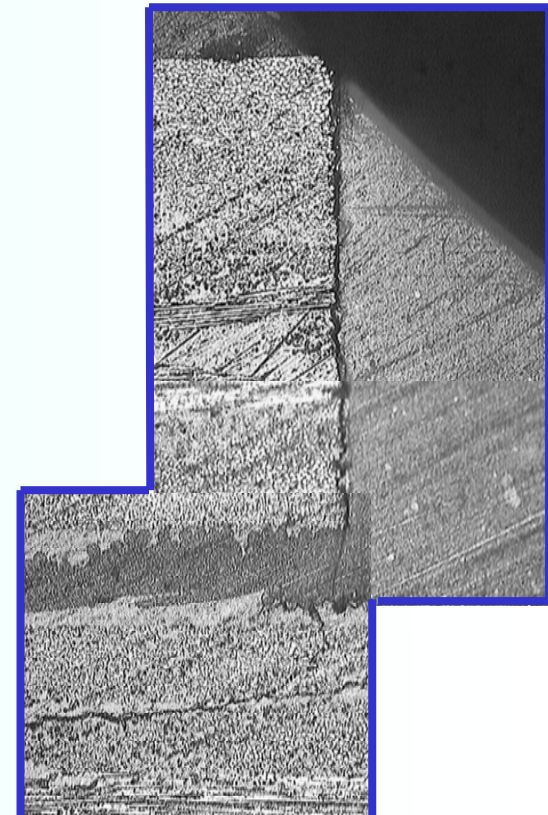
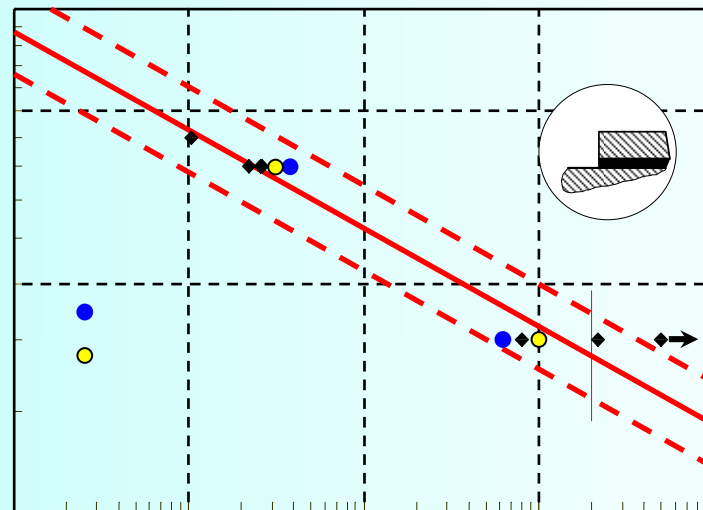
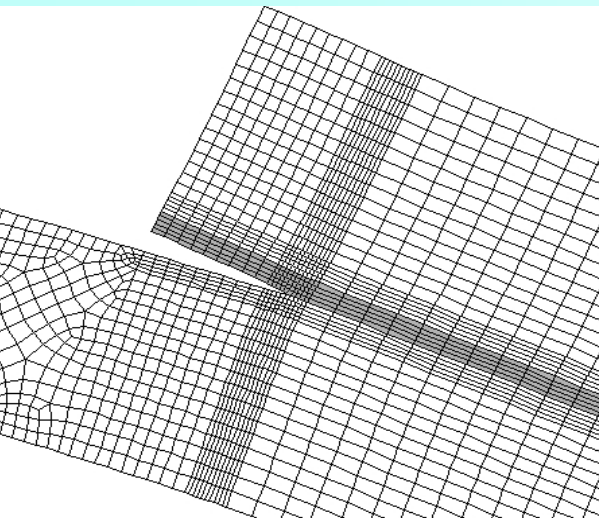


Gruppo di lavoro AIAS Tecniche di Giunzione
Vicenza 27-28 Marzo 2008

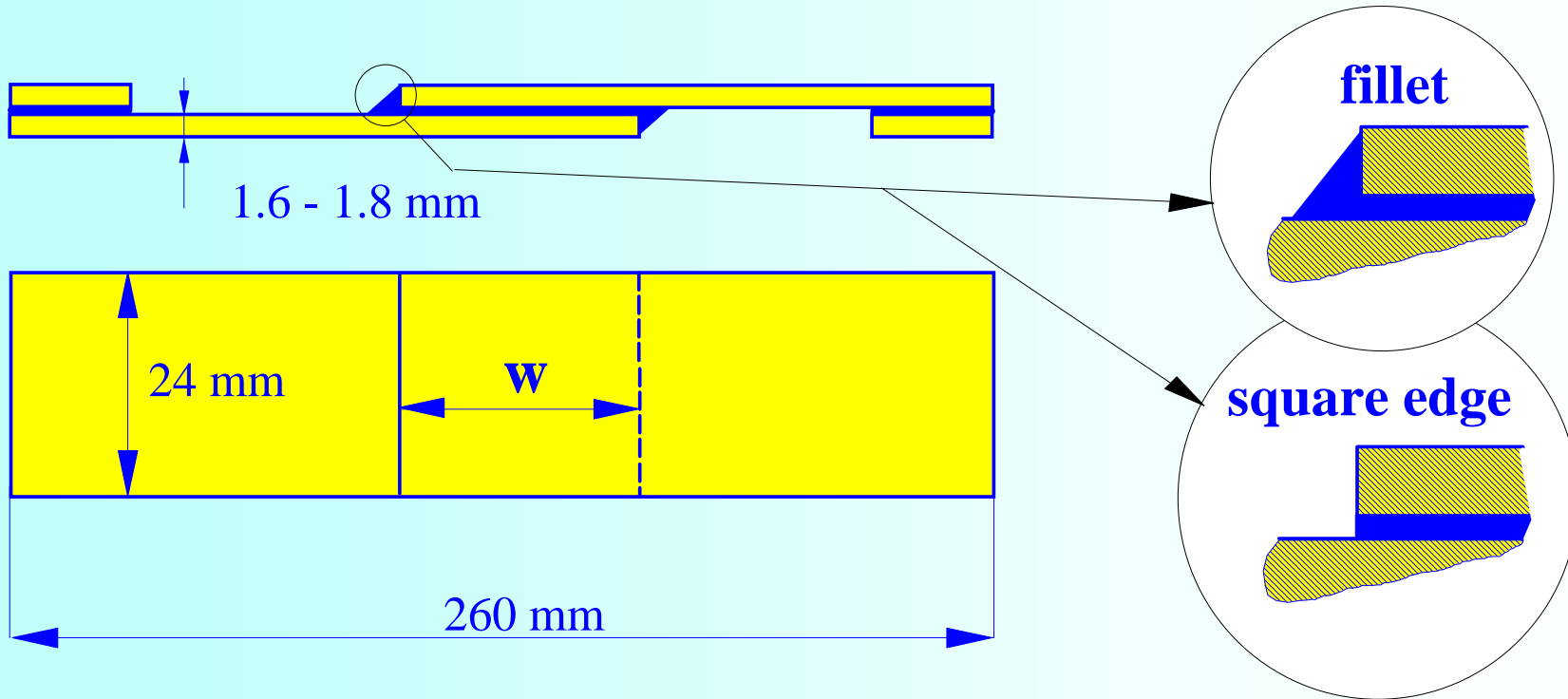
MODELLING THE FATIGUE BEHAVIOUR OF BONDED JOINTS IN COMPOSITE MATERIALS

M. Quaresimin,

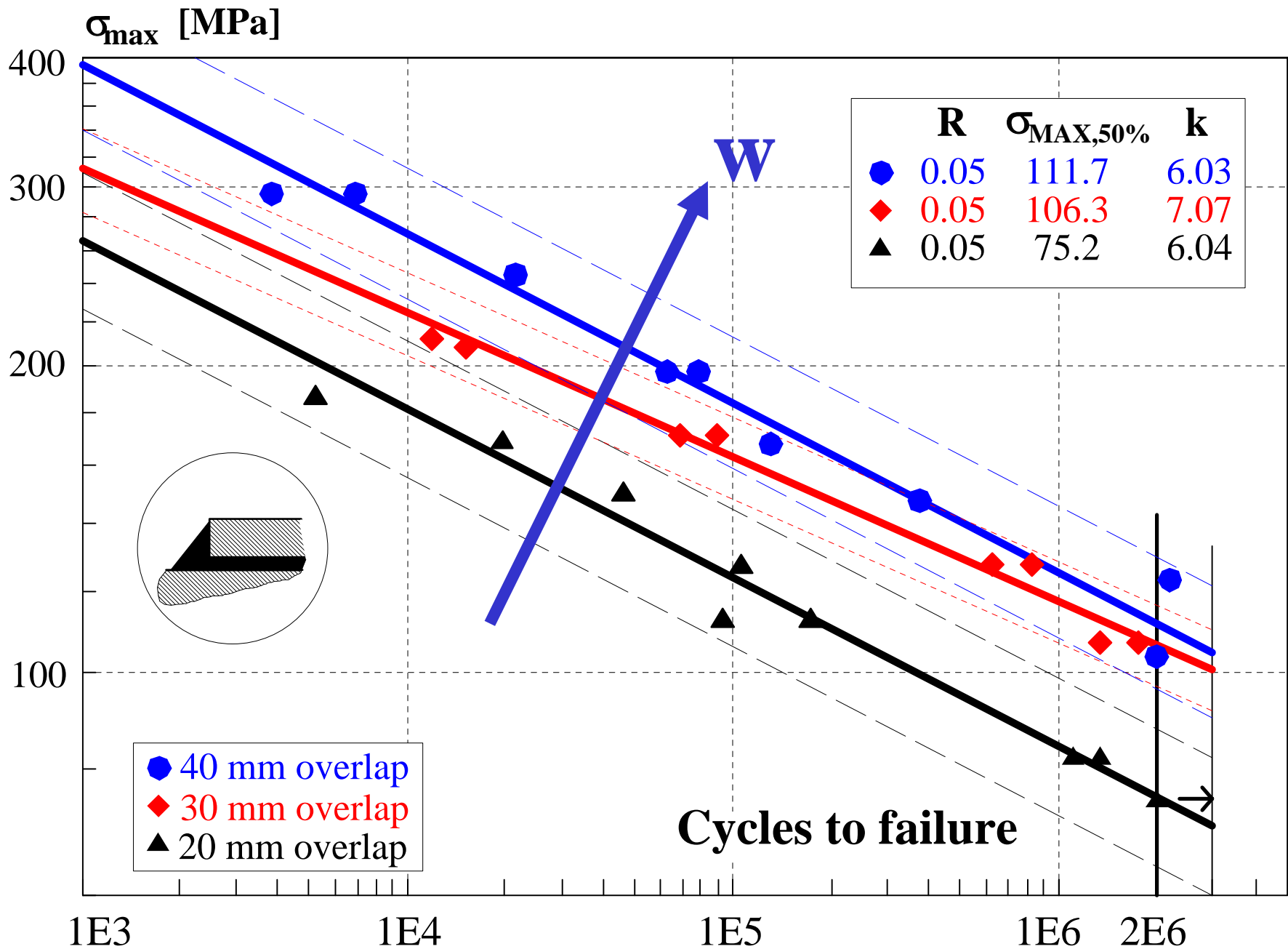
*Department of Management and Engineering
University of Padova*



