Analysis of Crack Propagation in Mechanical Components Presenting Multiples Cracks

Adan VEGA, Josemaría MORAZAN, Carlos PLAZAOLA, Ilka BANFIELD

Technological University of Panama

SENACYT
SECRETARIA NACIONAL DE CIENCIA , TECNOLOGIA E INNOVACION

ClassIBS
ISTHMUS BUREAU OF SHIPPING

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

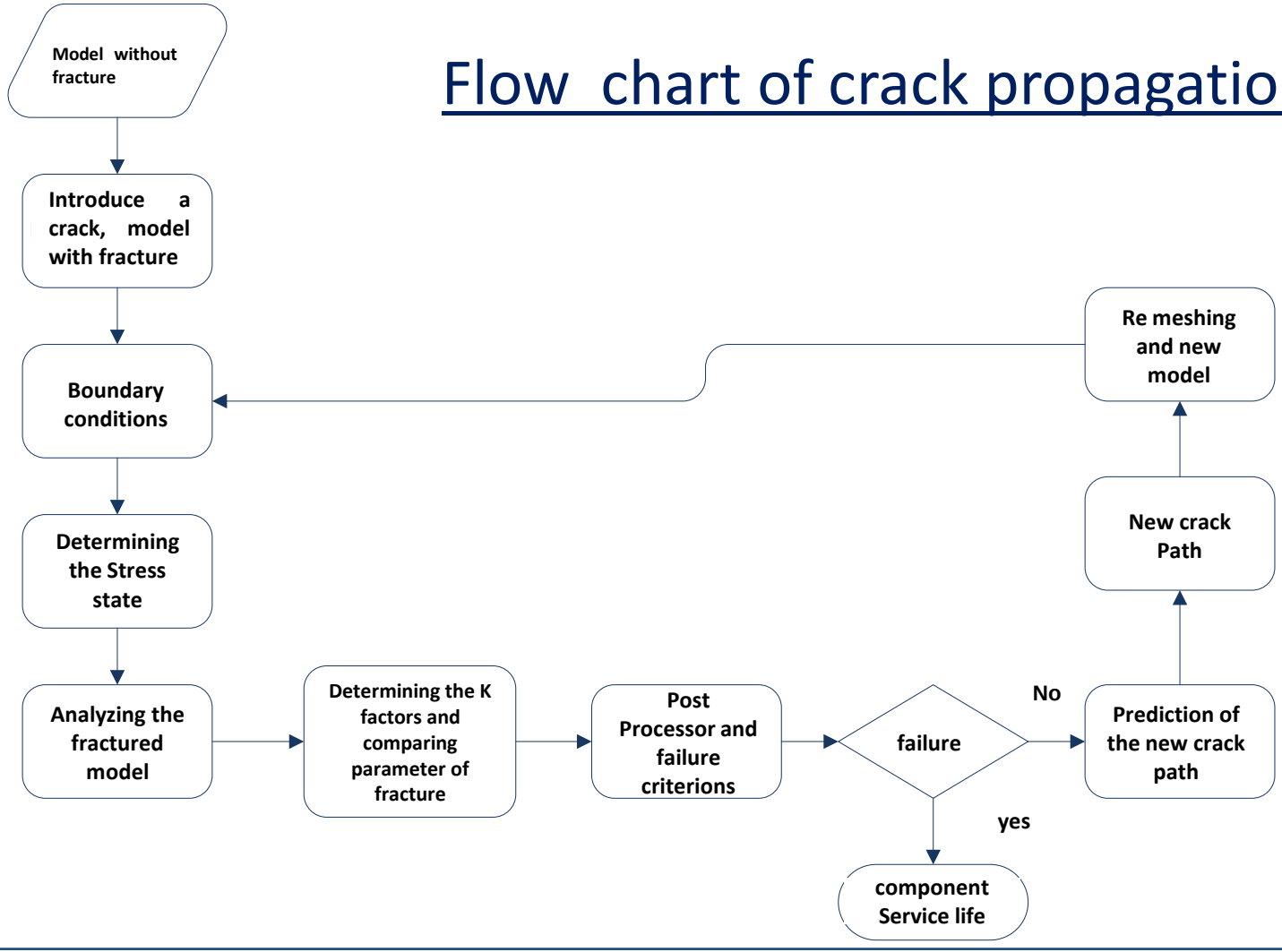
2. Reality is that defects and particularly cracks appear either in the manufacturing or generated in service

