# Intermittent Plastic Flow and Microstructure Evolution During Low Cycle Fatigue at Cryogenic Temperatures

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Austenitic steels at cryogenic temperatures, subjected to cyclic loading within the plastic deformation regime, undergo processes governed by the low thermal activation of the crystal lattice [1]. Cyclic deformation leads to strain-induced martensitic transformation, resulting in material hardening. At the same time, at temperatures approaching absolute zero, intermittent plastic flow is observed, manifested as cyclic stress drops at constant total strain. Both mechanisms significantly affect the course of low-cycle fatigue, particularly crack initiation and propagation. On the one hand, the phase transformation leads to material hardening with increasing plastic deformation; on the other hand, intermittent plastic flow may accelerate crack initiation.

Experimental studies carried out over a wide range of cryogenic temperatures have shown that the failure process is largely controlled by microstructural evolution. With increasing number of loading cycles, an increase in force amplitude is observed in crack opening displacement-controlled tests, up to the point of crack initiation. Ahead of the notch tip cyclically opened in Mode I, regions of α' martensite form, which delay crack initiation. At 77 K, crack initiation occurs only after reaching a high volume fraction of martensitic phase, whereas at 4.2 K, under conditions of intermittent plastic flow, initiation occurs at a lower number of cycles and at a lower fraction of this phase. This indicates a detrimental effect of intermittent plastic flow on low-cycle fatigue resistance.

The mechanism of crack propagation also depends on temperature and the character of plastic flow. At liquid nitrogen temperature, crack propagation is continuous, whereas at liquid helium temperature it proceeds in a intermittent manner, correlated with the occurrence of serrations [2]. Despite these differences, fracture surfaces in both cases exhibit fully ductile characteristics, indicating the dominant role of the retained austenitic matrix in the fracture process. During crack propagation, phase transformation continues to occur, and the distribution of the martensitic phase exhibits a bimodal character. Ahead of the current crack tip, a gradient microstructure develops, in which the distribution of martensitic phase corresponds to the stress field described by the Irwin solution, with the maximum volume fraction of the secondary phase decreasing with increasing crack length.

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