subsequently, a unified energy law is defined, and the governing equations for microstructure evolution in sintering are derived using variational principles. Our approach ensures thermodynamic consistency, with the driving force for particle motion derived from the system's free energy. Consequently, the proposed phase-field-micromechanics model guarantees the evolution of microstructure in a direction that reduces the system's energy. We rigorously validate this model against recent benchmarks of theoretical analysis [1].

KEYWORDS

Phase-field modeling; sintering; micromechanics

Funding Statement: Q.Y. was funded by the grant (No. 23010500400) from the Science and Technology Commission of Shanghai Municipality, and the grant (No. 12272214) from the Natural Science Foundation of China.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

1. Yang, Q. C., Gao, Y. X., Kirshtein, A., Zheng, Q., Liu C. (2023). A free-energy-based and interfacially consistent phase-field model for solid-state sintering without artificial void generation. *Computational Materials Science,229,* 112387.