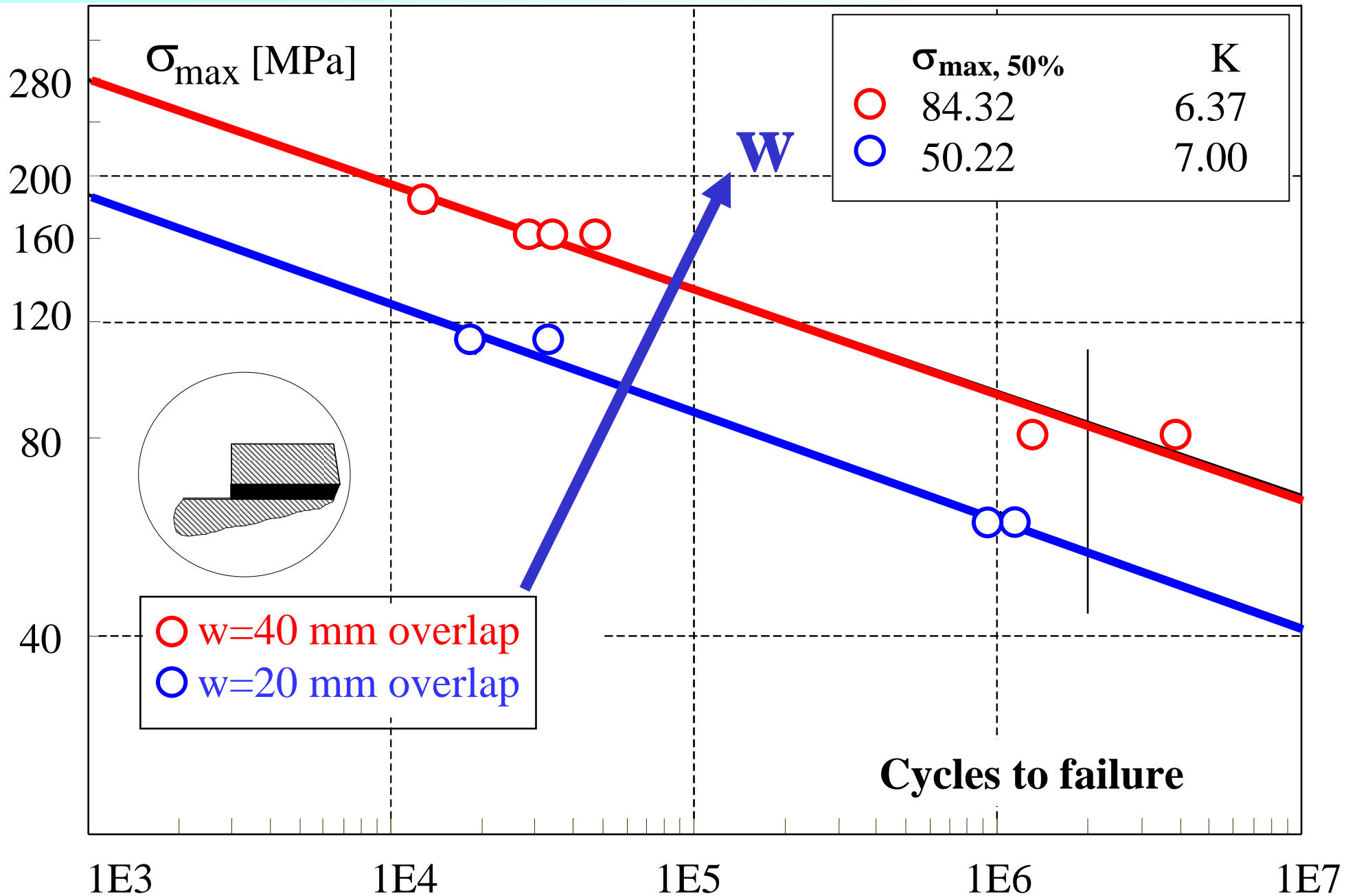
Bonded joints in composite material



Fatigue curves for $[0]_6$ joints with fillet

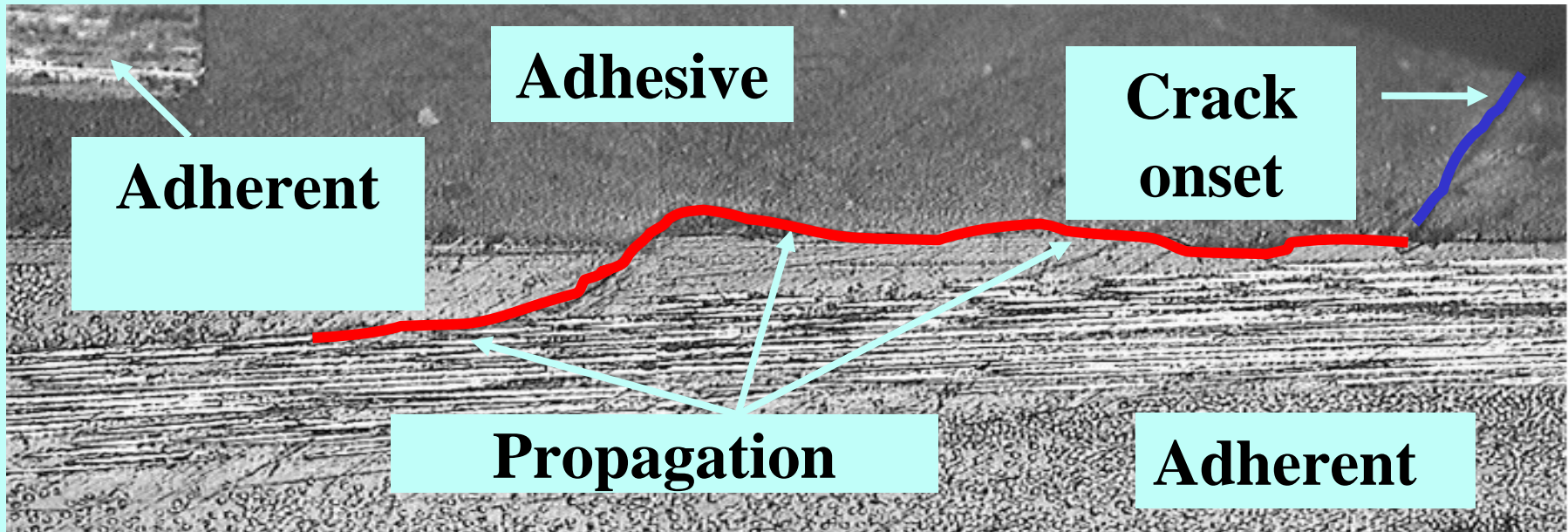
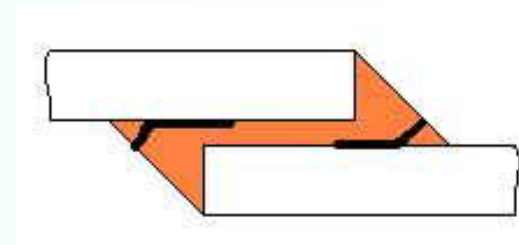


