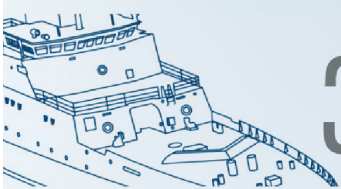


Analysis of Crack Propagation in Mechanical Components Presenting Multiples Cracks

Dr. ADAN VEGA SAENZ

Technological University of Panama



Outline

1. Introduction

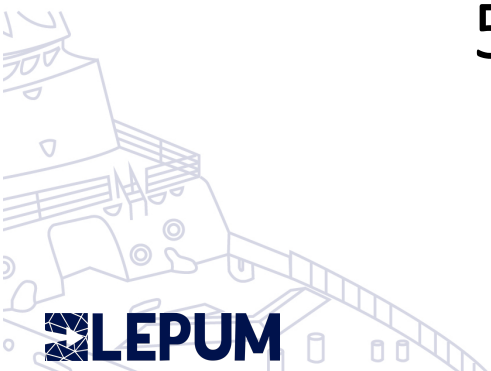
2. Modeling of the crack propagation mechanism

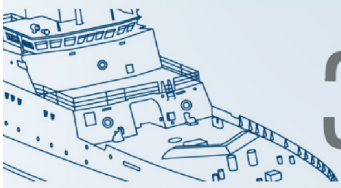
3. Application to real structures

4. Analysis of single cracks

5. Analysis of multiple cracks

6. Conclusions





Outline

1. Introduction

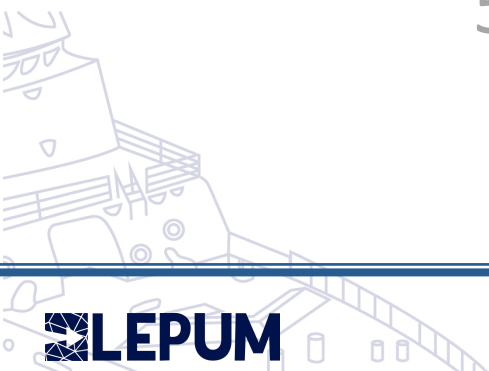
2. Modeling of the crack propagation mechanism

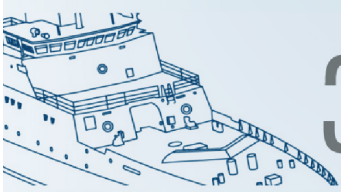
3. Application to real structures

4. Analysis of single cracks

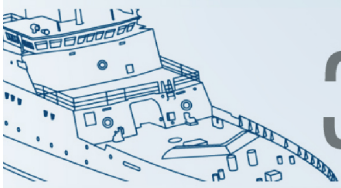
5. Analysis of multiple cracks

6. Conclusions





1. Design mechanical elements, under the assumption of the absence of defects in their manufacture and then consider its effect by safety factors is risky
2. Reality is that defects and particularly cracks appear either in the manufacturing or generated in service
3. It is therefore necessary to analyze its effect on the performance of the element or structure



