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# MORPHOLOGY OPTIMIZATION OF MICROSTRUCTURE FOR DUAL-COMPONENT STRUCURAL METAS

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Utilization of heterogeneity is recognized as a further direction of development of structure materials. A class of so-called dual-phase steels composed of ferrite and martensite phases is one of the representative examples which has been put to practical use. In this type of steels, the balance between strength and ductility is improved by heterogeneous distribution of the two different components at micro scale. The purpose of this study is to propose a CAE approach to use efficiently such effects of microscopic heterogeneity in materials research and development.

In a homogenization method based on finite element analysis, a representative volume element of an objective microstructure is modeled with finite elements and the deformation analysis is conducted under periodic boundary condition in control of macroscopic stress or strain [1]. As the numerical results, the deformation state of microstructure is obtained along with the corresponding macroscopic material response. By coupling with this computational homogenization method and a mathematical optimization method, the microstructure corresponding to a required performance can be found efficiently. Based on this framework, topology or morphology optimizations of microstructure have been reported in the fields of small-strain elasticity and thermal conductivity [2, 3]. In the application of this approach to nonlinear deformable microstructure, the main difficulties are how to deal with mixture state of materials during optimization process and what kind of optimization condition works well for the actual requirement.

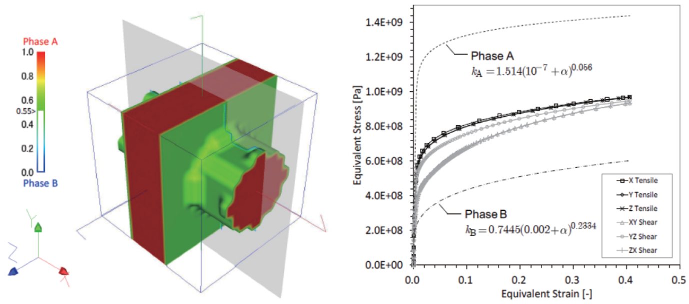
In this study, the computational optimization method for microstructure is applied to maximize the strength of a dual-component elastoplastic solid. A standard metal plasticity is employed to describe the material responses of each components and the material constants are determined from the macroscopic experiments of the corresponding single-component materials. For optimization calculations, the distributions of two densities are considered with node-based discretization [4] under a constraint condition to finally segregate two components. And here simple strain-constant analytical homogenization method, so-called mixture rule, is applied to handle the mixture state during the optimization process.

The maximization problem of the macroscopic external work, in the other words the macroscopic stored energy is defined for the optimization analysis, which means the maximization of macroscopic strength in this case. Here the resulting microstructure depends on the applied macroscopic stress tensor in optimization calculations.

In Fig.1 the optimized microstructure for macroscopic uniaxial deformation and its macroscopic responses for various deformation modes are illustrated, where only the stronger component of two components is depicted. The macroscopic response behaves anisotropic in connection with the applied macroscopic deformation mode in optimization analysis. By applying six independent components of stress tensor, the isotropic and high-strength microstructure shown in Fig.3 is synthesized as the result of optimization analysis.

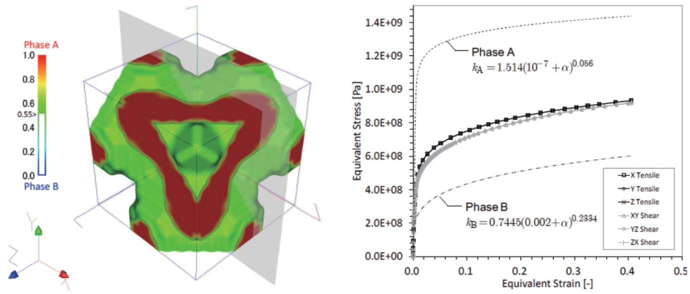
As above the computational optimization approach is validated by numerical results that reproduced a well-known feature in structural materials, i.e. the topology of stronger component at micro scale contributes the macroscopic strength.

Such a computational approach is flexible and widely applicable in various science and engineering fields The definition of optimization condition is essential. However handling massive computational efforts remain a practical issue to put into practical use.




(a) Optimized microstructure (b) Macroscopic response

Fig.1 Result of optimization analysis for macroscopic uniaxial tensile deformation: (a) density of phase A at micro scale, (b) macroscopic equivalent stress-strain curves for each stress components




(a) Optimized microstructure (b) Macroscopic response

Fig.2 Result of optimization analysis for six independent components of macroscopic stress: (a) density of phase A at micro scale, (b) macroscopic equivalent stress-strain curves for each stress components

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