Fatigue and Fracture Assessment of Butt Welded Joints and Thermal Cut Edges under Axial and Bending Loads

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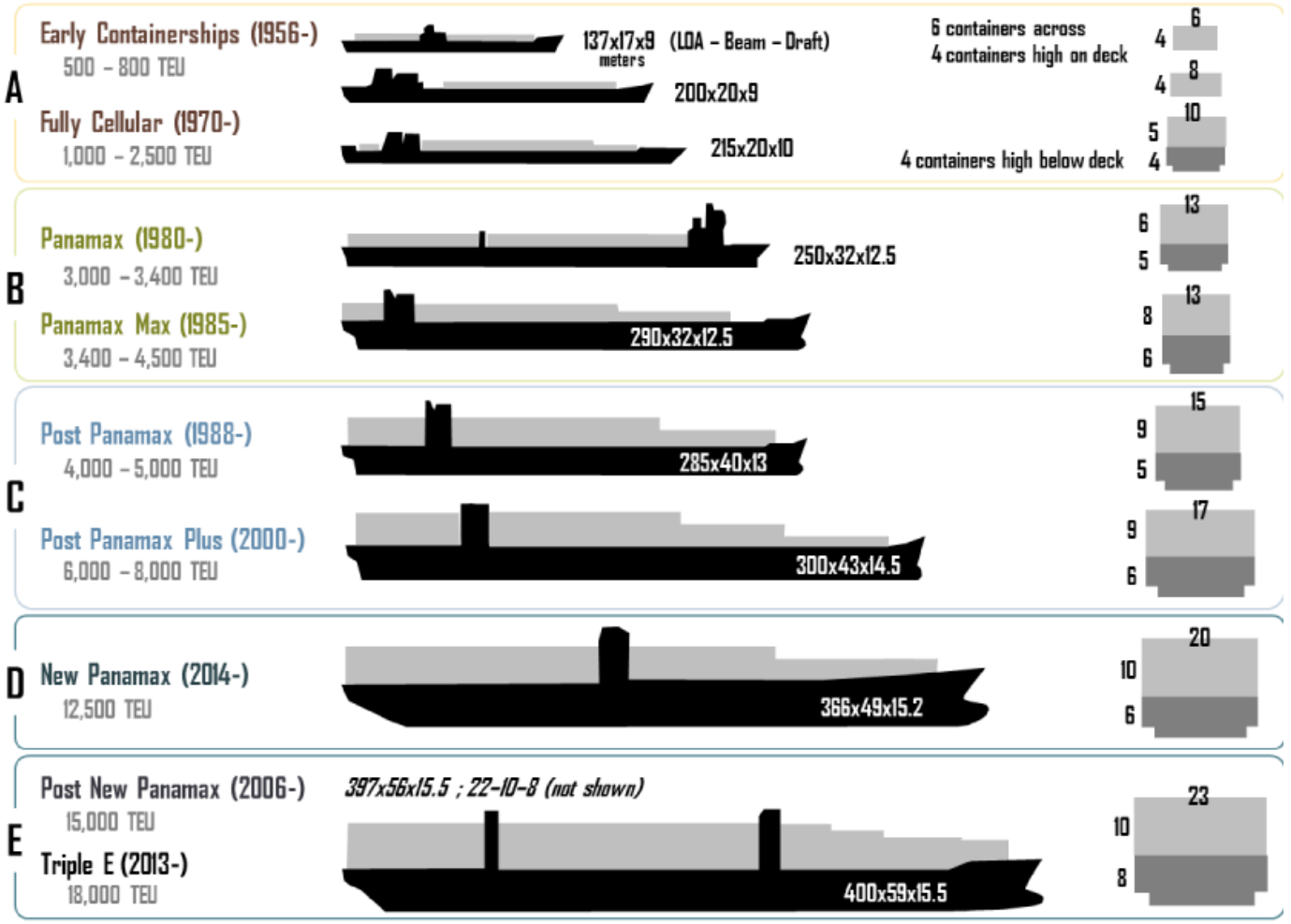
MOTIVATION

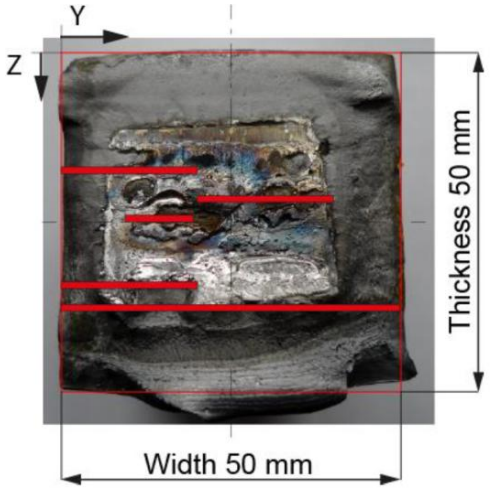
Evolution of Container Vessels



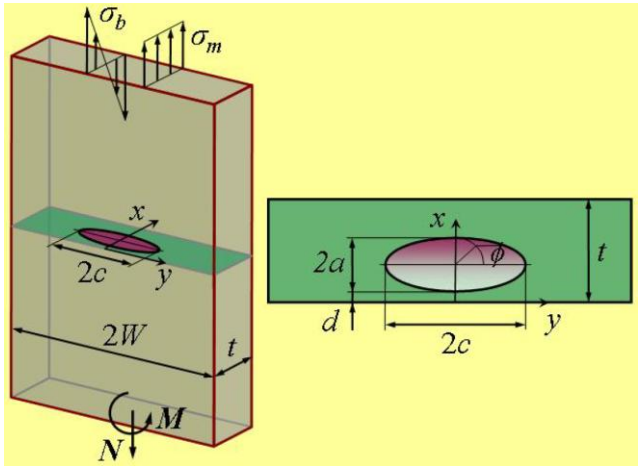
Source: Ashar and Rodrigue (2012): "The Geography of Transport Systems"
Available Online at http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/containerships.html

BUTT WELDED JOINTS WITH INTERNAL DEFECT

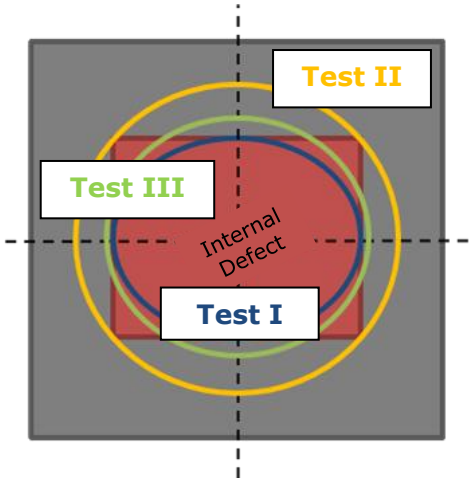
Internal Flaw and Model Shape/Dimensions



