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# The scatter in ductile fracture: Effect of material microstructure

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## Abstract

Ductile fracture by nucleation, growth and coalescence of voids is one of the main types of fracture in metal alloys. Typically, the simulation of ductile fracture is based on homogenised models that assume scale separation where the grain size is very small compared to the specimen size, thus neglecting the effect of microstructure at this scale. However, the current trend towards miniaturisation of specimens and devices (e.g. heat exchangers (1)) means that these conditions no longer apply, as in these cases the grain size is comparable to that of the structure. In fact, it has been shown both experimentally and numerically (2, 3) that the microstructure of the material influences the fracture strain and stress, leading to a scattering of the ductile fracture properties. The objectives of this study are (1) to develop methods to quantitatively characterise the fracture property scatter associated with material microstructure both experimentally and numerically, and (2) to predict ductile fracture properties as a function of sample size. The experimental characterisation is based on two model materials: a 6061 aluminium and a 316L steel obtained by additive manufacturing (WAAM). An optimised heat treatment was applied to both materials to obtain a large grain size and a high density of transgranular inclusions promoting ductile fracture. Tensile tests were performed on homothetically notched flat specimens to quantify fracture stresses and strains as a function of specimen size. The average fracture strains increase with decreasing specimen size (number of grains at the notch) and with increasing dispersion, allowing an estimation of the typical number of grains required in the notch region above which deterministic behaviour is recovered. The experimental results are rationalised by performing numerical simulations taking into account the microstructure and using homogenised constitutive equations for porous single crystals. From a statistical point of view, the simulations, once calibrated, allow to recover the experimental trends for the effect of the sample size on the fracture properties. Finally, from a deterministic point of view, the comparison between the numerical results obtained by considering the exact microstructure of a given sample obtained by Diffraction Contrast Tomography (DCT) and the experimental results is discussed.

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(2) A. Pineau, Modelling of scatter and size effects in ductile and brittle fracture, Transactions of the 14th International Conference on Structural Mechanics in Reactor Technology

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