17th International Conference on

Fracture and Damage Mechanics

4-6 September 2018

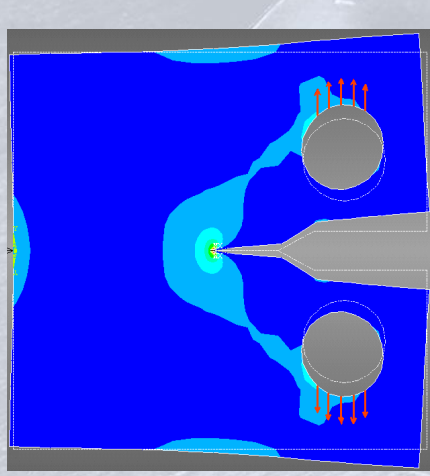
Seville, Spain

Key aspects in 3D fatigue crack closure numerical modelling

A. Gonzalez-Herrera, D. Camas and J. Garcia-Manrique

Department of Civil and Materials Engineering, School of Engineering University of Malaga, Spain.

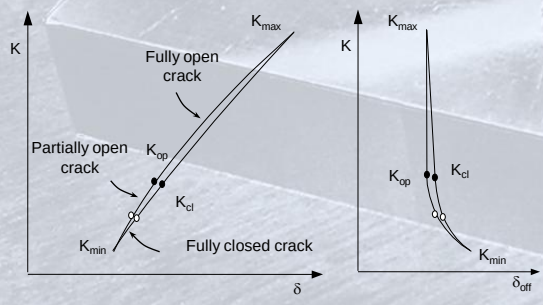
OUTLINE

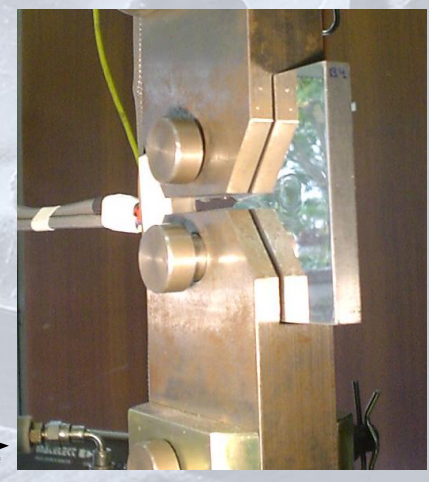


- Introduction
- General methodology
  - Load cycle and Crack Growth
  - Computing opening and closure
- Mesh size
- Plastic wake
- Conclusions

INTRODUCTION
Fatigue Crack Closure

- Elber (1970)
- ΔK_{eff}
- Plasticity Induced Crack Closure
- Experimental measurement





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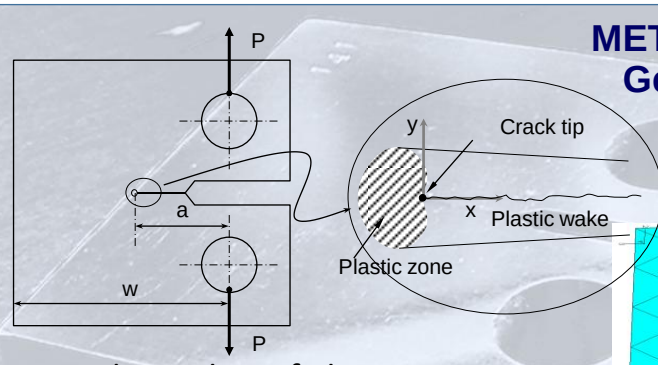
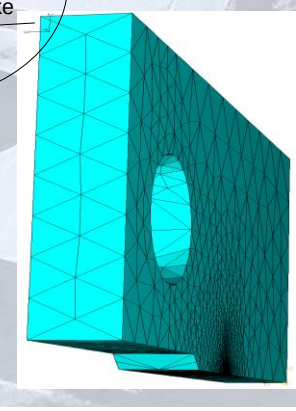
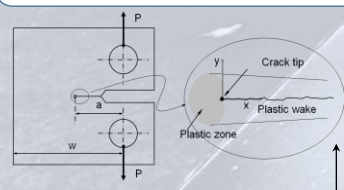
METHODOLOGY
General Issues

