A Probabilistic Multiaxial Two-Scale Model for Cast Materials in High Cycle Fatigue Regime: application to marine propellers

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Cast process is widely used in industry because it allows producing even huge structures with complex shapes (e.g. marine propellers) in a few operations. However, cast materials contain initial defects such as shrinkage pores which appear during the solidification of the melt alloy. Industrial feedback shows clearly that these defects are harmful regarding fatigue resistance. Moreover, some authors have demonstrated that they are the cradle of microplasticity phenomena which lead to the initiation of a fatal fatigue crack.

In the framework proposed here, it is assumed that fatigue failure is due to microplasticity activity which induces a dissipative energy. To describe this phenomenon, we propose here a multiaxial and probabilistic two scale model which takes into account cast defects by indirect approach, i.e. without describing size and shape of pores. We consider ¿sites¿ where microplasticity takes place, randomly distributed in an elastic matrix. As cast materials contain initial porosity, their mechanical behavior depends on hydrostatic pressure. So, we propose that microplasticity activation criterion takes into consideration first stress invariant as it is described in Berg`s elasto-plastic model. As microplasticity appears gradually, we suggest that the activation sites scenario follows a Poisson Point Process.

This model has been implemented in a post-processing tool called "Cast". Validation of the entire framework is based, on the one hand, on predictions of S-N curves and, on the other hand, by comparisons between experimental results and numerical predictions of life duration of a marine propeller.

This study is applied to the case of a cast copper-aluminium alloy often used for casting marine propellers.