Fatigue curves for $[0]_6$ joints with S.E. corner



Fatigue damage evolution

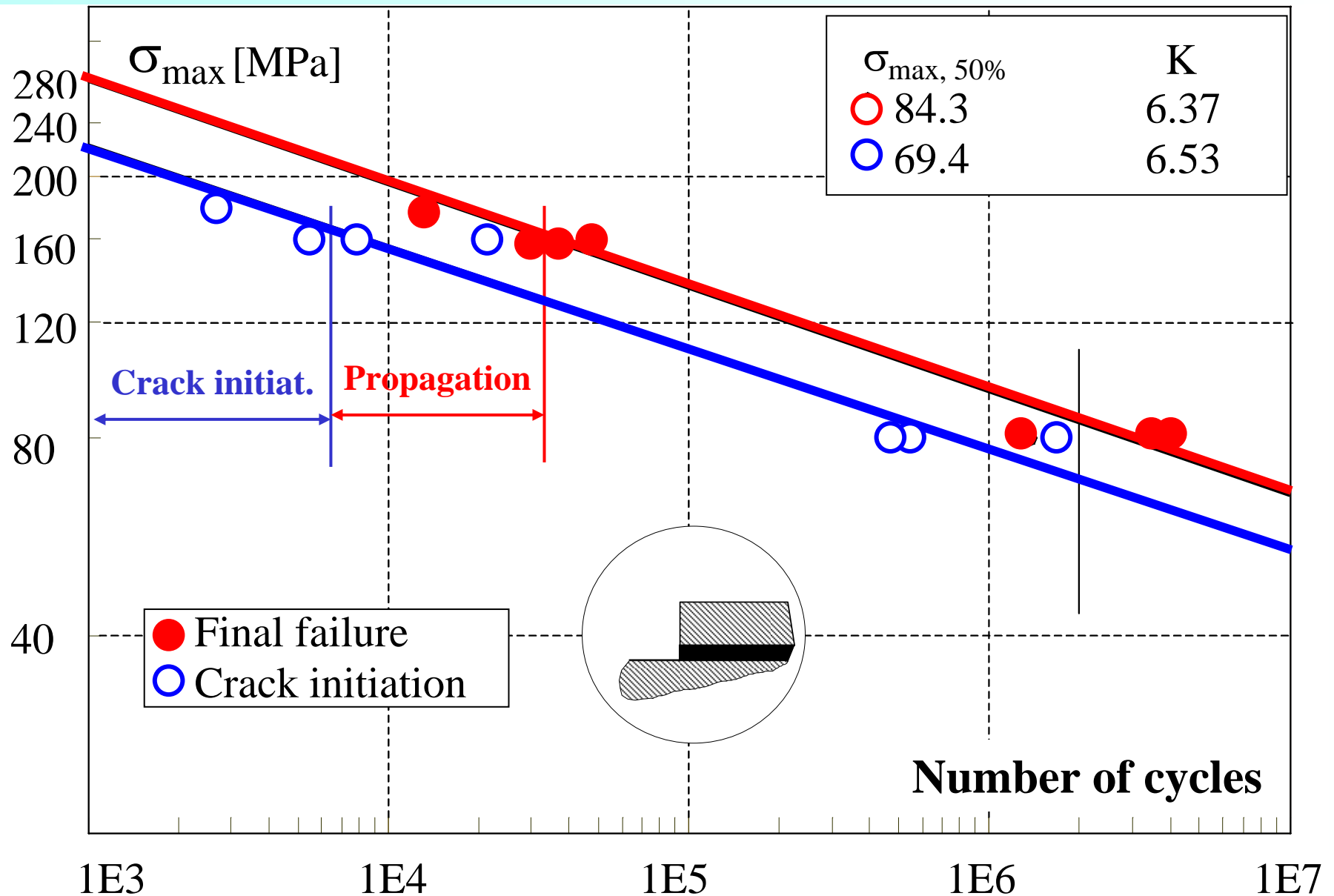
Fatigue damage evolution:
crack nucleation phase followed by propagation until to a critical length



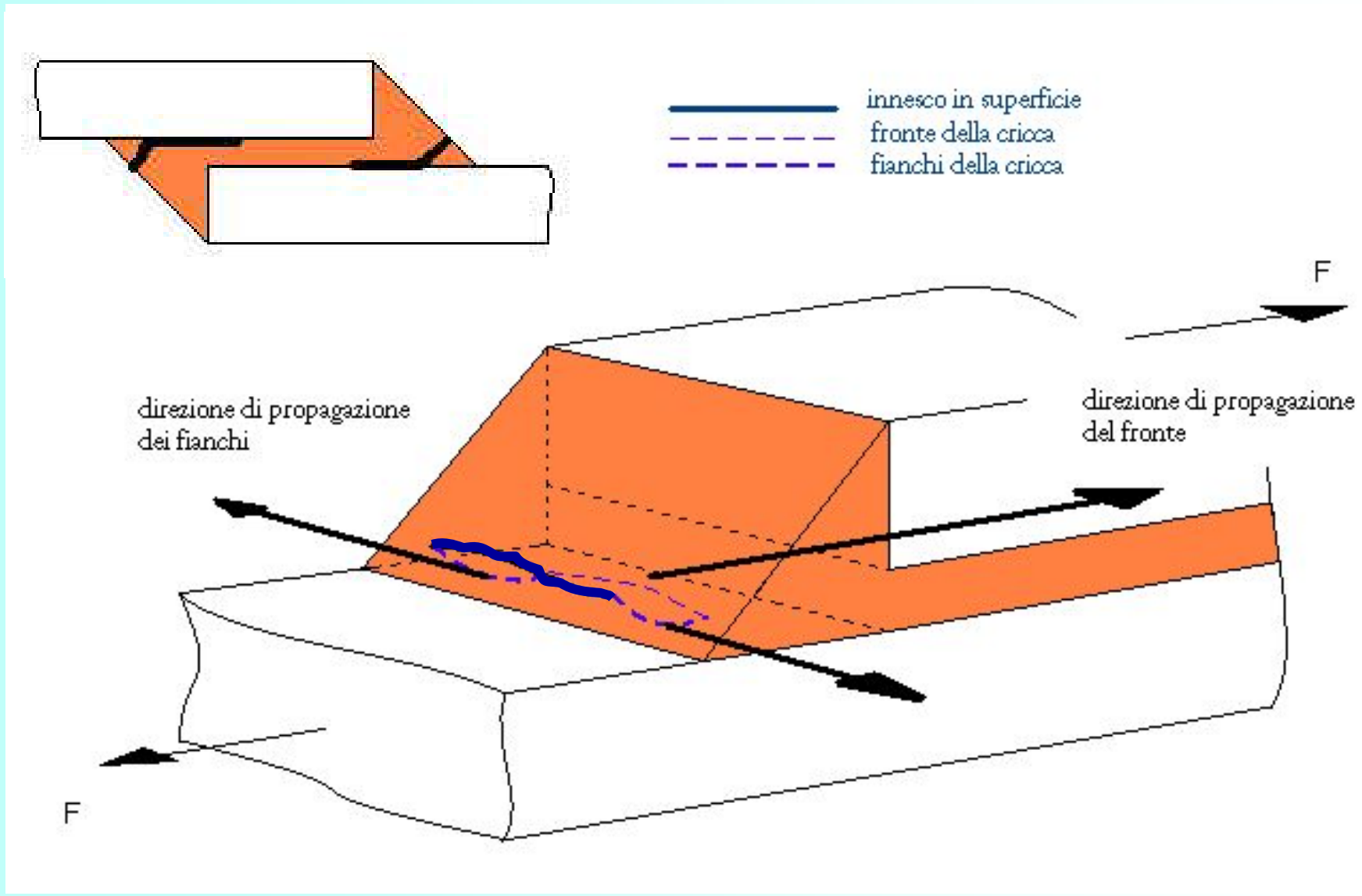
An extensive experimental program proved that the fraction of fatigue life spent for the crack nucleation is in general greater than 20% and up to 70%



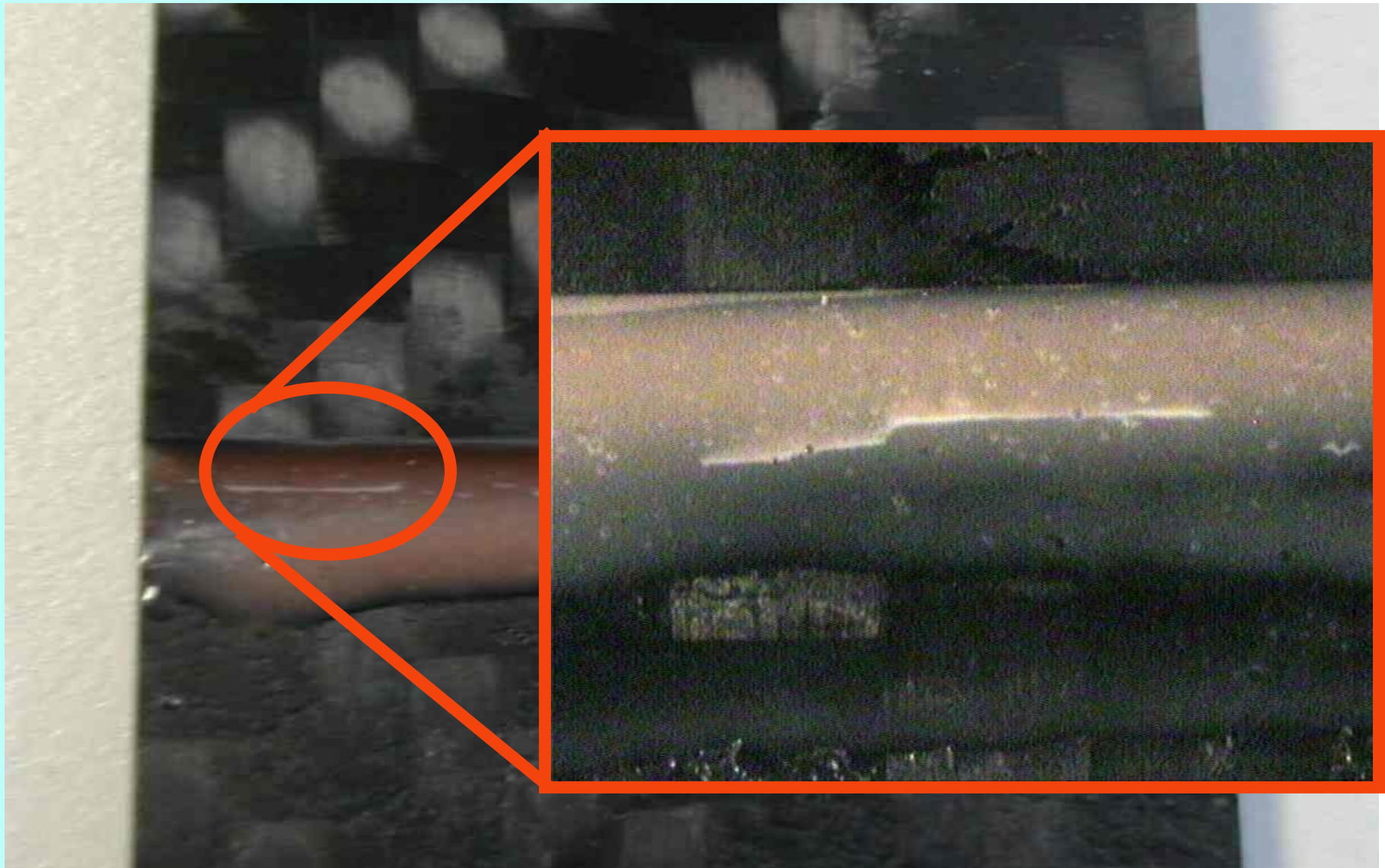
Fatigue curves for $[0]_6$ joints with S.E. corner



