17th International Conference on

Fracture and Damage Mechanics

4-6 September 2018

Seville, Spain

Numerical analysis of the pivot node in fracture problems

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Line of research: Develop a finite element methodology to improve the accuracy in the evaluation of 3-D phenomenon near the crack in fatigue simulation.

Fatigue simulation focused on crack closure determination.

Fracture simulation focused on stress intensity factor determination

INVOLVED FACTORS
Cross-influence?

- Crack closure criteria
- SIF calculation criteria
- Plastic wake generation
- Crack shape
- Contact simulation
- Mesh density

FEM simulations (Ansys software) with:

- CT specimen.
- Mode I load
- Aluminum 2024-T35 material
- No previous plastic wake generated

Objectives:

- Mesh requirement
- COD vs J-integral K_I determination
- Thickness, load level and crack shape influence
- 3-D effects through thickness
- Influence on fatigue parameters

Pivot node (P_I) identification

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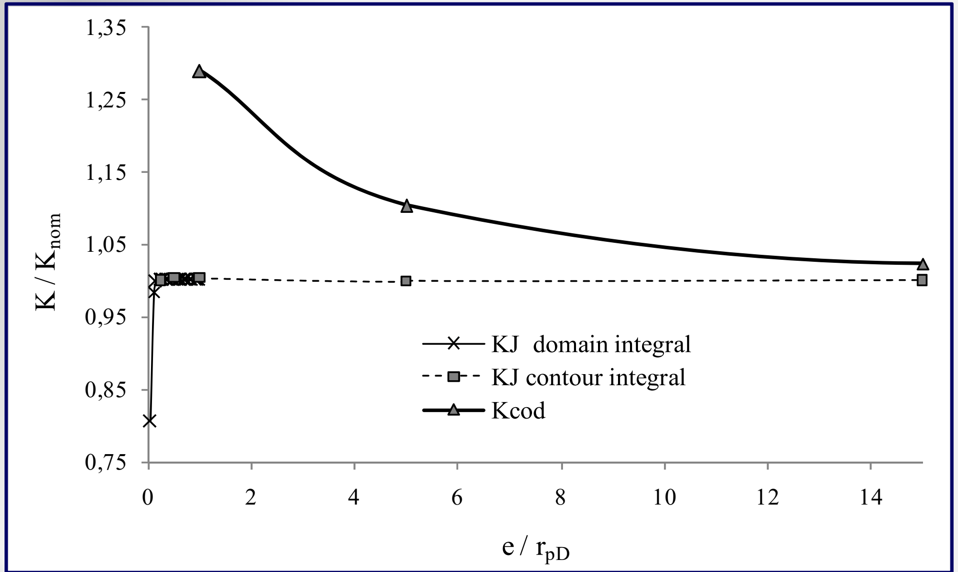
K_I calculation (1)(2)

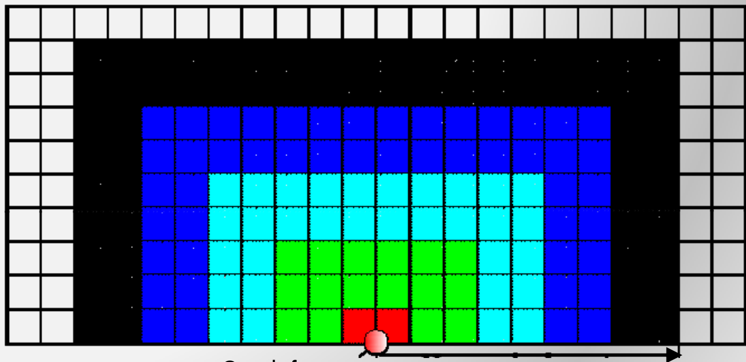
- 3-D evolution related to the nominal one (K_{nom})
- J-integral presents better accuracy that COD methods to detect tridimensional variations near the crack (K_J)
- Plane strain hypothesis (b=3-12mm, Knom=10-40MPa $m^{1/2}$)

