Coupled thermo-electrical discrete element model of electric current activated/assisted sintering

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ABSTRACT

A novel discrete element model of coupled thermo-electrical phenomena in the electric current activated/assisted sintering (ECAS) will be presented. Sintering is a powder metallurgy technology in which a bulk material is consolidated from a loose or weakly bonded powder at an elevated temperature below the melting point. ECAS is a non-conventional sintering technique in which heat is generated by an electric current flowing through the powders and/or the graphite tools, thus exploiting the Joule effect.

Thermal and electrical phenomena in the powder are modelled using spherical particles bonded by cohesive necks, characteristic to sintering process. The flow of electrical current and heat generation in a particle assembly is modelled along with the heat absorption and heat flow. The electrical and thermal processes are fully (two-way) coupled. The thermal and electrical conductance models are based on the authors' own model presented in [1]. Additionally, both thermal and electrical models take into account a reduced resistance at the interface between connected particles.

The DEM thermal, electrical and thermo-electrical models have been validated by comparison with detailed solutions of specially designed benchmarks of two and three particles discretized with finite elements. It is demonstrated that the simple particle model yields the same temperature evolution, resultant heat fluxes and electrical current as the more complex finite element model. Thereafter, the particle model was validated by evaluation of the effective thermal and electrical conductivities of porous materials manufactured with the ECAS technique. Numerical results have been compared with the experimental data given in [2].

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†‡REFERENCES

[1] J. Rojek, R. Kasztelan, and R. Tharmaraj, "Discrete element thermal conductance model for sintered particles", *Powder Technology*, **405**, 117521 (2022).

[2] S. Nosewicz, G. Jurczak, T. Wejrzanowski, S.H. Ibrahim, A. Grabias, W. Węglewski, K. Kaszyca, J. Rojek, and M. Chmielewski, "Thermal conductivity analysis of porous NiAl materials manufactured by spark plasma sintering: Experimental studies and modelling", *International Journal of Heat and Mass Transfer,* **194**, 123070-1-19 (2022).