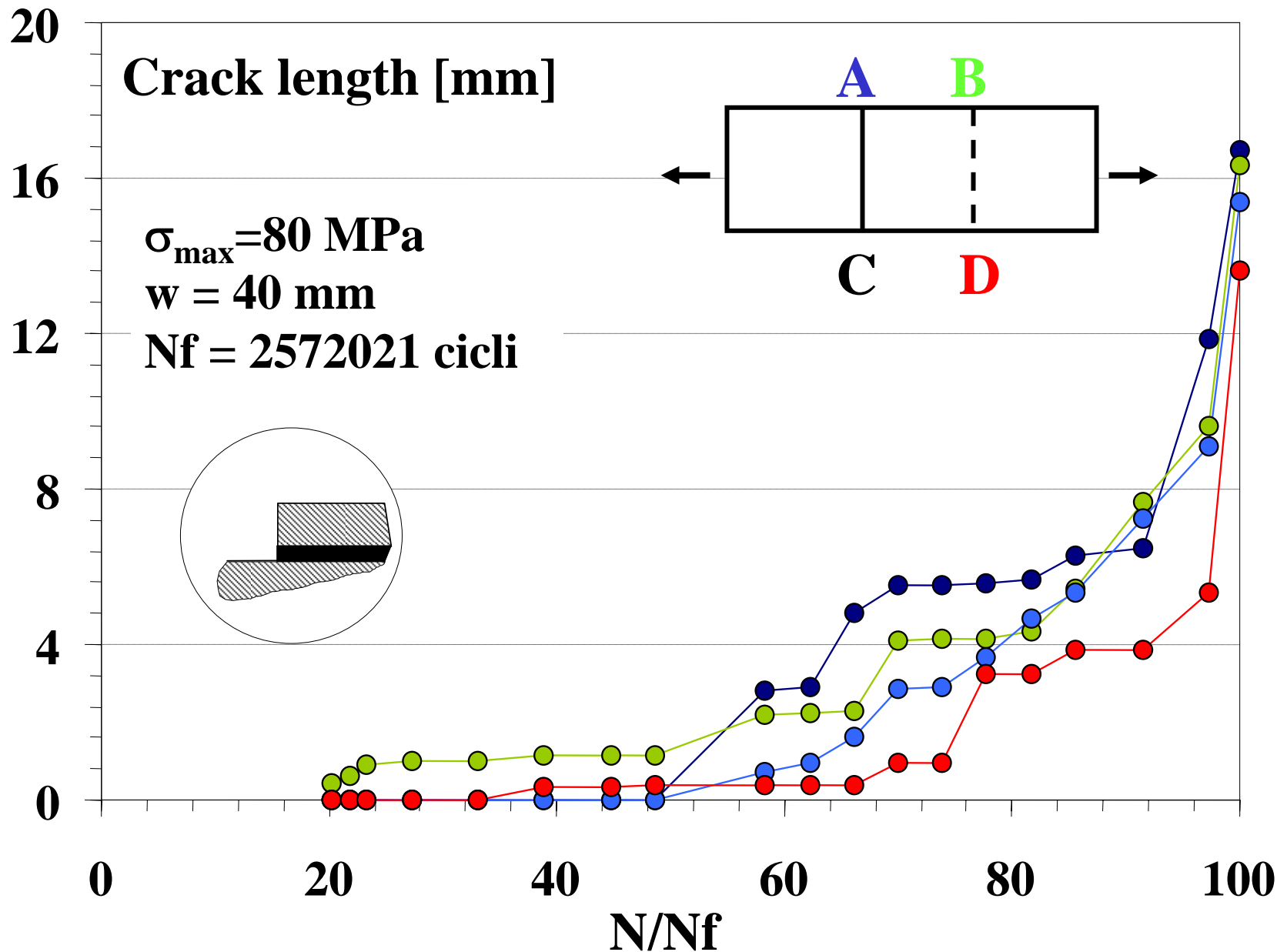
Crack nucleation phase



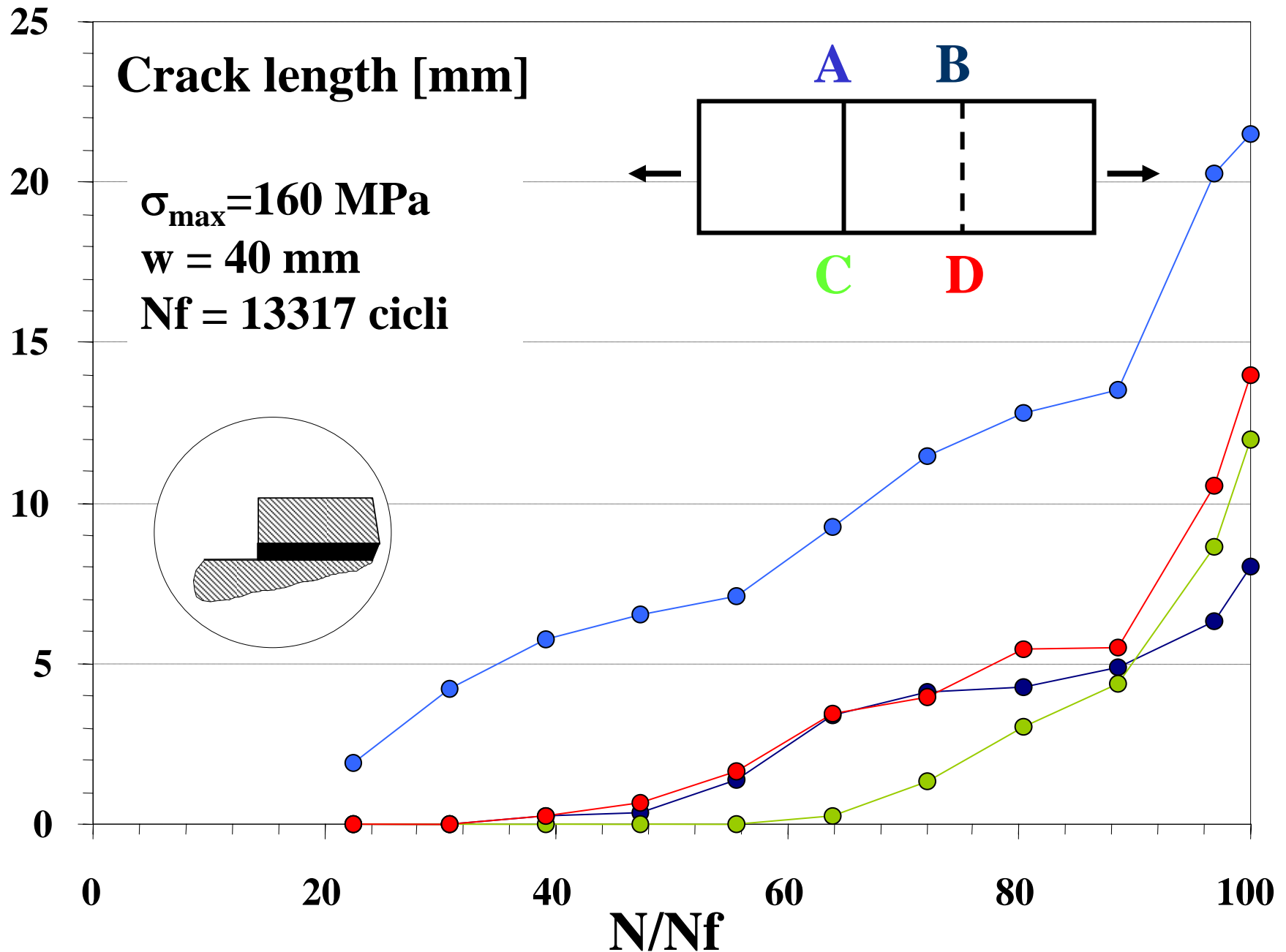
Crack nucleation phase



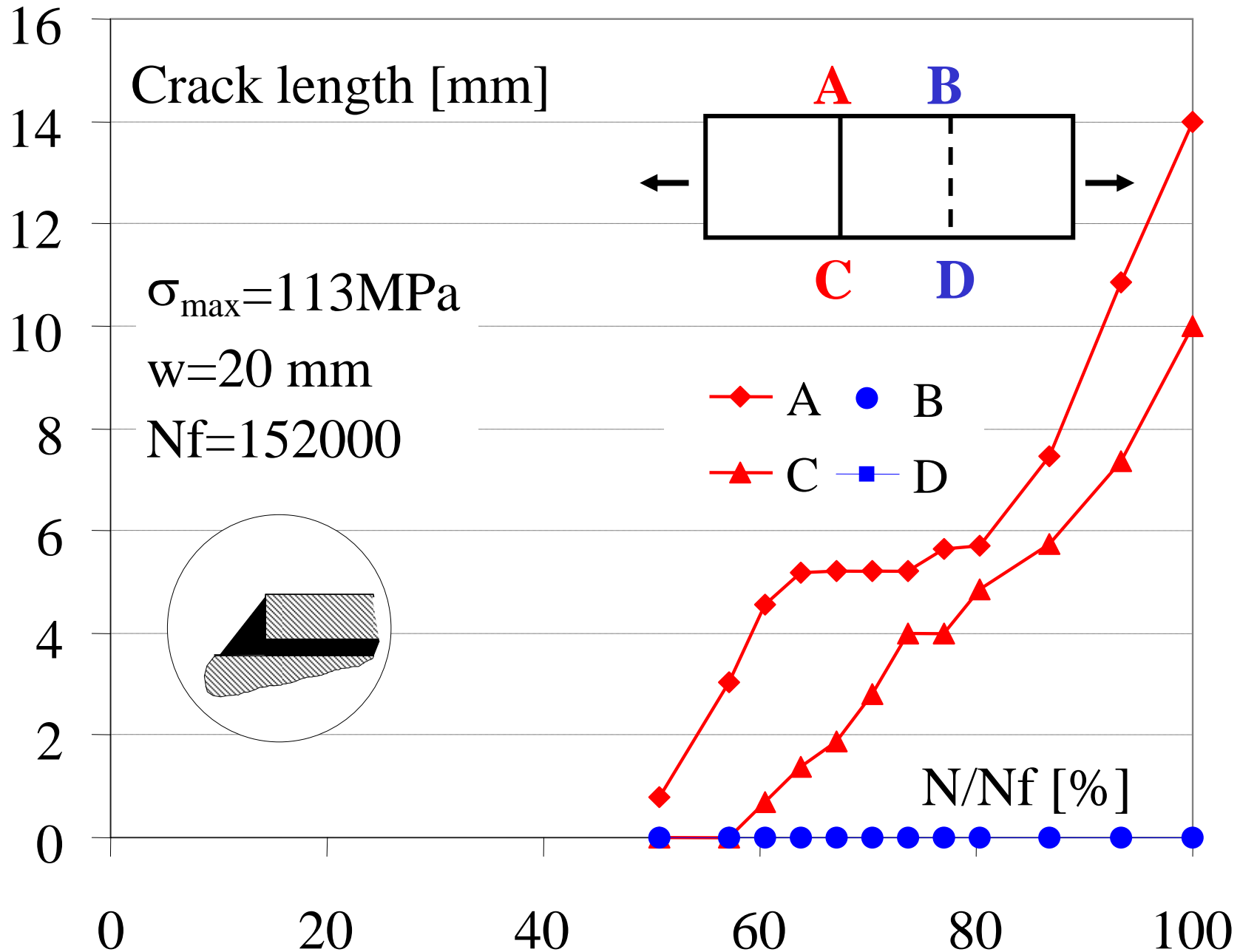
Crack propagation - I



