Predicting ductile fracture in ferrous and nonferrous metals during upset forging using an ellipsoidal void model

Kazutake Komori

Department of Mechanical Systems Engineering, School of Engineering, Daido University
10-3, Takiharu-town, Minami-ward, Nagoya-city, Aichi-prefecture, 457-8530, JAPAN
e-mail: komori@daido-it.ac.jp, web page: https://www.daido-it.ac.jp/

ABSTRACT

Ductile fracture is a microscopic phenomenon because it occurs through nucleation, growth, and coalescence of voids. Also, as the ductile fracture criteria that are widely used for metal-forming processes, such as those introduced by Cockcroft and Latham, Brozzo, and Oyane, are derived from a macroscopic viewpoint, improving the prediction accuracy for a microscopic ductile fracture phenomenon using a macroscopic ductile fracture criterion is challenging. Although nucleation and growth of voids are simulated in the Gurson model, the coalescence of voids cannot be simulated intrinsically. Hence, for instance, the coalescence of voids is assumed to occur when the void volume fraction reaches a critical value. However, this assumption is inappropriate, because the critical void volume fraction depends on the stress state. Hence, the coalescence of voids should be evaluated using a model with a definite physical meaning.

Recently, the author has attempted to predict ductile fracture during tensile testing of a sheet and a bar from a microscopic viewpoint [1, 2]. The author's proposed model of void coalescence is based on the two-dimensional void model proposed by Thomason and that proposed by Melander and Ståhlberg, which were also derived from a microscopic viewpoint. Both the Thomason model and Melander and Ståhlberg model assume that the void is rectangular and the direction of the major axis of the void coincides with the direction of the maximum principal stress. In contrast, the author's proposed model assumes that the void is ellipsoidal and makes no assumptions about the relationship between the direction of the major axis of the void and the direction of the maximum principle stress. Hence, the author's void model can be used for simulating metal-forming processes.

In this study, the ellipsoidal void model [1, 2], which was proposed by the author previously, is evaluated by the upset forging of a cylinder, which is one of the fundamental forging process. A number of experimental researches on the prediction of ductile fracture during the upset forging of a cylinder have been performed. However, researches on the effect of prestrain applied to a cylinder on ductile fracture have hardly been performed. Hence, in this study, the effect of prestrain, which is applied to a bar by drawing, on ductile fracture during upset forging of a cylinder, has been clarified numerically and experimentally.

REFERENCES

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