77 K FATIGUE CRACK GROWTH RATE OF MODIFIED CF8M STAINLESS STEEL CASTINGS

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Introduction

The National Compact Stellerator Experiment (NCSX) under construction at PPPL has complex modular superconducting coils that are structurally supported by a modified CF8M cast steel. The life of the machine is fatigue limited, resulting in the need for fatigue crack growth rate measurements of the CF8M. Fatigue crack growth rate (FCGR) tests are conducted according to ASTM E647 to determine the Stage II (Paris Regime) crack growth. In the Paris regime (FCGR from about 10^{-5} mm/ cycle to 10^{-3} mm/cycle) the crack growth rate obeys a power law ; $da/dn = C*\Delta K^m$, where; da/dn = crack growth rate, ΔK = stress intensity factor range (Kmax-Kmin) and C, m = constants related to material, test temperature, etc.

Results and Discussion

The crack growth rates are analyzed in terms of the Paris law parameters and the fatigue cracks in the duplex microstructure follows preferential paths of least resistance. The castings have a dendritic microstructure that tends to be coarse and inhomogeneous in both composition and the phase distribution. The cast material has irregular crack growth behavior that is attributed to the macroscopic dendritic microstructure. The multiple tests allow the crack growth rate variability to be well documented FIGURE 1. The results show that a ΔK of 60 $MPa*m^{0.5}$ produces da/dn's that range from $2x10^{-4}$ to $5x10^{-4}$ mm/cycle. The erratic crack growth rate behavior is attributed to preferential path crack growth caused by the orientation differences between different dendrites in the microstructure. The boundaries between the branches of the dendrites can be weaker than the dendrite core thus the crack tries to stay in the matrix material. The preferential crack path was also observed in the prior low temperature FCGR research on CF8M [1]. FIGURE 2 is high magnification SEM photograph of the fatigue fracture surface that exhibits fatigue striations within the dendritic grains. Close examination reveals that there are small steps (or striations) within the larger striations which probably represent the crack growth per cycle.The large shelf running horizontalyl across the figure is a dendrite branch which impedes growth in that direction. The range of crack growth rates that could be expected has been documented with error bars that bracket the relatively large quantity of tests (15) that were performed.

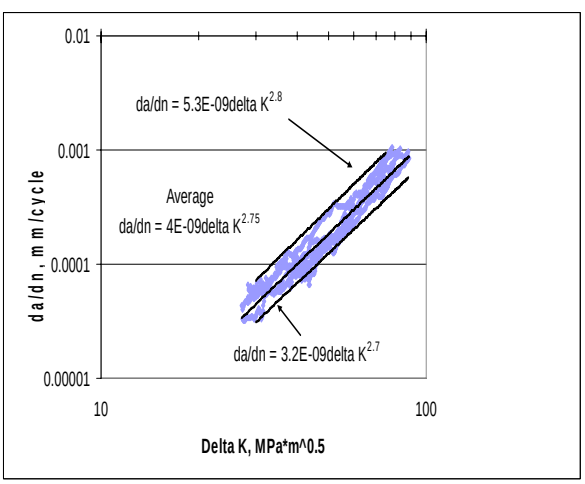

FIGURE 1. 77 K FCGR results .

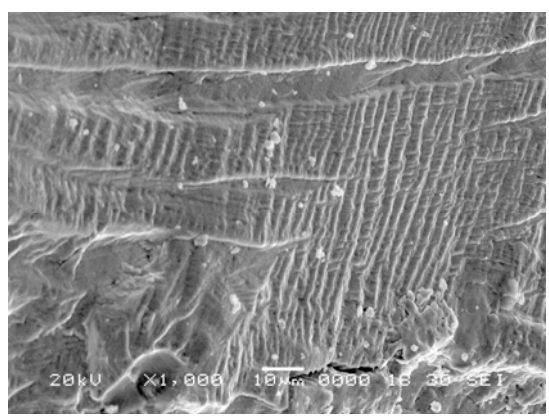

FIGURE 2. SEM photo of fatigue striation in the fracture surface.

References

[1] Purtscher P.T., et al. "Fatigue Crack Growth of Duplex Stainless Steel Castings at 4 K" Materials Studies for Magnetic Fusion Energy Applications, NBS IR 84-3000, 1984 Report to Department of Energy.