Xiang Guo, Assoc. Prof., Tianjin University, China
lecture on
Micromechanical simulation on strength, ductility, fracture resistance, and ballistic performance of bimodal nanostructured metals

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School of Mechanical Engineering, Section of Manufacturing Technology,
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1st floor, Building Ξ, Mechanical Engineering Building Complex, NTUA Campus

Abstract

Bimodal nanostructured (NS) metals, consisting of coarse grained (CG) and nano-grained (NG) regions, have proved to have both high strength and good ductility. Our numerical investigation is based on the combination of a mechanism-based strain gradient plasticity theory and a micromechanics composite model.

Our results on the overall fracture behavior show that both crack bridging in the CG inclusions and crack deflection in the NG matrix can significantly toughen the bimodal NS Cu. The results also show that there exists a critical volume fraction of CG inclusions for some microstructures at which the overall fracture resistance is at its minimal state and thus it should be avoided in material design.

Our results on the overall ballistic performance indicate that microstructures can significantly affect the velocity history of the bullet as well as limit velocity and maximum displacement of the specimen. The analysis also suggests that, to improve the ballistic performance, the CG inclusions need to have regular distribution and, under the condition of same distribution, they also need to have a longer projection perpendicular to the direction of impact. The simulations show that when the abrasion effect is not considered, the ballistic performance depends heavily on their ductility rather than their strength.

Our 3D results on the overall strength and ductility reveal that both the shape and distribution of CG inclusions significantly affect the overall ductility, while the former has more prominent influences than the latter. Spherical CG inclusions result in excellent overall ductility under all considered spatial distributions, while CG inclusions with sharp edges and corners facilitate microcrack initiation. However, the earlier microcrack initiation does not necessarily lead to a lower ductility since proper combinations of the shape and distribution of CG inclusions may retard microcrack propagation and thus enhance the overall ductility.

In the above work the element deletion method is employed so that the properties of the interfaces are not considered. The cohesive finite element method is then used to uncover the effects of cohesive strength and the microstructural attributes on the tensile fracture behavior of the bimodal nanostructured metals. The simulations show that when the cohesive strength of two phases reaches a certain level, the true stress-strain curves of any microstructure saturate.

Relevant publications

Q.D. Ouyang, **X. Guo**(*), X.Q. Feng. 3D microstructure-based simulations of strength and ductility of bimodal nanostructured metals. *Material Science and Engineering A*, **677**, 76–88 (2016).

X. Guo(*), G. Yang, G.J. Weng. The saturation state of strength and ductility of bimodal nanostructured metals. *Materials Letters*, **175**, 131–134 (2016).

X. Guo(*), G. Yang, G.J. Weng, L.L. Zhu. Numerical simulation of ballistic performance of bimodal nanostructured metals. *Material Science and Engineering A*, **630**, 13–26 (2015).

X. Guo(*), R. Ji, G.J. Weng, L.L. Zhu, J. Lu. Micromechanical simulation of fracture behavior of bimodal nanostructured metals. *Material Science and Engineering A*, **618**, 479–489 (2014).

X. Guo(*), X.Y. Dai, L.L. Zhu, J. Lu. Numerical investigation of fracture behavior of nanostructured Cu with bimodal grain size distribution. *Acta Mechanica*, **225**, 1093–1106 (2014).

Biographical note: Dr. Xiang GUO obtained his PhD from City University of Hong Kong in 2006 and his thesis was *Elastic Property and Buckling Behavior of Carbon Nanotubes*. He joined School of Mechanical Engineering at Tianjin University in 2011 as an associate professor. His current research focuses on computational fracture mechanics and nano-mechanics. He accomplished a National Science Foundation of China (NSFC) project *Numerical investigation of toughening mechanism in layered metal with nanograined interface layers*. His ongoing NSFC project is *Optimization of ballistic performance of new hybrid plate containing stainless steel with nanograined layer for helmets*. He has published 30 SCI papers.