$$K_{nom} = \frac{P}{B\sqrt{W}}\left\{\frac{2+\frac{a}{W}}{\left(1-\frac{a}{W}\right)^{\frac{3}{2}}}\cdot\left[0.886+4.64\cdot\left(\frac{a}{W}\right)-13.32\cdot\left(\frac{a}{W}\right)^{2}+14.72\cdot\left(\frac{a}{W}\right)^{3}-5.6\cdot\left(\frac{a}{W}\right)^{4}\right]\right\}$$

$$J = \int_A \left(\sigma_{ij}\frac{\partial u_j}{\partial x_1} + w\partial u_{1i}\right)\frac{\partial q}{\partial x_i}\,dA$$

$$K_J = \sqrt{J\frac{E}{(1+\upsilon^2)}}$$





1. Garcia-Manrique, J., Camas, D., Lopez-Crespo, P., Gonzalez-Herrera, A. Stress intensity factor analysis of through thickness effects. Int J Fatigue 2013; 46:58-66.
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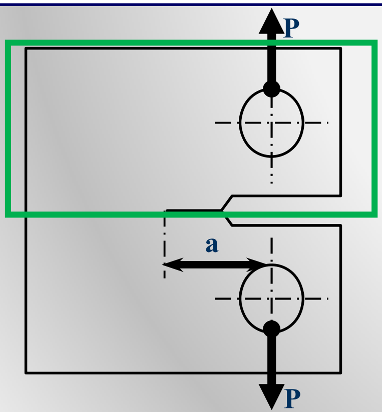
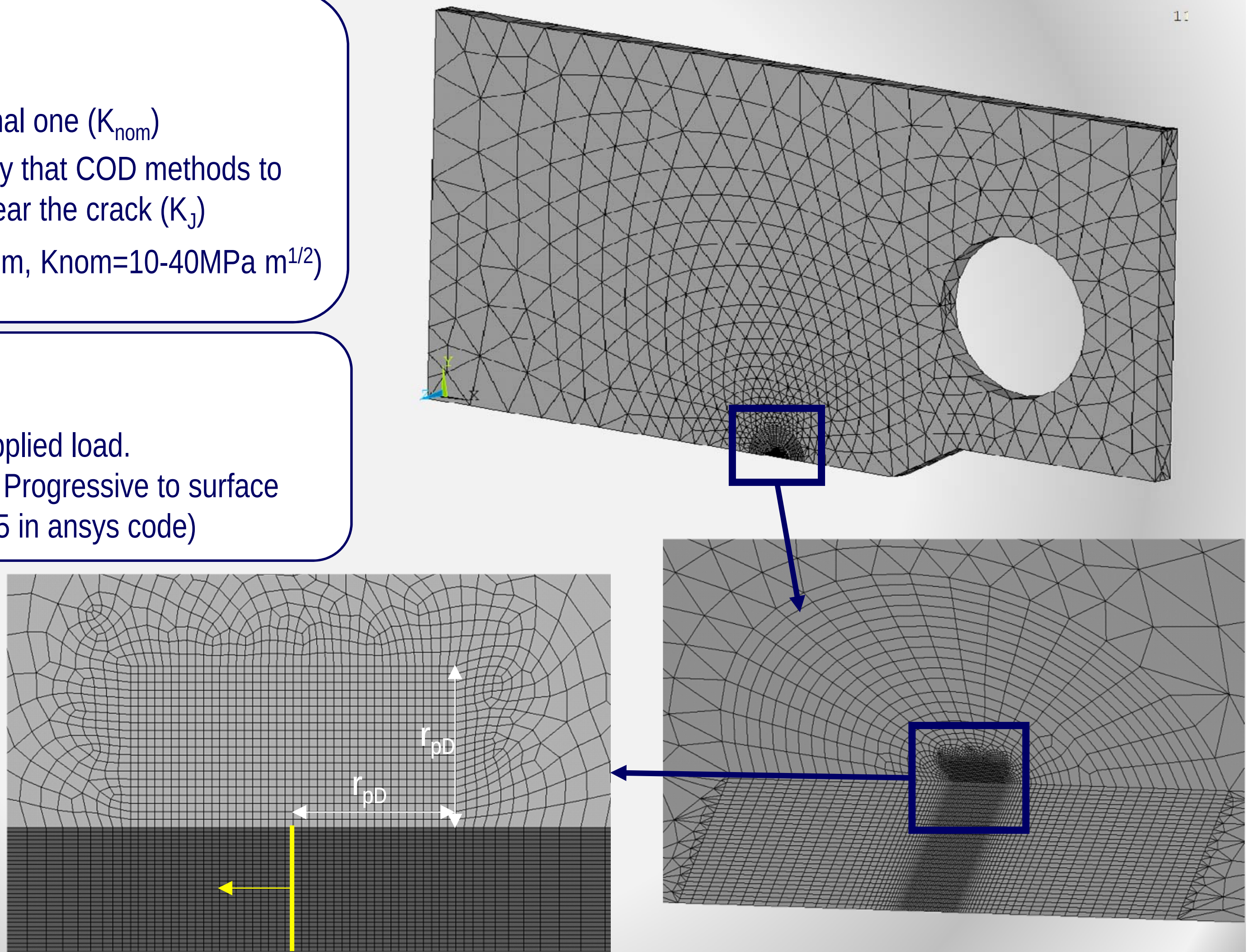
Mesh conditions[1][2]