Source: DNV GL (2015): "Fatigue Characterization of YP47 Welds", DNV GL Internal Report



Source: *Fraunhofer IWM Verb* Software

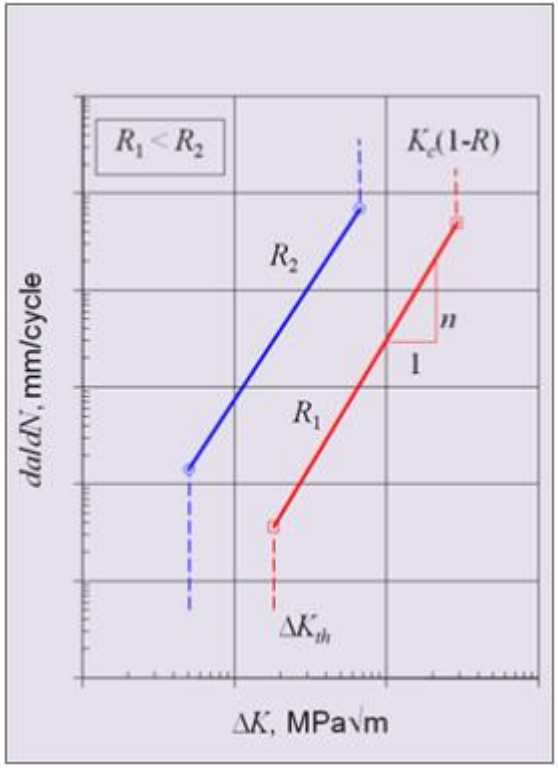


BUTT WELDED JOINTS WITH INTERNAL DEFECT

Basic and Parameters Formulation

Paris-Erdogan Law

$$\frac{da}{dN} = C\Delta K^n, \quad \Delta K_{th} \le \Delta K \le (1-R)K_c$$



Source: ***Fraunhofer IWM Verb*** **Software**

Table of Parameters Adopted for Simulation

Reference	C (-)	ΔK_{th} (MPa.m$^{1/2}$)	K_c (MPa.m$^{1/2}$)	n (-)
IIW 2008	$1.65 \cdot 10^{-8}$	5.40	1000	3.00
Series A	$4.78 \cdot 10^{-9}$	8.22	1000	3.00

Doerk, O.; Shin, S.-B.; and An, G.-B. (2014): "*Design Impact of Fracture Mechanics Properties of High Toughness YP47 Welds*", ISOPE (Busan)

Stress Ratio

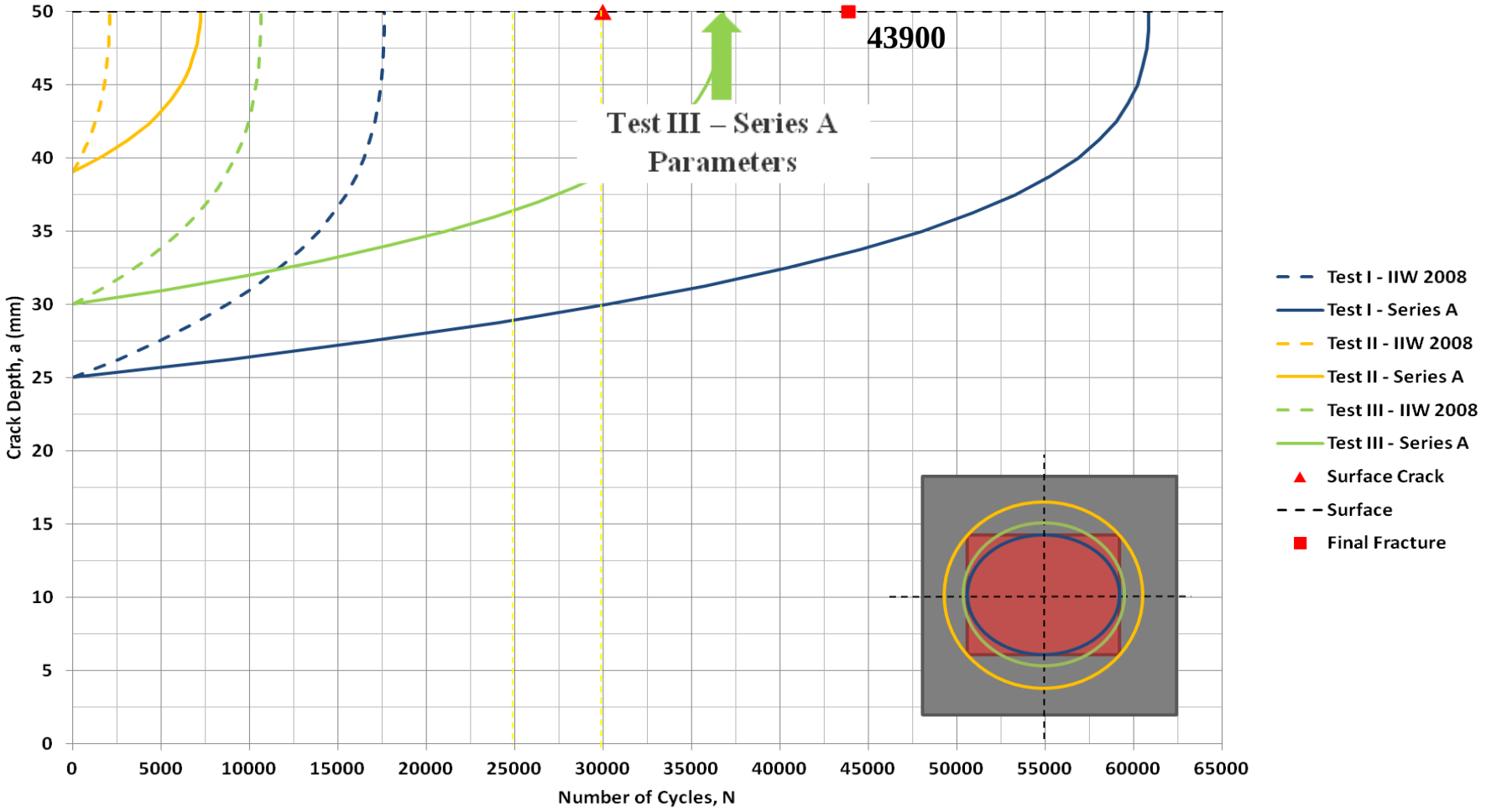
- $R = 0$

Stress Range (constant)