Outline

1. Introduction

2. Modeling of the crack propagation mechanism

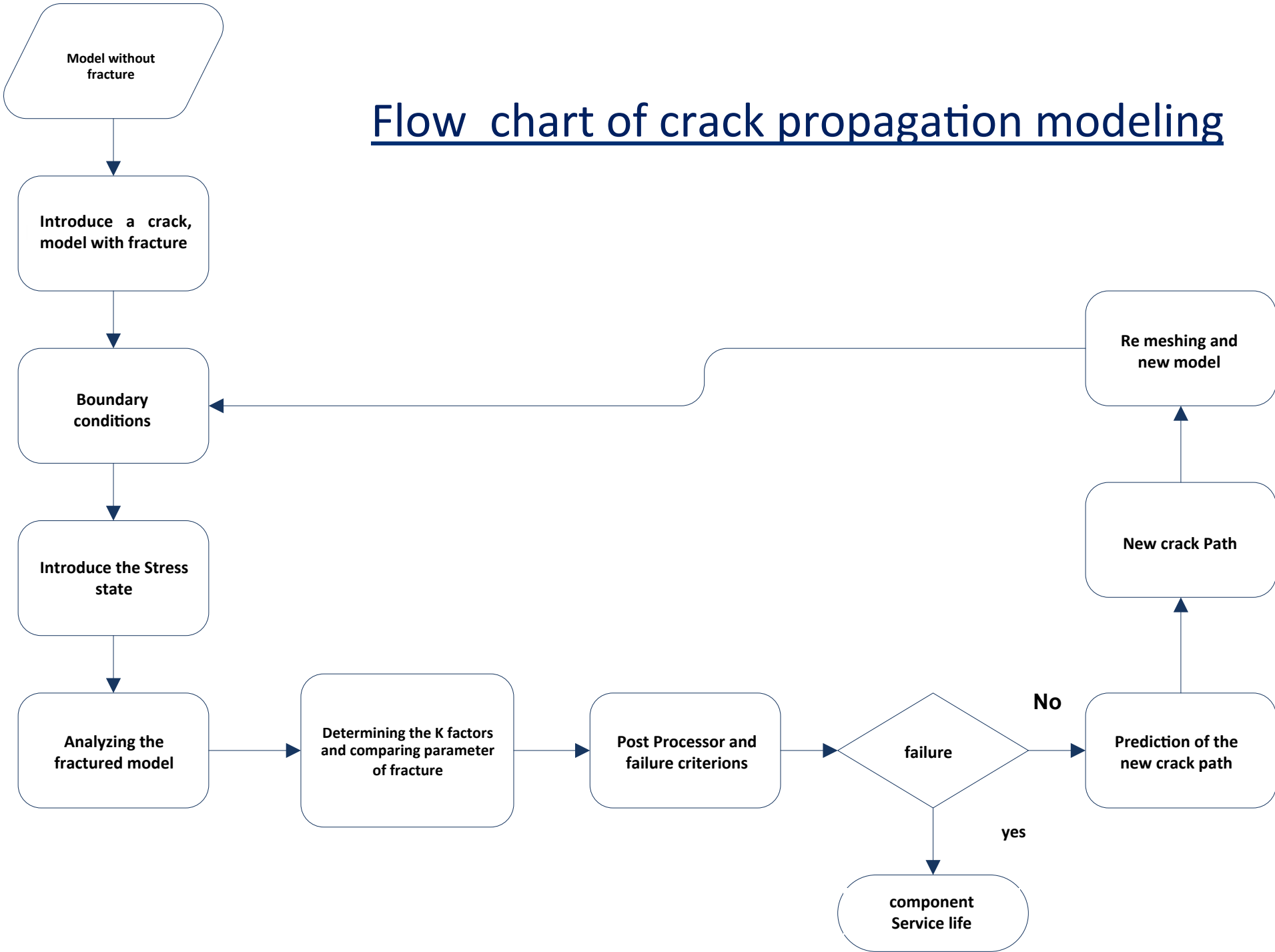
3. Application to real structures

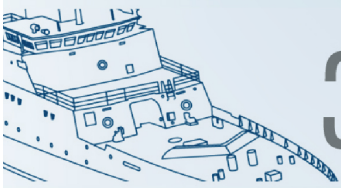
4. Analysis of single cracks

5. Analysis of multiple cracks

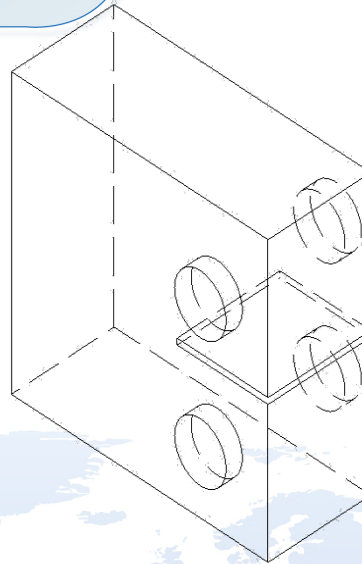
6. Conclusions

Flow chart of crack propagation modeling





Working piece

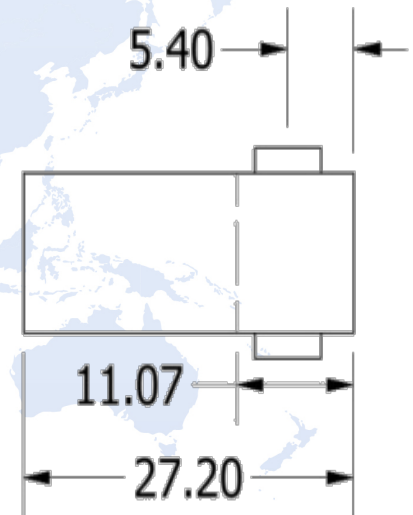
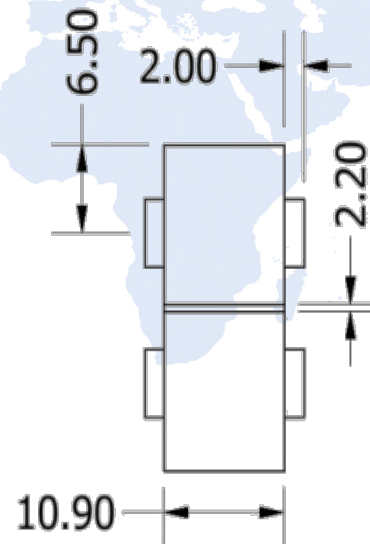
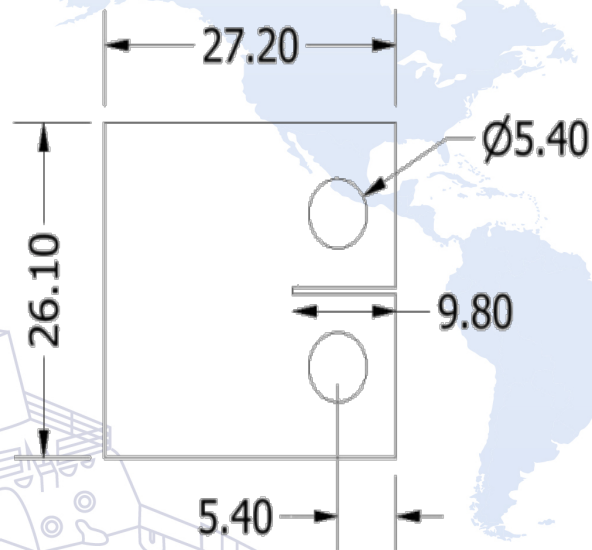


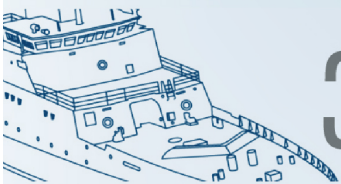
ASTM E-399

Material: AISI/SAE 1045

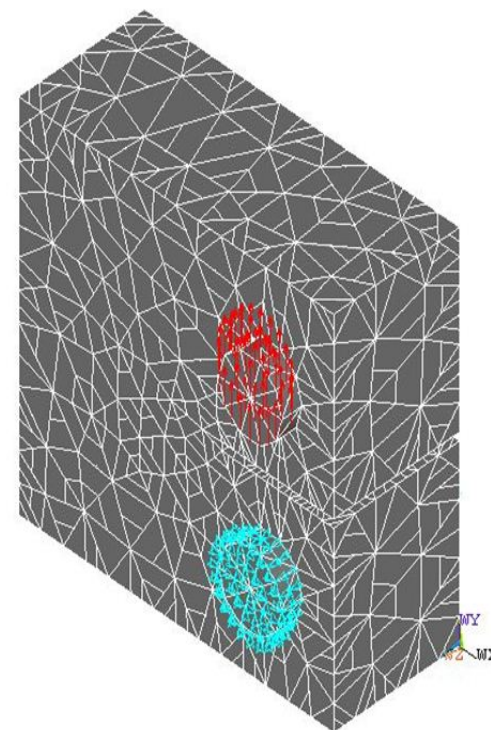
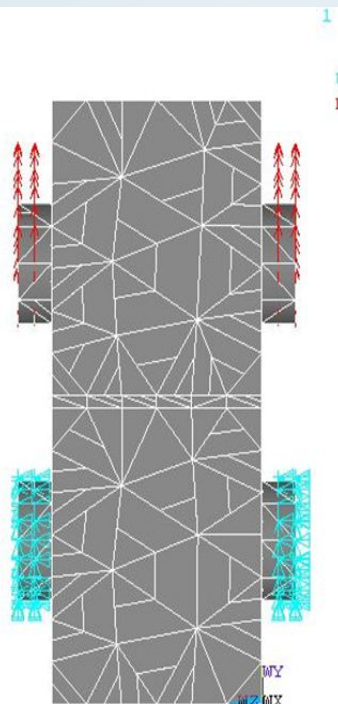
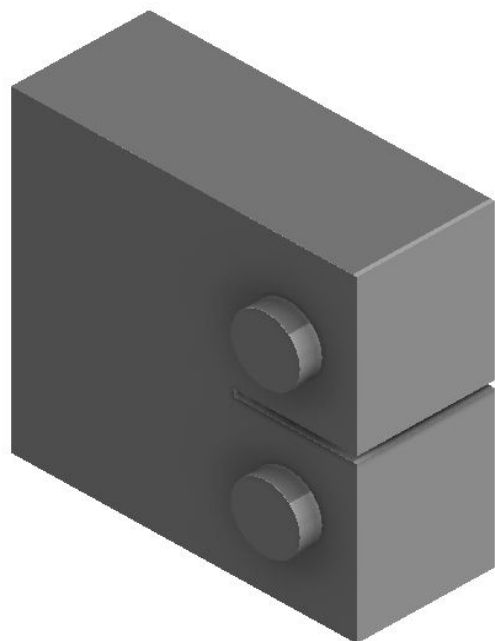
$\sigma_y = 419 \text{ MPa}$

$\sigma_u = 673 \text{ MPa}$





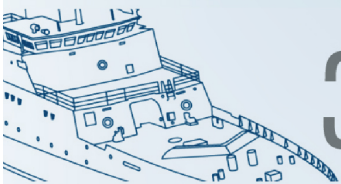
FEM Model



Type of element	number of element	number of nodes
Tetrahedral	68927	1378540
Parallelepipeds	3200	32000
Wedge	1600	24000
Piramydal	1600	20800
Total	75327	1455340

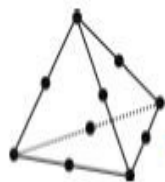
Software:

1. ANSYS APDL (for stress state generation)
2. Frac3D (to insert the crack)
3. ANSYS Fatigue (to determine the life service)



Element types around the crack

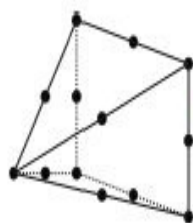
Tetrahedral elements
far from the crack



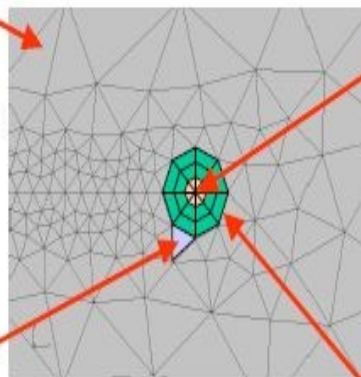
Wedge elements for
singularity simulation

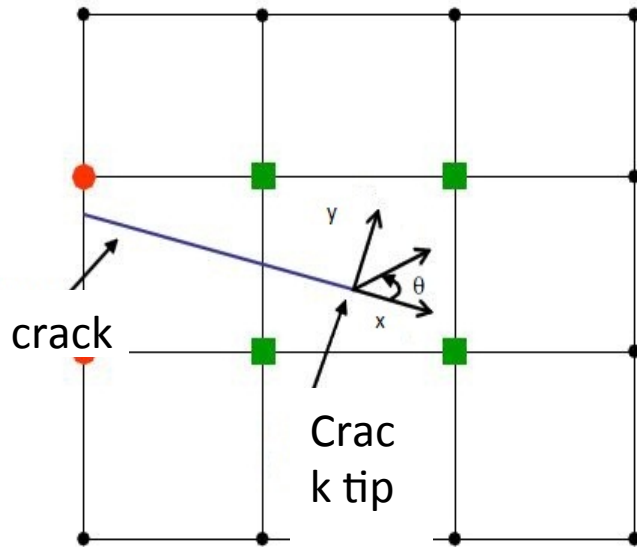
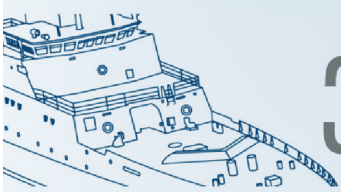


Pyramidal elements for joint
tetrahedral and parallelepipeds
elements



Two rings of
parallelepipeds
elements





Method of analysis

- Extended Finite Element Method (XFEM) by enrichment

This suppresses the need to mesh and remesh the discontinuity surfaces

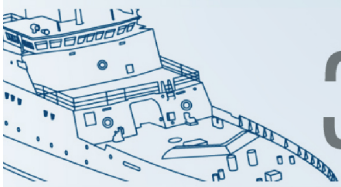
to calculate the strain energy release rate and the state of stresses:

J -Integral:

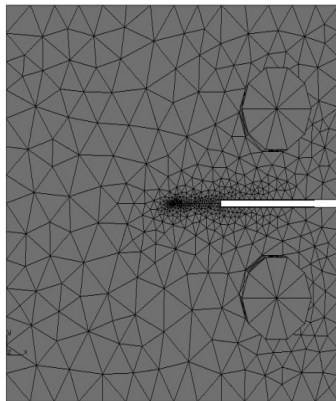
$$J = \int_{\Gamma} \left(W dy - T \cdot \frac{\partial u}{\partial x} d\Gamma \right)$$

