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Thermo-Electric Model for FAST/SPS Sintering in Discrete Element Framework

Abstract

A discrete element model is developed to simulate two-way coupling of thermal and electrical problem in electric current assisted sintering (ECAS) process. ECAS is a powder consolidation process which combines uniaxial pressure with temperature, generated via current (Joule heating), to enhance cohesive inter-particle bonds and hence densification. A wide range of materials, both conductive and nonconductive ones, can be sintered using ECAS process. Here we focus on conductive materials, therefore we investigate coupled current and temperature phenomena in sintered materials.

The pipe network model is used to model both heat transfer and electric current between particles. The electrical and thermal conductance of the pipes connecting centres of spherical particles model is based on the authors' own model proposed in [1]. The conductance is dependent on the material conductivity and the radii of the necks formed and growing between particles during sintering. Moreover, particle-particle contact resistance is also considered and added to the model.

The model is verified by comparison with finite element simulations of benchmark examples. The thermal, electrical and thermoelectrical problems have been defined for simple three particle configurations and analysed both with the DEM and FEM. Heat fluxes, temperature and current distribution obtained in the DEM analyses were found to be consistent with the more established but complex and time consuming FEM model.

Thereafter, the DEM model was applied for more complex problems. It was used to determine thermal and electrical conductivity of porous material. For calibration and validation of the model, copper and NiAl samples are manufactured using ECAS/SPS with different processing parameters. Experimental results for electrical and thermal conductivity of these partially sintered porous materials are then compared to the DEM results [2].

Literature:

[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).

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