- $\Delta\sigma = 150$ N/mm²

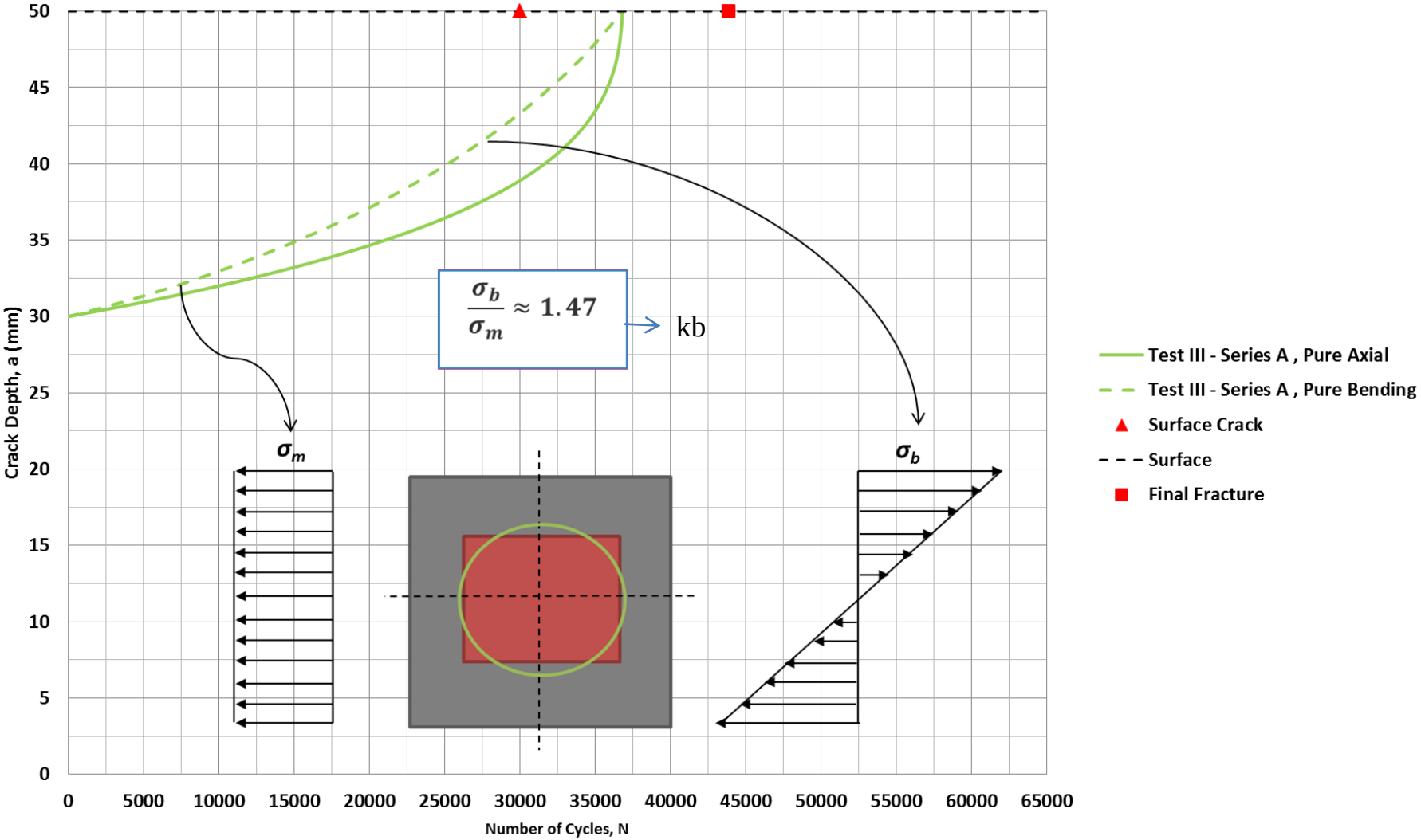
BUTT WELDED JOINTS WITH INTERNAL DEFECT

Results for Pure Axial Simulation



BUTT WELDED JOINTS WITH INTERNAL DEFECT

Result for Bending at Same Number of Cycles from Axial



BUTT WELDED JOINTS WITH INTERNAL DEFECT

Comparison with Literature (*Maddox*)

Reference	*Fatigue Strength Enhancement Factor, kb*
BS7608:1993	**1.27**
***Maddox* Exp.**	**1.20**
***Maddox* Eq.**	**1.18**
FM kb from Simulation	**1.47**

$$k_b = 1 + \left\{ \frac{0.7}{t^{0.2}} + 0.5 \cdot \log \frac{L}{t} \right\}$$

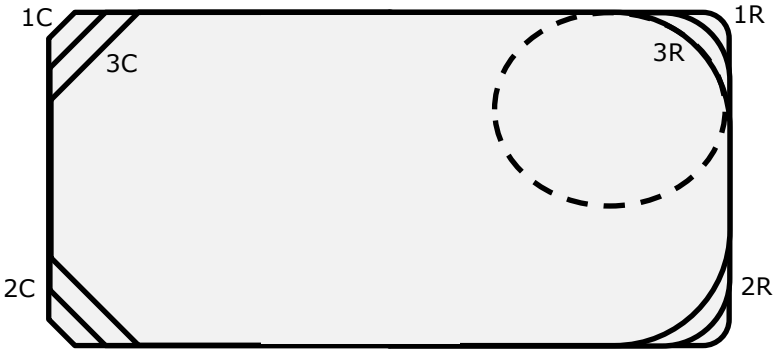
$$k_{tb} = \left(\frac{25}{t_{eff}} \right)^n \cdot \left[1 + 0.18\Omega^{1.4} \right]$$

