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Finite element modeling of superplastic co-doped yttria-stabilized tetragonal-zirconia polycrystals

Key words:

Finite element analysis (FEA), Y_2O_3-stabilized tetragonal-zirconia polycrystals (Y-TZP), Superplasticity

Introduction

- Ceramics have good resistance to fatigue, abrasion, and chemical corrosion, and are resistant to erosion at high temperatures. Hence, their applications are extensive in both household and industrial products.

- Through the tailoring of very refined particles, tetragonal-zirconia polycrystals (TZP) retain a metastable tetragonal phase at room temperature and have been shown to have excellent plastic properties.

- Combining the superplastic properties of ceramics with processing techniques, such as sheet formation, blowing, stamping, forging, and spinning, would support the industrial manufacture of complex ceramic pieces for applications in aerospace, defense, and automobile manufacturing, among others.

- However, before that is practical, we must gain more understanding of superplastic ceramics in respect of mechanical stress distribution and fracture mechanisms at a macroscopic level when the materials deform.

- It is intended, by means of solid mechanics or plasticity theory, to provide further analysis of the deformation progress of superplastic ceramics so that uses of this kind of material may be developed on the basis of safe designs.

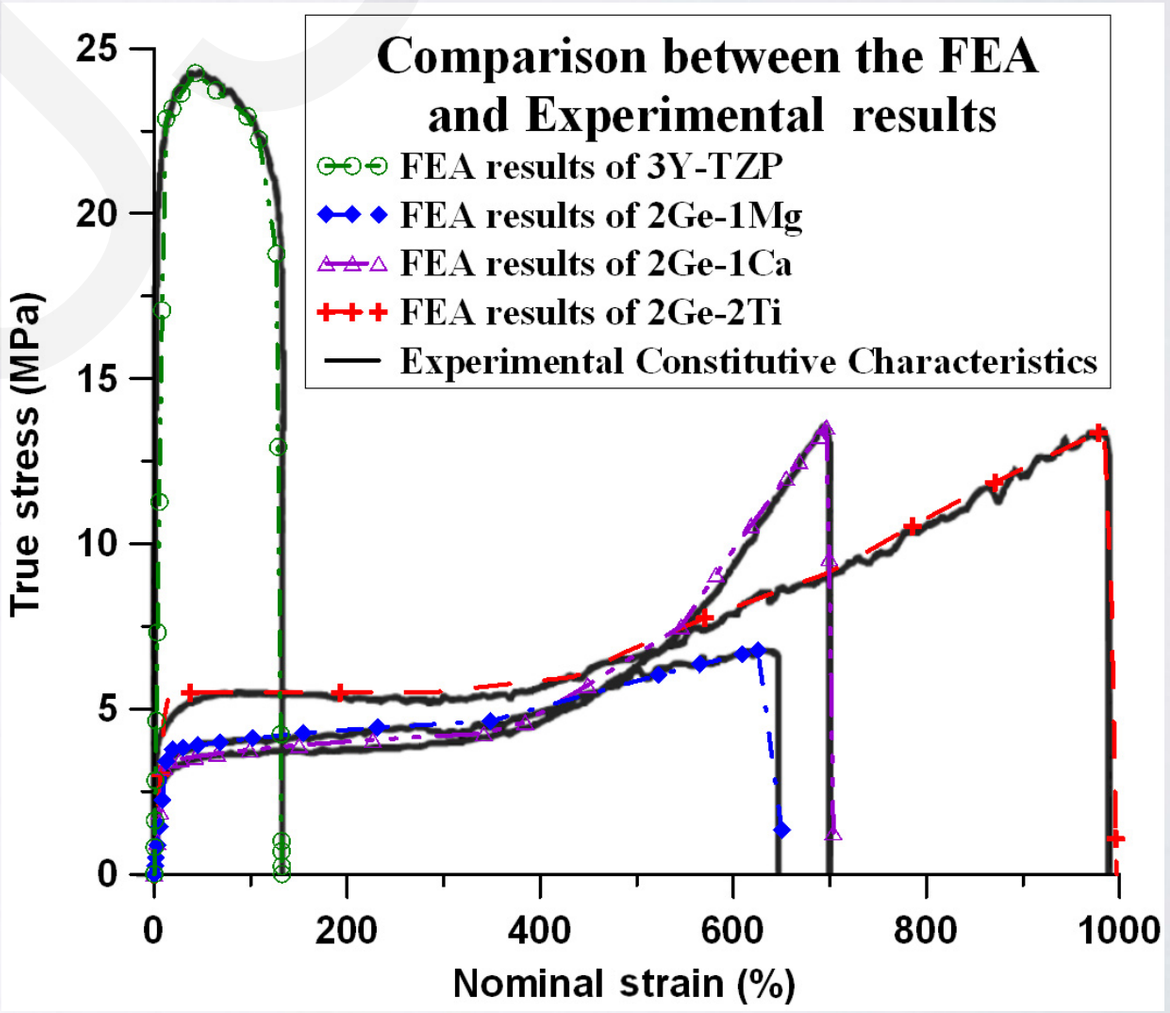
Methods

- A numerical finite element model based on the theory of plasticity to simulate the uniaxial stress-strain progress of co-doped 3Y-TZP is proposed.

