# Mode I fatigue-fracture behaviour of adhesives subjected to single and periodic overloads

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## Introduction

Most bonded structures experience variable amplitude fatigue (VAF) loading conditions, where overloading is included. Contrary to other materials, where crack growth retardation has been observed, for adhesives, only acceleration effects following overloads have been reported [1-3]. In these studies, brittle adhesives were considered, and thus plasticity induced phenomena, that are associated with retardation, are negligible. Given the uncertainty associated with the influence of overloads, mainly in ductile adhesives, and the lack of studies on VAF of adhesives, it is essential, to evaluate experimentally the influence of overloads so that these can be included in fatigue life estimation procedures.

## Experimental methodology

Double-cantilever beam (DCB) specimen, bonded by a ductile methacrylate adhesive, were used in this study. Three different loading spectra, as schematically represented in Figure 1 were considered: Constant Amplitude (CA), Single Overload (SO) and Periodic Overload (PO). For the SO spectra, distinct number of cycles to overload ($N_{SOL}$) and overload magnitude ($F_{OL}$) were contemplated. Regarding the PO spectra, two number of cycles between overloads ($N_{POL}$) were used.

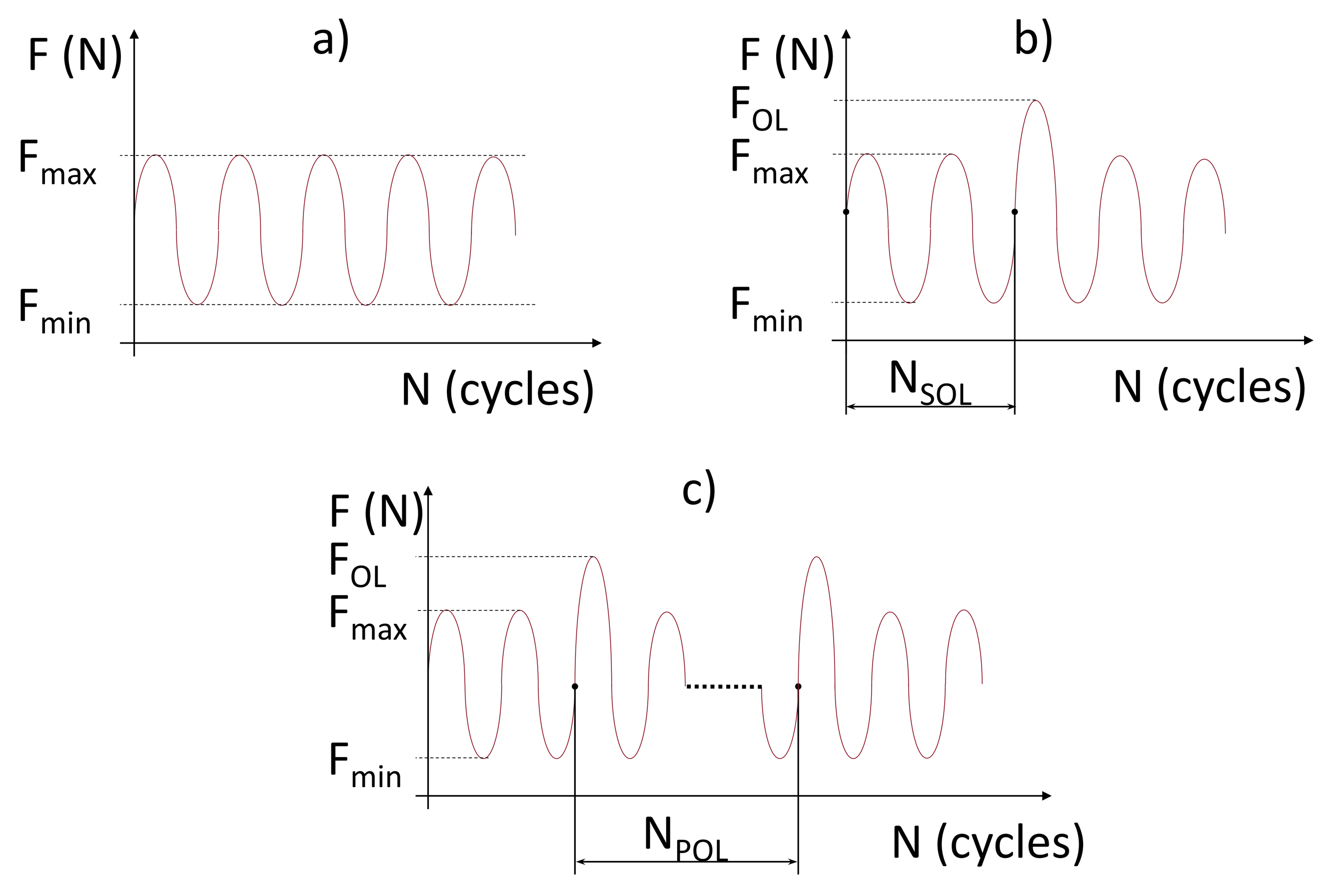


Figure 1 – Considered loading spectra: a) CA; b) SO; C) PO.

## Experimental results

### Total fatigue life

The fatigue life for all tested conditions is shown in Figure 2. It is shown in Figure 2a that, SOs can increase the fatigue life when compared to the CA condition. Up to an $N_{sol}$=5500, this increase is greater for higher $N_{sol}$. Such behaviour is associated to the formation of a higher plastic region ahead of the crack tip, that resists against crack propagation. However, if applied later, the overload causes premature failure as the strength of the joint is reduced due to fatigue damage.

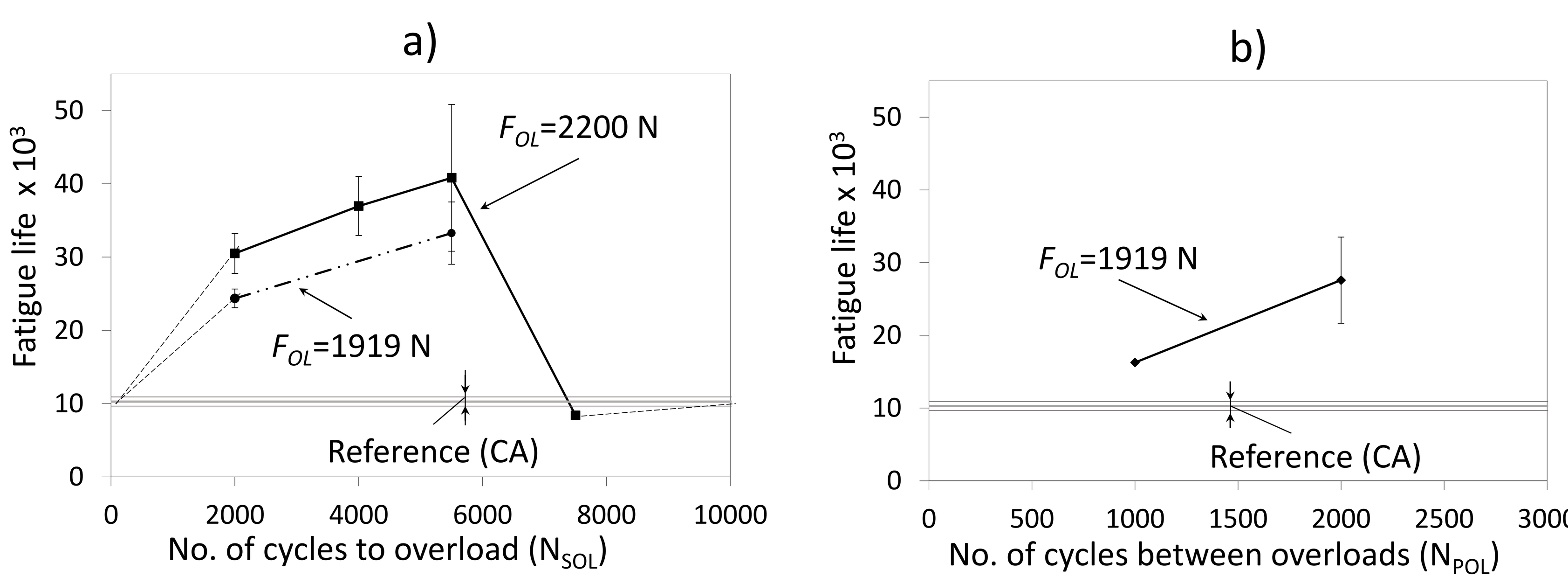


Figure 2 – Total fatigue life results: a) CA vs SO; b) CA vs PO.