3. It is therefore necessary to analyze its effect on the performance of the element or structure

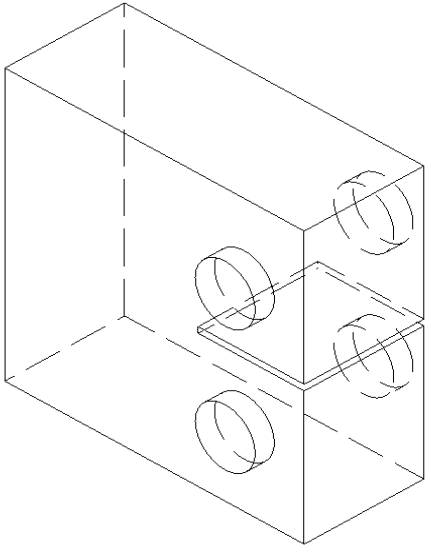
Outline

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

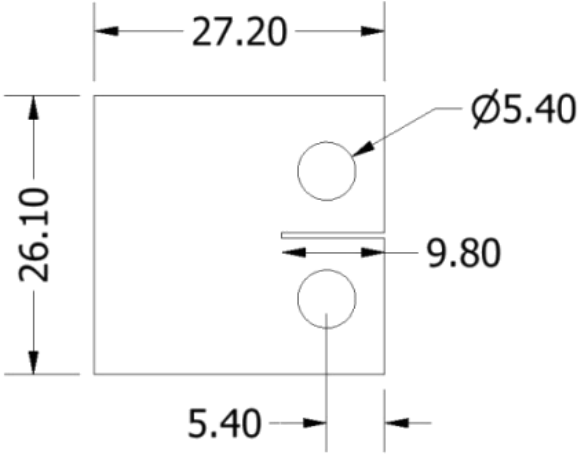


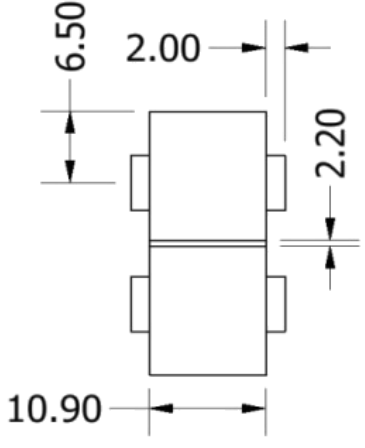
ASTM E-399

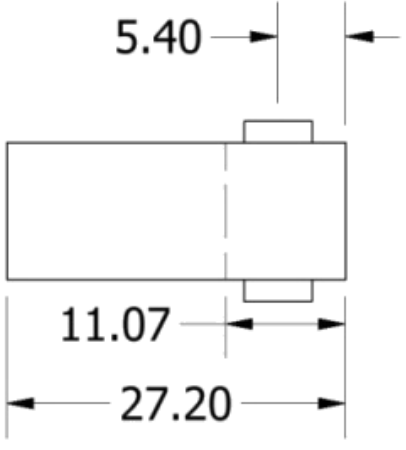
Material: AISI/SAE 1045

σ_y = 419 MPa

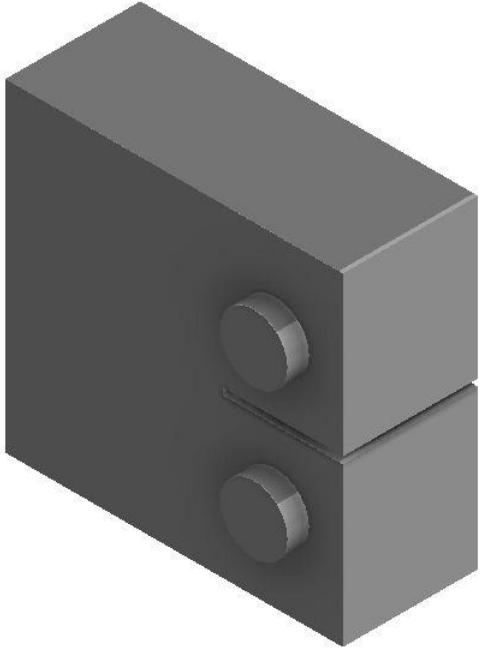
σ_u = 673MPa

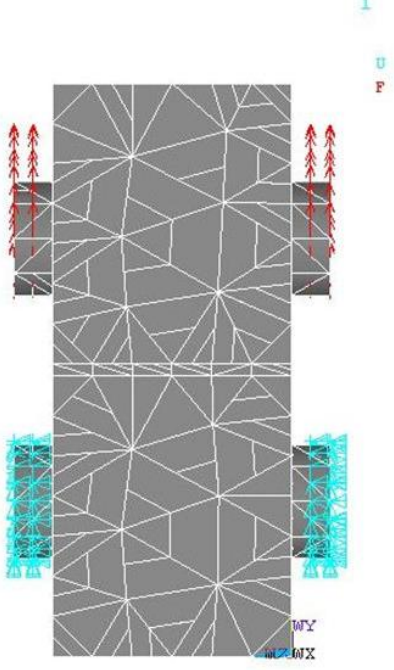


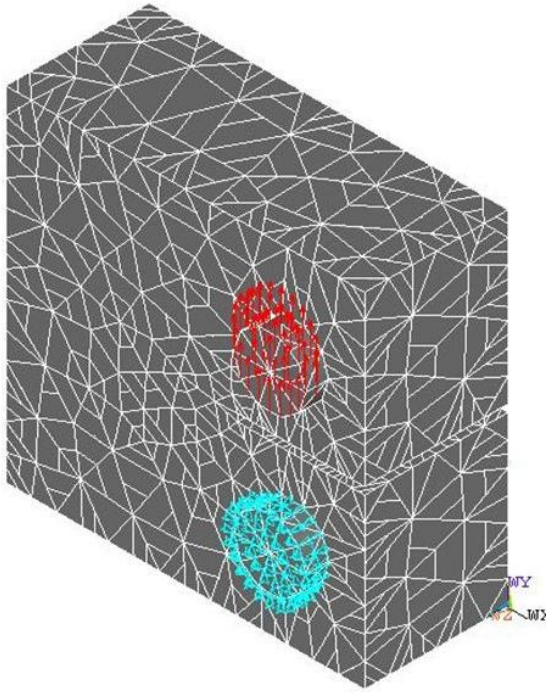