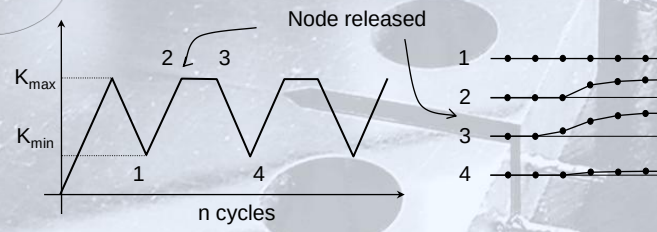


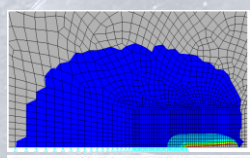


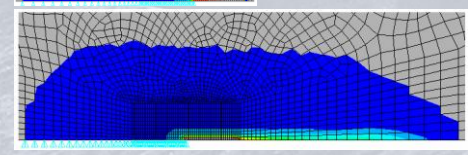
- High number of elements
- Non linearity
  - Plasticity
  - Contact
- High number of load cycles

METHODOLOGY
Load Cycles and Crack Growth









Key points
- Crack advance per cycle, Δa_i
- Total crack advance, Δa_w

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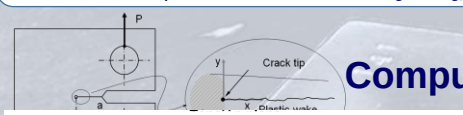
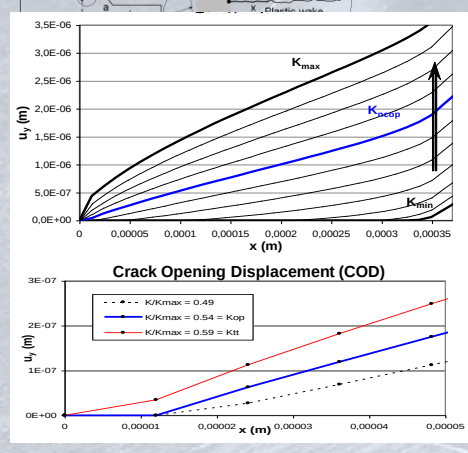
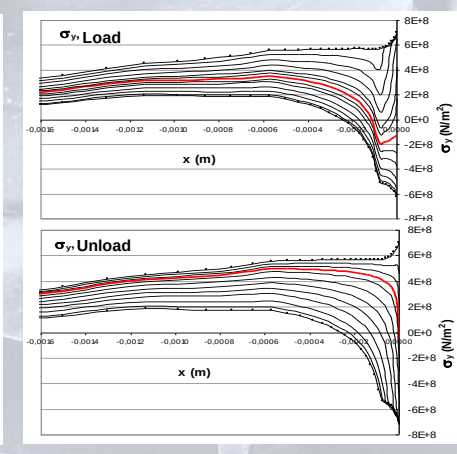
METHODOLOGY
Computing Opening and Closure







Node Contact: K_{nc}

Tip Tensile: K_{tt}

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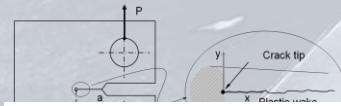