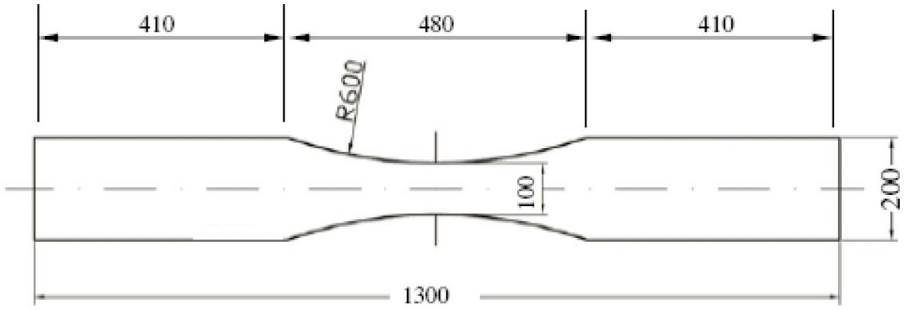
Source: Maddox, S. J. (2015): "Allowance for bending in fatigue design rules for welded joints", IIW XIII-2580-15

THERMAL CUT EDGES (TCE)

Thermal Cut Edge Scantling/Treatments

Selle, H. von (2014): "Recent Fatigue and Fracture Research Activities", DNV GL - Brochure