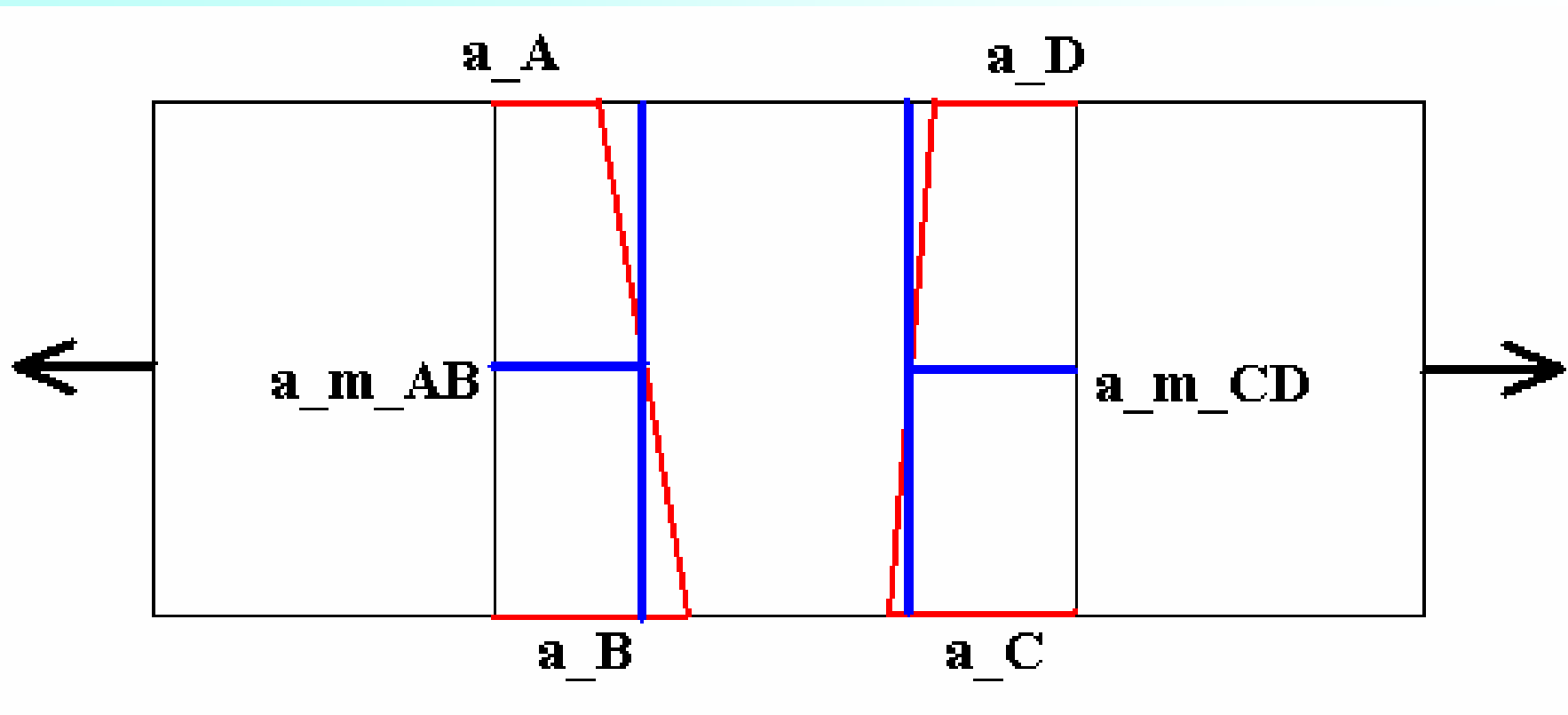
Crack propagation - II



Crack propagation - III



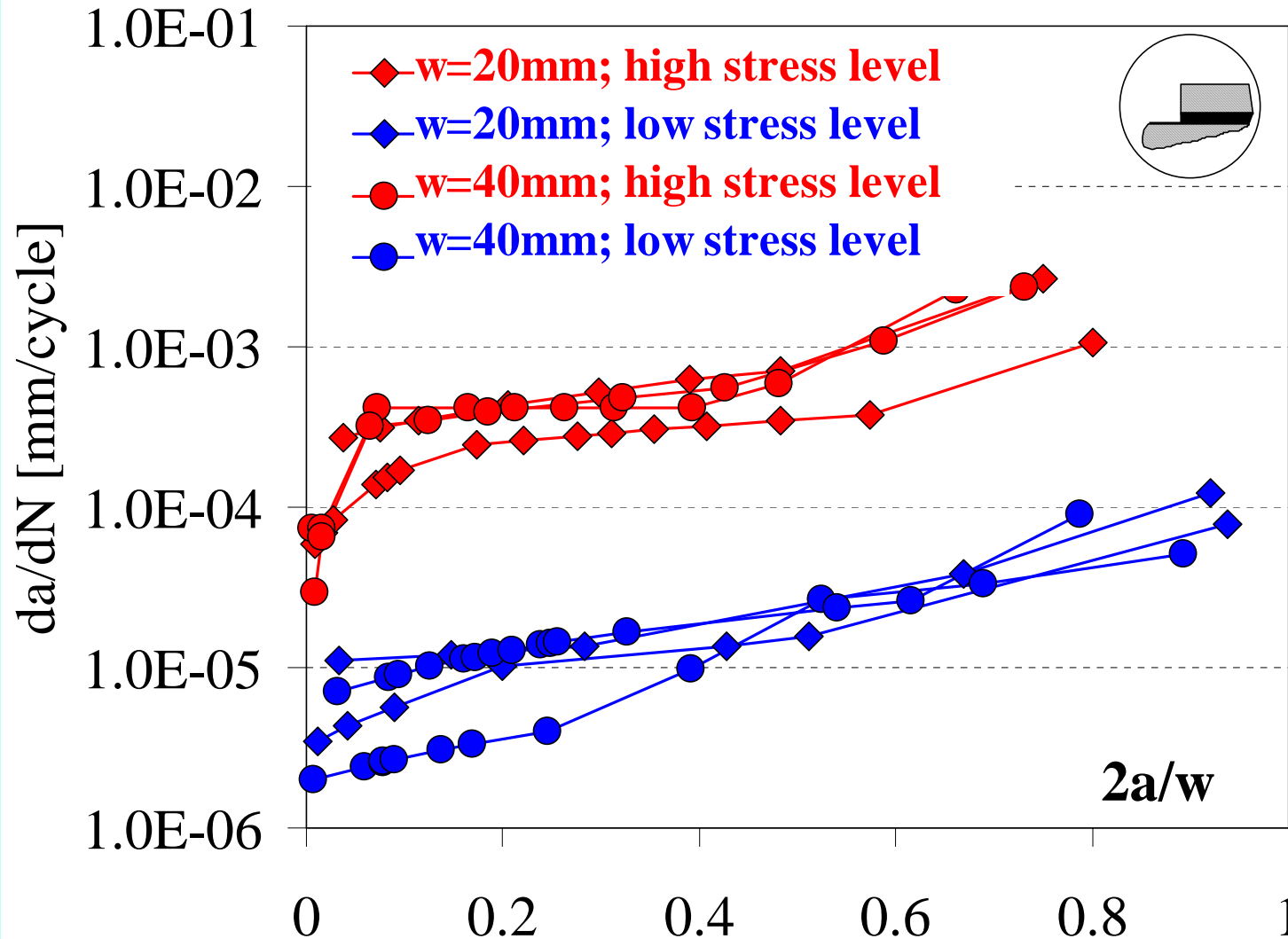
Simplified hypothesis on the crack front