FEM Model





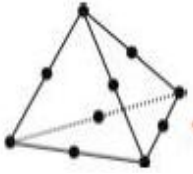


Type of element	number of element	number of nodes
Tetrahedral	68927	1378540
Parallelepipeds	3200	32000
Wedge	1600	24000
Piramydal	1600	20800
Total	**75327**	**1455340**

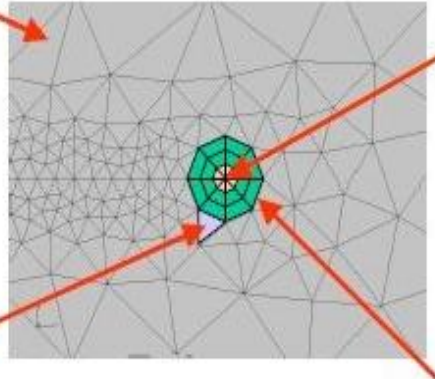
Software:

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

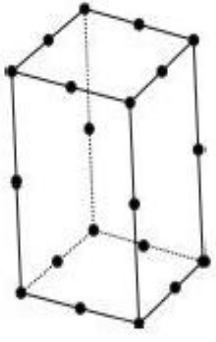


Tetrahedral elements far from the crack



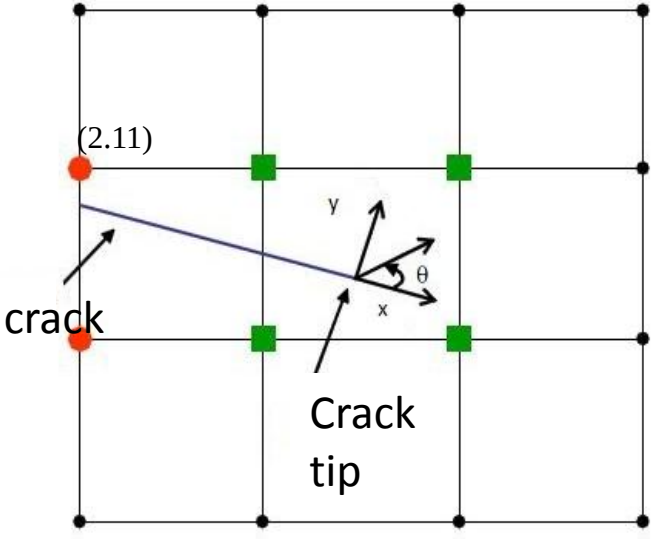
Wedge elements for singularity simulation