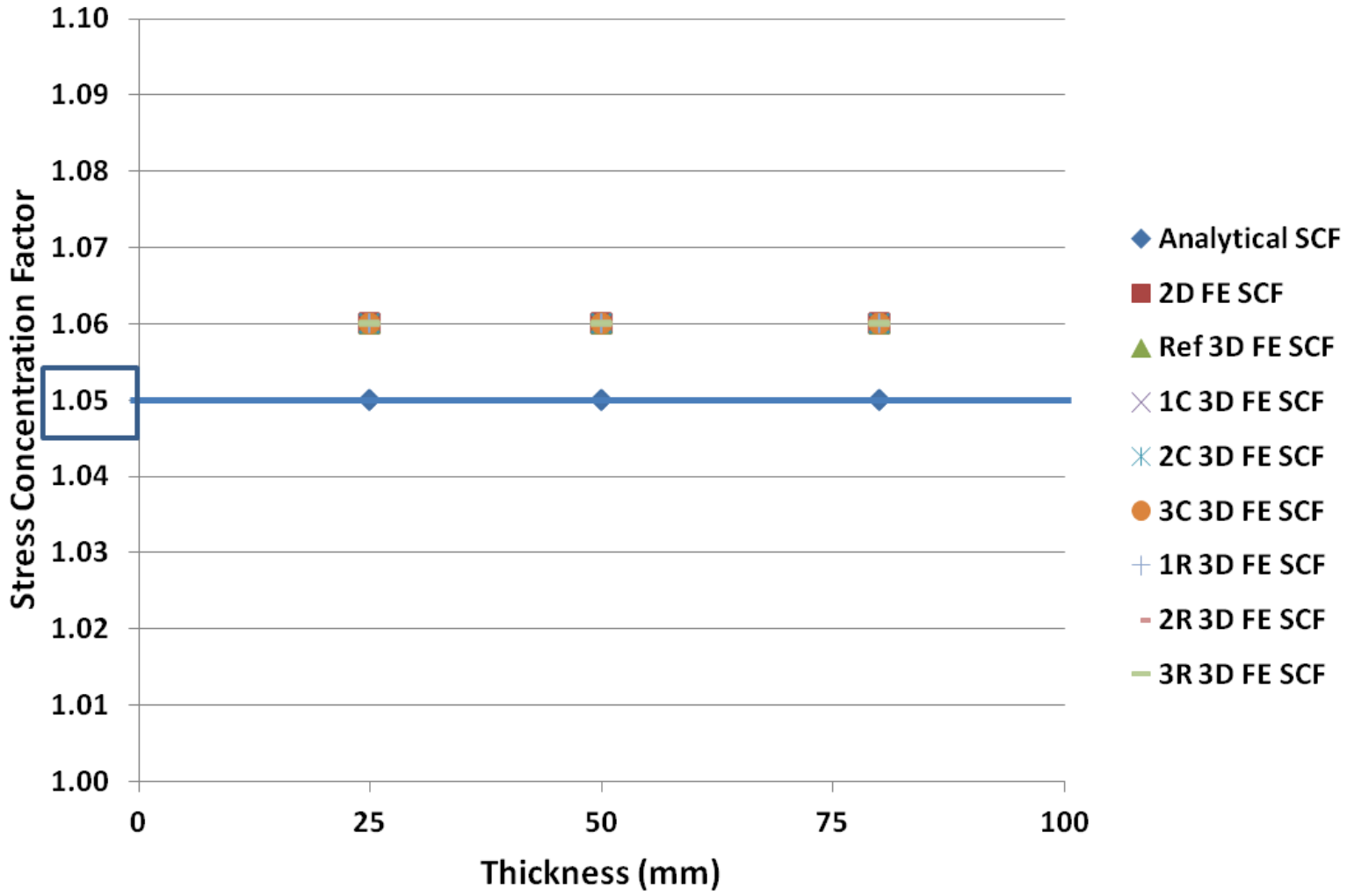




t = 25, 50 and 80mm

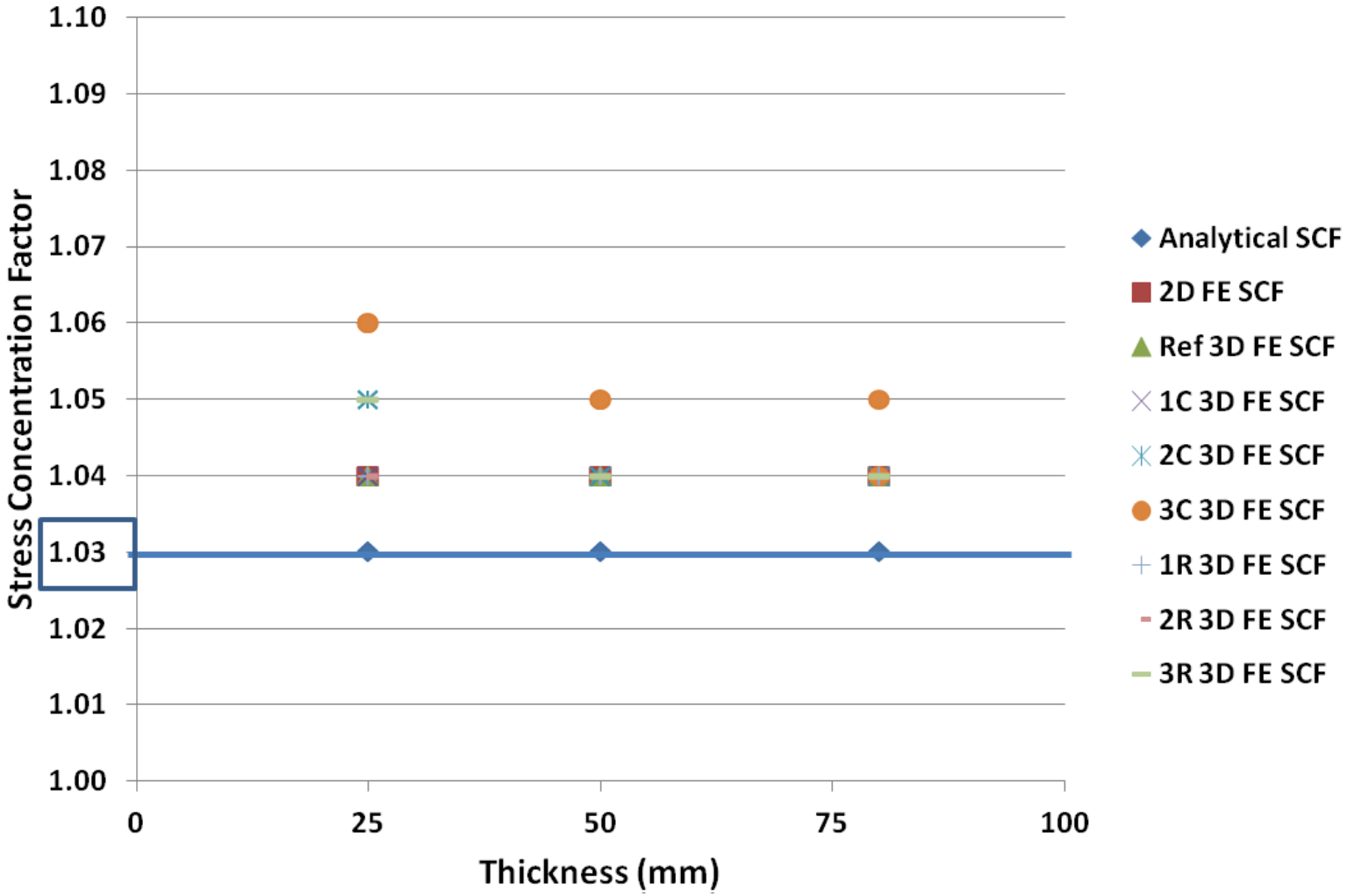
THERMAL CUT EDGES (TCE)

Stress Concentration Factor Results for Axial



THERMAL CUT EDGES (TCE)

Stress Concentration Factor Results for Bending



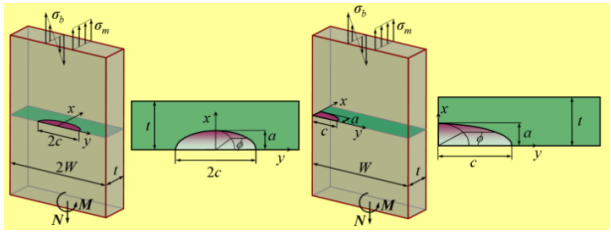
THERMAL CUT EDGES (TCE)

Parameters of Fracture Mechanics Analysis of TCE

- Stress ratio R = 0.1;
- Stress range $\Delta\sigma$ of 252MPa, 270MPa, 306MPa, 360MPa and 423MPa;
- FKM Guidelines parameters for base materials (YP36, YP40 and YP47);
- Crack models: Quarter and Semi-elliptical;
- Thickness of 25, 50 and 80mm; and
- Initial crack size of a_0 = 1.1 mm and a_0/c_0 = 1.

Material	C (-)	ΔK_{th} (MPa.m$^{1/2}$)	Kc (MPa.m$^{1/2}$)	m (-)
YP36	$5.96 \cdot 10^{-9}$	8.20	1000	2.88
YP40	$3.15 \cdot 10^{-9}$	10.40	1000	3.07
YP47	$5.67 \cdot 10^{-8}$	8.30	1000	2.26

Berger, C. et al (2009): "*FKM-Guideline Fracture Mechanics Proof of Strength*", VDMA Verlag GmbH