M -Integral:

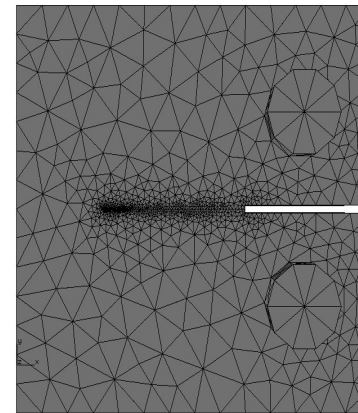
$$M^{(1,2)} = \int_A \left[\left(\sigma_x \frac{\partial u_x^{(2)}}{\partial x} + \tau_{xy} \frac{\partial u_y^{(2)}}{\partial x} + \sigma_x^{(2)} \frac{\partial u_x^{(1)}}{\partial x} + \tau_{xy}^{(2)} \frac{\partial u_y^{(1)}}{\partial x} - \sigma_{ij} \varepsilon_{ij}^{(2)} \right) \frac{\partial q}{\partial x} + \left(\tau_{xy} \frac{\partial u_x^{(2)}}{\partial x} + \sigma_y \frac{\partial u_y^{(2)}}{\partial x} + \tau_{xy}^{(2)} \frac{\partial u_x^{(1)}}{\partial x} + \sigma_y^{(2)} \frac{\partial u_y^{(1)}}{\partial x} \right) \frac{\partial q}{\partial y} \right] dA$$



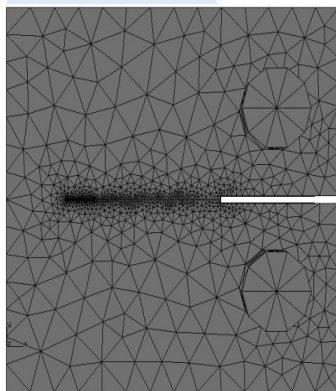
Example of the Crack Propagation Sequence



