Numerical simulation of dynamic failure using an instability based ductile fracture model

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The ductility of metals subjected to dynamic loading conditions is affected by several constitutive effects such as strain hardening, strain rate sensitivity, thermal softening, and damage softening due to microscopic void growth. Phenomenological ductile failure models such as the Johnson-Cook (JC) damage model [1] include several heuristic parameters to account for the above effects, although their values are difficult to calibrate uniquely from a standard set of experiments for a given material. This leads to non-transferability of the fracture parameters from lab scale specimens to structural components subjected to more complex non-proportional loading paths. In this study, a micromechanics-based model of ductile failure under dynamic loading conditions [2] is used to predict fracture in dual-phase steel specimens subjected to a range of loading paths from quasi-static and dynamic tension, shear and low velocity projectile impact [3]. Crack initiation at a material point is assumed to coincide with the onset of a plastic instability as a result of the competition between strain and strain rate hardening and thermal and void softening effects. Predictions obtained using the JC and the instability-based (IB) models mentioned above are compared with the experimental data under both quasi-static and dynamic loading conditions. It is shown that the IB model is able to quantitatively predict fracture in most specimen types and loading conditions using only the parameters related to the material's plastic stress-strain response and void nucleation as inputs, which can be calibrated from standard tests. Some discrepancies between the predictions of the isotropic model and experiments are observed under low triaxiality loading conditions such as shear. A relatively simple modification of the crack initiation criterion accounting for the effect of void shape changes is shown to improve the model predictions at low triaxialities.

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