ON THE MECHANISM OF CYCLIC CRACK PROPAGATION IN AA2024-T3 ALLOY

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Background info

To improve predictive capabilities, the effect of cyclic loading on the microscopic mechanisms of crack tip formation and its closure should be thoroughly understood.

To this aim, existing literature proposed various models to explain the development of crack tip profiles and consequently the formation of fracture surface features.

Disagreements among these models exists and needs to be addressed. Models built on experimental evidences, collected from carefully designed experiments, are needed.

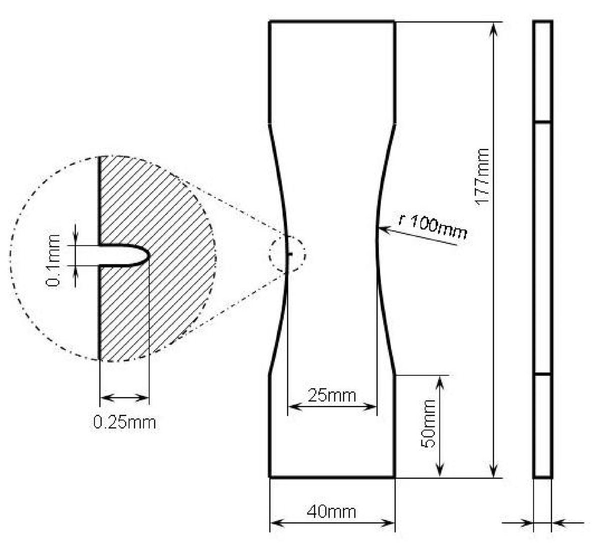
Aim of the study

The aim of this study is to improve the understanding of the mechanisms governing the growth of fatigue cracks at cycle-by-cycle level.

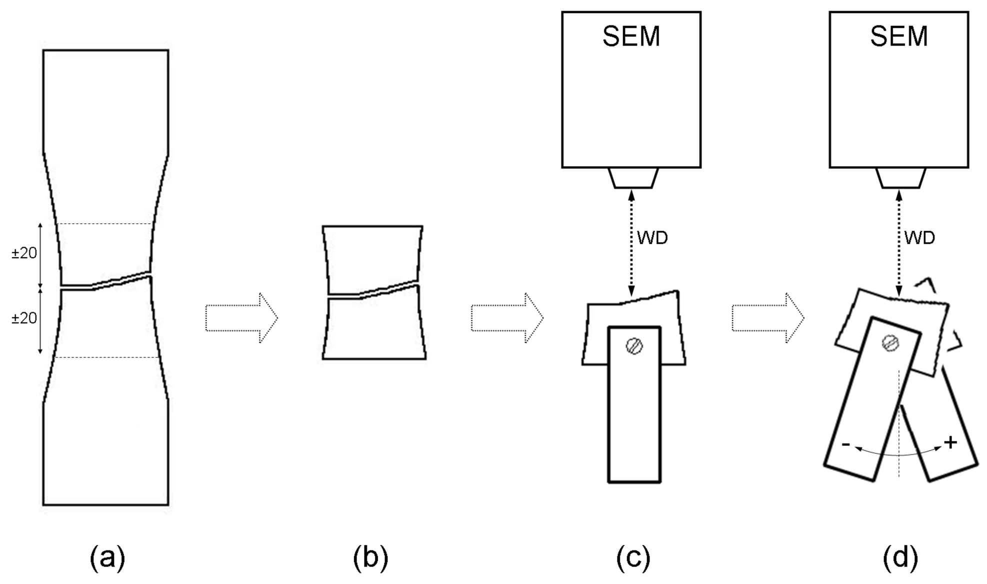
A fractographic study was performed in order to characterize the occurrence of typical surface features. The geometrical changes, occurring at the very crack tips during the application of tensile and compression load excursions, were also studied by employing so called "freezing" load sequences.

The obtained information led to new insights captured in a novel mechanistic model.