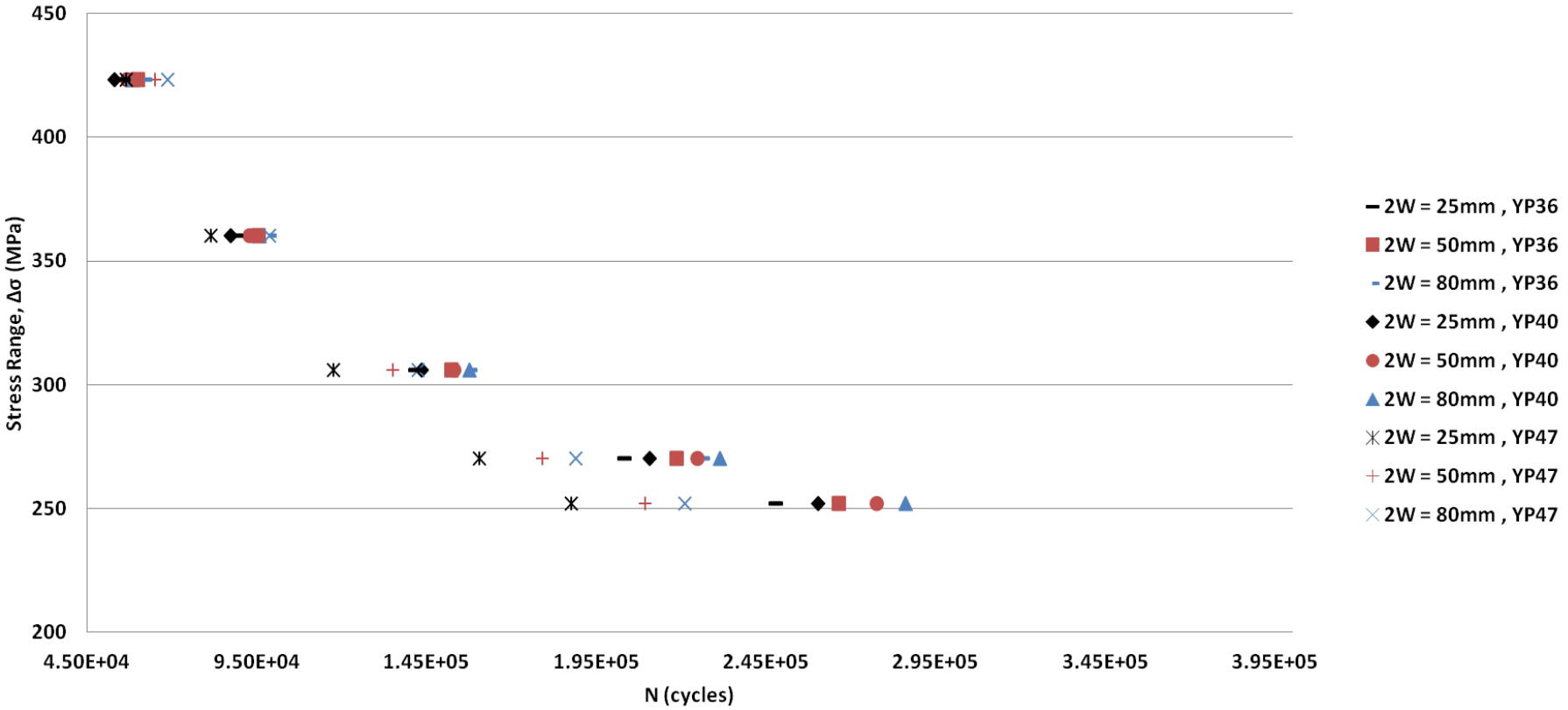


Source: *Fraunhofer IWM Verb* Software

THERMAL CUT EDGES (TCE)

Results for Fracture Mechanics Analysis of TCE

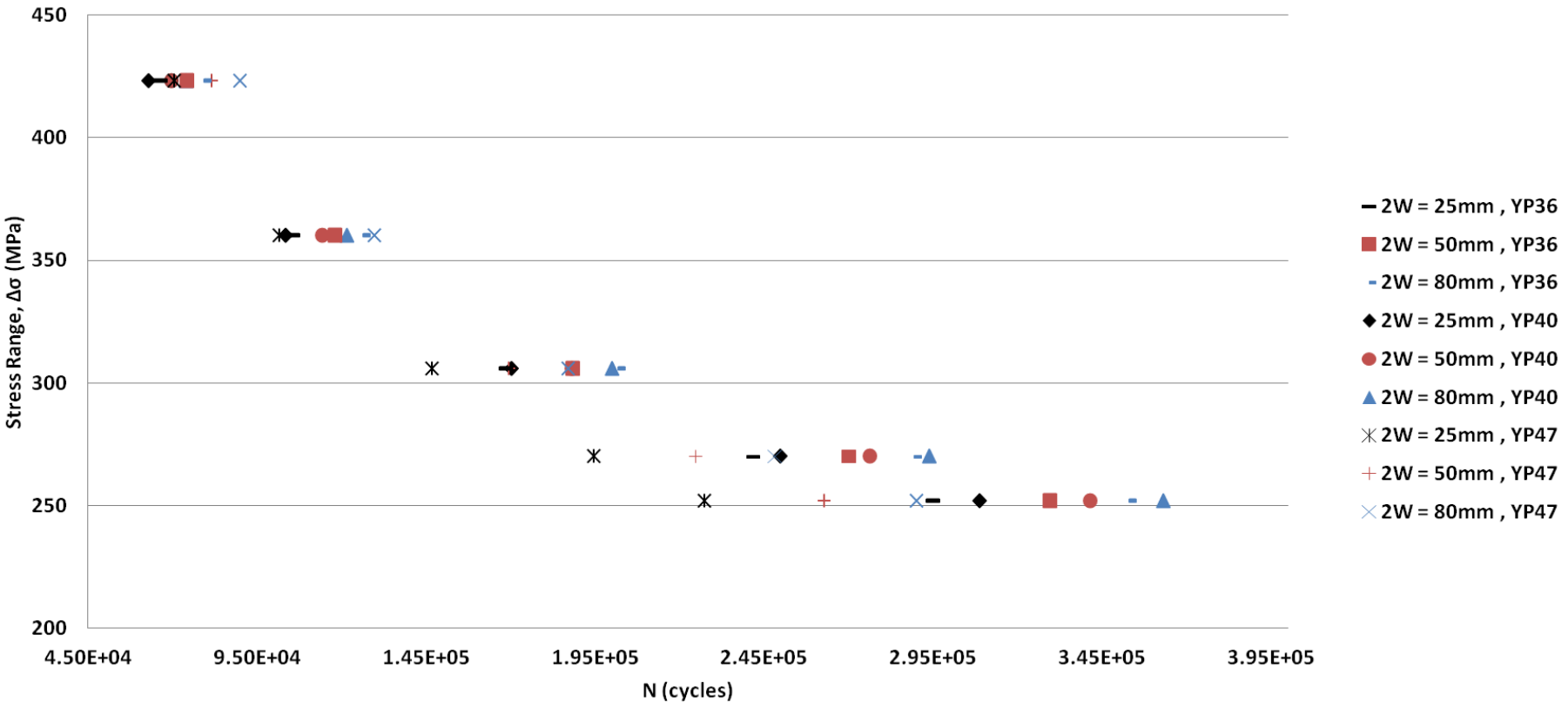
Quarter Corner Crack under Axial



THERMAL CUT EDGES (TCE)