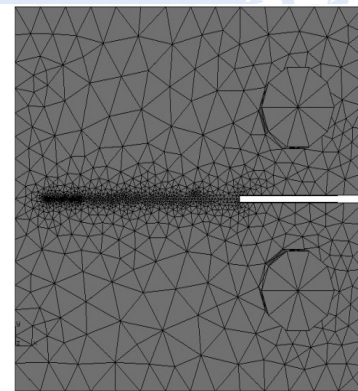
After 5E+3 cicles



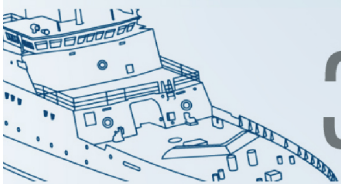
After 2E+4 cicles



After 6E+4 cicles

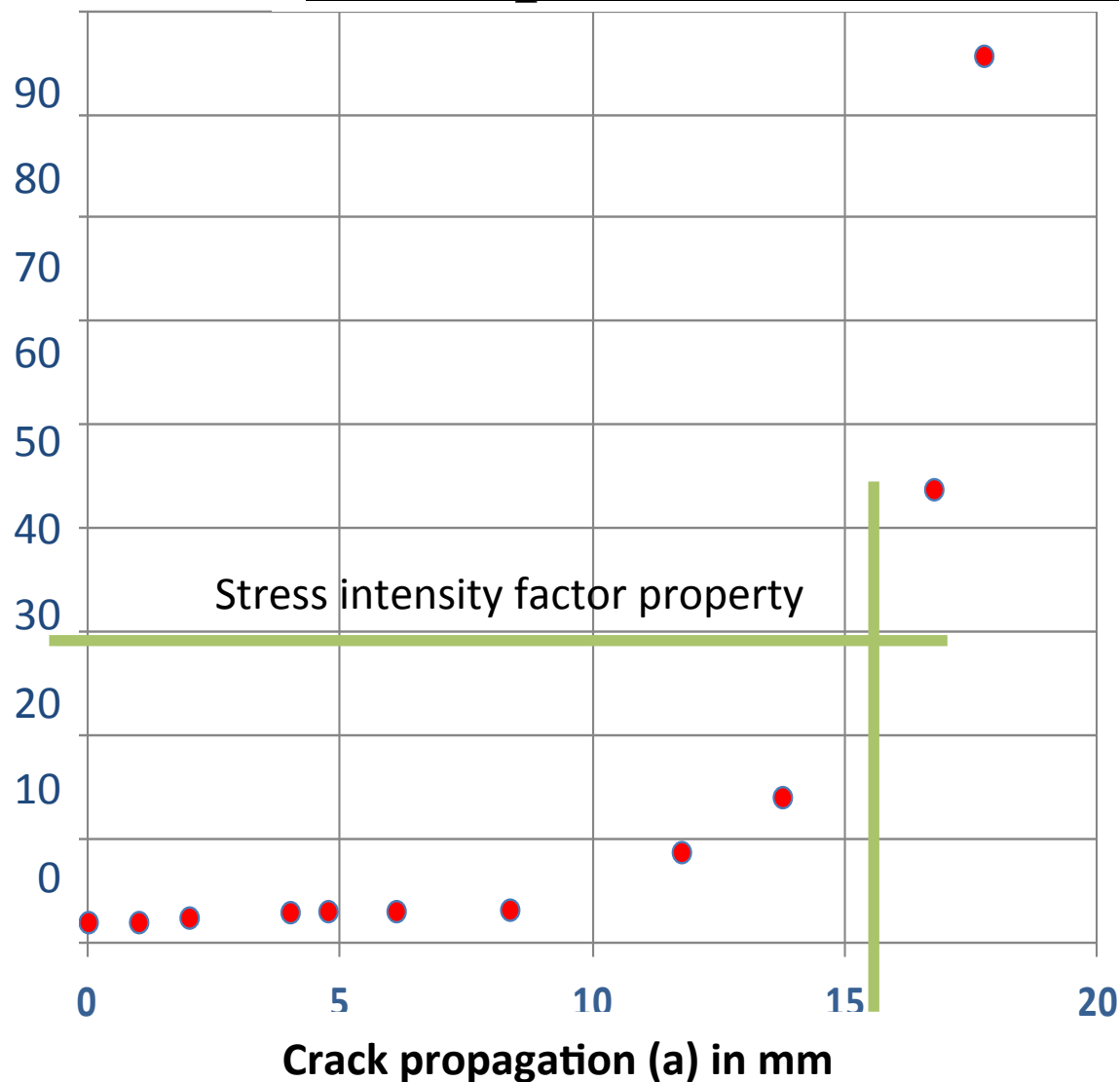


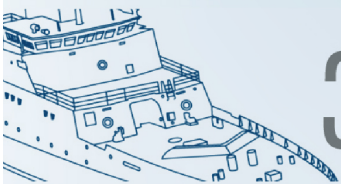
After 8E+4 cicles



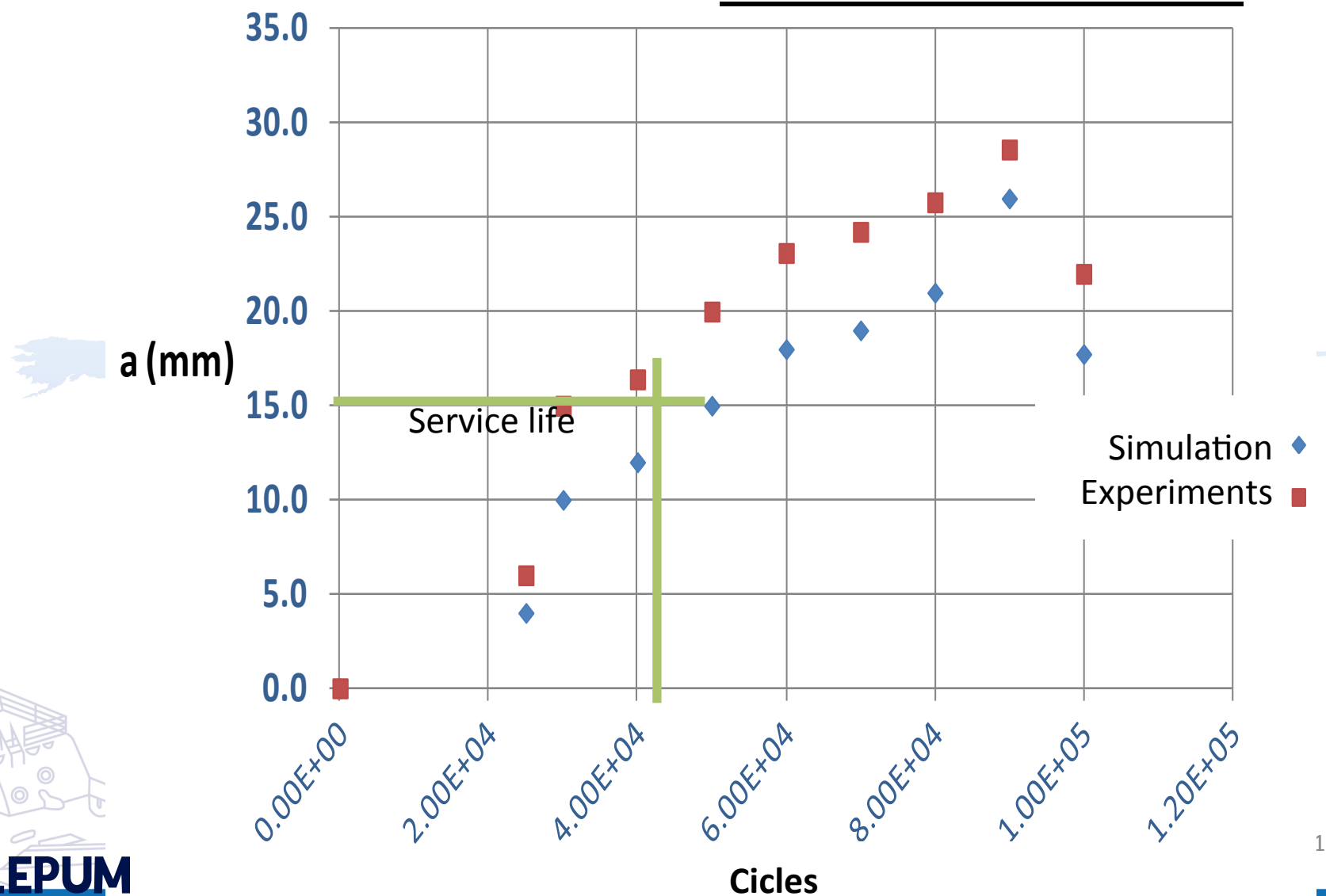
Example of the Results

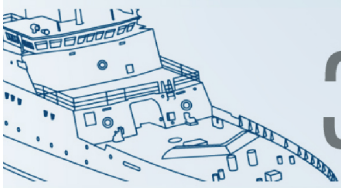
KL max
(MPa.mm^{1/2})





Results Validation





Outline

1. Introduction

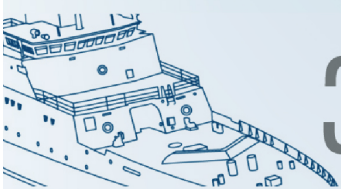
2. Modeling of the crack propagation mechanism

3. Application to real structures

4. Analysis of single cracks

5. Analysis of multiple cracks

6. Conclusions

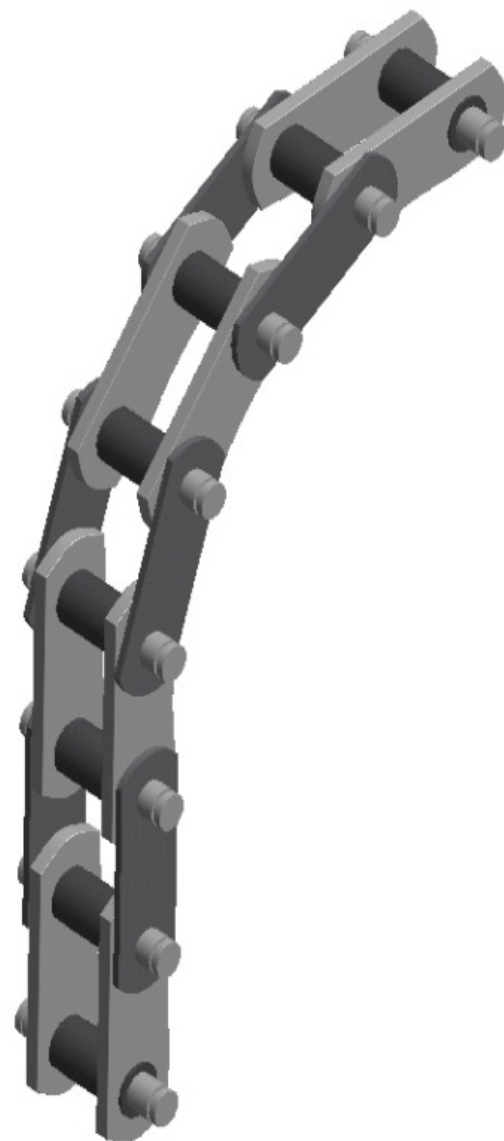


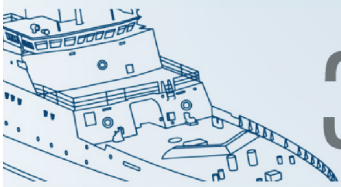
Model of a Chain

Weight: 25 tons

Length between supports: 70 meter

Failure: some after 2 years
others after 6 months





Outline

1. Introduction

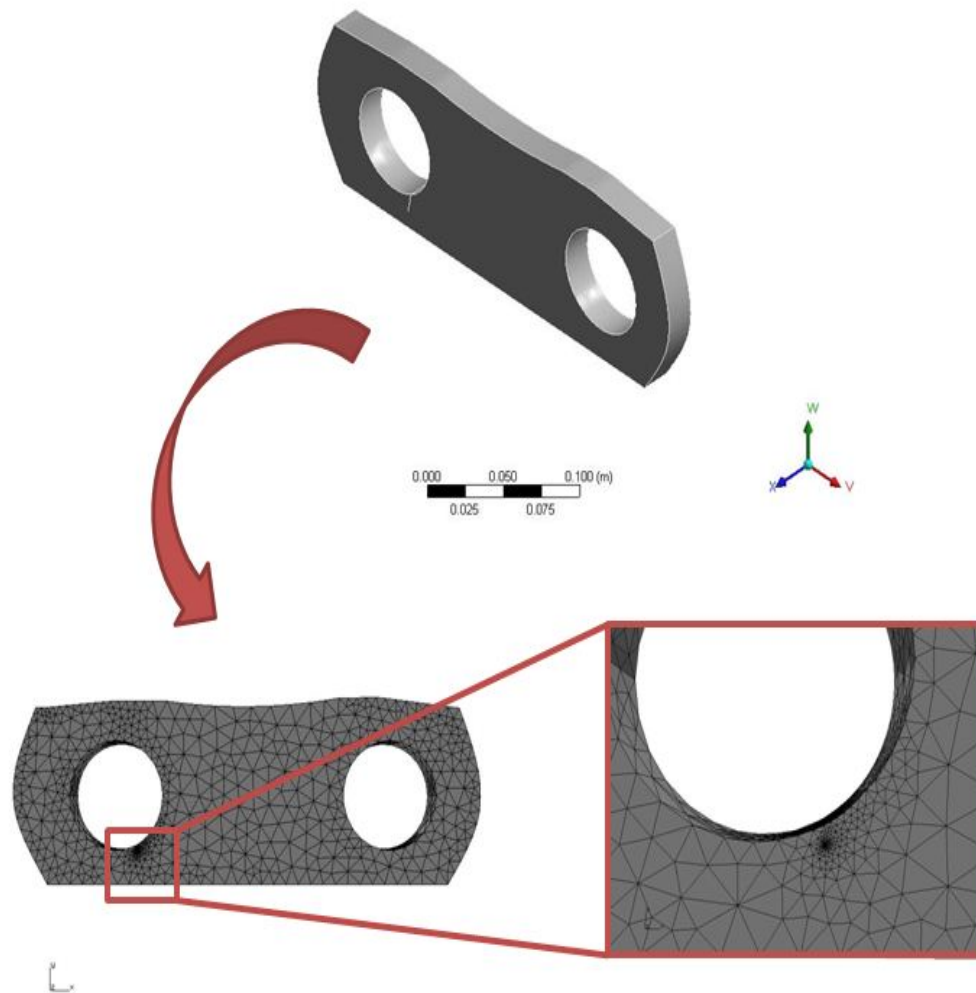
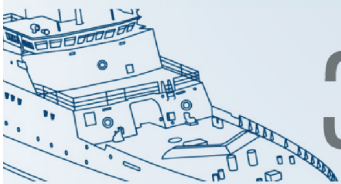
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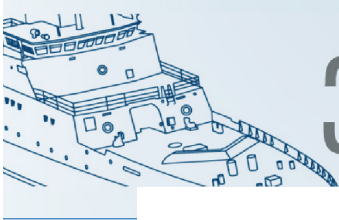
3. Application to real structures

