A Fractographic Study of Fatigue Crack Propagation

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A fractographic study was carried out on the fatigue crack propagation process with a special reference to correlation between fracture surface topography and macroscopic variables such as crack propagation rate, stress or strain intensity factor and crack tip opening displacement.

Test materials were aluminium alloys (2017-T4, 5052-0, 7075-T6) and carbon steels (0,38 % C, 0,15 % C annealed). In the case of aluminum alloys, well defined regular striations were observed in the range of crack growth rate from 0,05 -- 10 microns per cycle, above which dimple patterns were predominant and below which striation-like patterns of irregular appearance and/or brittle river-like patterns covered most part depending on materials and crack growth rate. Spacing of the regular striations agreed fairly well with macroscopic crack growth rate. In the case of the carbon steel, irregular striation-like patterns occupied major part of the fracture surface. However, careful examinations revealed that there were regular striations also in these cases, although the frequency of their appearance was much less. Their spacing also about the same as the macroscopic rate. The range of crack growth rate where they appeared was 0,05 -- 1 microns per cycle. A better correlation was obtained between striation spacing and stress intensity factor K when K/σ_B (σ_B: tensile strength) was used rather than K/E (E: elastic modulus).
Effect of stress change on crack growth rate was also studied by means of striations spacing measurements. A retardation or an acceleration of crack growth rate was observed after stress decrease or increase,

respectively, in the case of repeated tension, while there was no or little effect of stress change in the case of alternating tension-compression. These results could be accounted for neither by change of stress intensity nor by change of crack tip opening displacement, but by the residual compressive stress at the crack tip of such magnitude that it changes stress state there from repeated tension to alternating tension-compression. Existence of the residual stress was suggested also by the crack closure in the case of repeated tension. The distance within which the appreciable retardation appeared after stress decrease was about the same as the plastic zone size ahead of the crack tip as determined by micro-hardness measurements. The hardening itself was not large enough to account for the retardation.