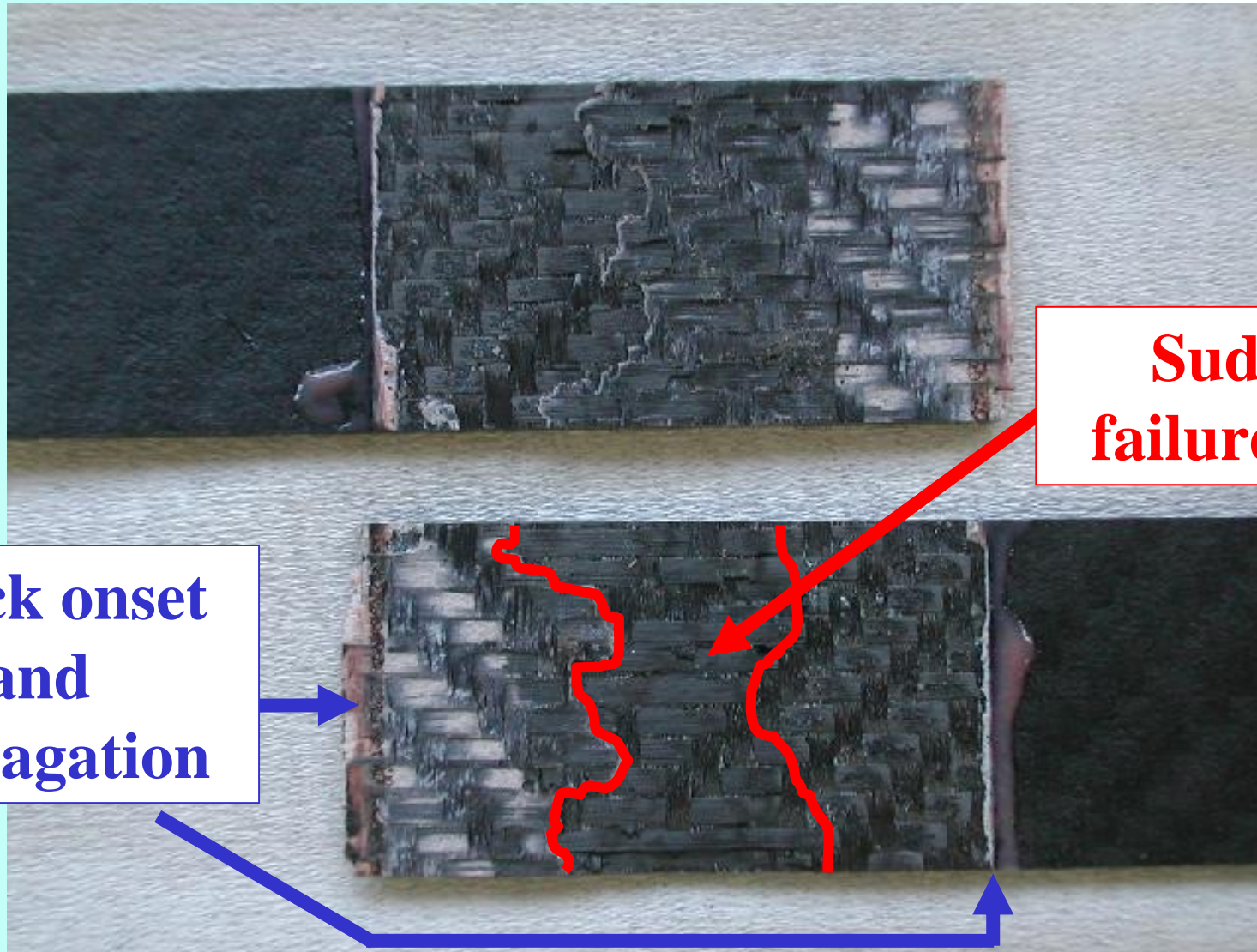
- Average crack length
- Linear crack front



Crack propagation – growth rate II



Fatigue failure surfaces



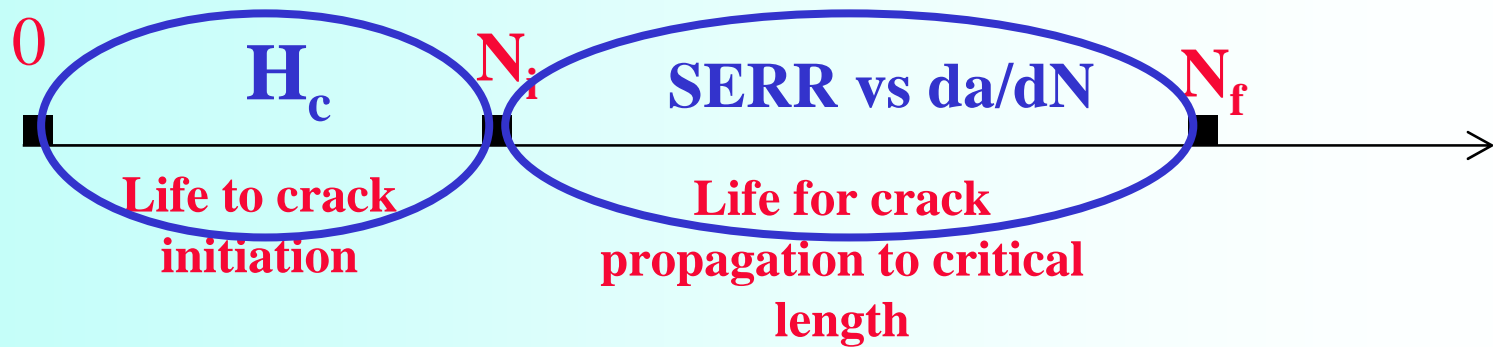
**Crack onset
and
propagation**

**Sudden
failure zone**

Failure surfaces, $[0]_6$ joints with fillet



Life prediction model



- The nucleation phase is estimated on the basis of the intensity of the local stress field (H) (Lefebvre e Dillard 1999, Ishii et al. 1999, Kinloch et al. 2000, Lazzarin, Quaresimin, Ferro P., 2002).
- The final propagation phase up to a critical length of the crack/(delamination) or to a critical SERR can later assessed by integrating a suitable power law relating the crack growth rate to the strain energy release rate (SERR). (Kinloch e Osiyemi 1993, Crocombe et al 2002)



Life prediction procedure

INPUT DATA: material properties, overlap, geometry corner, maximum applied stress σ_0