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:

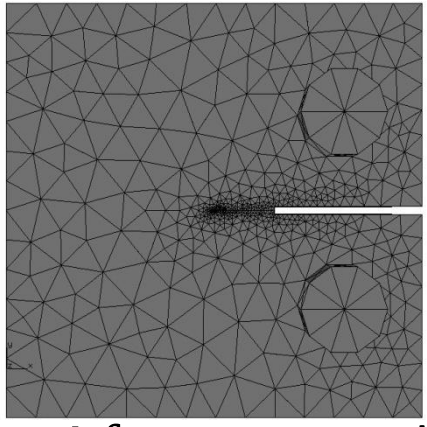
$$J = \int_{\Gamma} \left(W dy - T . \frac{\partial u}{\partial x} \, d\Gamma \right)$$

M -Integral:

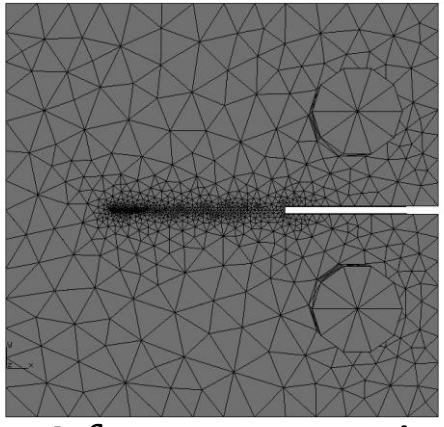
$$M^{(1,2)} = \int_A \left[\left(\sigma_x \frac{\partial u_x^{(2)}}{\partial x} + \tau_{xy} \frac{\partial u_y^{(2)}}{\partial x} + \sigma_x^{(2)} \frac{\partial u_x^{(2)}}{\partial x} + \tau_{xy}^{(2)} \frac{\partial u_y^{(2)}}{\partial x} - \sigma_{ij} \varepsilon_{ij}^{(2)} \right) \frac{\partial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

LEPUM

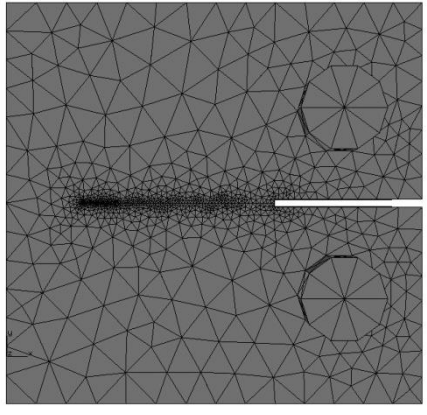
Example of the Crack Propagation Sequence



