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Simulation of the Kitagawa-Takahashi diagram using a probabilistic approach for cast Al-Si alloys under different multiaxial loads

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Abstract

This article describes a microstructural-based high cycle fatigue strength modelling approach applied to different cast Al-Si alloys used in an automotive context. Thank to different casting processes (gravity die casting and lost foam casting), associated with several heat treatment (T7 and Hot Isostatic Pressing-HIP), three alloys with very different microstructures have been obtained. In a vast experimental campaign undertaken to investigate the fatigue damage mechanisms governing these alloys under different multiaxial loading conditions, it was shown that the principal crack initiation mechanisms for the porosity-free alloy are either the formation of persistent slip bands (PSB) or the rupture and/or debonding of eutectic particles. For the porosity-containing alloys, the fatigue damage is always controlled by crack growth from pores. In order to take into account these fatigue damage mechanisms, a probabilistic model using a combination of the Dang Van and a modified LEFM criteria is proposed. The modified LEFM criterion is able to take into account the influence of the grain size on the threshold of the stress intensity factor.

It is shown that for the porosity-free alloy, the predictions are good for combined tension-torsion loads with $R = -1$. However, because the crack initiation mechanisms are not the same depending on the hydrostatic stress, the predictions are non-conservative for the uniaxial and equibiaxial tension loads with $R = 0.1$. For the porosity-containing alloys, the predictions are very good for the uniaxial, combined tension-torsion and equibiaxial tension loads with both $R = -1$ and $R = 0.1$. As observed experimentally, the proposed model can also predict a more pronounced