Mesh density proportional to the applied load.
Regular meshing around the crack. Progressive to surface
Linear element selection (SOLID185 in ansys code)





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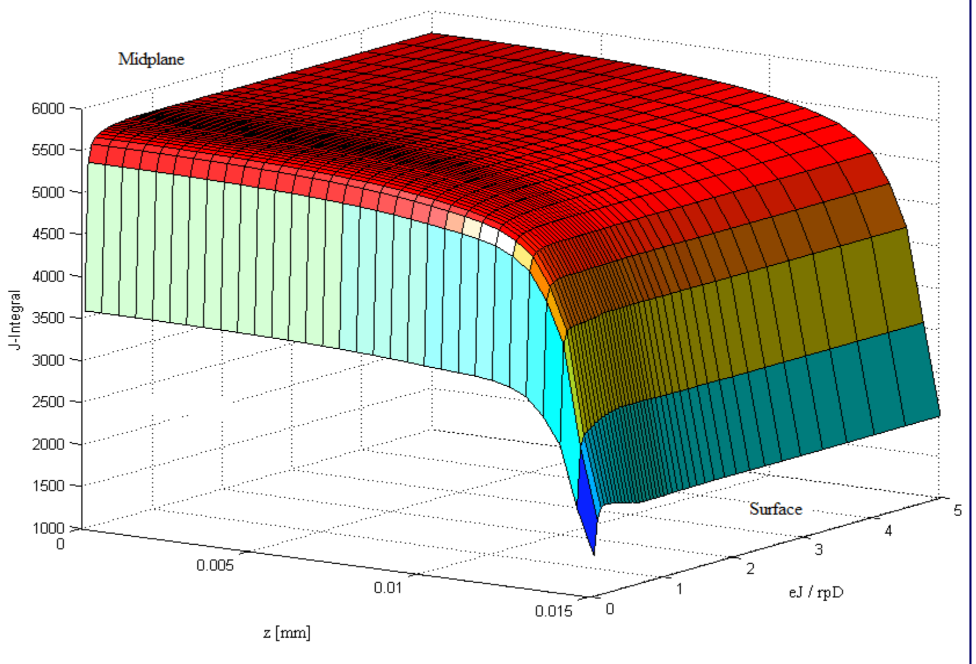
Analysis of minimum element size near the crack. Both in crack direction (t_{mex}<1/20 r_{pD}) and through thickness (t_{mez} <1/40 b).



Influence of distance e_J in the J-integral calculation through thickness in 3D simulation. (K_{nom} =20 MPa·$m^{1/2}$, b=3mm, a=20mm)