$H_{0 \max}$ from FE analysis

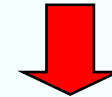


$\Delta H_0 - N_i$ scatter band



$N_{\text{crack onset}}$

$G_{I\max}(a), G_{II\max}(a)$ from FE analysis



$G_{\text{eqv}}(a)$ or $G_{\text{TOT}}(a) = G_{\text{IC}} \Rightarrow a_f$



Integration of FCGR curve



$N_{\text{propagation}}$

$$N_{\text{failure}} = N_{\text{crack onset}} + N_{\text{propagation}}$$



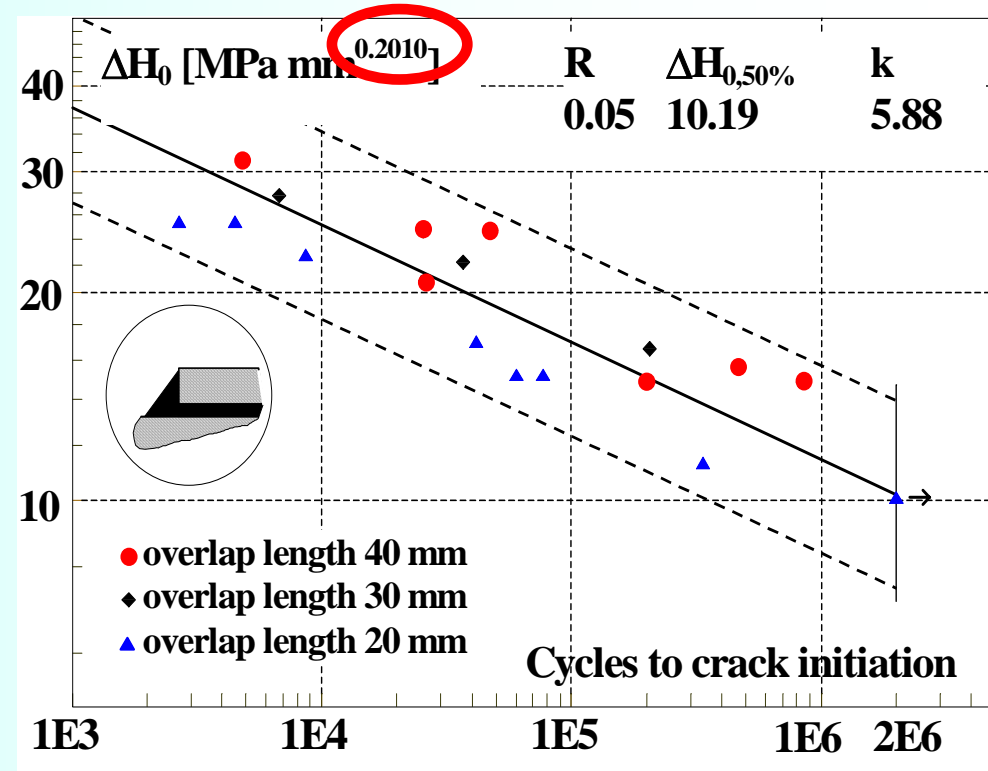
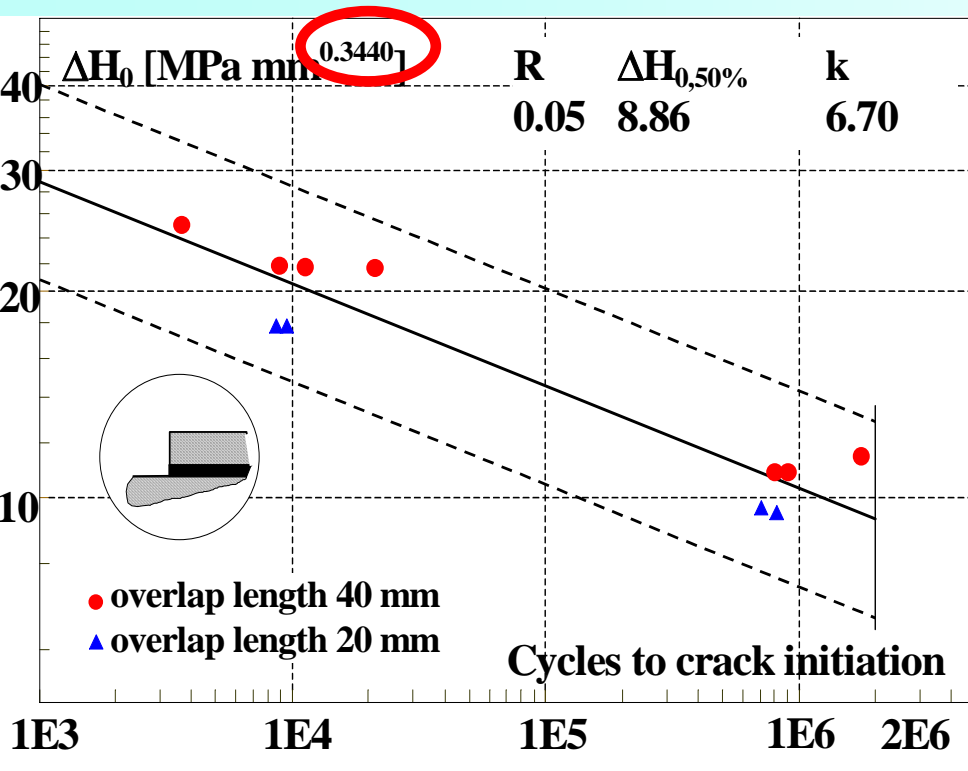
Assessment of life spent in the nucleation phase

The analysis of the fatigue damage evolution allowed the number of cycles to crack initiation to be identified.

All the fatigue data to crack initiation were then expressed in terms of the generalised stress intensity factor range ΔH_0 at the singularity and reanalysed together keeping as a unique variable the geometry corner



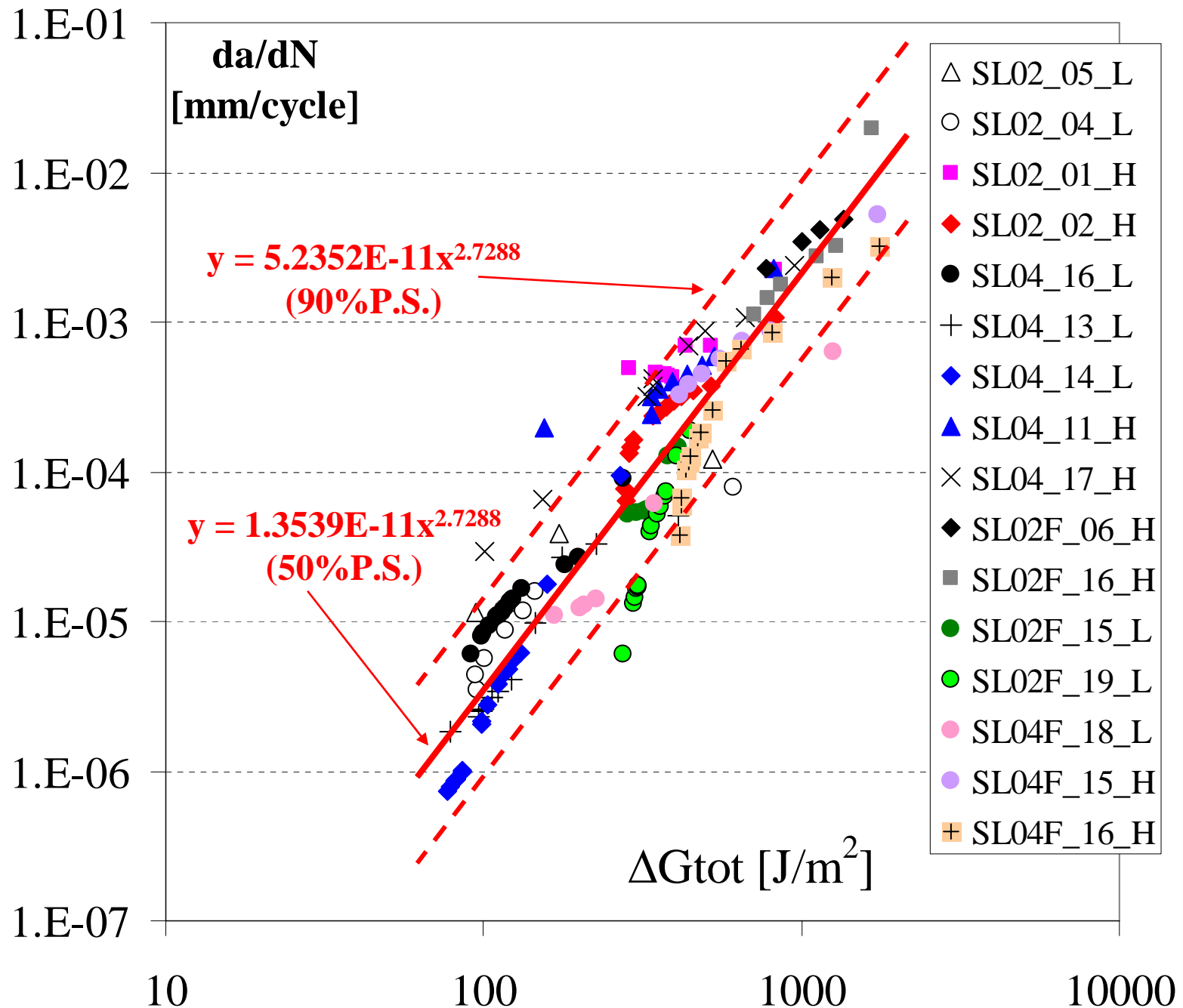
Assessment of life spent in the nucleation phase



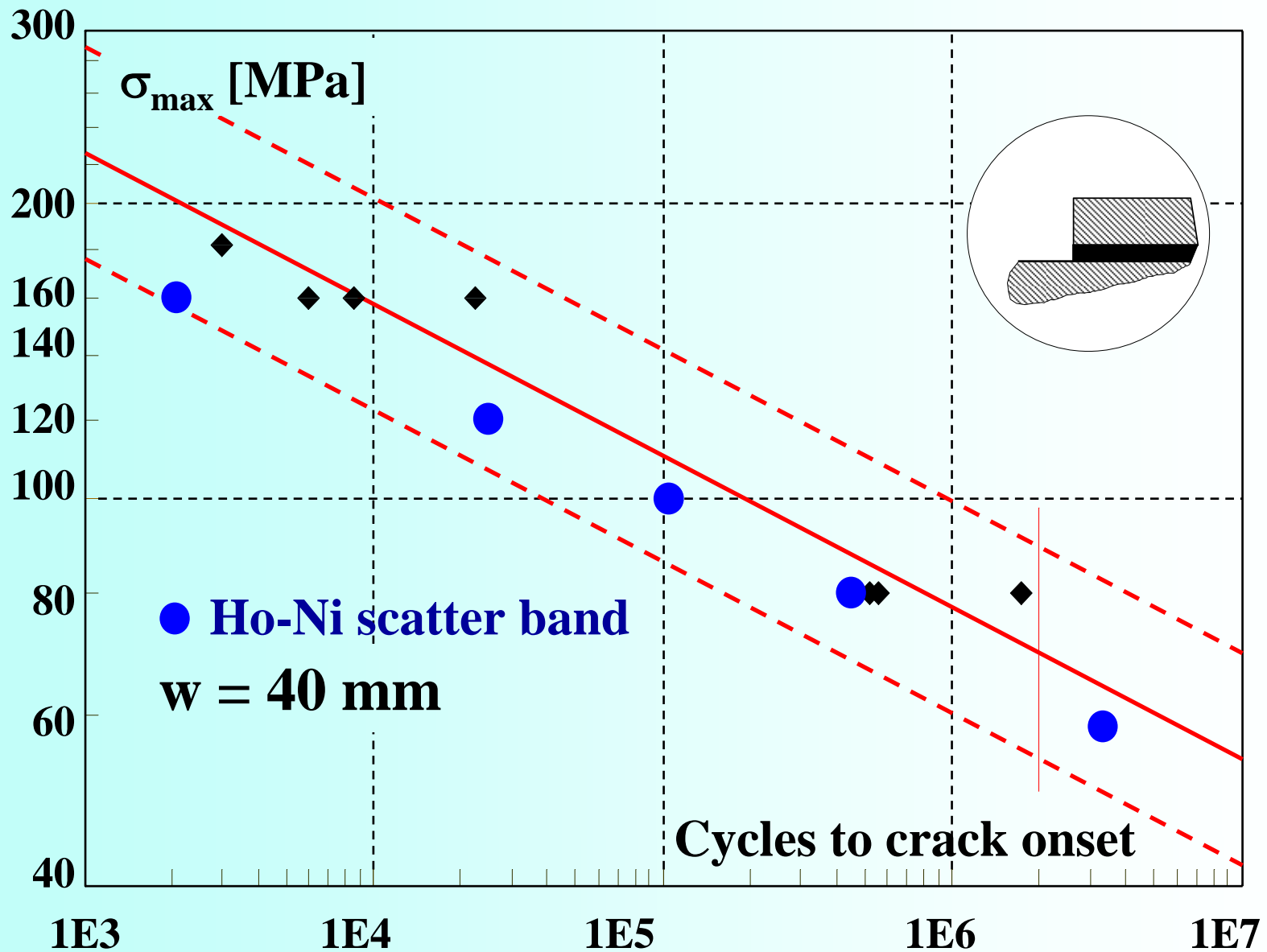
For each geometry corner, a single fatigue scatter band can be defined, in spite of the overlap length, which is suitable to predict the behaviour of different series.