4. Analysis of single cracks

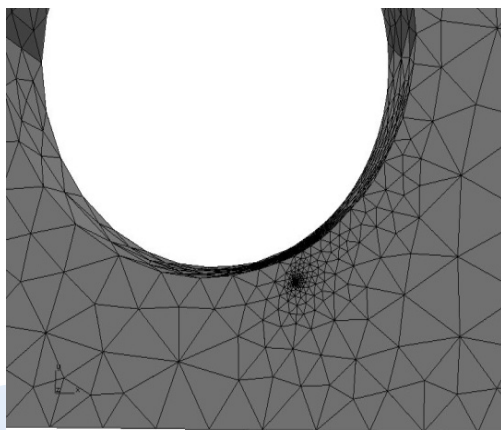
5. Analysis of multiple cracks

6. Conclusions

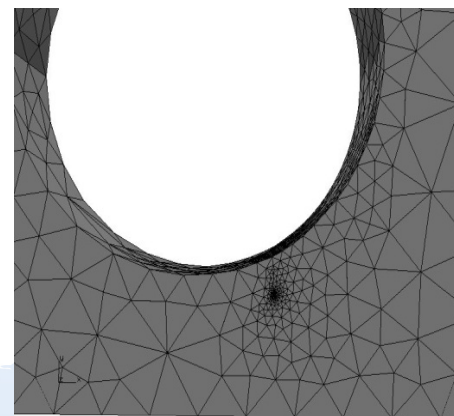




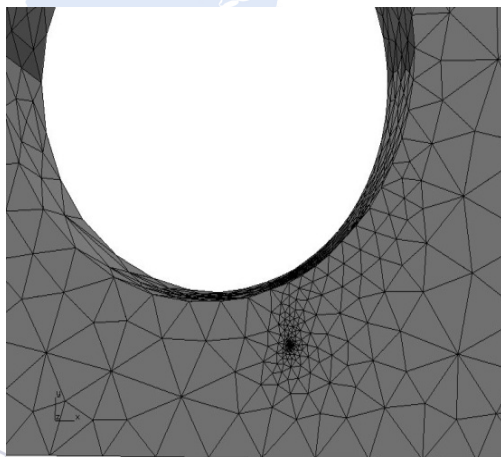
Example of the Crack Propagation Sequence



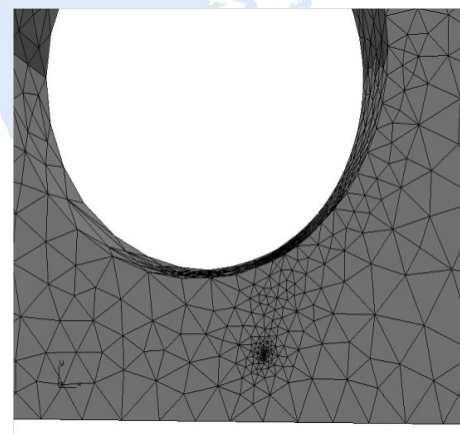
After 5E+3 cicles



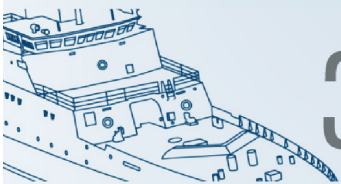
After 2E+4 cicles



After 6E+4 cicles



After 8E+4 cicles



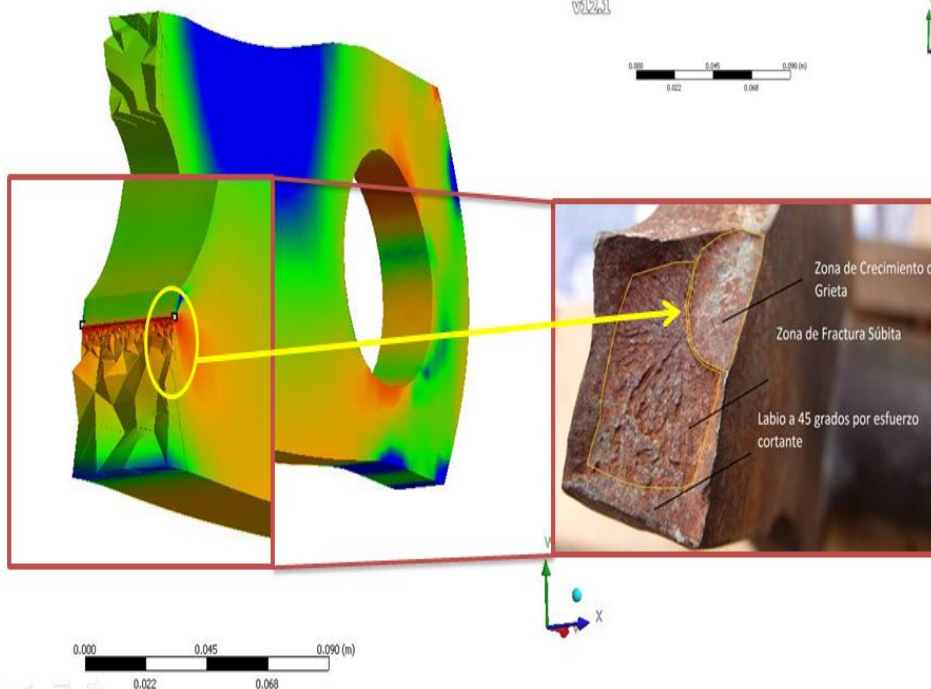
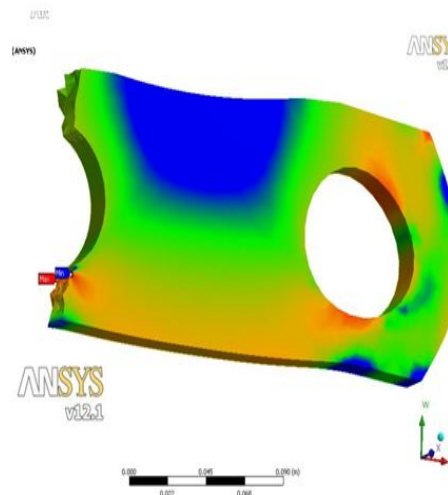
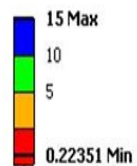
B: Static Structural (ANSYS)