Methodology

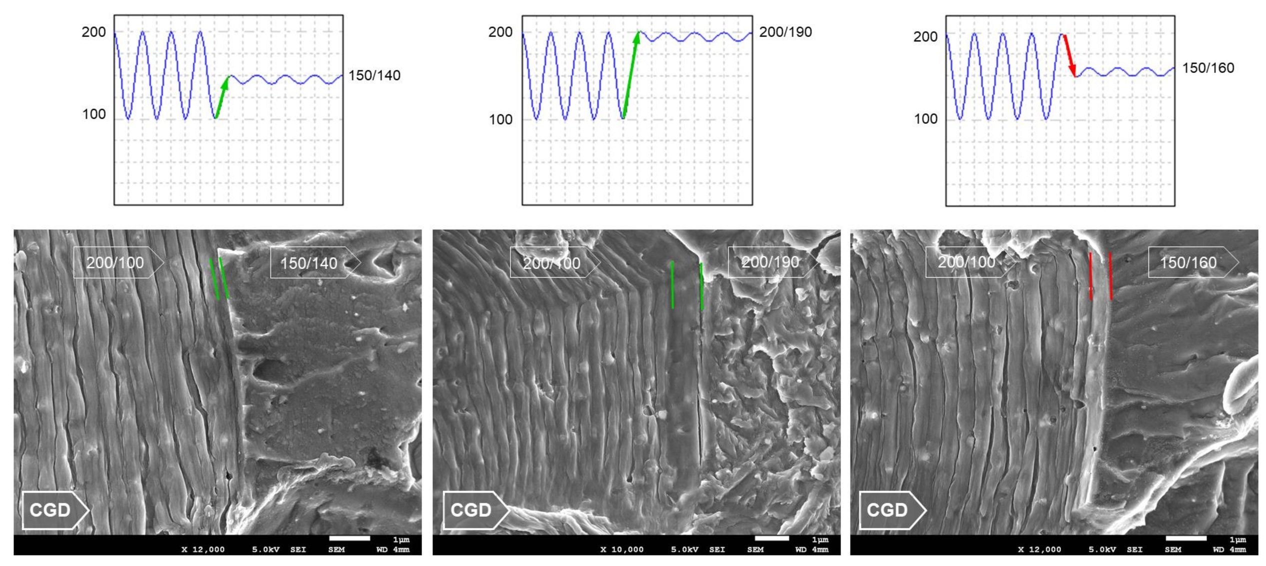


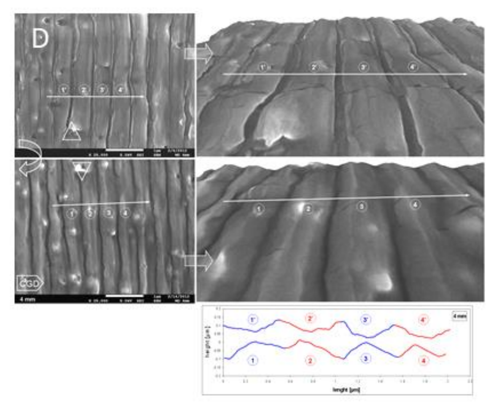
Geometry of the specimen used in the testing program.



Procedure for specimen preparation for (c) fractographic analysis and for (d) stereo-fractographic analysis.