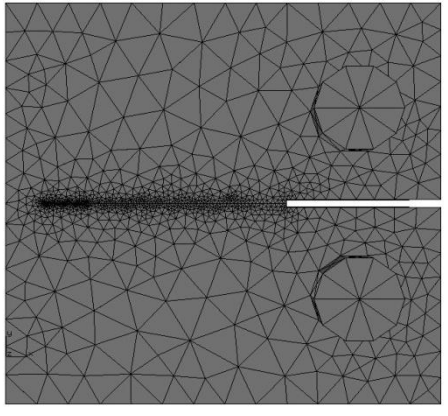
After 5E+3 cicles



After 2E+4 cicles

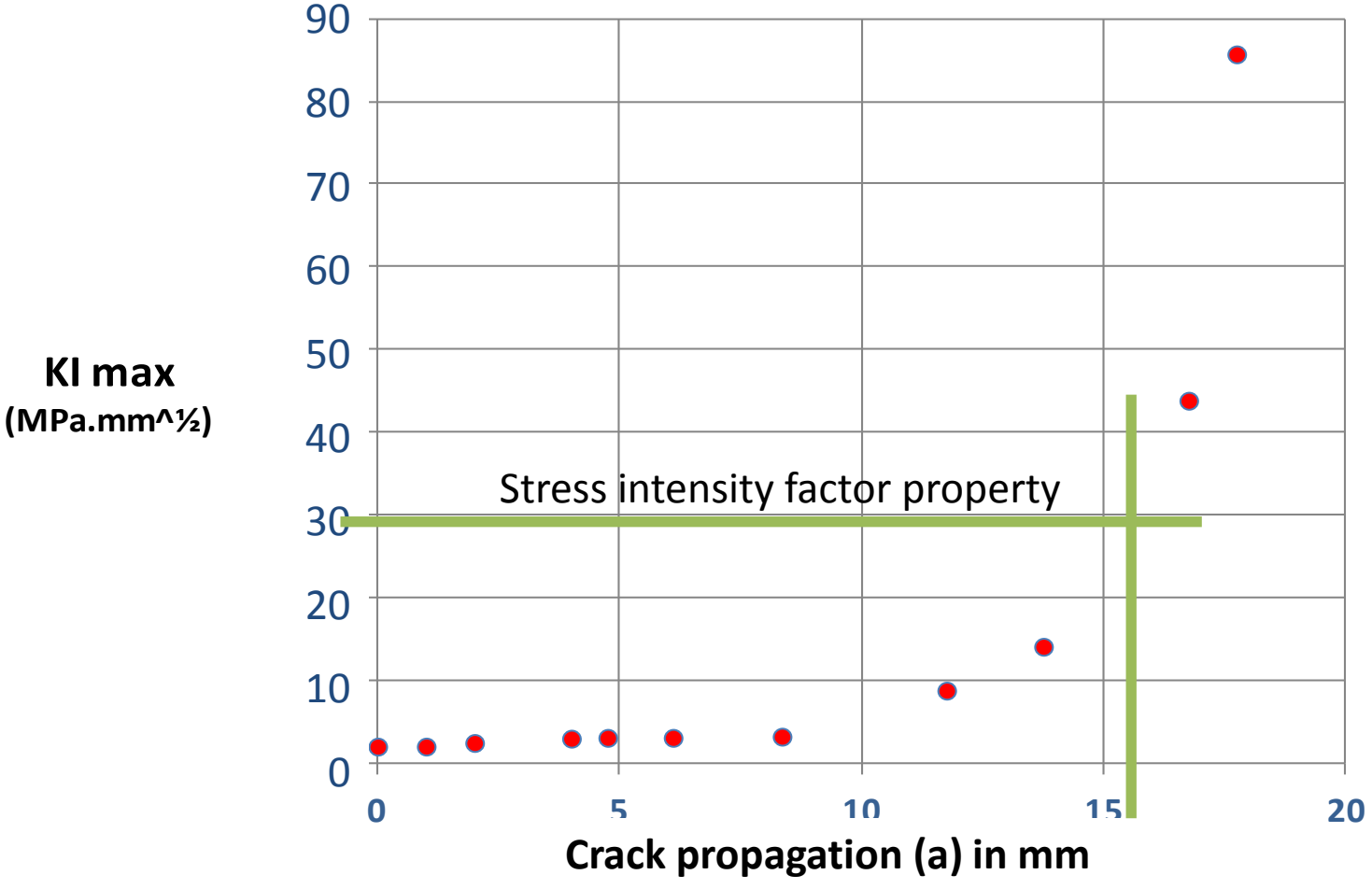


After 6E+4 cicles

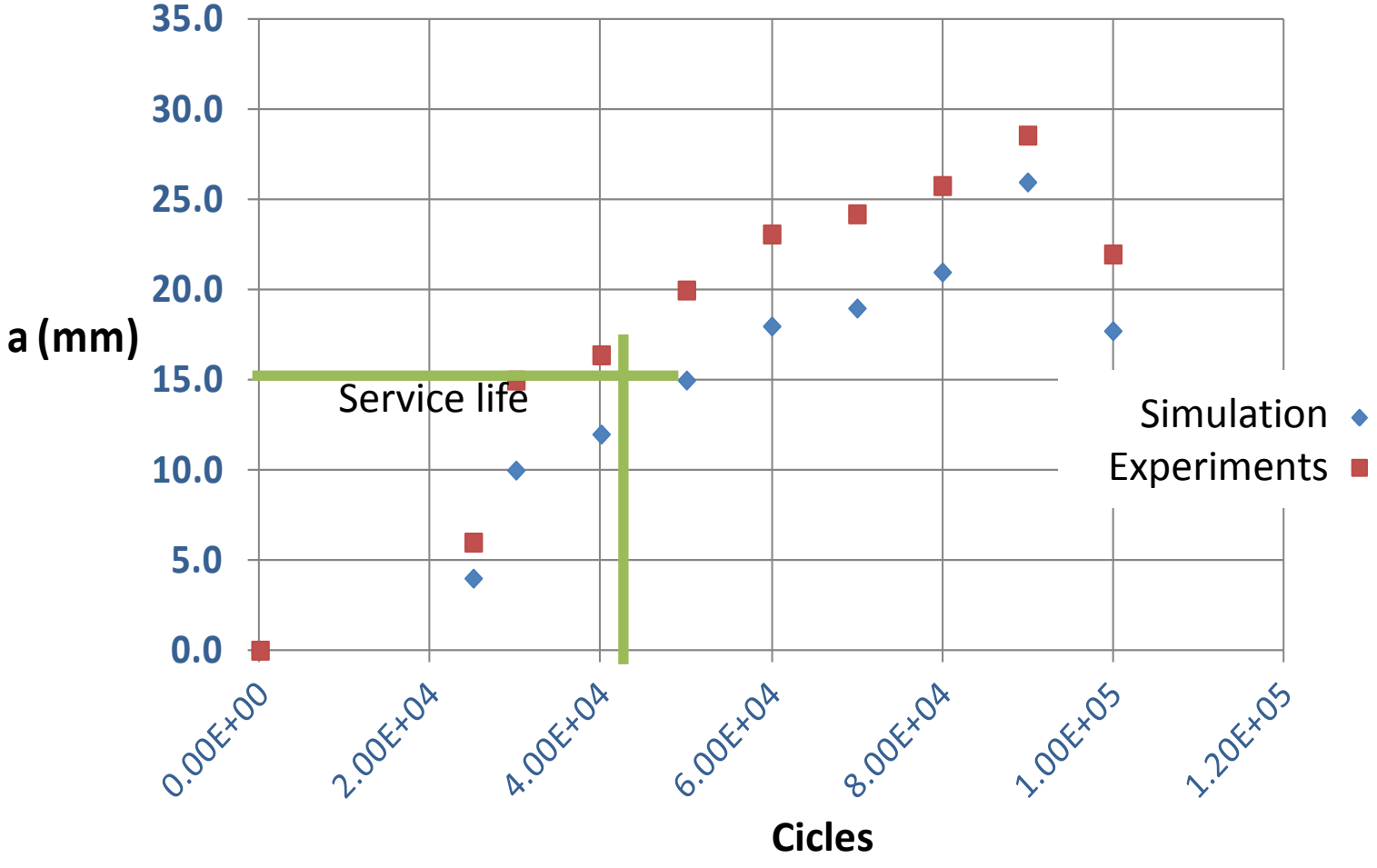


After 8E+4 cicles

Example of the Results



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