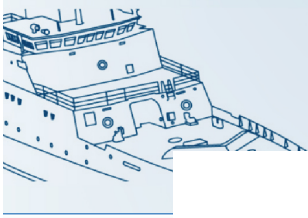
Safety Factor

Type: Safety Factor

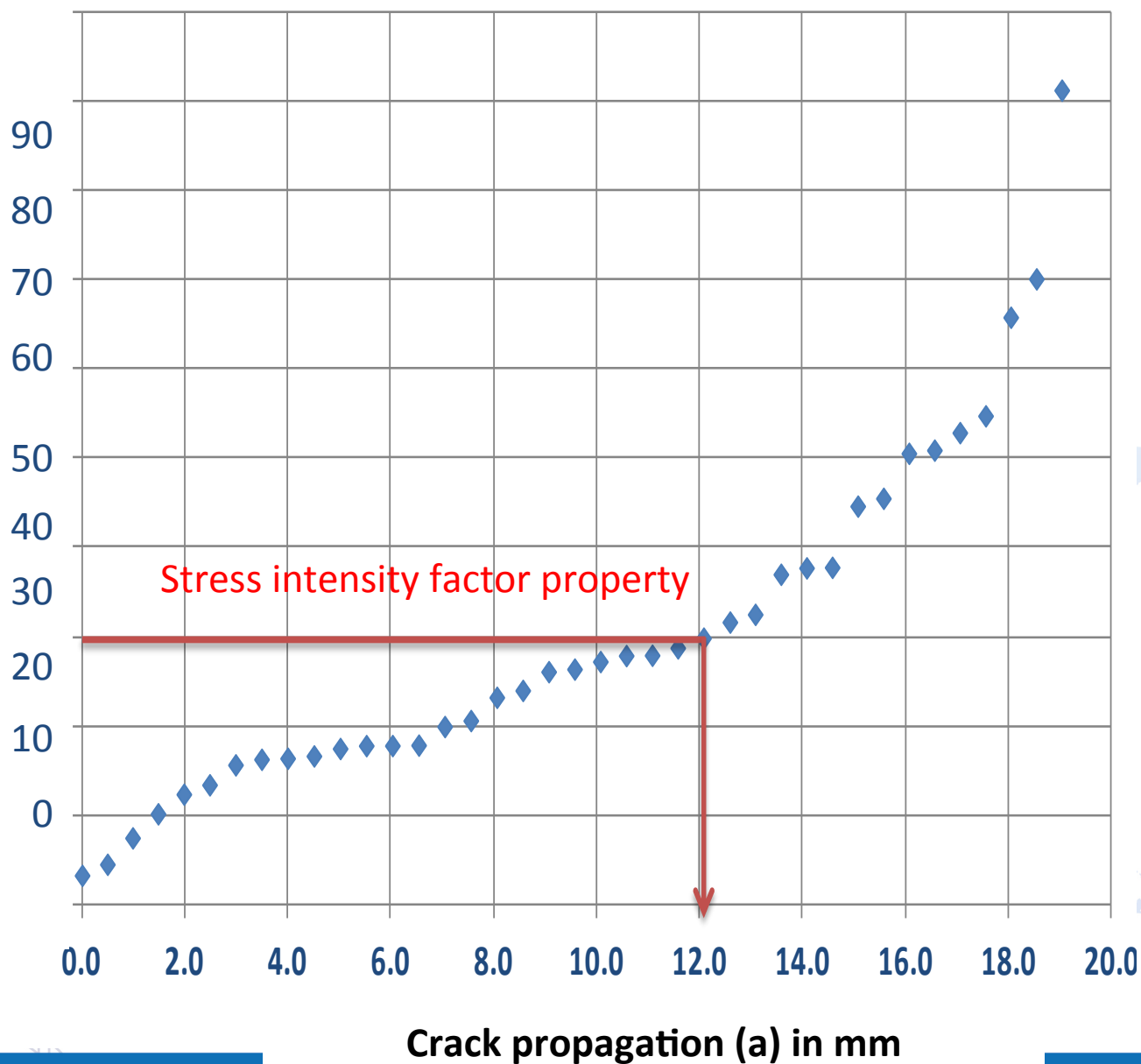
Time: 0

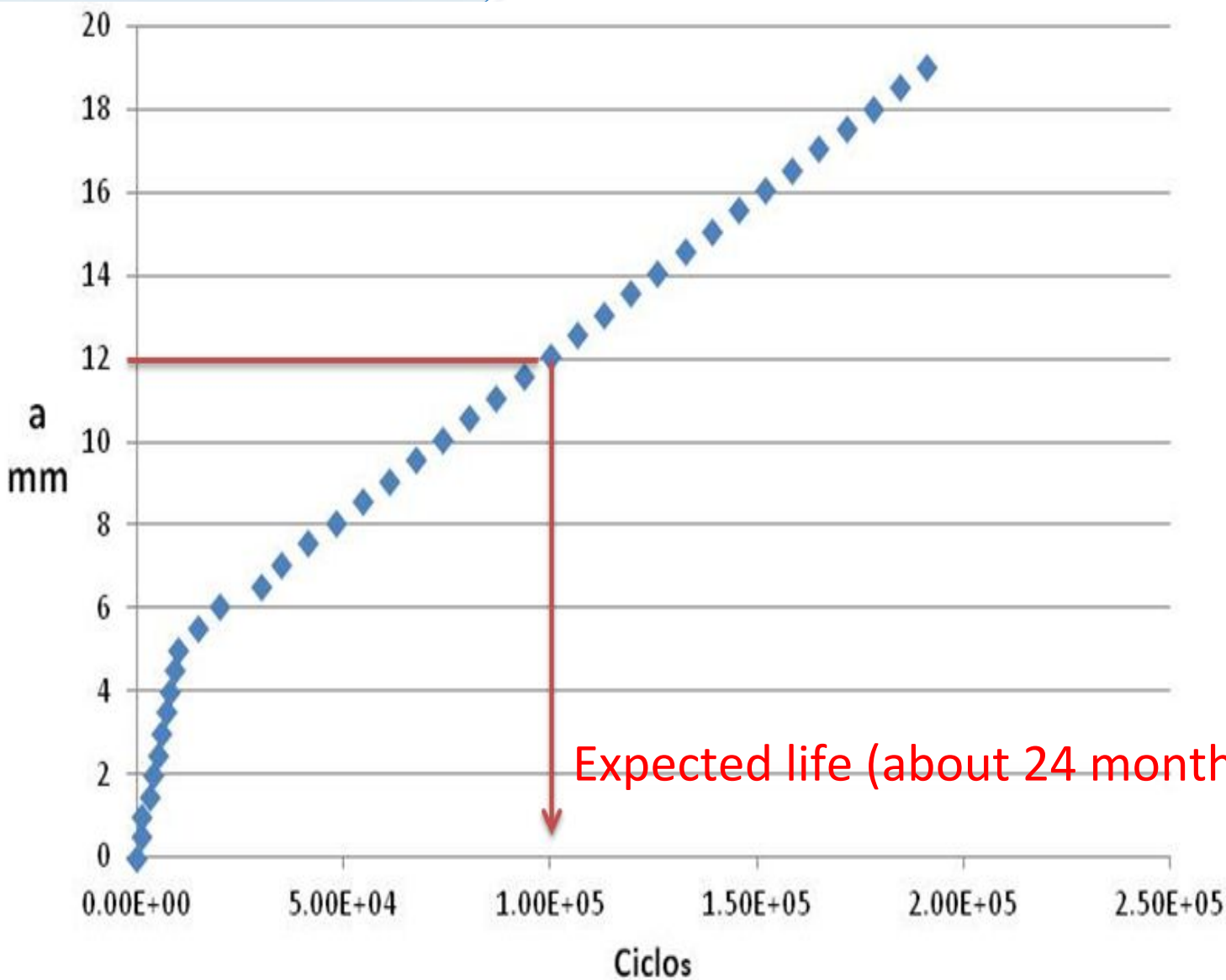
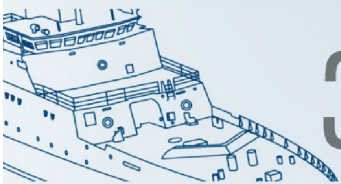
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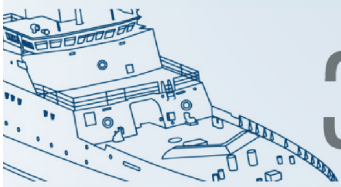
KI
(MPa.mm^{1/2})





Expected life (about 24 months)





Outline

1. Introduction

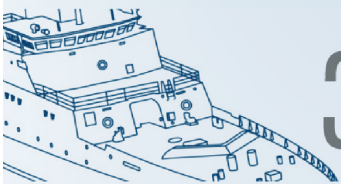
2. Modeling of the crack propagation mechanism

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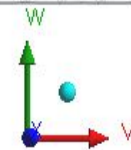
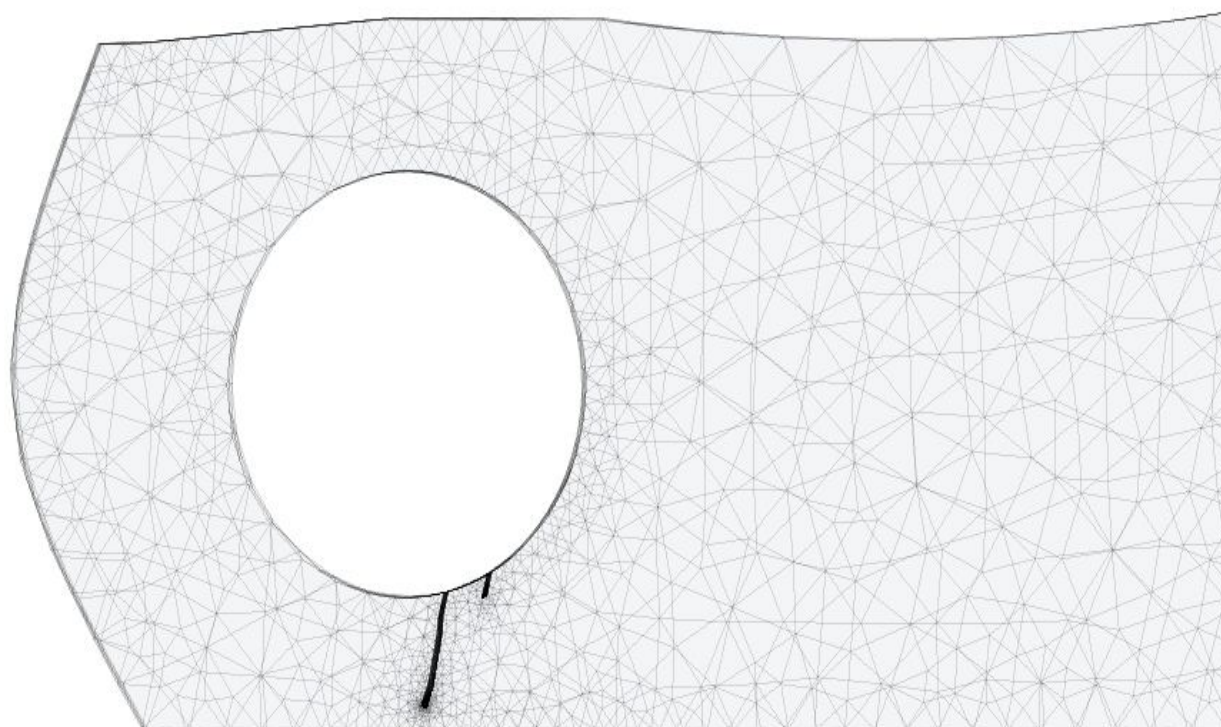
4. Analysis of single cracks