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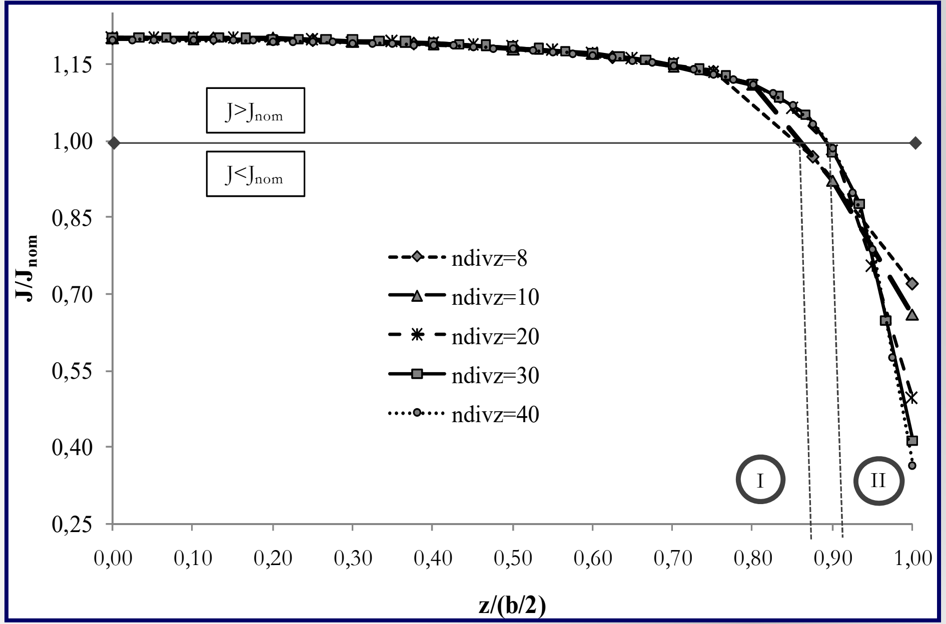

Evolution of J-integral through thickness in a straight crack front for different mesh densities (K_{nom} =20 MPa·$m^{1/2}$, b=3mm, a=20mm)

1. Garcia-Manrique, J., Camas, D., Lopez-Crespo, P., Gonzalez-Herrera, A. Stress intensity factor analysis of through thickness effects. Int J Fatigue 2013; 46:58-66.
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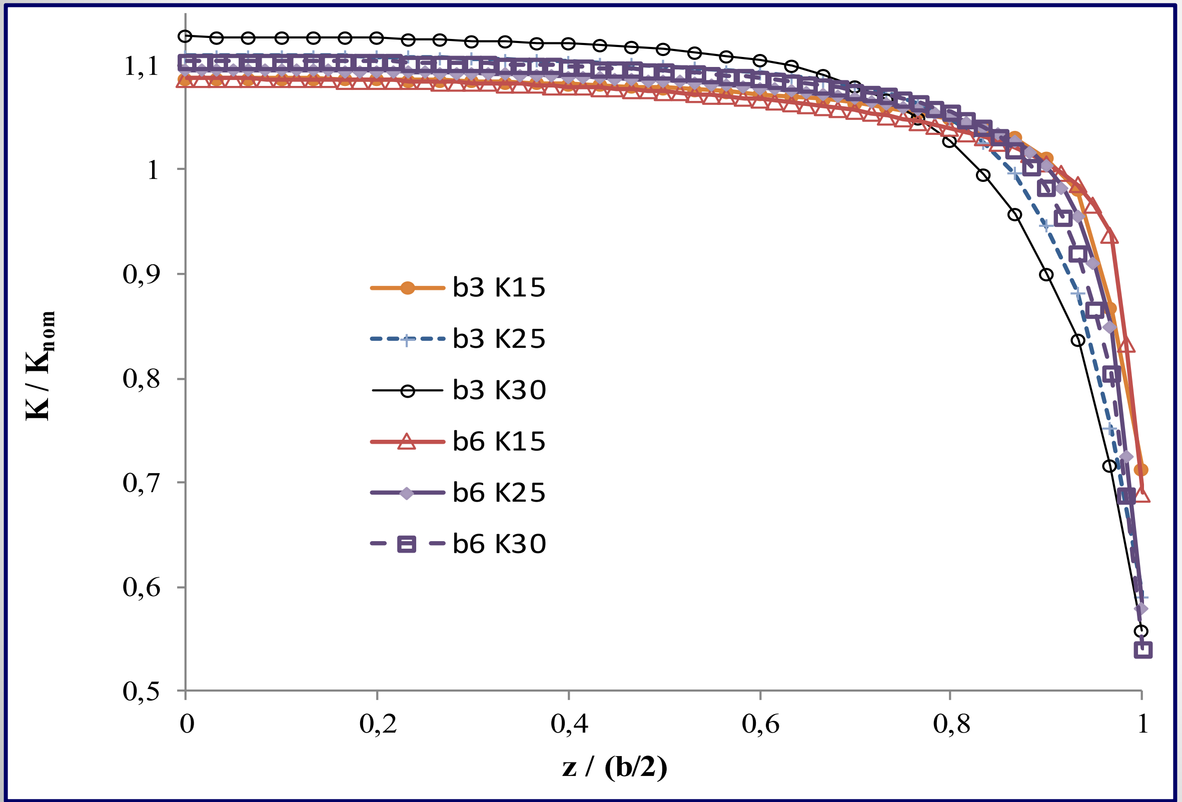
Pivot node [3]

