S11 Particle-based methods in computational mechanics

List of abstracts

ID 50: *Investigation of the behavior of intact and cracked steel plates under static and dynamic loading* – M. Khomami Abadi, M. Zaman Kabir

ID 103: *Numerical modelling of thermal properties of particulate lightweight composites* – D. Mačiunas, R. Kačianauskas, J. Rojek, V. Antonovič, J. Malaiškiene, R. Stonys

ID 124: *Performance of the thermal discrete element method implemented on shared-memory architectures* – A. Kačeniauskas, R. Pacevič, R. Kačianauskas, A. Džiugys

ID 176: *Modelling of fluid flow in porous materials using a DEM-based novel coupled thermo-hydro-mechanical mesoscopic approach* (keynote) – M. Krzaczek, M. Nitka, J. Tejchman

ID 198: *DEM simulation of thin elastic membranes for granular jamming applications* – H. Götz, P. Müller, T. Pöschel

ID 218: *Numerical study of heat conduction of spark plasma sintered materials* – S. Nosewicz, G. Jurczak, T. Wejrzanowski, S. H. Ibrahim, A. Grabias, W. Węglewski, K. Kaszyca, J. Rojek, M. Chmielewski

ID 228: *Determination of thermal conductivity of porous materials manufactured by FAST/SPS by DEM simulation* – J. Rojek, R. Kasztelan, T. Ramakrishnan, S. Nosewicz, K. Kaszyca, M. Chmielewski

ID 242: *MercuryDPM: Fast, flexible, particle simulations* (keynote) – A. Thornton, T. Weinhart

ID 255: *The Particle Finite Element Method in solid mechanics - Aspects on contact mechanics and plasticity* – M. Schewe, A. Menzel

ID 257: *Simulation of elastic wave propagation in concrete using Discrete Element Method* – M. Knak, M. Nitka, J. Tejchman, M. Rucka

NUMERICAL STUDY OF HEAT CONDUCTION OF SPARK PLASMA SINTERED MATERIALS

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Presented work proposes the comprehensive analysis of heat transfer and thermal conductivity of porous materials manufactured by spark plasma sintering (SPS). Intermetallic nickel aluminide (NiAl) was selected as the representative material. Due to the complexity of the studied matter, the following investigation was based on experimental, theoretical and numerical approaches. The samples were manufactured in different combinations of SPS process parameters - sintering temperature, time and external pressure and next tested by laser flash method to determine the effective thermal conductivity of porous samples. Moreover, the extensive microstructural characterization was performed using scanning electron microscopy (SEM) and micro computed tomography (micro CT) with a special focus on the structure of cohesive bonds (necks) formed during the SPS process. The experimental results of thermal conductivity were compared with various theoretical models results (parallel, Maxwell-Eucken, Landauer) and numerical one. Here, a finite element framework based on micro CT was employed to analyze the macroscopic (ETC, geometrical and thermal tortuosity) and microscopic parameters (heat fluxes magnitude with angle deviation, local tortuosity) for samples with various porosity. The comparison of different approaches of ETC evaluation revealed the necessity of consideration of additional thermal resistance related to sintered necks and located on powder particle contacts. Since the micro CT analysis cannot determine the grain (particle) boundaries, a special methodology/algorithm was implemented to identify the corresponding spots in the volume of FE samples. Such specified finite elements were treated as the resistance phase with lowered thermal conductivity. The algorithm has been verified by simple benchmarks showing a desirable efficiency. To calibrate the new FE approach with experimental results, multiple simulations with various content of resistance phase elements and different values of thermal conductivity of the resistance phase have been performed for each sample. Finally, the Landauer relation has been modified to take into account the thermal barrier of necks and their thermal conductivity depending on sample densification. Modified theoretical and FE models brought updated ETC results, which after comparing with the experimental one reveals satisfied agreement.