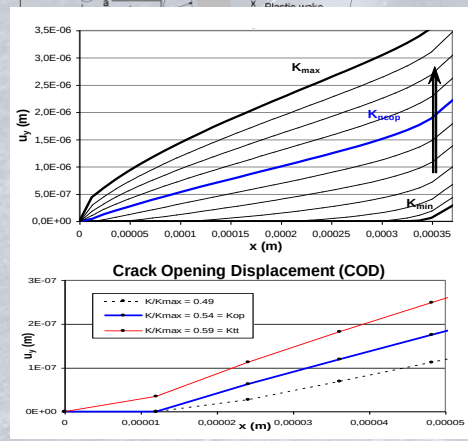

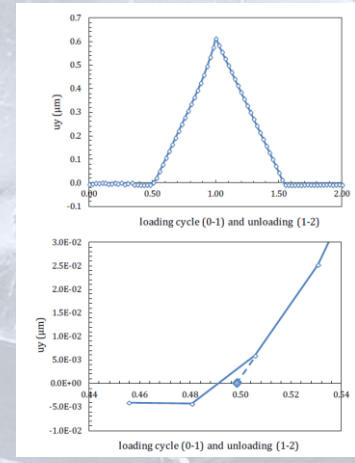

Node Contact: K_{nc}

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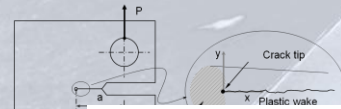
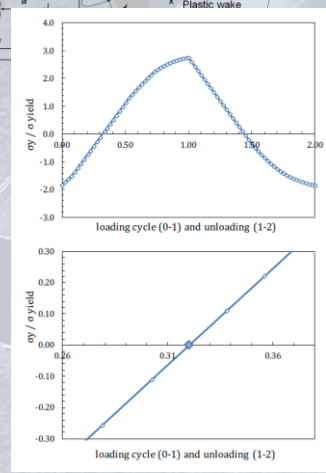
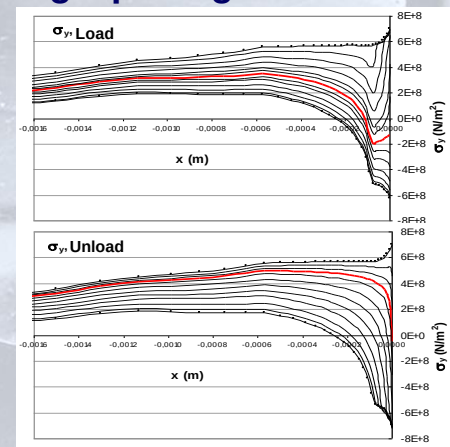
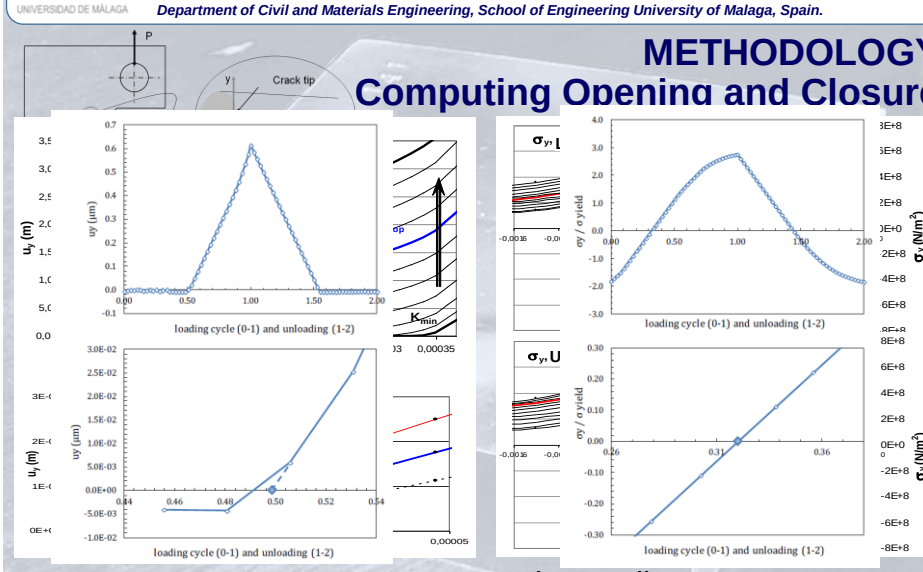