For PO, Figure 2b, a less significant increase in fatigue life is observed, being almost negligible for the lowest $N_{POL}$. This shows that very frequent overloads can have a negative impact, mostly due to its nefarious effect that in later stages.

## Acknowledgements

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### Fatigue Crack Growth (FCG) curves

FCG curves were obtained using the compliance-based beam method, Figure 3. These, relate the FCG rate (*da/dN*) with the ratio between the maximum energy release rate and the mode I fracture energy ($G_{max}/G_{IC}$) . Figure 3a shows the FCG curve for CA. It is characterized by 4 different region. In region I, there is a decrease in the FCG rate that could be related to the precracking procedure, the mechanism of which is illustrated in Figure 3b. Region II is responsible for a large portion of the fatigue life, with the lowest values of *da/dN*. Region III presents a stable crack propagation phase, while region IV corresponds to a rapid crack growth.

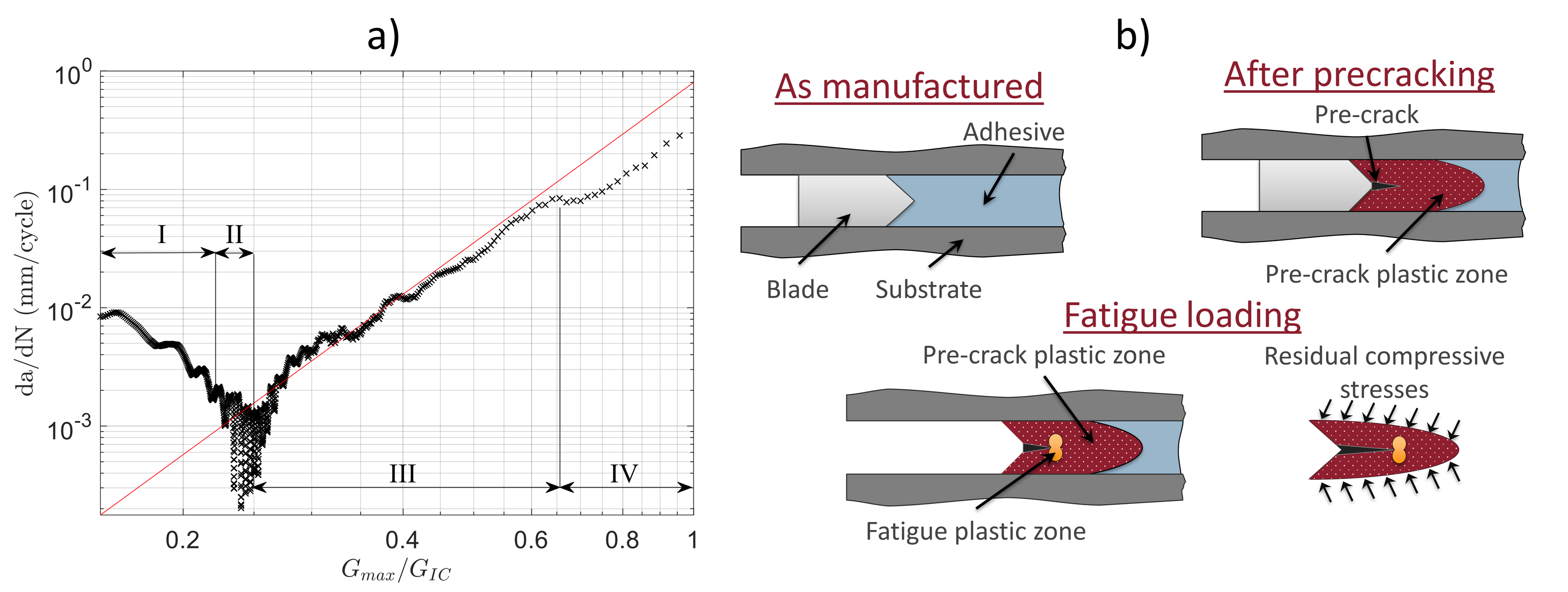


Figure 3 – a) CA FCG curves; b) Illustration of the mechanism in region I.