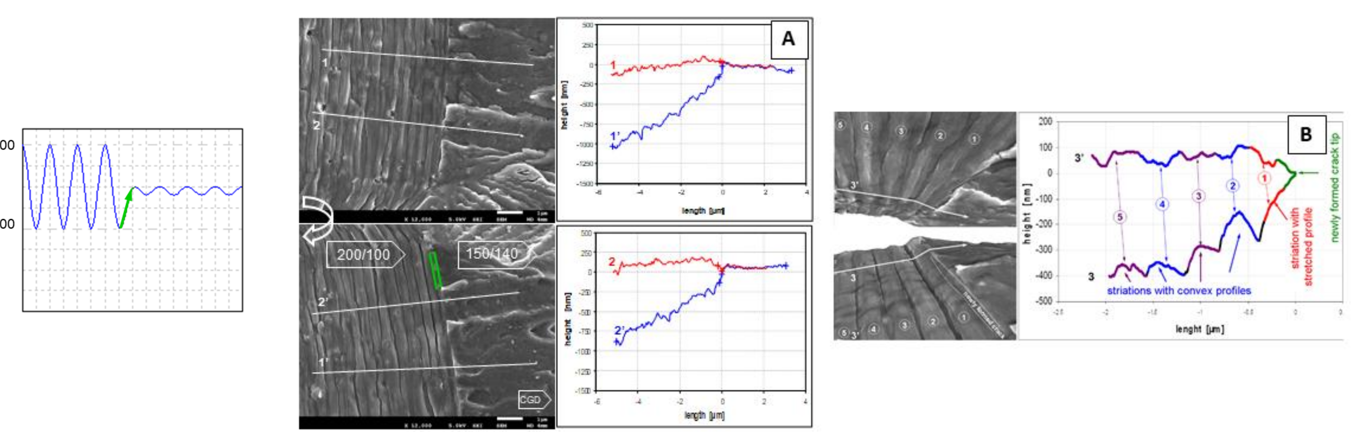
Loading sequences used to produce the "frozen" fracture surface features.



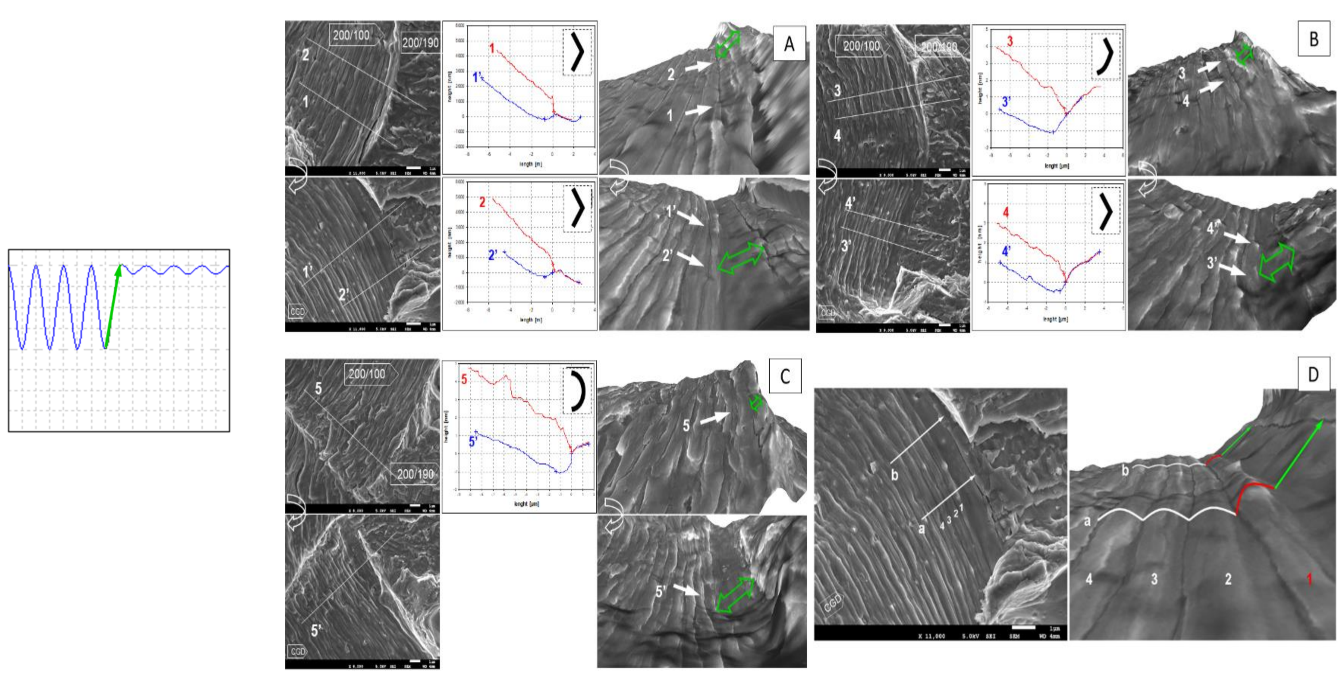


Typical CA surface striation appearance and profiles.