Tip Tensile: K_{tt}

METHODOLOGY
Computing Opening and Closure



Node Contact: K_{nc}

Tip Tensile: K_{tt}

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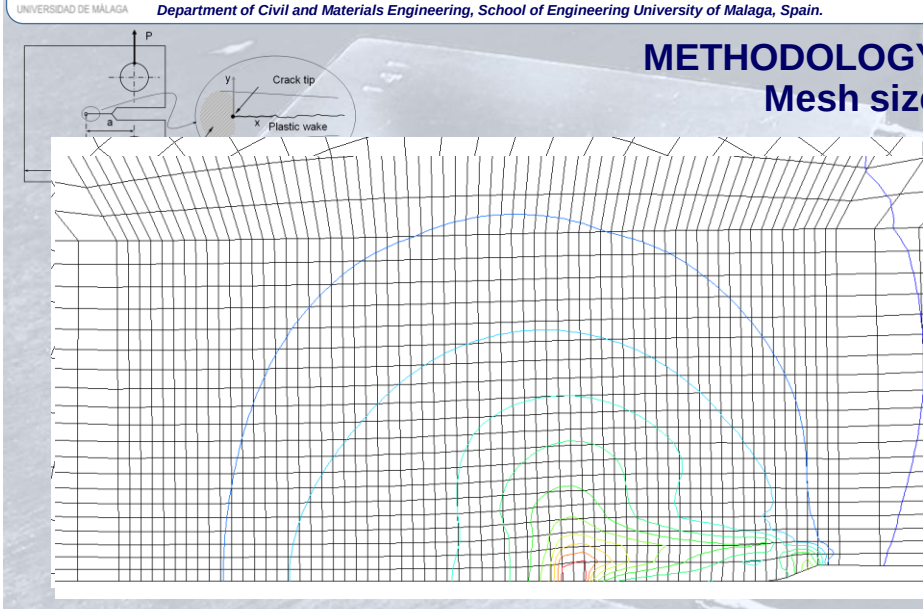
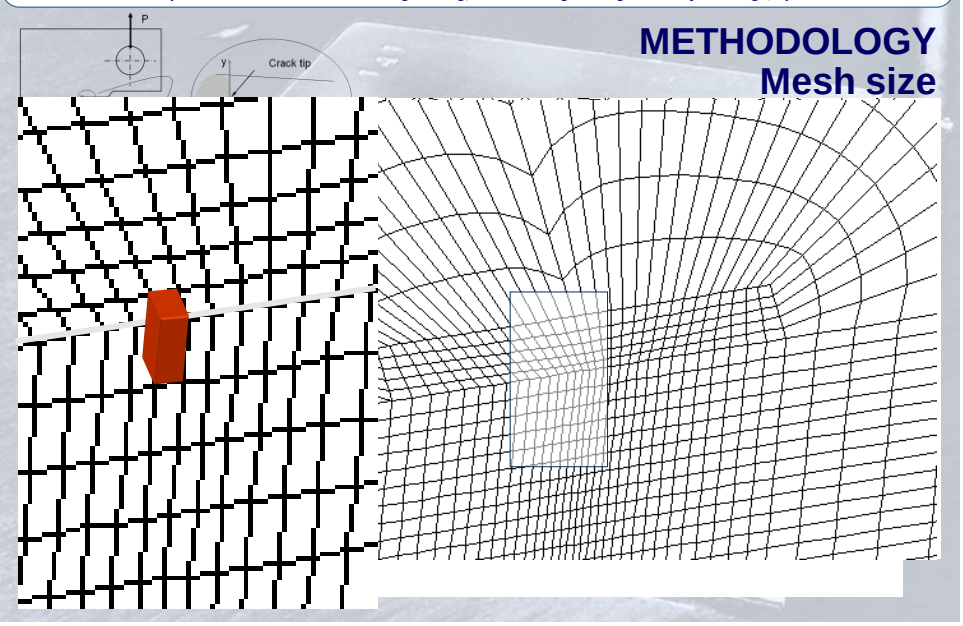
METHODOLOGY
Mesh size



