DUCTILE FRACTURE OF LOW-YIELD-POINT STEEL UNDER DIFFERENT STRESS STATES

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Abstract

Low-yield-point steel LYP225, distinguished from the ordinary carbon structural steels by lower yield strength, preferable strain-hardening and better ductility, is widely applied in metallic dampers. Ductile fracture of these dampers after severe earthquakes were commonly observed. This paper experimentally investigates the ductile fracture of LYP225 steel under different stress states, and predicts the fracture initiation with the Hosford-Coulomb fracture model.

1. Introduction

Based on the microcosmic observation of the ductile metals under large plastic deformation, the initiation of ductle fracture is due to the void growth and coalescence inside the metals. There exists two different mechanisms of void coalescence, i.e., the internal necking of ligaments between voids resulting from volumetric void growth and the shear-linkup in the ligaments between voids caused by void elongation. While the necking mechanism controlled by the stress triaxiality is dominant at high triaxialities, the shearing mechanism,which is sensitive to Lode angle, is important at low triaxialities. The Hosford-Coulomb fracture model is a micro-mechanism inspired damage indicator model, and describes the fracture strain of ductile metals under different stress triaxiality and Lode angle. It is postulated that ductile fracture initiates after proportional loading when the linear combination of the Hosford equivalent stress and the normal stress acting on the plane of maximum shear exceeds a critical value. This paper applies the Hosford-Coulomb model to predict the fracture initiation of LYP225 steel. Various tests were conducted to obtained the fracture strain of LYP225 steel under different stress states, and the model parameters were calibrated based on the test results.

2. Results

LYP225 steel exhibits excellent ductility in tests. The engineering strain of the necking point in the uniaxial monotonic test exceeds 0.2 and the elongation after fracture is larger than 0.4. Almost all of the obtained plastic strain of LYP225 steel at the fracture point is higher than 1, and the lowest fracture strain is 0.925 and obtained from the flat grooved plate (FGP), of which the Lode angle parameter $\bar{\theta}$ is approximately equal to zero.

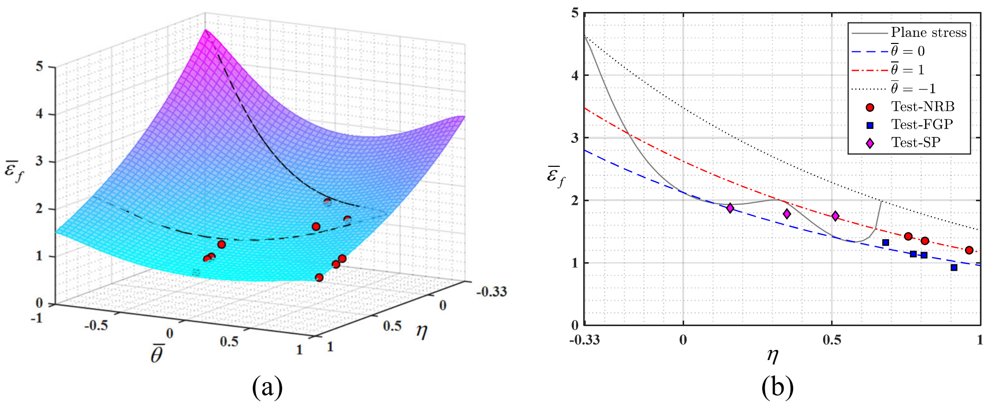

Fig.1 – Test results and the Hosford-Coulomb fracture surface of LYP225 steel.