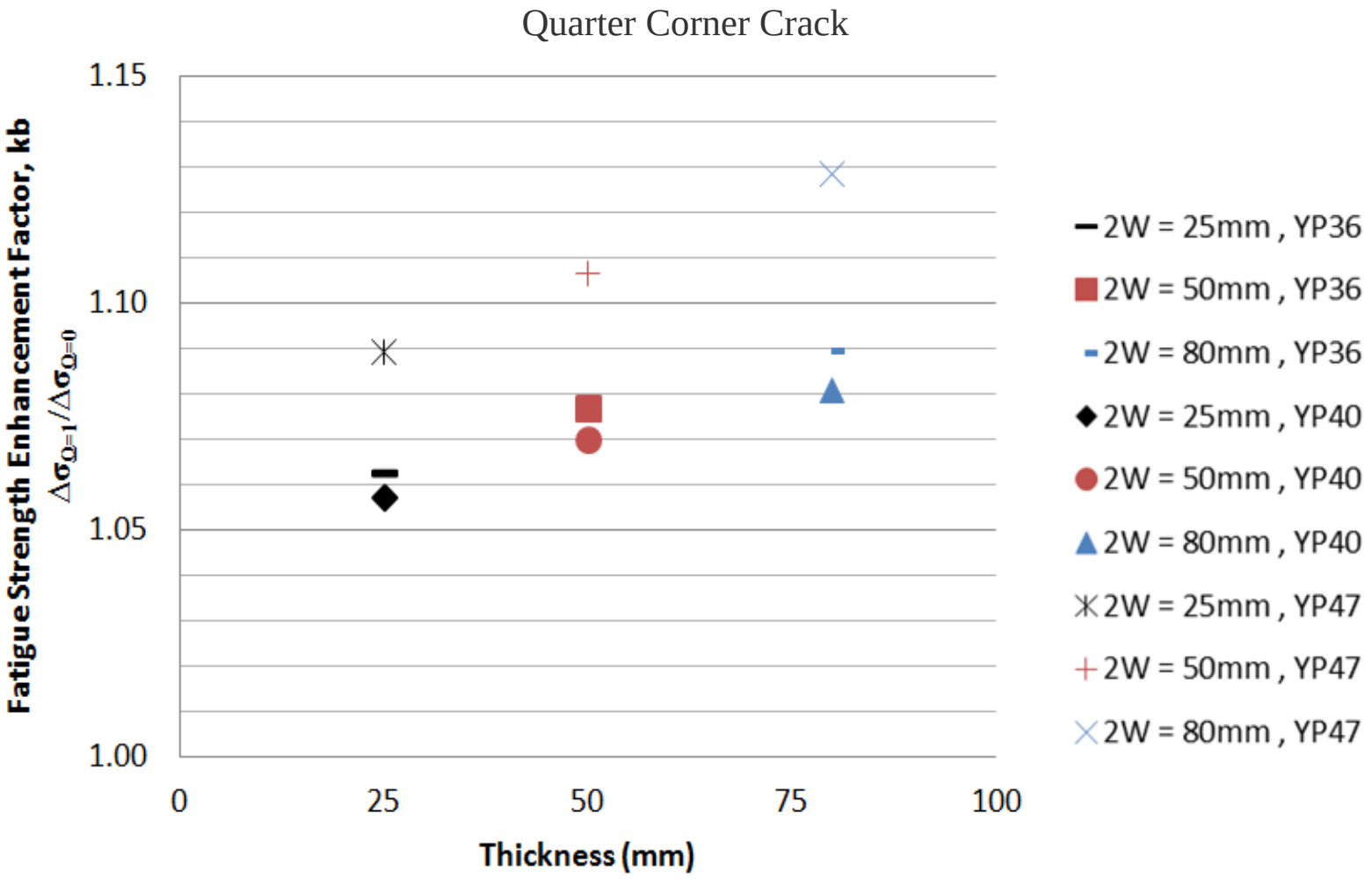
Results for Fracture Mechanics Analysis of TCE

Quarter Corner Crack under Bending



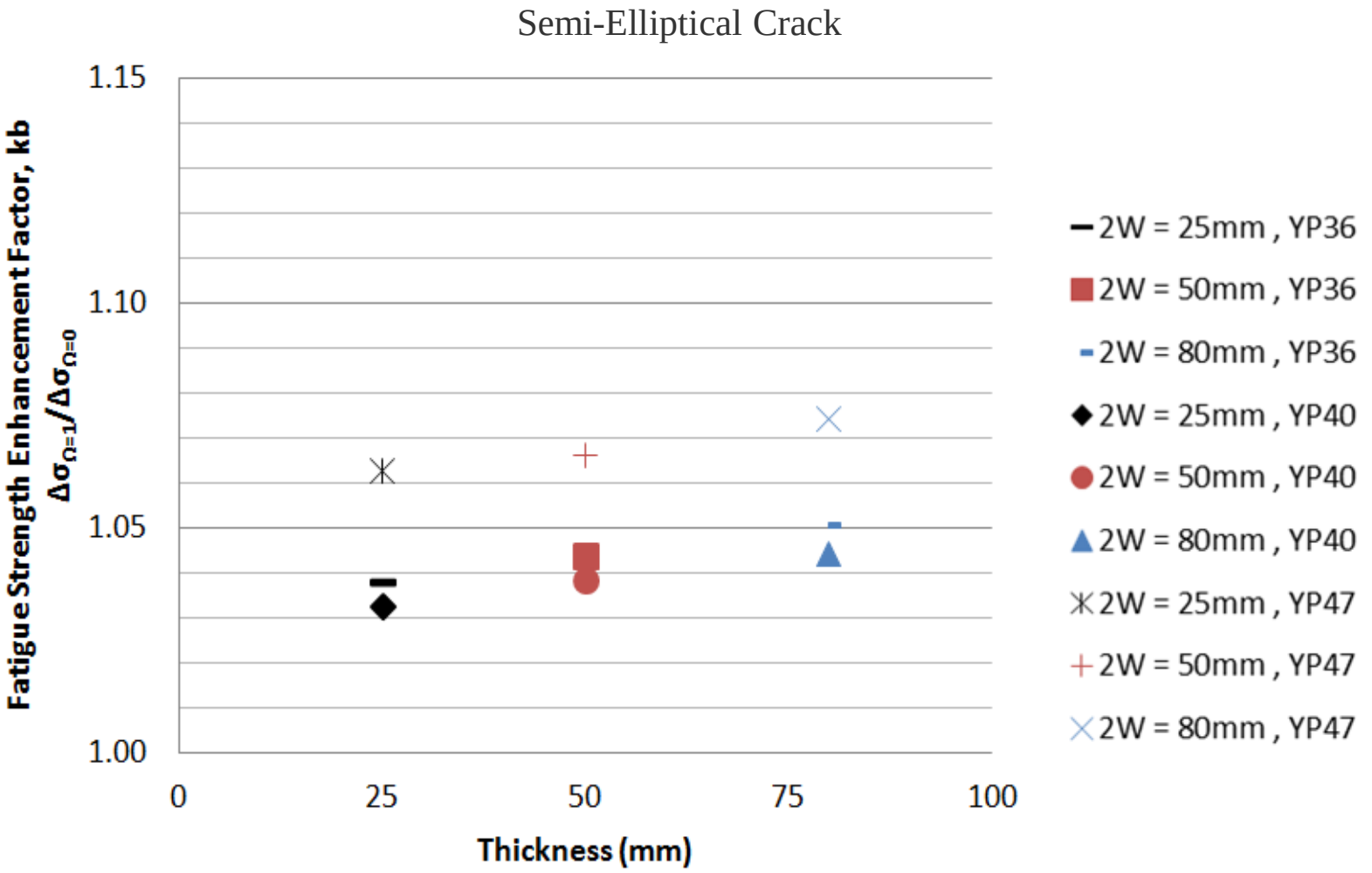
THERMAL CUT EDGES (TCE)