METHODOLOGY
Mesh size



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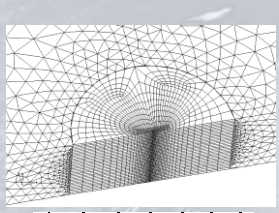

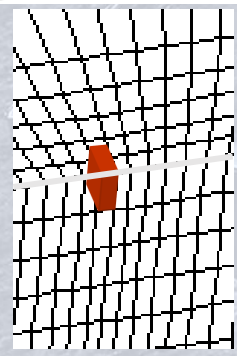

Tri-dimensional models			
Thickness	**3 mm**	**6 mm**	**12 mm**
Number of elements	37838	64016	148898
Number of nodes	158995	238010	498016
Number of variables	404471	591631	1205131
Minimum element size, s_{me}	10 μm	10 μm	10 μm
Thickness division size, h_b	42.86 μm	60 μm	60 μm
Number of divisions of the thickness	35	50	100
Element shape ratio	4.3 to 1	6 to 1	6 to 1

Gonzalez-Herrera, A., Zapatero, J., *Tri-dimensional numerical modelling of plasticity induced fatigue crack closure.* **Eng Fract Mech 2008;75**:4513-4528

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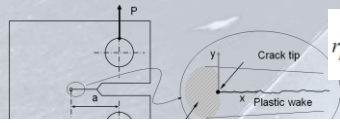
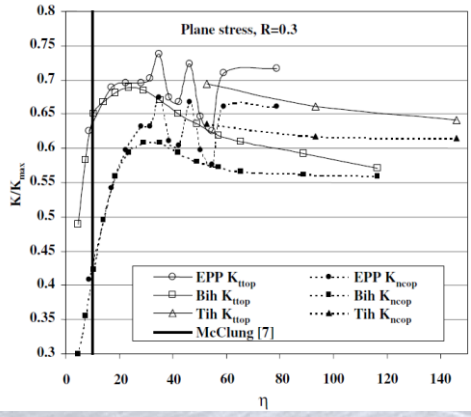
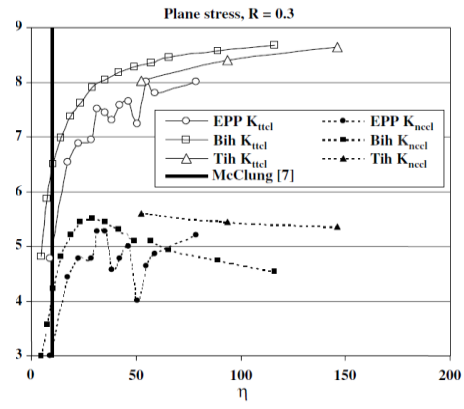


$$r_{pD} = \frac{\pi}{8\alpha}\left(\frac{K_I}{\sigma_y}\right)^2 \qquad \eta = r_{pD} / s_{me}$$

METHODOLOGY
Mesh size





Gonzalez-Herrera A, Zapatero J. *Influence of minimum element size to determine crack closure stress by the finite element method* **Eng Fract Mech 2005;72**:337–55.

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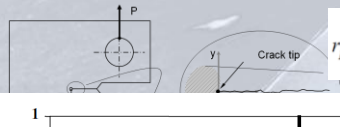
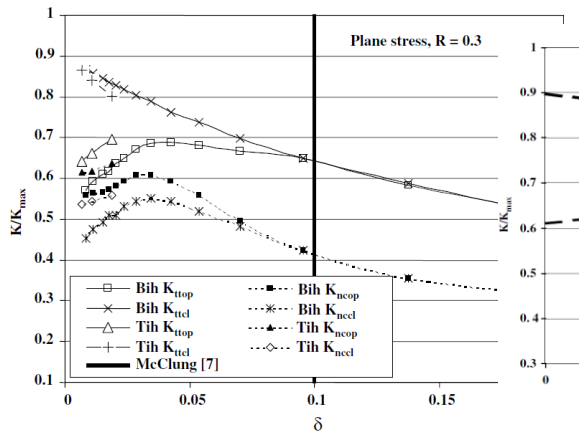
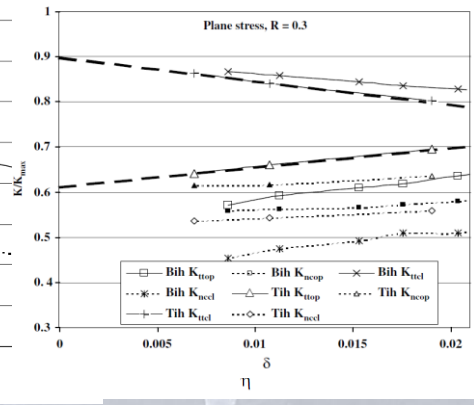


