Thermo-electric coupled DEM model for multiphysics phenomena in Spark Plasma Sintering Process

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KEYWORDS: *Discrete element method (DEM), Effective properties, Coupled multiphysics problem, Heterogeneous microstructure*

ABSTRACT

The interest in Spark Plasma Sintering (SPS) has been increasing in recent years, reflecting its potential to be a sustainable and ecological technology. SPS is a powder consolidation process that employs electric current to generate heat (Joule effect) while simultaneously applying pressure to achieve densification. The complexity of the process stems from the interdependence of electrical, thermal and mechanical problems. Modelling of this complex process requires a coupled modelling approach where each physical phenomenon is addressed separately and then combined to build a complete model. In this work, a coupled microscopic thermo-electric model is developed within discrete element framework. In the discrete element method (DEM), each particle is considered a discrete element, hence making it suitable for modelling of sintered materials. An original DEM model, based on sintering geometry where two particles are connected via neck, was presented in [1]. This model is revised by including grain boundary resistance to account for porosity in the necks and by adding neck-size correction to compensate for non-physical overlaps at higher densities. The revised DEM model is used to simulate thermal and electrical conduction and evaluate the effective properties of partially sintered porous material with heterogeneous microstructure. The numerical results are compared with experimentally measured thermal and electrical conductivities of porous NiAl manufactured using SPS. The coupled thermo-electric model allows to establish a relation between applied current and heating rate for the sintering process. The proposed DEM model can be used for microscopic analysis and can be integrated with sintering models to have a fully coupled thermo-electric-mechanical model for the SPS process [2].

ACKNOWLEDGEMENT: Research funded by National Science Centre, Poland, project no. 2019/35/B/ST8/03158

REFERENCES

[1] J. Rojek, R. Kasztelan, and R. Tharmaraj, Discrete element thermal conductance model for sintered particles. *Powder Technology*, Vol. 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, *Int. J. Heat Mass Transf.*, 194(123070), 2022