- The material model was an elastic-plastic model, which simulated the elastic response using Hooke's law and the plastic strain hardening response using the flow rule associated with the von Mises yield criterion combined with the isotropic hardening rule.

- The simplified constitutive law used for the numerical simulations is based on piecewise linear connections at the turning points of different deformation stages on the experimental stress-strain curves.

- The presented FEM was verified with the tensile test experiments on superplastic 3Y-TZP, 2Ge-1Mg, 2Ge-1Ca, and 2Ge-2Ti ceramics performed by Sasaki *et al*. (2001).

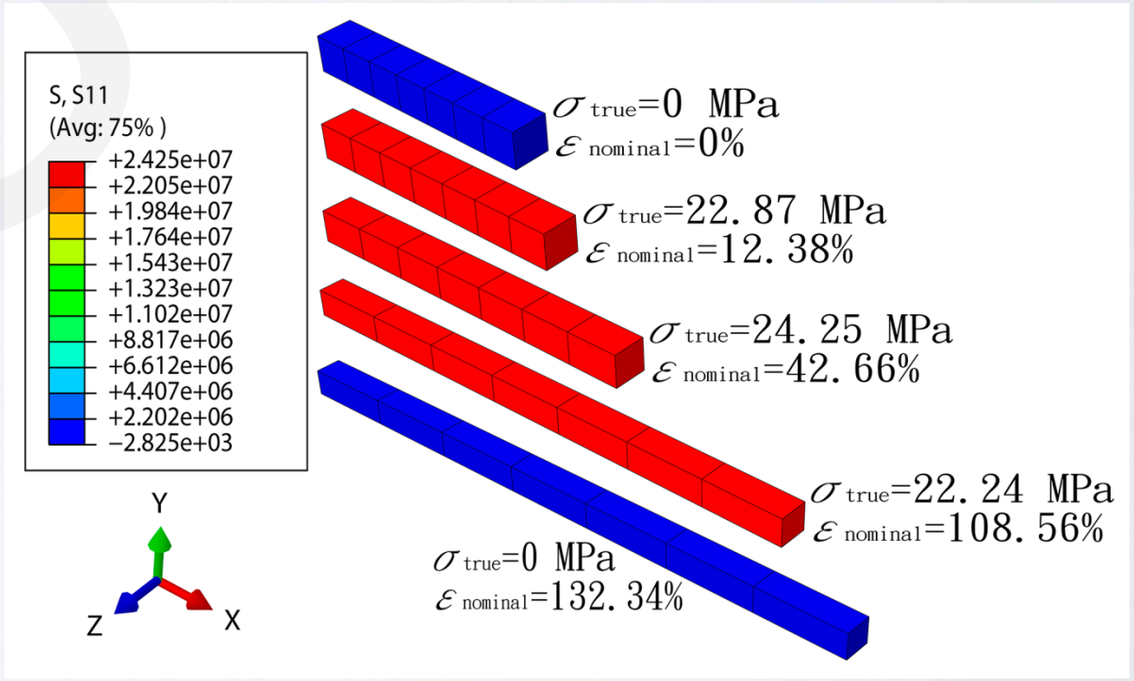


Conclusions

- The results showed that the stress-strain relationships analyzed by the presented FEM agreed well with the experimental data, and the errors for the maximum stress and strain were all less than 1% for the four compositions studied.

- The final deformed shapes (i.e., width and thickness) of the FEA were consistent with the results of tensile tests. These verifications confirm the reliability of the presented FEM, which can be used to analyze the mechanical behavior of materials such as superplastic co-doped 3Y-TZP ceramics.

- This research gives a feasible model for simulating the constitutive characteristics of superplastic ceramics and to some degree makes up for the lack of numerical analysis available for this kind of material. In addition, this paper offers a model for analyzing applications related to the development of manufacturing process improvements, mechanical analyses, fracture predictions, and safe design specifications for superplastic ceramics.



Stress and strain history of the FEA at different stages of deformation for 3Y-TZP