$$r_{pD} = \frac{\pi}{8\alpha}\left(\frac{K_I}{\sigma_y}\right)^2 \qquad \eta = r_{pD} / s_{me} \qquad \delta = 1/\eta$$

METHODOLOGY
Mesh size





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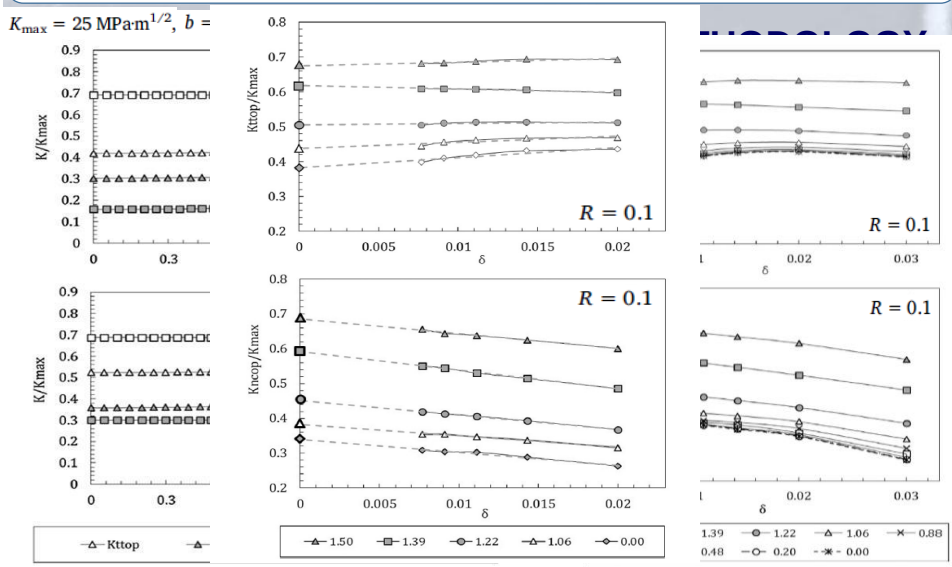

Camas, D. et al., *Numerical modelling of three-dimensional fatigue crack closure: mesh refinement*, **Int J Fatigue 2018;113**:193-203

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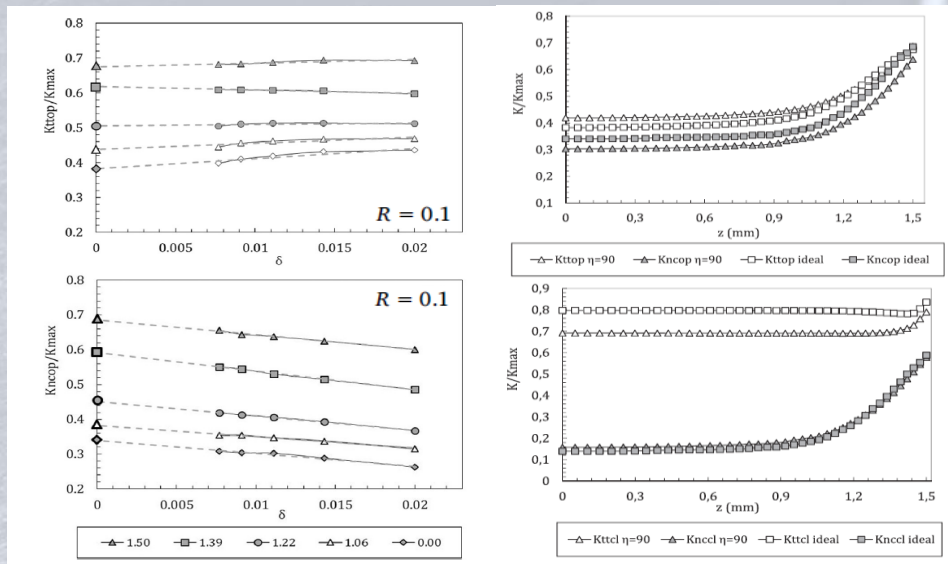