Regarding the SO condition, Figure 4a, after the application of an overload, a sudden increase in fatigue crack growth rate is observed. However, after a certain number of cycles, the *da/dN* decreases and reaches a minimum value (lower than under CA). Furthermore, the number of cycles spent in this low *da/dN* region is higher. This is due to the extension of the plastically deformed region ahead of the crack tip, that induces residual compressive stresses and resist against crack propagation. Eventually, the crack grows out of this region, and then, the FCG curve assumes a similar shape to the one for CA.

For PO, Figure 4b, it is shown that every overload causes an increase in $G_{max}$, being more pronounced for later stages of the fatigue life, which is associated to the increase in displacement caused by sudden crack propagation. Moreover, the lowest values of *da/dN* are higher than for SO, showing that the maximum retardation of the overload is not achieved if applied repeatedly.

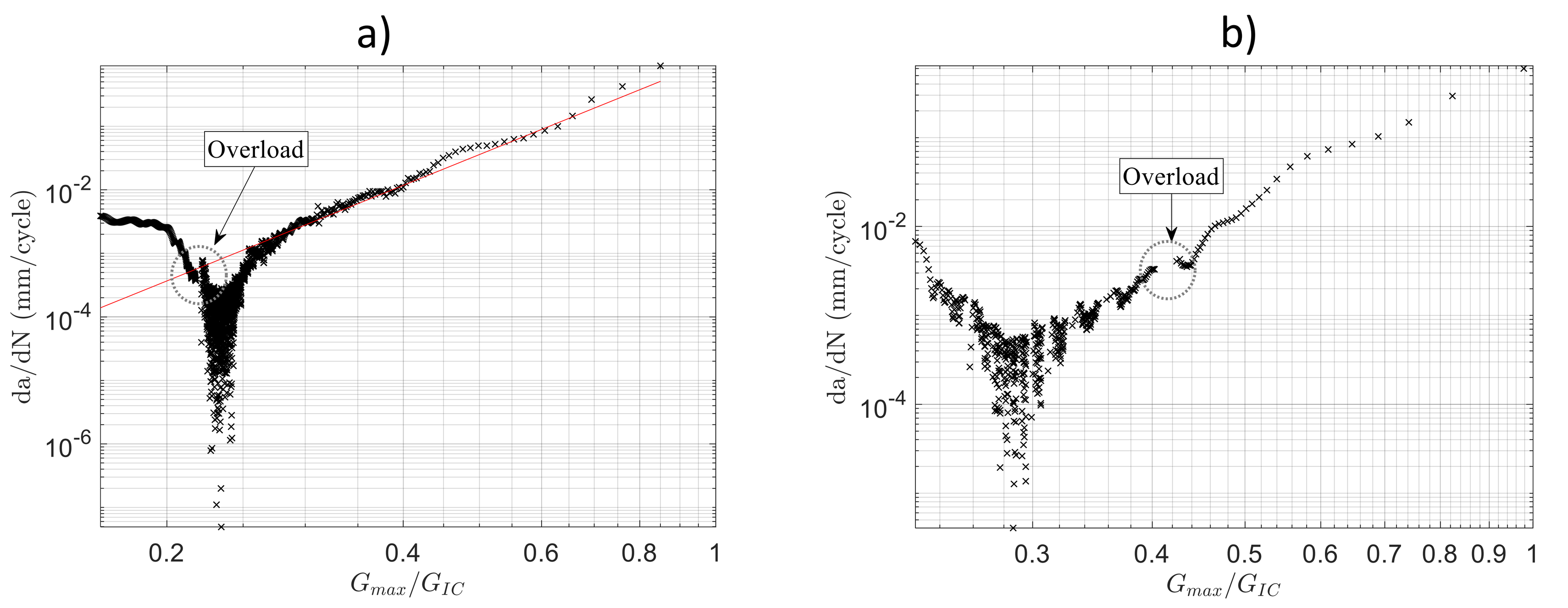


Figure 3 – FCG curves: a) SO; b) PO.

## Conclusions

Overloads can significantly increase the total fatigue life of bonded joints. This increase can go up to four times when compared to CA, which is associated with the development of plasticity induced phenomena following an overload. However, if applied at later stages, it can have a nefarious effect and quicken the failure. For the PO spectra, a moderate increase in the total fatigue life is observed for two main reasons: the periodic repetition does not allow the maximum retardation to be achieved and the damaging effect of overloads applied after a certain number of cycles.

## References


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