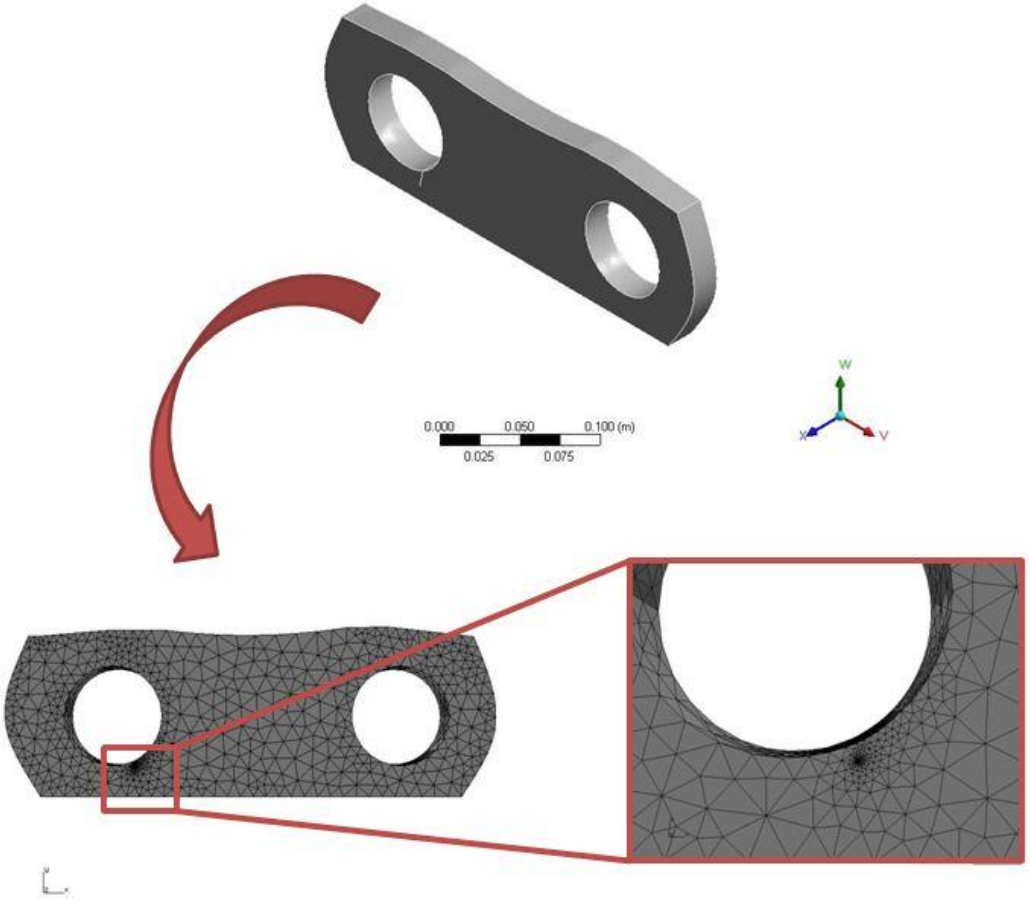
Model of a Chain

Weigh: 25 tons
Length between supports: 70 meter

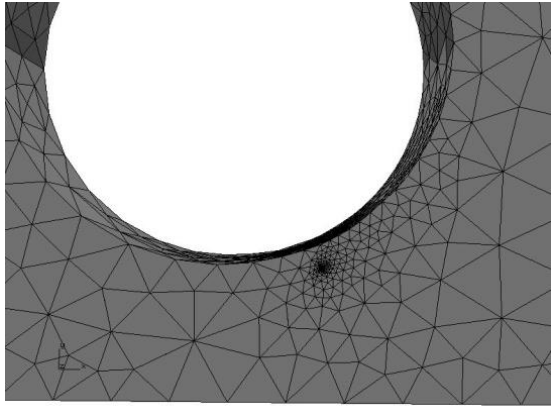
Failure: some after 2 years
others after 6 months

Outline

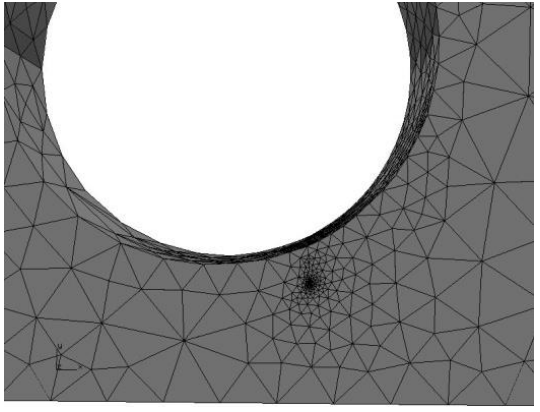
1. Introduction
2. Modeling of the crack propagation mechanism
3. Application to real structures
4. Analysis of single cracks
5. Analysis of multiple cracks
6. Conclusions


0.000
0.050
0.100 (m)
0.025
0.075
W
V

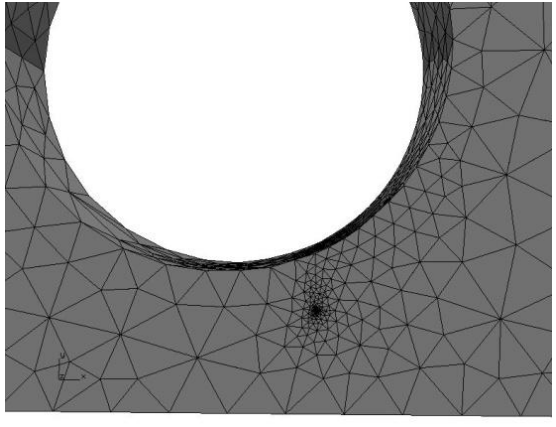
Example of the Crack Propagation Sequence