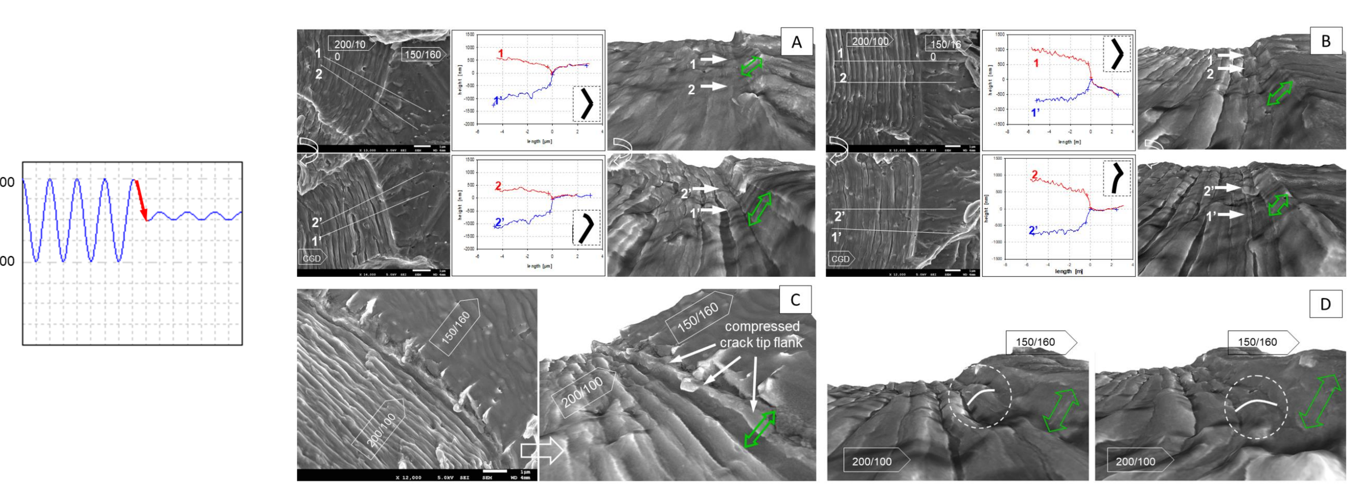
Observations - Model - Conclusions



(A) Mating fracture surface appearances and selected surface profile pairs at loading 100→150MPa. (B) Detail of mating surface striations joined at apparent crack tip.

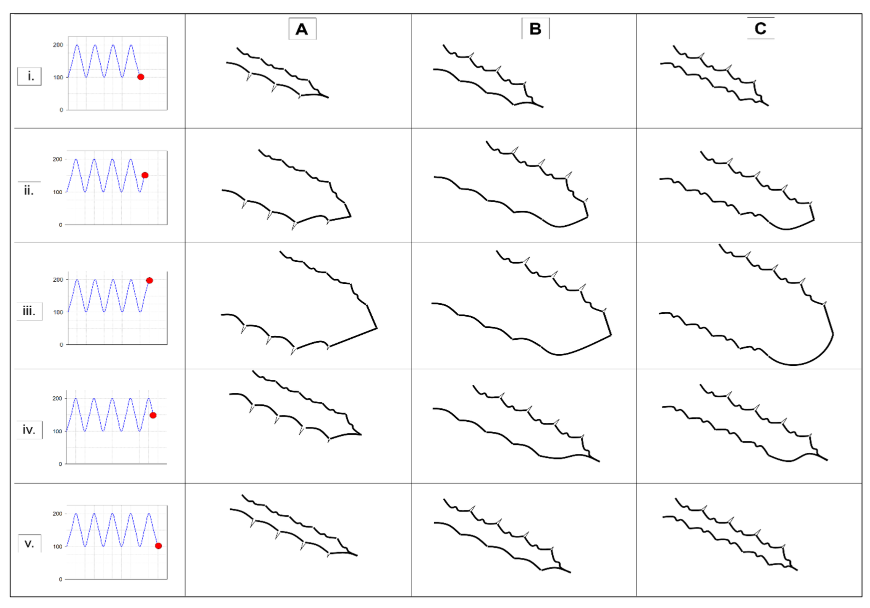


(A-C) Mating fracture surface appearances and selected surface profile pairs at loading 100→200MPa. (D) Detail of surface ridge - crack tip flank and out of plane (stretched) surface striations in the wake of crack tip.

