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PROPOSAL AND USE OF A VOID MODEL FOR THE EVALUATION OF DUCTILE FRACTURE IN SHEET METAL FORMING

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ABSTRACT

We have developed a new computer program based on a conventional computer program of the finite-element method. Using this computer program, the behavior of crack propagation after ductile fracture can be analyzed. The simulation of inner fracture defects in drawing [1] and the simulation of shearing [2] have been performed, and the validity of the computer program has been demonstrated. In these simulations, the fracture criterion is that the material fractures when the void volume fraction of the material reaches a certain value. However, the fracture criterion does not necessarily have a definite physical meaning, microscopically.

Microscopically, ductile fracture occurs through the nucleation, growth and coalescence of voids. Hence, much analytical and experimental research on the nucleation, growth and coalescence of voids has been performed. Thomason proposed a model of void coalescence based on internal necking of the intervoid matrix ligaments [3]. The model was derived from the upper bound method, in which the material is assumed to fracture when the energy required to coalesce voids by internal necking is less than the energy required to deform the material homogeneously. The model of void coalescence is useful, since it has definite physical meaning.

In the Thomason model, the following assumptions are made.

*The shape of a void is a rectangle.

*The longitudinal direction of a void coincides with the direction of maximum principal stress.

In other words, the direction of principal strain is assumed not to change during plastic deformation in the model. However, the direction of principal strain changes during plastic deformation in metal forming processes. Hence, the model cannot be utilized in the analysis of metal forming processes.

In our previous papers [4, 5, 6], we proposed a new model, based on the Thomason model, which can be utilized in the analysis of metal forming processes. In our model, the following assumptions are made.

*The shape of a void is a parallelogram.

*The longitudinal direction of a void does not coincide with the direction of maximum principal stress.

In other words, the direction of principal strain is assumed to change during plastic deformation in our model. Our model is incorporated into a computer program of the finite-element method which we had previously developed to analyze the behavior of crack propagation after ductile fracture [1, 2]. The simulation of ductile fracture behavior in bulk metal forming is performed, and the validity of our proposed model is clarified by comparing the analytical results with the experimental results.

Metal forming processes are classified into bulk metal forming processes and sheet metal forming processes. The validity of our proposed model is confirmed in bulk metal forming, such as drawing and shearing. Hence, in this paper, the validity of our proposed model is evaluated in sheet metal forming. First, the experiment of bore expanding test is performed using a circular sheet and the radius of the bore at which the sheet fractures is obtained. Next, the simulation of bore expanding test is performed using our proposed microscopic model and the analytical results are compared with the experimental results.

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