FEW OBSERVATIONS ON THE OPTIMAL CONFIGURATION OF SOME COMMON TYPES OF BRIDGES

T. Sadowski([1], L. Marsavina[2] and E. Craciun([3]
[1]*Lublin University of Technology, Poland*
[2]*Politehnica University of Timisoara, Romania*
[3]*Ovidius University Constanta, Romania*

1. General

Two-phase ceramic composite materials (e.g. Al2O3/ZrO2) have a non-linear and complex overall response to applied loads due to: different phases, existence of an inital porosity, development of limited plasticity and internal microdefects. All microdefects act as stress concentrators and locally change the state of stress, leading to the development of mesocracks and finally macrocracks. Experimental results show that defects develop mainly intergranular and cause inhomogeneity and induced anisotropy of the solid. Modelling of such material response is possible by multiscale approach describing different phenomena occurring at different scales: micro- meso- and macro-.

Constitutive modelling of two phase ceramic composites obeys description of the:

- elastic deformations of initially porous material,
- limited plasticity active slip systems,
- cracks initiation and propagation.

All these phenomena develop during deformation of the composite at different level of descriptions:

- the microscopic level is associated with the degradation phenomena developing at the length scale corresponding to the single grain. Shear bands, micropores inside of grain or at the grain boundaries act as a crack initiators. Moreover, mismatch of the thermal expansion coefficient of different phases creates additional stress concentration at the grain boundaries, which decreases toughness of this part of material. Nucleated microcracks tend to grain boundaries, at which can be arrested or can spread along the nearest grain boundary due to significantly less fracture toughness of this part of composite, or can pass trough a grain boundary to the adjacent grain,
- the mesoscopic level corresponds to a set of grains, which create so called Representative Surface (or Volume) Element (RSE or RVE). The basic elements of the defect structure inside polycrystal are meso-cracks, which diameters correspond to the single straight facet of the grain boundaries structure. Kinked and wing (zig-zag) cracks are consequences of the deformation development inside the composite material,
- the macroscopic level corresponds to the dimensions of the tested sample of the material. The composite is treated as a continuum with properties of the polycrystal, at this level of analysis, calculated as averaged values over of RSE (or RVE) with application of analytical micromechanical model or with the help of finite element analysis.

Thus, the following constitutive rule can be proposed in order to describe above general features of the quasi-static deformation process of the material

(1) $$\varepsilon_{ij} = S_{ijkl}\left(\sigma_{mn}, p, \omega^{(i)}\right)\sigma_{kl}$$

where S_{ijkl} is the compliance tensor, ε_{ij} is the strain tensor, σ_{kl} is the stress tensor, p is the porosity parameter and $\omega^(i)$ are sets of parameters defining the presence of different kinds of defects i developing inside the material. The initial porosity of the material is assumed to be closed and distributed in grains (p_g) and along grain boundaries (p_{gb}). Both types of porosity $(p = p_g + p_{gb})$ influence the initial value of the compliance tensor S_{ijkl} and the initial stage of deformation process, i.e. elastic deformation. It increases the component of S_{ijkl} in comparison to the material without porosity.

One can distinguish two mechanisms of cracks initiation and propagation in two phase polycrystalline materials:

- the first mechanism is caused by stress concentrations at pores boundary. This kind of crack propagates perpendicularly to the load direction, when the energy release rate G satisfies the following condition is:

  (2) $$G(\sigma_{ij}, p_g) \geq \gamma_g^{cr},$$

  where γ_g^{cr} is the critical value of the grain surface energy

- the second mechanism is due to crack propagation along grain boundaries including kinking process. The description of crack propagation process is strongly influenced by grain boundary porosity p_{gb}. Namely, any crack (straight or kinked one occupying grain boundaries) can propagate if the energy release rate G satisfies the following condition

  (3) $$G(\sigma_{ij}, \phi, p_{gb}) \geq \gamma_{gb}^{cr}(p_{bg}),$$

  where ϕ describes orientation angle of cracks in RVE, γ_{gb}^{cr} is the critical value of the grain boundary surface energy

The multiscale modelling was illustrated by several examples of description of deformation process for different types of composites.

Acknowledgment

This work was financially supported by Ministry of Science and Higher Education within the statutory research number S/20/2013