Some results to study the influence of thickness and maximum load in K_J distribution. *Non-dimensionalized with K_{nom} and thickness (b/2).*



Stress intensity factor distribution in straight crack front. Thickness b= 3 mm and b= 6 mm. K_{max}=15, 25 and 30 MPam$^{1/2}$. Non-dimensionalized results along the thickness.

3. J. Garcia-Manrique, D. Camas-Peña, J. Lopez-Martinez, A. Gonzalez-Herrera, Analysis of the stress intensity factor along the thickness: The concept of pivot node on straight crack fronts, Fatigue Fract. Eng. Mater. Struct. 41 (2018).

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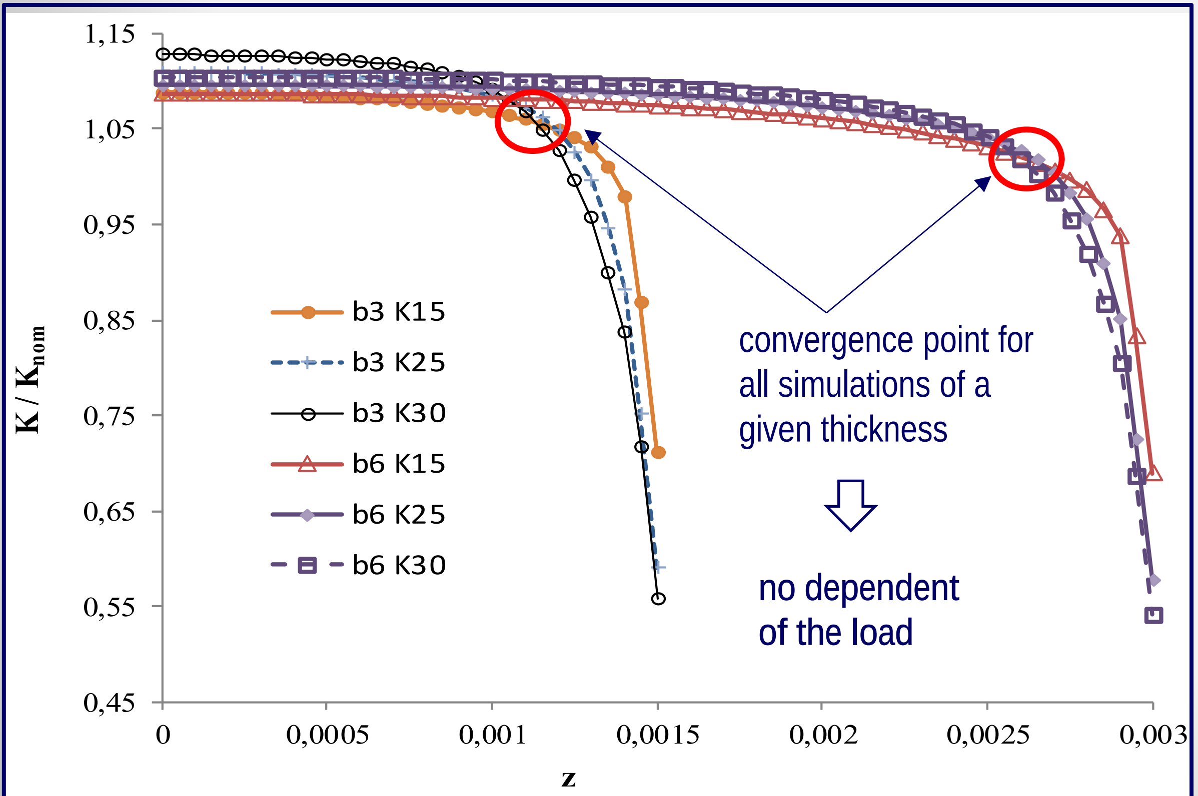

Stress intensity factor distribution in straight crack front. Thickness b= 3 mm and b= 6 mm. K_{max}=15, 25 and 30 $MPam^{1/2}$. Results along the thickness.

sustained growth?

crack front shape would pivot around it?

