

A Fracture Mechanics Evaluation on the Circumferentially Cracked Turbo Generator Shafts

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Abstract

Turbo generator shafts are often subjected to complex dynamic torsional loadings, resulting in generation and propagation of circumferential cracks. Mode III fatigue crack growth generally results in a fracture surface consisting of peak and valleys, resembling a sawtooth. The fracture surface roughness depends on the material microstructure, the material yield strength, and the applied cyclic torque amplitude. This crack pattern can severely affect the vibration characteristics of the shafts. Evaluating the effect of the circumferential cracks on the vibrational characteristics and torsional dynamic response of these turbo-generator shafts is important, not only to assure the structural integrity, but also for evaluating the potential of the vibration-based monitoring of the turbo-generator shafts as a non-destructive evaluation technique. The accurate evaluation of the torsional dynamic response of these structures entails considering the local sources of energy loss in the crack vicinity. The two most common sources of the energy loss are the local energy loss due to the plasticity at the crack tip and frictional energy loss due to interaction of mutual crack surfaces. A theoretical procedure for evaluating the values of the system loss factors corresponding to these sources of energy loss is presented. Furthermore, the local flexibility is obtained by evaluating the resistance of the crack section of the shaft to the rotational displacement. The shaft material is assumed to be elastic perfectly plastic. The effects of the applied Mode III stress intensity factor and the crack surface pattern parameters on the energy loss due to the friction and the energy loss due to the plasticity at the crack tip are investigated. The results show that depending on the amplitude of the applied Mode III stress intensity factor, one of these energy losses may dominate the total energy loss in

the circumferentially cracked shaft. The results further indicated that the torsional dynamic response of the turbo-generator shaft is significantly affected by these two sources of the local energy loss.

Keyword : Turbo-generator shafts, Circumferential crack, Transient torsional loading, Crack surface interaction, Crack tip plasticity, Torsional dynamic response, Local energy loss