6th International Virtual Conference of Engineering Against Failure

23-25 June 2021 Abstract no. 207

http://iceaf.eu/sites/default/files/inline-files/E-Book%20of%20Abstracts_V04.pdf

Phase-Field Modeling of Fracture in Cr-Al_2O_3 Metal–Ceramic Composites with Experimental Verification

Hossein Darban[1], Kamil Bochenek[1], Witold Węglewski[1], Michał Basista[1]

[1] *Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland, email: hdarban@ippt.pan.pl*

The metal-ceramic composites are advanced structural materials which have wide range of industrial applications in, for instance, aerospace, automotive, and energy sectors. The metal-ceramic composites are being often used in harsh environments characterized by severe thermomechanical loading and chemical aggression. Under such conditions, fracture is one of the main failure modes which needs to be well understood.

Both experimental and numerical works are available in the literature regarding the fracture behavior of different metal-ceramic composites. For instance, the fracture mechanisms in the Cu-Al_2O_3, Al-Al_2O_3, and Al-SiC composites are studied in [1] using three-point bending tests. Finite element modeling is used, for instance in [1-3], to study the fracture mechanisms taking place at the vicinity of the crack tip in metal-ceramic composites with consideration of the real microstructure. However, these finite element models belong to the discrete approaches which have the drawback of huge computational costs.

In order to overcome the computational limitation of the discrete approaches, a homogenized phase-field model is used in this work to simulate the fracture in the chromium-alumina metal-ceramic particulate composites fabricated by powder metallurgy, and to predict their fracture toughness. Composites with different reinforcement volume fractions and the matrix material grain sizes are considered. To reduce the computational tasks, the composites are modeled as homogeneous isotropic materials whose elastic properties are calculated by the rule of mixture. A novel approach is proposed to determine the phase-field length scale parameter by measuring the process zone length at the vicinity of the crack tip through the microscale observations of the fracture surfaces. It is found that the reinforcement volume fraction does not considerably change the fracture length scale. However, the composites with bigger chromium grains have a wider process zone.

A staggered finite element solution scheme based on the model presented in [4] is used to solve the phase-field equations. In order to validate the numerical results, fracture experiments are conducted on the single-edge V-notched beams under four-point bending. The predicted values of fracture toughness by the homogenized phase-field model are in excellent agreement with those obtained from the experiments. It can thus be concluded that a physically meaningful phase-field length scale parameter can be obtained from direct measurements at the vicinity of the crack tip.

References

[1] Agrawal P, Sun CT. Fracture in metal–ceramic composites. Compos Sci Technol 2004;64(9):1167-78.

[2] Wang L, Fan Q, Li G, Zhang H, Wang F. Experimental observation and numerical simulation of SiC3D/Al interpenetrating phase composite material subjected to a three-point bending load. Comp Mater Sci 2014;95:408-13.

[3] Wu Q, Xu W, Zhang L. Microstructure-based modelling of fracture of particulate reinforced metal matrix composites. Compos Part B: Eng 2019;163:384-92.

[4] Molnár G, Gravouil A, Seghir R, Réthoré J. An open-source Abaqus implementation of the phase-field method to study the effect of plasticity on the instantaneous fracture toughness in dynamic crack propagation. Comput Methods Appl Mech Eng 2020;365:113004.