Probing the structure and mechanical properties of the graphite nodules in ductile cast irons via nano-indentation

Little is known today about the mechanical properties of the graphite nodules, despite the key influence these particles have on the performance of ductile cast irons. To address this issue, nano-indentation tests were performed on the cross-section of a nodule whose sub-surface morphology was characterized via 3D computed tomography. From the recorded load vs. penetration curves, the spatial variation of the maximum indenter penetration $h_{\text{max}}$ and of the reduced Young's modulus $E^*$ was determined. It was observed that the pattern of $h_{\text{max}}$ presents features which, statistically, cannot be explained with the experimental error. Conversely, they can be justified by a model which takes into account the geometrical interaction between the indenter and the local orientation of the graphite platelets forming the nodule. To the authors’ best knowledge, this result constitutes the first direct proof of a clear link between internal structure and mechanical properties of the nodules. The existence of a non-negligible mechanical anisotropy implies that the calculated mean value of $E^*$ can only be seen as indicative of a sort of “averaged” elastic stiffness. Caution should then be used when assessing the elastic response of the entire nodule just on the basis of this parameter, as complex anisotropic effects associated with the non-random orientation of the graphite platelets can be foreseen.

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