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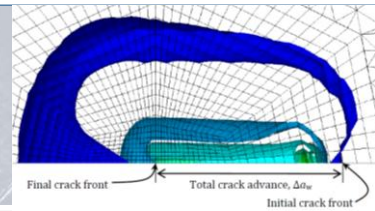
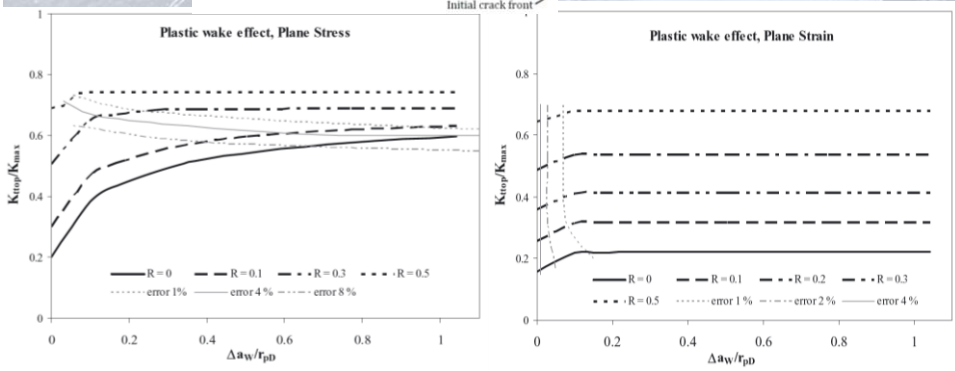
METHODOLOGY
Plastic wake





Gonzalez-Herrera A, Zapatero J. *Numerical study of the effect of plastic wake on plasticity-induced fatigue crack closure.* **Fatigue Fract Eng Mater Struct 2009;32**:249–60.

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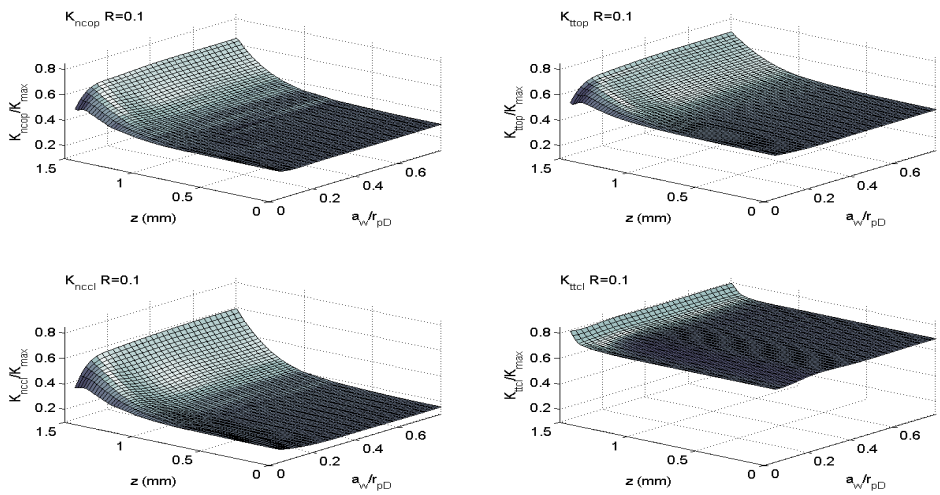

