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Micromechanics of oxide inclusions in ferrous alloys: inclusion strength

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Non-metallic inclusions (NMI), and in particular oxide inclusions, are present in steels as a direct consequence of the steelmaking process. These small precipitates, which have many different morphologies, compositions, and structures, are largely known to affect the mechanical properties of steel products. While the relation between the steelmaking practice and the characteristics of oxide inclusions has received large attention, much remains to be learned about the local structure and properties of the oxides themselves and the influence they exert on properties of the steel in which they are contained. In this work, oxide inclusions of various compositions are produced by melting and deoxidizing high purity iron under a controlled atmosphere. The chemistry of the oxides is varied by selecting the amount and type of deoxidant agents, notably between silicon, calcium and aluminium. Local inclusion properties are measured by means of instrumented indentation and by in-situ micromechanical testing performed on individual inclusions. The latter is performed by milling, with a focused ion beam (FIB), inclusions partially exposed by selective dissolution of the matrix. This produces “C-shaped” bend test samples out of each single oxide particle that are tested in bending by imposing a compressive force. Coupling data with finite elements simulations, strength values are obtained for different inclusion compositions. Data reveal that spherical oxide inclusions in iron alloys break at stress values that approach the peak fracture strength of dry silica.

Keywords: inclusions, iron, steel, silica, strength

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