Creep-fatigue interactions in pure Tantalum under constant and variable amplitude

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Due to its specific mechanical properties, tantalum is often used in strength-demanding military applications. High cycle fatigue (HCF) behaviour of pure tantalum, however, has been rarely reported and the mechanisms at stake to account for deformation under cyclic loadings are still badly understood [1-2]. This presentation aims at better understanding the HCF damage mechanisms encountered in pure tantalum under such loadings.

HCF loadings at various frequencies were performed in tension at room temperature on commercially-pure tantalum. Mean stress effects and frequency effects were investigated in the aim of clarifying the interaction between fatigue and creep.

For symmetrical loadings (R=-1, i.e. under zero mean stress), fracture mechanisms were observed to vary from intergranular to transgranular when the maximum stress was decreased. This transition can be observed in Fig. 1, and the transition stress was estimated.

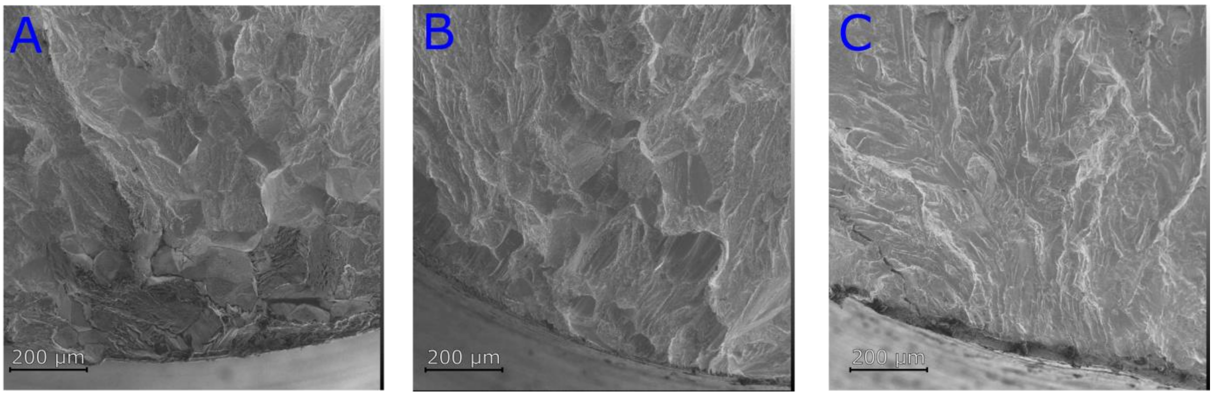

Figure 1 : *Fracture surfaces of three tantalum specimens loaded in fatigue under symmetrical tension (R=-1). With decreasing maximum stresses, the crack initiation mode is varying from intergranular (A) to transgranular (C).*

For non-symmetrical loadings (R>0, with sufficiently large mean stress), a transition was also observed from extensive necking to intergranular initiation, as shown in Fig. 2. Important creep activation was deduced from the presence of necking. This prevalence of creep at room temperature was actually confirmed by two other phenomena:

a) The large influence of the frequency on fatigue life, as shown in Fig. 3(a), indicating time-dependent damage.
b) Important creep deformation during room-temperature creep tests, cf. Fig. 3(b).

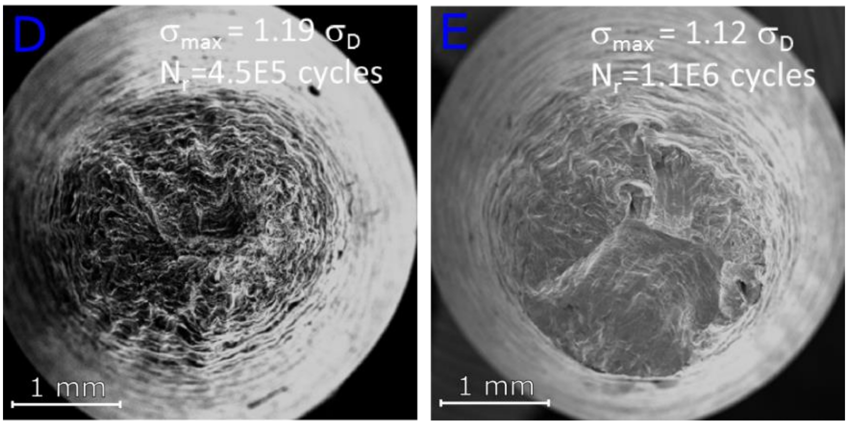

Figure 2 : *Fracture surfaces of two tantalum specimens loaded in fatigue under non-symmetrical tension (same $\sigma_{mean} > 0$). With decreasing maximum stresses, extensive necking (D) is converted to intergranular initiation (E).*

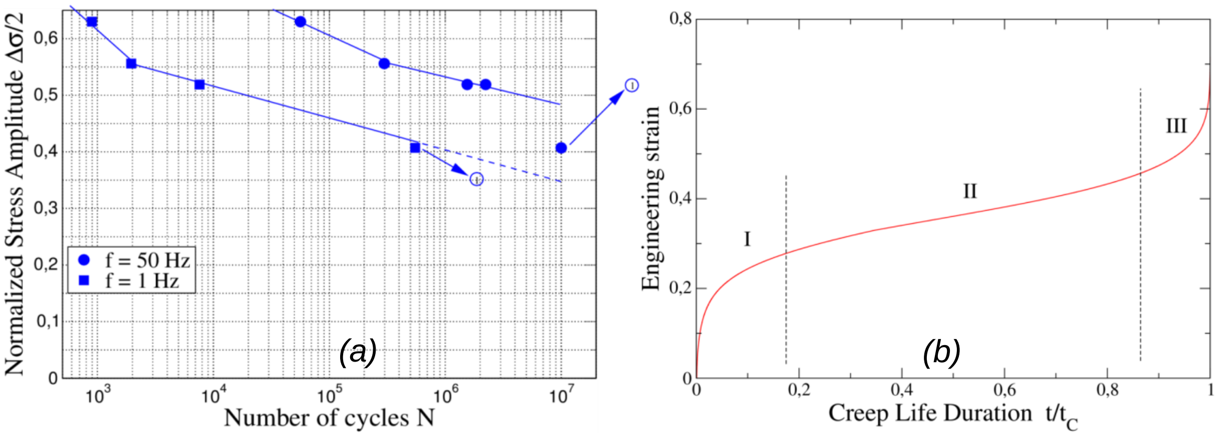

Figure 3 : *(a) S-N curves demonstrating a drop in life duration when the fatigue tests frequency was decreased from 50 Hz to 1 Hz.*
(b) Creep deformation measured during creep testing at room temperature.

Finally, complex sequential loadings, representative of in-service loadings, were applied to pure tantalum specimens. The contribution of each loading sequence to the overall damage was quantified. It was shown that linear cumulative damage rules (analogous to Miner's law to account for fatigue damage and for creep damage) failed to predict life duration of pure tantalum. The ONERA model [3-4], which specifically accounts for creep-fatigue interactions, granted better results. However, it is important to notice that this model uses engineering stresses as input, assuming that the specimen cross-section does not evolve drastically during fatigue/creep deformation. Such hypothesis needs to be revisited as the true stress seems a more realistic input to account for creep damage.

References

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