Fatigue crack propagation in ferritic ductile irons: is K a useful parameter?

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Introduction. Ductile cast irons (DCIs) are characterized by a wide range of mechanical properties, mainly depending on microstructural factors, as matrix microstructure (characterized by phases volume fraction, grains size and grains distribution), graphite nodules (characterized by size, shape, density and distribution) and defects presence (e.g., porosity, inclusions, etc.). Versatility and higher performances at lower cost if compared to steels with analogous performances are the main DCIs advantages.

In the last years, the role played by graphite nodules was deeply investigated by means of tensile and fatigue tests, performing scanning electron microscope (SEM) observations of specimens lateral surfaces during the tests ("in situ" tests). "Pure" ferritic matrix – graphite nodule debonding is only seldom observed and the main ferritic DCI damaging micromechanism consists in cracks nucleation and propagation in the graphite external shell coming from the reduced carbon solubility in γ phase during cooling process ("onion-like" mechanism). A second damaging micromechanism is sometimes observed together with the "onion-like" mechanism: cracks nucleation and propagation in graphite nodule center ("disgregation" mechanism). The importance of this damaging mechanism is dependent on the loading conditions and is probably influenced by the graphite nodule nucleation mechanism during solidification. Focusing ferritic matrix, damaging implies the emanation of slip lines corresponding to the nodule equator (lower stress values) and the nucleation and propagation of short cracks (higher stress values): final rupture is due to the linkage of cracked graphite nodules by microcracks, with the formation of larger cracks.

In this work, ferritic DCIs fatigue resistance is investigated considering both crack initiation process (by means of fatigue tests performed on tensile microspecimens) and fatigue crack propagation micromechanisms (by means of Compact Type specimens and according to ASTM E399 standard). On the basis of experimental results, and considering loading conditions and damaging micromechanisms, the applicability of ASTM E399 standard on the characterization of fatigue crack propagation resistance in ferritic DCIs is critically analyzed, mainly focusing the stress intensity factor amplitude role.