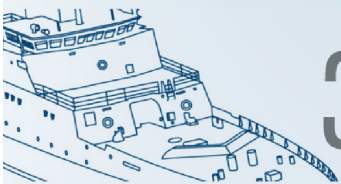
5. Analysis of multiple cracks

6. Conclusions

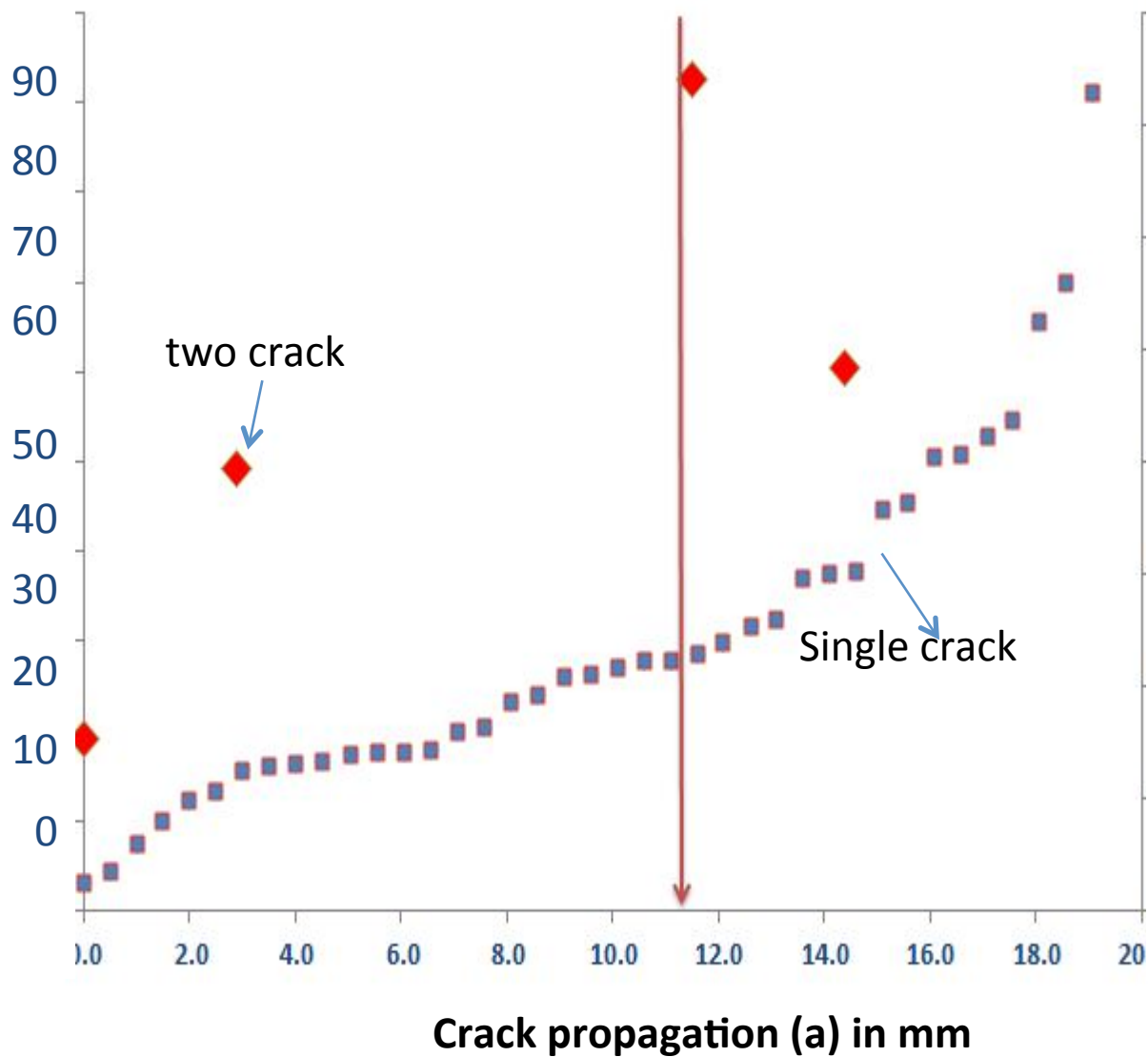


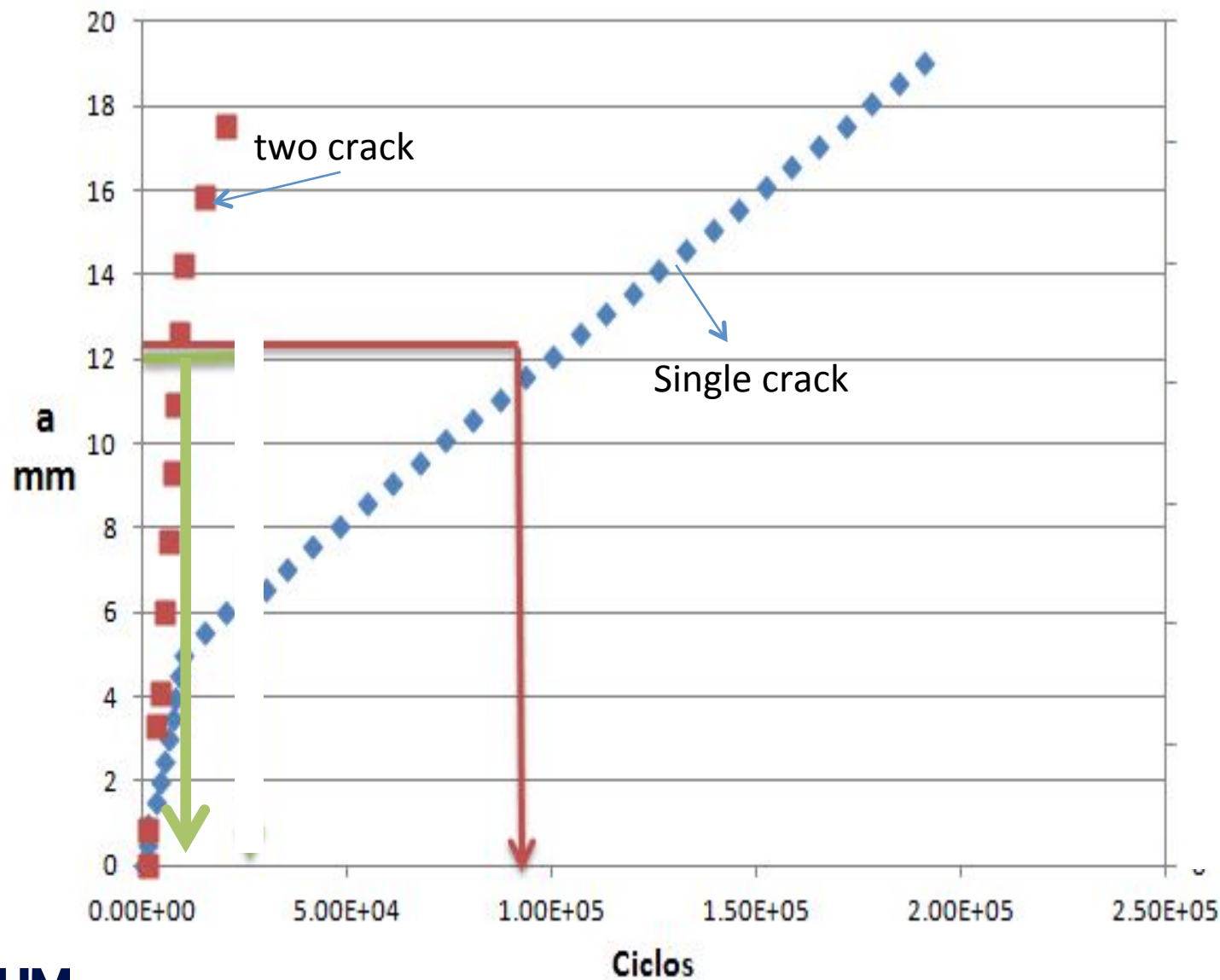
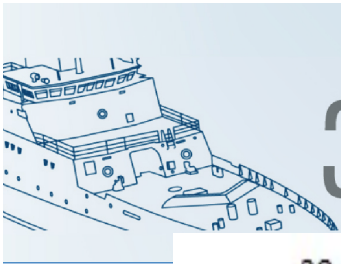
ANSYS
v12.1