3. J. Garcia-Manrique, D. Camas-Peña, J. Lopez-Martinez, A. Gonzalez-Herrera, Analysis of the stress intensity factor along the thickness: The concept of pivot node on straight crack fronts, Fatigue Fract. Eng. Mater. Struct. 41 (2018).

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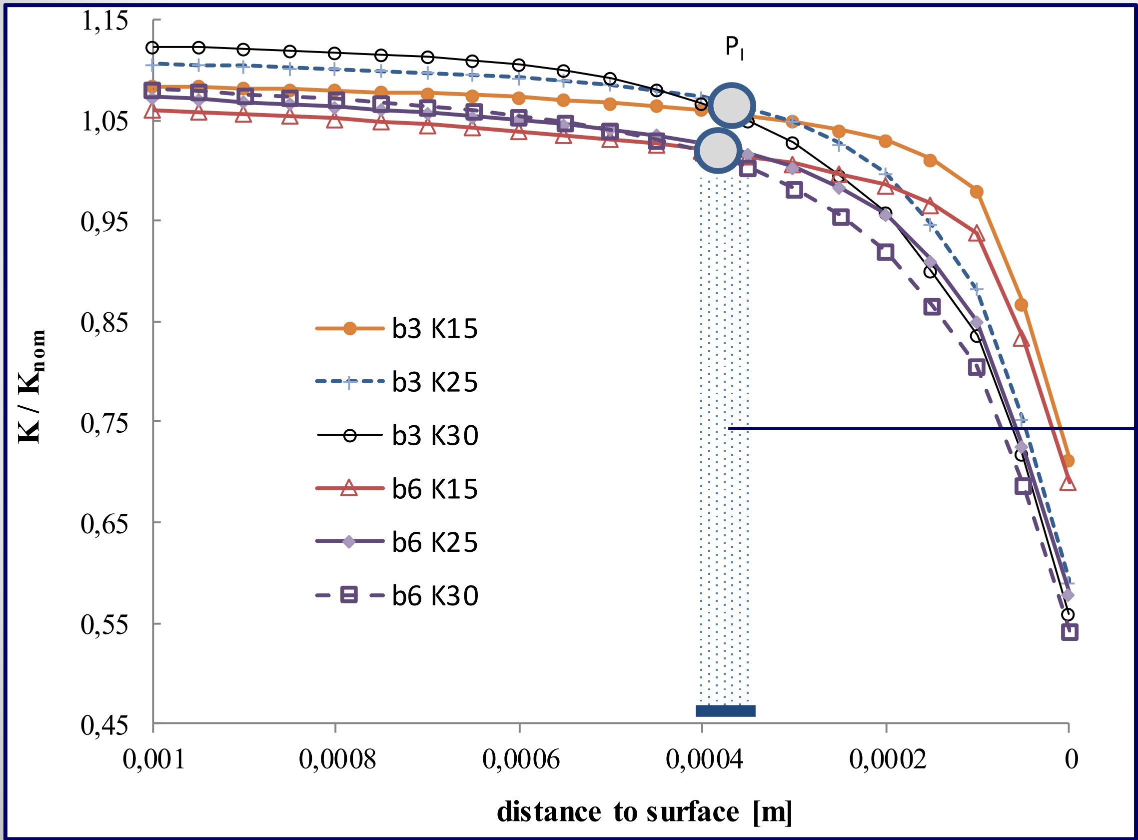
Pivot node [3]

Some results to study the influence of thickness and maximum load in K_J distribution. *X-axis : distance to surface*



Stress intensity factor distribution in straight crack front versus distance to the surface. Thickness b= 3 mm and b= 6 mm. K_{max}=15, 25 and 30 $MPam^{1/2}$.

located at the same distance from the exterior

⇩

no dependent of the total thickness

Oportunity to improve the correlation of numerical and experimental results

3. J. Garcia-Manrique, D. Camas-Peña, J. Lopez-Martinez, A. Gonzalez-Herrera, Analysis of the stress intensity factor along the thickness: The concept of pivot node on straight crack fronts, Fatigue Fract. Eng. Mater. Struct. 41 (2018).

