Multi-scale Simulations for early stage of ductile failures

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ABSTRACT

In this paper, the microscopic void growing processes are simulated by using the multi-scale modeling method, to clarify the mechanisms of macroscopic ductile failures in general metallic materials.

Since the pioneering works by Gurson[1], Tvergaard & Needleman[2] and Lemaitre[3], the continuous damage mechanics have been one of major research fields in material modeling. The basic concept of the continuous damage models is very simple, that is, the assume existence of micro voids in metallic materials and their mechanical behaviors (void nucleation, growth and cracking) in micro structures cause macroscopic material properties, such as, tensile strength (peak in Stress-Strain curves), softening behavior after the peak and failures of materials. The so-called damage parameters or volume fractions of micro voids is major state variable in macroscopic damage models and their evolution laws are major part of these researches. In nowadays, many variations of damage models have been reported, and some of them are used in engineering simulations to predict the failures of structures/materials. In such simulations, many of engineers seek more reliable material models for ductile failures, since the properties govern failure modes and loads of the structures and they expect to design the failures. Most of these researches have been phenomenological approaches. and we cannot find any literatures which discuss the relationship between the microscopic void growing processes and the macroscopic mechanical properties. For example, recent damage models employ additional loading parameters; “the load angle” and “stress triaxiality”, which represents the dependency of ductile failures on shearing stress components and static pressures. However, it is difficult to control these loading parameters in testing environments, and which leads to essential difficulties for exact observations in the experiments.

The global-local simulation method[4] based on the mathematical homogenization are used in this paper, to simulate the micro-macro coupling behavior in ductile failure processes. We discuss the relationships between the deformations in micro void and the macroscopic stress-strain behaviors, through some representative global-local simulations.

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