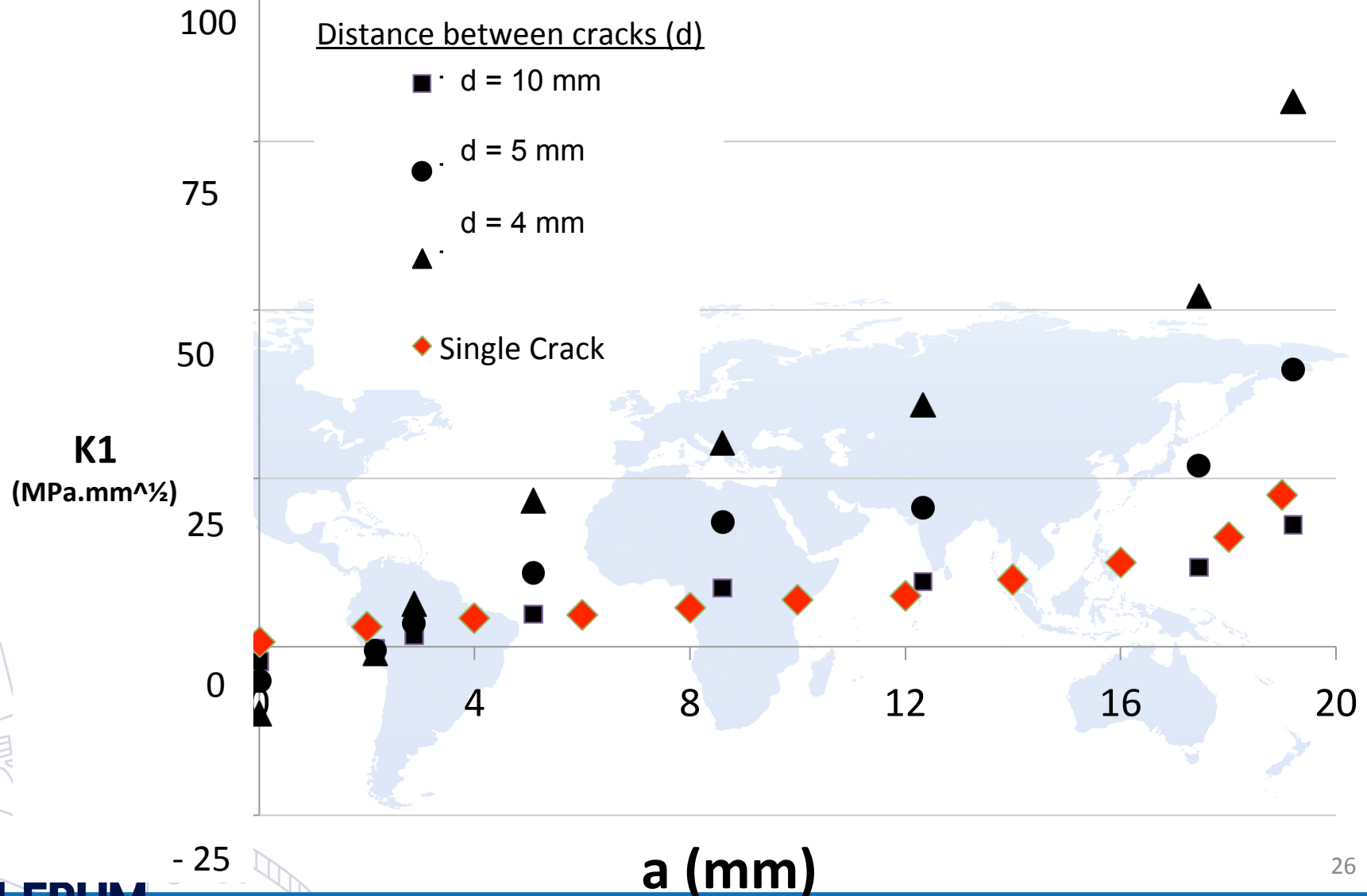
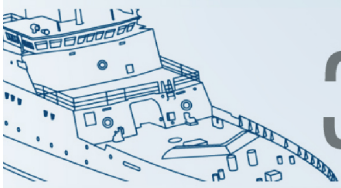


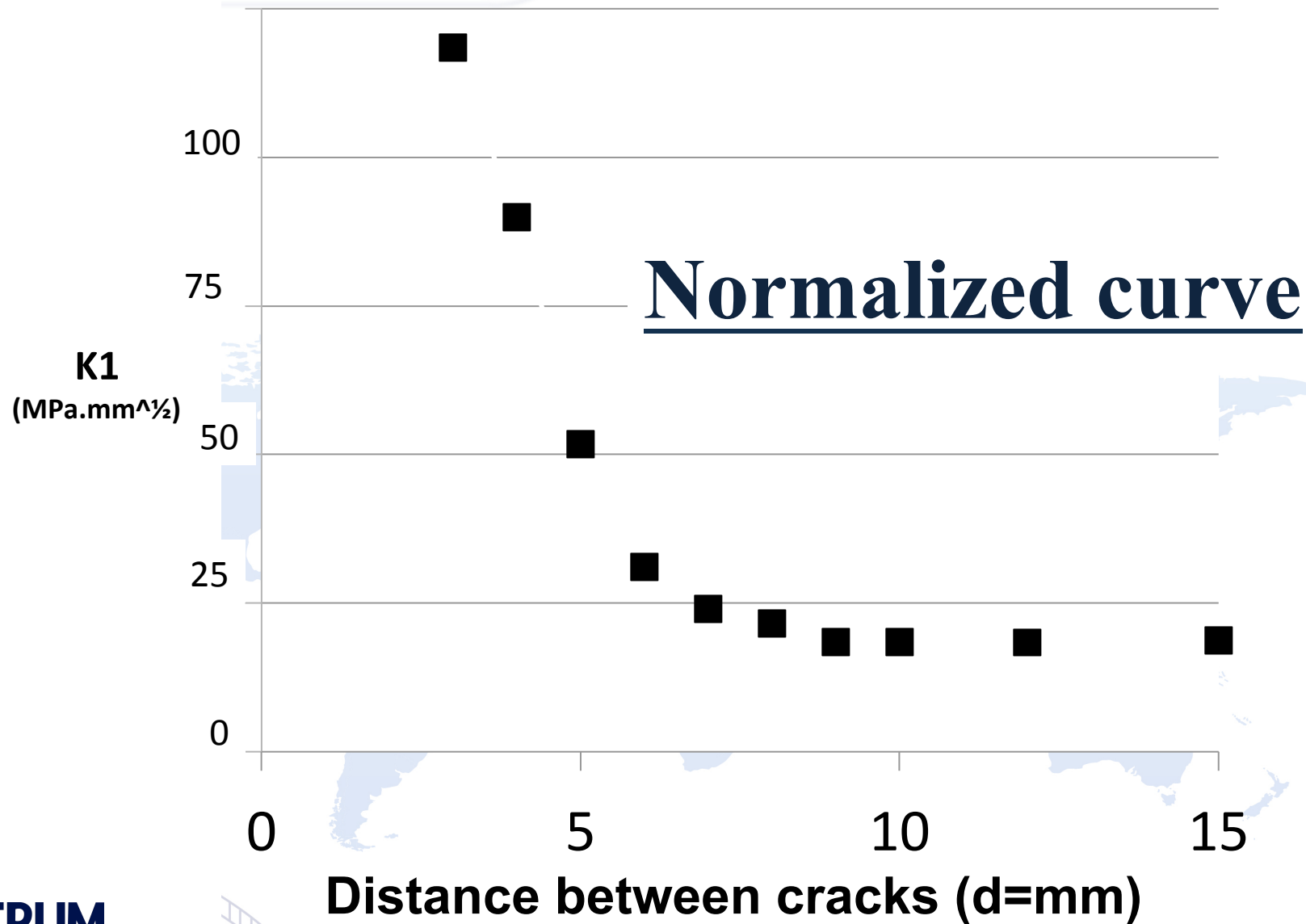
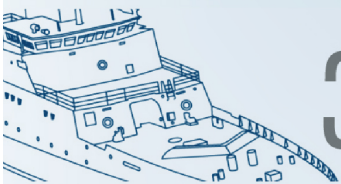


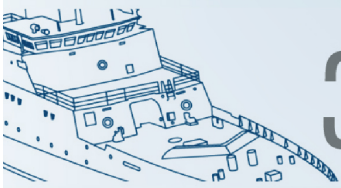
KI
(MPa.mm^{1/2})











Outline

1. Introduction

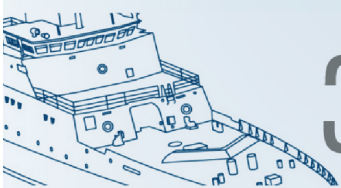
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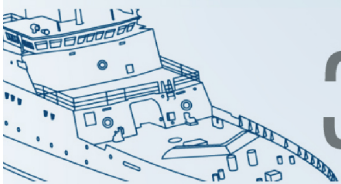
conclusions

This work approaches the problems of crack growth and propagation using the Extended Finite Element Method by Enrichment.

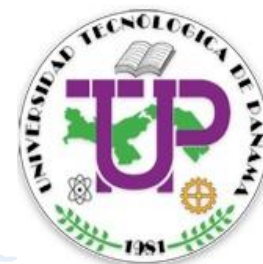
Through the application of Enrichment Functions it is possible to lay aside the dependence on remeshing to redirect the new boundaries of the growing crack.

We have studied the influence of two crack on the analysis of crack propagation. We found that for short distance it is necessary to consider both crack.

It is also founded that the effect of a second crack on the crack propagation can be described as a function of the distance between both cracks.



Thank you very much for kind attention



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