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Dimple Fracture Simulation under Mixed Mode Loading Condition

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Summary

Dimple fracture under mixed mode loading condition is studied experimentally and numerically. At first, ductile fracture test is conducted by changing mixed mode ratio, K_{II}/K_I, from K_{II}/K_I=0 to 0.25. By the mixed mode loading, it is found that fracture surface becomes much rough than that of mode I fracture. It is also found that ductile fracture growth direction deviates from original plane. Then, fracture growth direction is measured along crack front, and it was found that growth direction at mid-plane of the specimen is opposite from that at free surface. At mid-plane, fracture growth direction becomes slightly smaller as mixed mode ratio increases.

On fracture surface, many voids with different sizes are observed not only at mid-plane but also at free surface region, where shear-lip fracture occurs. Diameter of them are measured and it was found that; (1) Average void diameter at mid-plane decreases a little due to increase of mixed mode ratio, and (2) Void diameter is much smaller at free surface than that at mid-plane. It becomes clear that there are two factors affecting ductile fracture processes, one is mixed mode ratio and another is thickness effect.

Three-dimensional finite element analyses are conducted to study effects of these factors. For the simulation of ductile fracture, Gurson's constitutive equation is used with large deformation theory. For the void nucleation, stress controlled nucleation condition and equivalent plastic strain controlled condition are employed. Two cases, pure mode I, and KII/KI=0.25, are analyzed.

At mid-plane, ductile crack grows toward to maximum stress triaxiality zone. It becomes obvious that stress triaxiality is controlling parameter for ductile fracture at mid-plane of the specimen. It means that voids easily grow larger at mid-plane. At free surface, it was shown that equivalent plastic strain is controlling parameter for fracture. It is related with void nucleation. But stress triaxiality is small at free surface. As a result, many small voids are nucleated at free surface, but they don't grow largely. These numerical results agree with experimental observation very well qualitatively. Ductile fracture directions at mid-plane and free surface by numerical simulation also agree with experimental ones quantitatively.

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