Comparison Results of Fracture Mechanics Analysis TCE



THERMAL CUT EDGES (TCE)

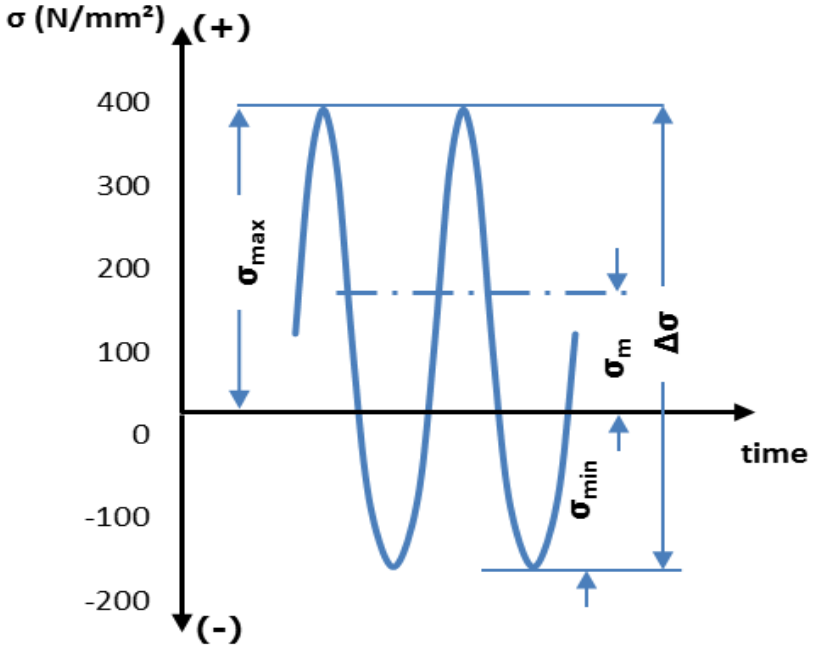
Comparison Results of Fracture Mechanics Analysis TCE



THERMAL CUT EDGES (TCE)

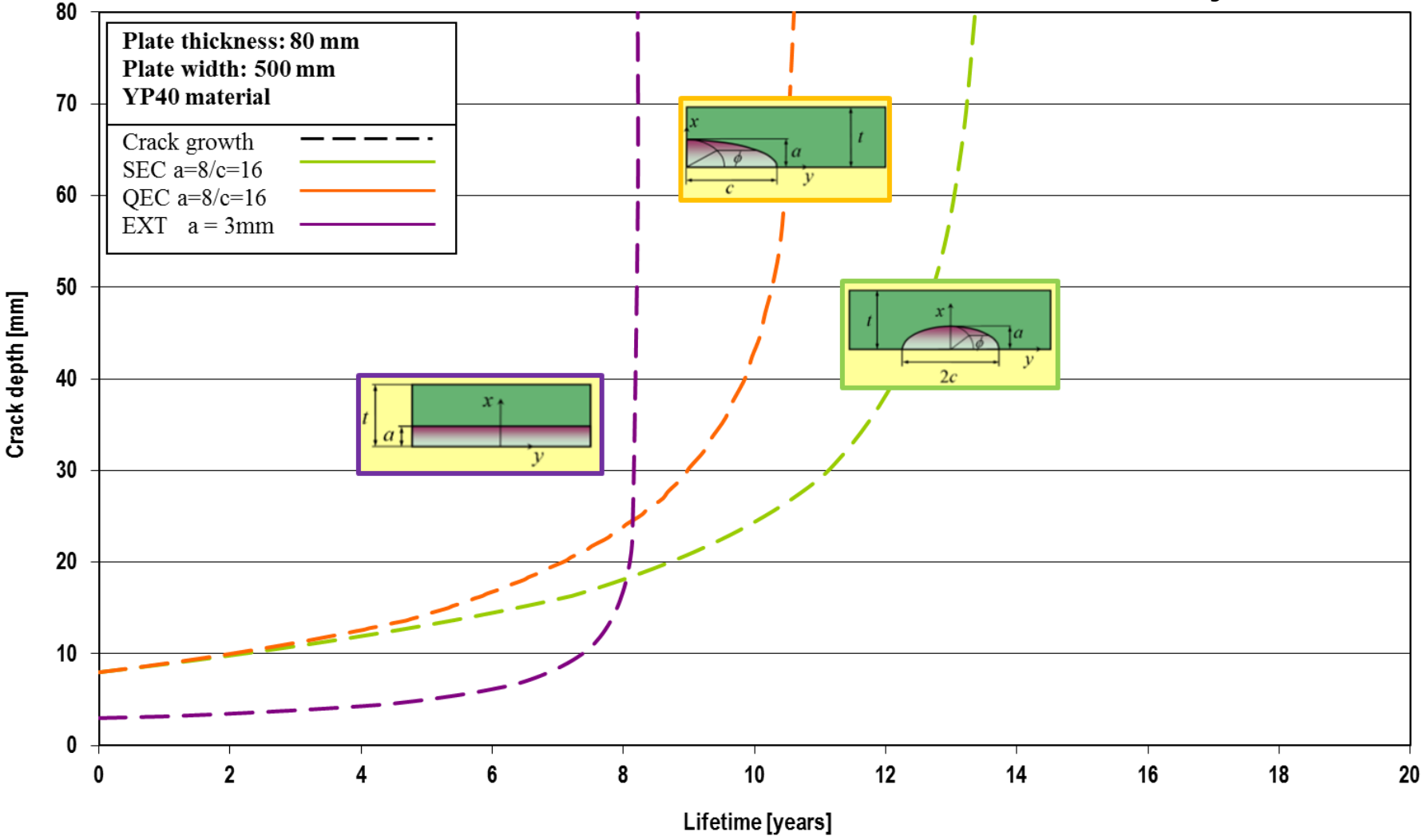
Parameters for Variable Loads Fracture Mechanics Analysis

- Calculation according to GL Rules;
- Plate from amidship; YP40; t = 80mm; FAT125;
- R = -0.4; $\Delta\sigma$ = 552N/mm²; σ_{max} = 392N/mm² and σ_{min} = -160N/mm²



THERMAL CUT EDGES (TCE)

Results for Variable Loads Fracture Mechanics Analysis



CONCLUSION

- Fracture mechanics can successfully estimate lifetime;
- Lifetime will be affected by crack size, shape and parameters.
- Fatigue enhancement due to bending;