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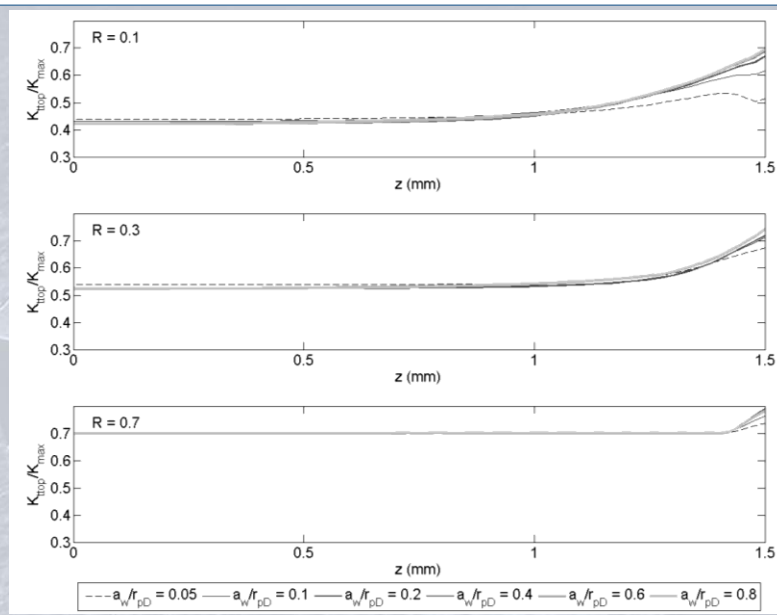

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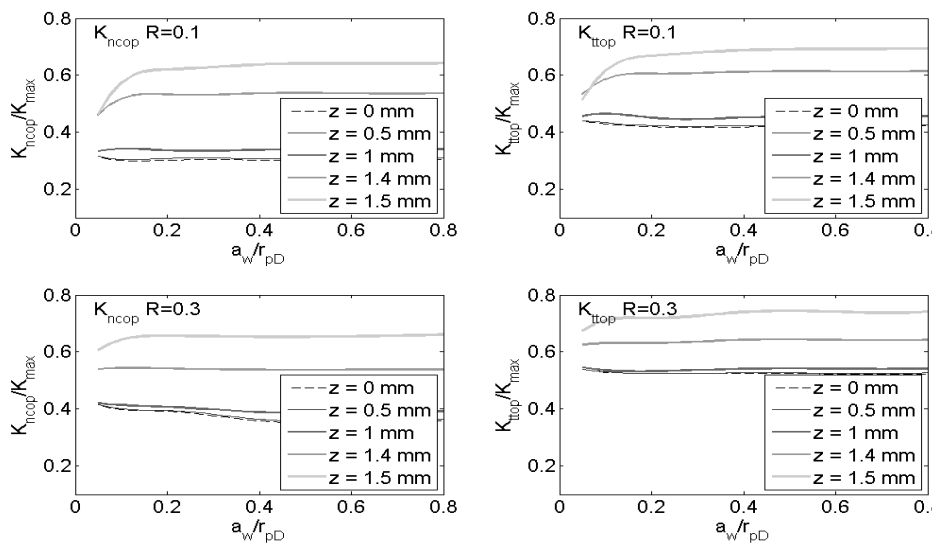

CONCLUSIONS

- This paper summarises the main learning and recommendations from the numerical modelling experience of the authors.

- The influence of the minimum element size on crack opening and closure results has been analysed considering a three-dimensional model. The error can be minimized when a minimum element size is established as $\delta<0.015$ for K_{ttop} and $\delta<0.03$ for K_{ncop}

- Regarding the influence of the plastic wake length, a plastic wake extension of $0.2r_{pD}$ for R=0.1 and $0.1r_{pD}$ for R=0.3 and R=0.7 would be acceptable. Results obtained in 3D case are less restrictive than those obtained in the 2D case.