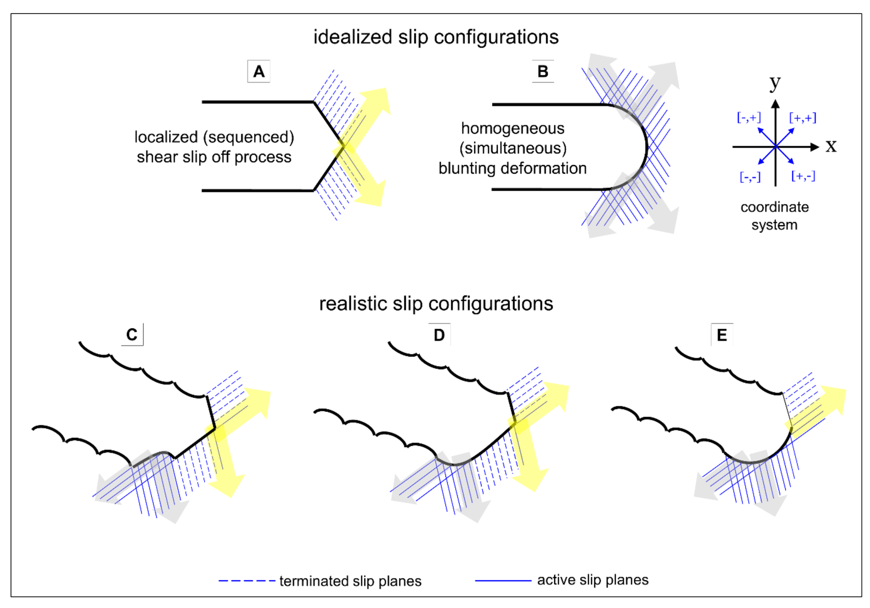


(A-B) Mating fracture surface appearances and selected surface profile pairs at loading 200→150MPa. (C-D) Detail of surface ridge - crack tip flank and partially deformed surface striations in the wake of crack tip.

Proposed mechanistic model for crack growth via (A) sharp V-shaped profile; (B) partially sharp V-shaped/circular crack tip profile and (C) near circular crack tip profiles.



Crack tip profiles with (A) localized shear slip process; (B) homogeneous blunting; (C-E) combined localized shear and homogeneous blunting process.



1. It could be concluded that fatigue cracks grow assuming various tip profiles and associated plastic deformation characteristics, along different crack depths and ranges of SIFs. In particular:
   - at crack depths (<2 mm), the crack tip grows maintaining predominantly symmetric, V-shaped profile.
   - at slightly increased crack depths (2-4 mm), the crack tip grows maintaining several, distinctly different, profiles: asymmetric, V-shaped profile; asymmetric, partially plastically distorted V-shaped profile; profile with apparent blunt, asymmetric U-shaped profile.
   - at further crack depths (>5 mm), the crack tip is assumed to grow maintaining predominantly asymmetric, blunt, U-shaped profile.

The formation of asymmetrically shaped crack tip profiles is associated with the tilting of the local fracture planes with respect to the far field load.

2. The mechanism responsible for the formation of surface striations is the more complex product of a synergic action between INTRINSIC and EXTRINSIC mechanisms.
   - the cyclic deformation of surface striations positioned in the wake of active crack tip was observed experimentally.
   - this process has direct effect on the formation of striations with convex profiles and characteristic rippled textures.
   - the same process has also direct effect on the formation of surface cracks and surface fissures.

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