During tests, the stess triaxiality η and Lode angle parameter $\bar{\theta}$ of material did not remain constent, but in most specimens the stesss states at the loading region remain steady. The strain-weighted average of stress

triaxiality and Lode angle parameter before fracture are used to define the stress states of specimens. Test results and the calibrated Hosford-Coulomb fracture surface are shown in Fig. 1. The test results (red points in Fig. 1(a)) nearly located on the calibrated fracture surface, indicating the Hosford-Coulomb model can well describe the fracture strain of LYP225 steel under different stress states. Fig. 1(b) shows the fracture strain under different stess triaxiality, and the curves respresent the results from the Hosford-Coulomb model and the scatter represents the test results. The plastic fracture strain of material decreases with the increase of stress triaxiality, which can be observed from both test results and model prediction. While the Lode angle parameter of notched round bars (NRB) is approximately equal to 1, the Lode angle parameter of flat grooved plates (FGP) is approximately equal to 0. The fracture strain of $\bar{\theta}=0$ is lower than other stress states, as indicated by both test results and model prediction. The shear plates (SP) are in shear-tension condition and the test results are located between the $\bar{\theta}=0$ and $\bar{\theta}=1$ curves.
Using a linear damage evolution law, the damage evolution of each specimen under monotonic loading is given in Fig. 2. Fig. 2(a) shows that the damage of each specimen at the fracture initiation is around 1. Since it is postulated in the fracture prediction that the fracture initiates when the damage reachs 1, the simulation results indicate the Hosford-Coulomb model can well predict the ductile fracture of LYP225 steel. As evaluated in Fig. 2(b), the average discrepancy between the test and simulated results over the fracture initiation is 4.02%.

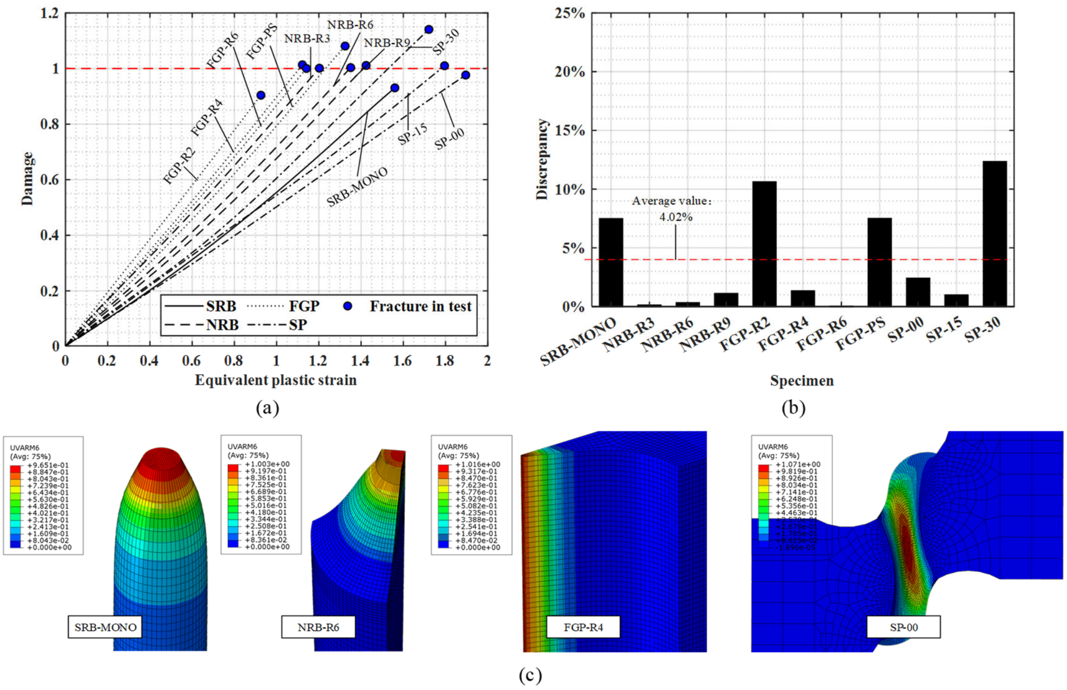

Fig.2 – The damage distribution and evolution of LYP225 specimens.

3. Conclusions

The influence of stress states on the ductile fracture should be considered, since the fracture strain varies when the stress triaxiality and Lode angle vary. The Hosford-Coulomb model can well predict the ductile fracture of LYP225 steel.

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