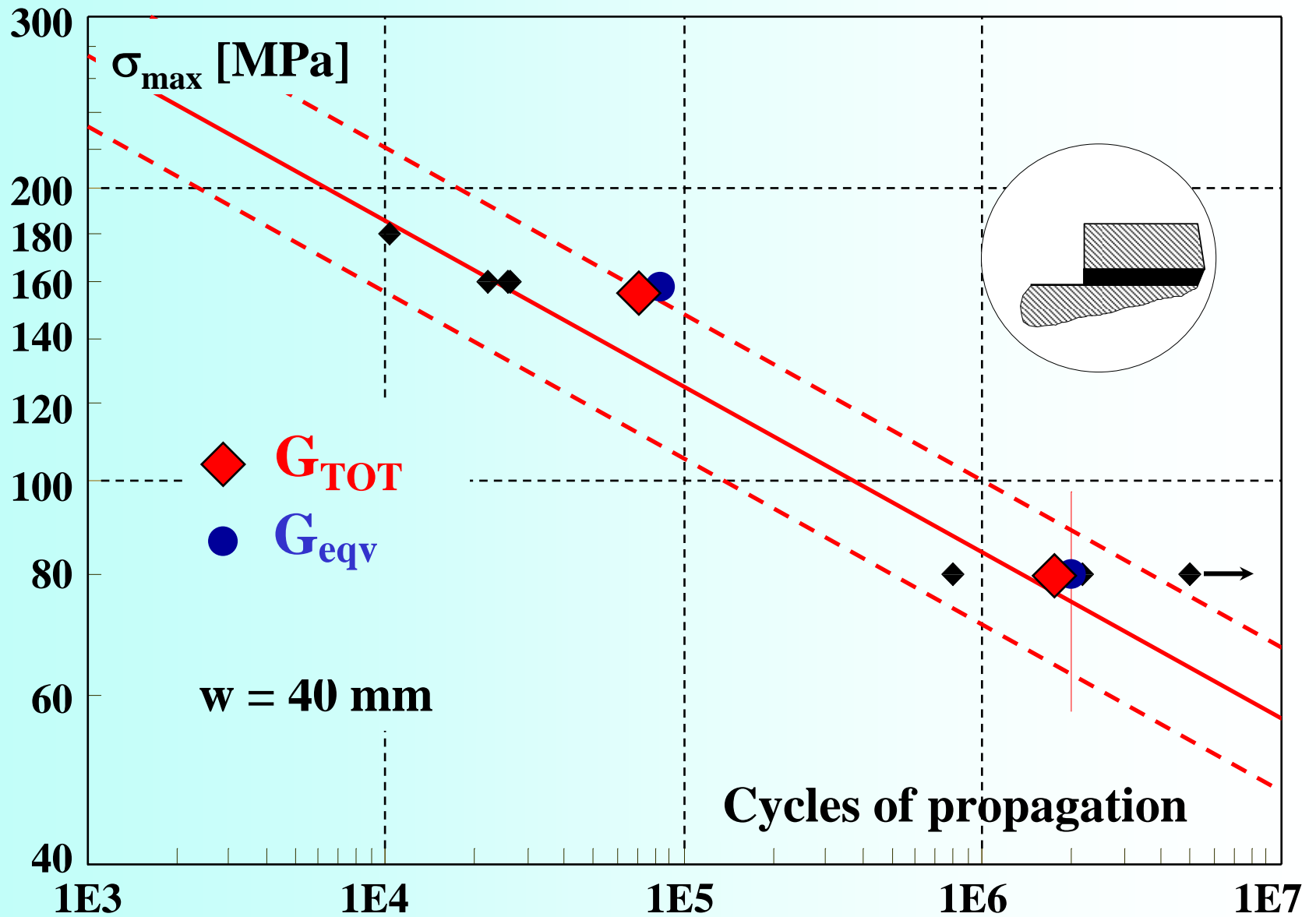
FCGR Paris-like curve (G_{tot})



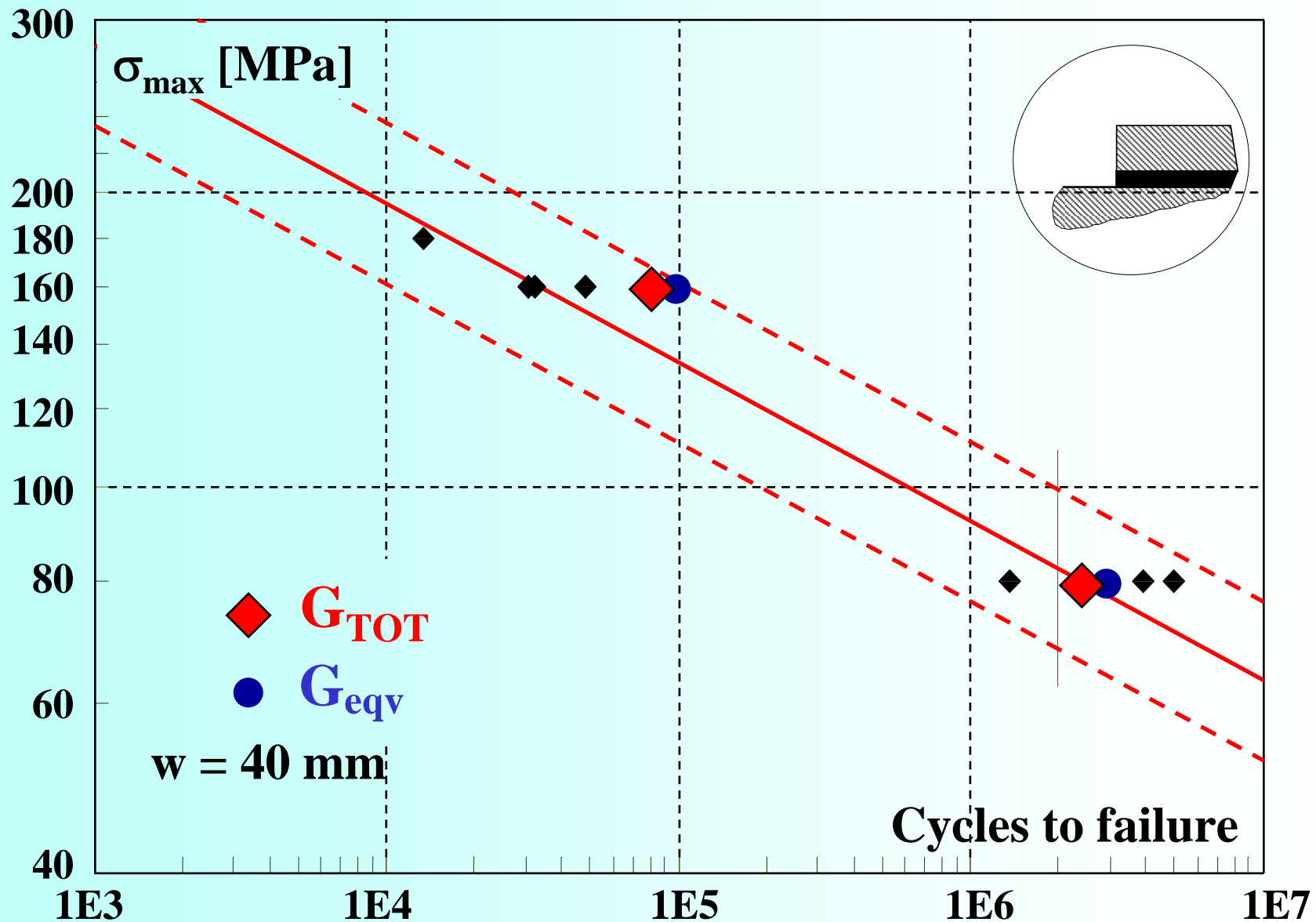
Validation: life to crack initiation



Validation: life spent for crack propagation



Validation: fatigue lifetime to failure



Recent publications on this subject

Quaresimin M., Ricotta M., Fatigue behaviour and damage evolution of single lap bonded joints in composite material, Composites Science and Technology, vol. 66, 2006, pp. 176-187.

Quaresimin M., Ricotta M., Stress intensity factors and strain energy release rates in single lap bonded joints in composite materials, Composites Science and Technology, vol. 66, 2006, pp. 647-656.

Quaresimin M., Ricotta M., Life prediction of bonded joints in composite materials, International Journal of Fatigue, vol. 28, 2006, pp 1166-1176.

Meneghetti G., Quaresimin M., Ricotta M., Influence of the layer orientation at the interface on the fatigue behaviour of bonded joints in composite materials, accepted for publication in International Journal of Fatigue



Present and future activities

- **Assessment of crack initiation and crack growth in mixed mode loading via stiffness measurements (on SLJ and DLJ) (LVDT and/or strain/clip gauges)**
- **Assessment of Paris curve for the adhesive under pure Mode I and Mode II on DCB or ENF samples**
- **Model validation using fracture data from pure loading and equivalent formulation for the SERR**