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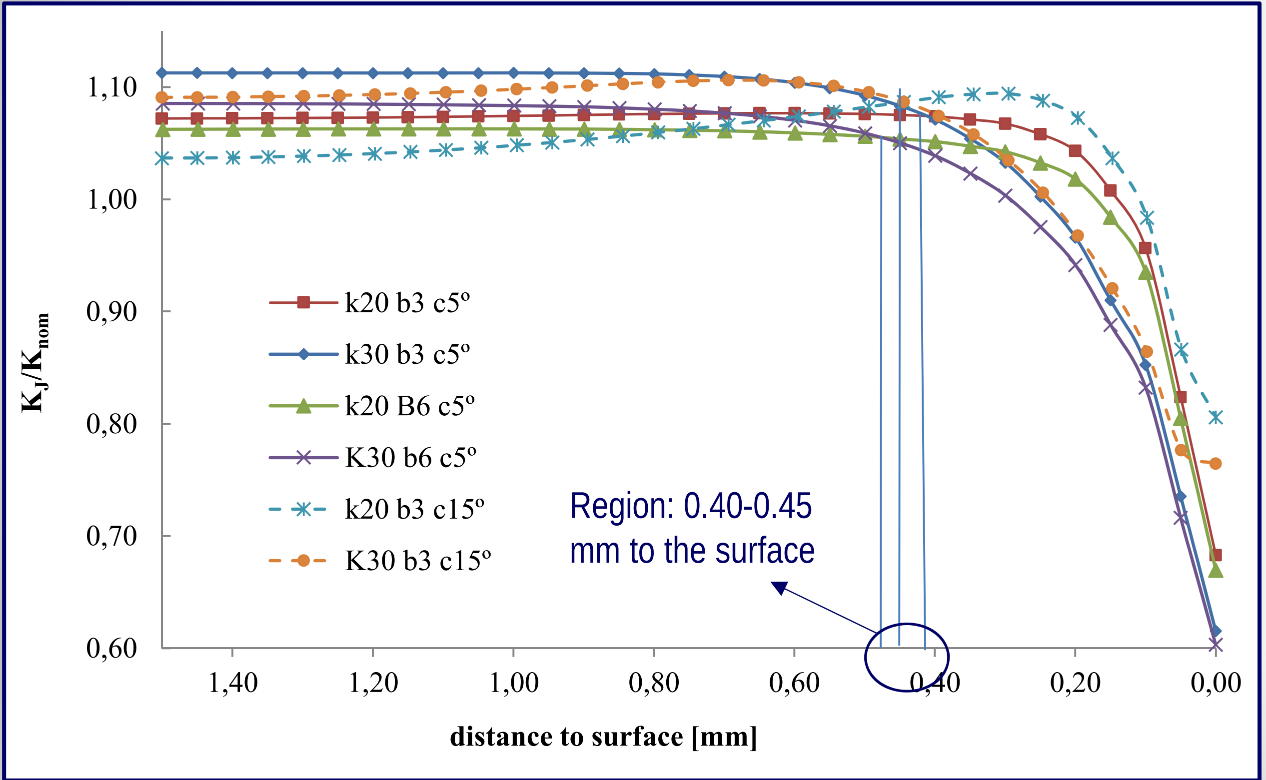
Pivot node

Some results to study the influence of crack shape curvature in the location of pivot node



Stress intensity factor distribution in curve crack front versus distance to the surface. Thickness b= 3 mm and b= 6 mm. Curvature 5 and 15º. K_{max}= 20 and 30 $MPam^{1/2}$.

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CONCLUSION

Through FEM evaluation of K_I , we can identify a narrow region where the binomial influence of load level and thickness disappear.

It becomes a region that characterizes the crack growth phenomenon and presents interesting characteristics for the numerical-experimental correlation.

THANK YOU FOR YOUR ATTENTION