Accepted Manuscript

Elastic-plastic properties of metal matrix composites: Validation of mean-field approaches

M. Kursa, K. Kowalczyk-Gajewska, M.J. Lewandowski, H. Petryk

PII: S0997-7538(17)30599-5

DOI: 10.1016/j.euromechsol.2017.11.001

Reference: EJMSOL 3507

To appear in: *European Journal of Mechanics / A Solids*

Received Date: 4 August 2017

Revised Date: 10 October 2017

Accepted Date: 2 November 2017

Please cite this article as: Kursa, M., Kowalczyk-Gajewska, K., Lewandowski, M.J., Petryk, H., Elastic-plastic properties of metal matrix composites: Validation of mean-field approaches, *European Journal of Mechanics / A Solids* (2017), doi: 10.1016/j.euromechsol.2017.11.001.

Elastic-plastic properties of metal matrix composites: validation of mean-field approaches

M. Kursa*, K. Kowalczyk-Gajewska, M.J. Lewandowski, H. Petryk

Institute of Fundamental Technological Research (IPPT PAN), Pawińskiego 5B, 02-106 Warsaw, Poland

Abstract

Several micromechanical and numerical approaches to estimating the effective properties of heterogeneous media are analyzed. First, micromechanical mean-field estimates of elastic moduli for selected metal matrix composite systems are compared with the results of finite element calculations performed for two simplified unit cells: spherical and cylindrical. Advantages and deficiencies of such numerical verification of analytical homogenization schemes are indicated. Next, predictions of both approaches are compared with available experimental data for two composite systems for tension and compression tests in the elastic-plastic regime using tangent and secant linearization procedures. In the examined range of strain and ceramic volume content, both the Mori-Tanaka averaging scheme and the generalized self-consistent scheme lead to reliable predictions when combined with the tangent linearization, while the use of secant moduli results in a too stiff response. It is also found that the mean-field predictions for a small ceramic volume content are very close to the results obtained from the finite-element analysis of a spherical unit cell.

Keywords: metal-matrix composites, effective properties, analytical estimates, numerical homogenization, nonlinear analysis

1. Introduction

Availability of reliable and efficient methods for predicting the effective properties of a heterogenous material is vital for the design process of composites. With an increasing computer power and development of high resolution imaging techniques for microstructure characterization the computational homogenization (Kouznetsova et al., 2001; Zohdi and Wriggers, 2005) gains popularity in this field. By using the computed tomography (CT) scans a numerical model of the actual microstructure can be constructed and subjected to the mechanical or thermomechanical finite element (FE) analysis in order to determine the overall material behaviour, see e.g. (Węglewski et al., 2013; Jung et al., 2014) for application of that approach to metal matrix composites. However, the FE-based homogenization technique has its limitations. First, due to a high computational cost a reduced number of microstructure representative volumes can only be considered, so that the extensive parametric study, required for the optimal design process, is often burdensome or even impossible. Second, there is another difficulty when using FE analysis which is connected with the problem of fulfilment of the representativeness condition for the volume element under consideration, see e.g. (Hill, 1963; Kanit et al., 2003; Ostoja-Starzewski, 2006). The final selection is usually a trade-off between the fair proximity to the real microstructure and

*Corresponding author
Email address: mkursa@ippt.pan.pl (M. Kursa)