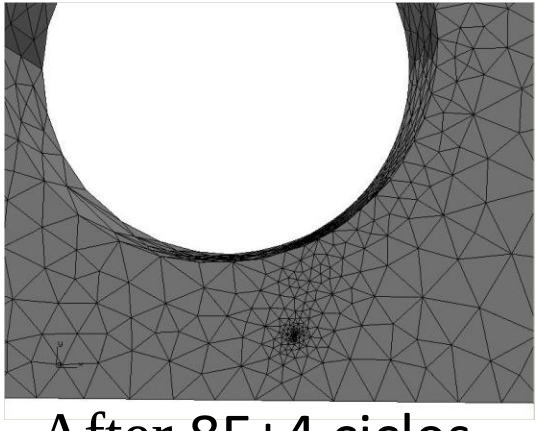
After 5E+3 cicles



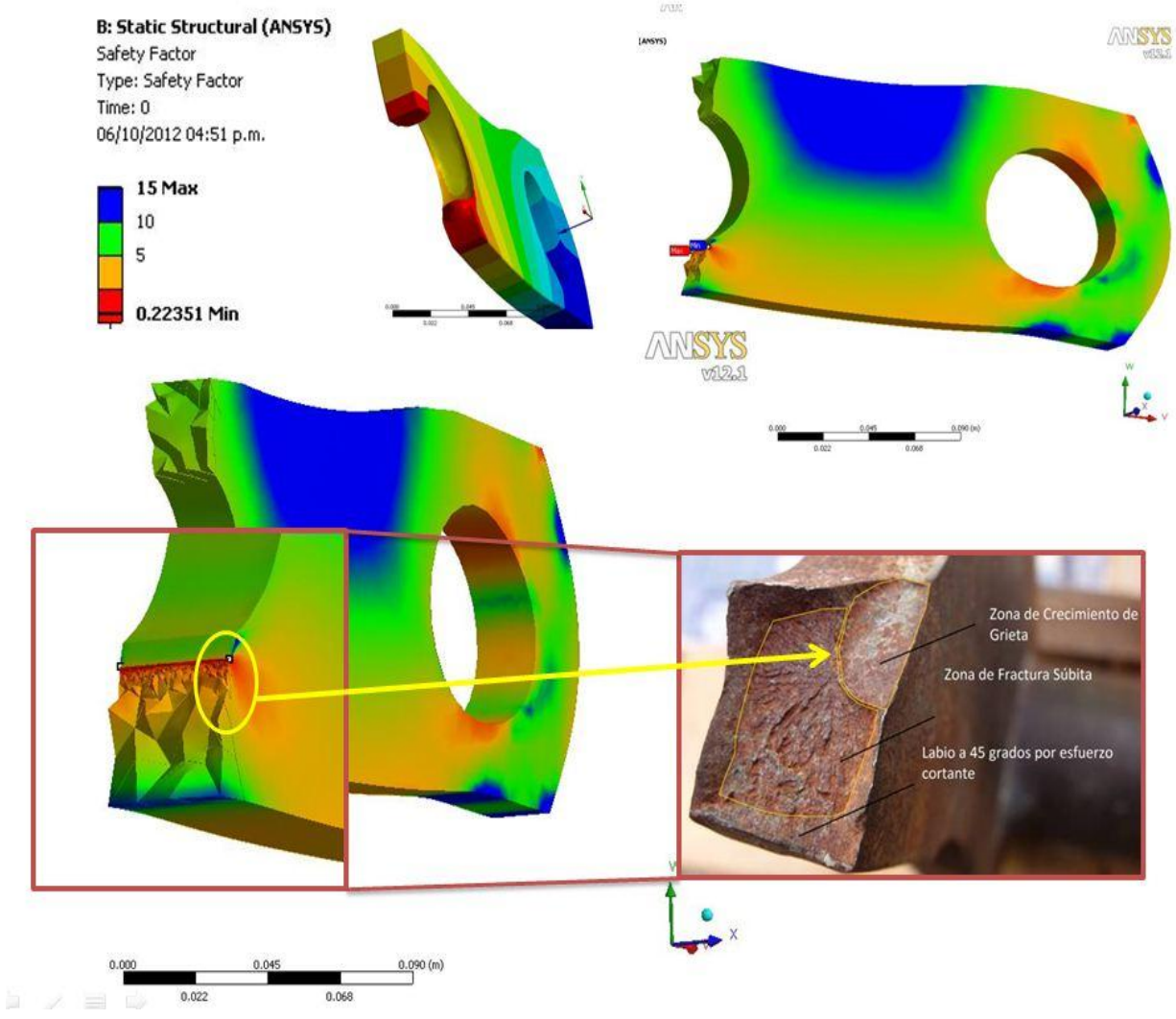
After 2E+4 cicles

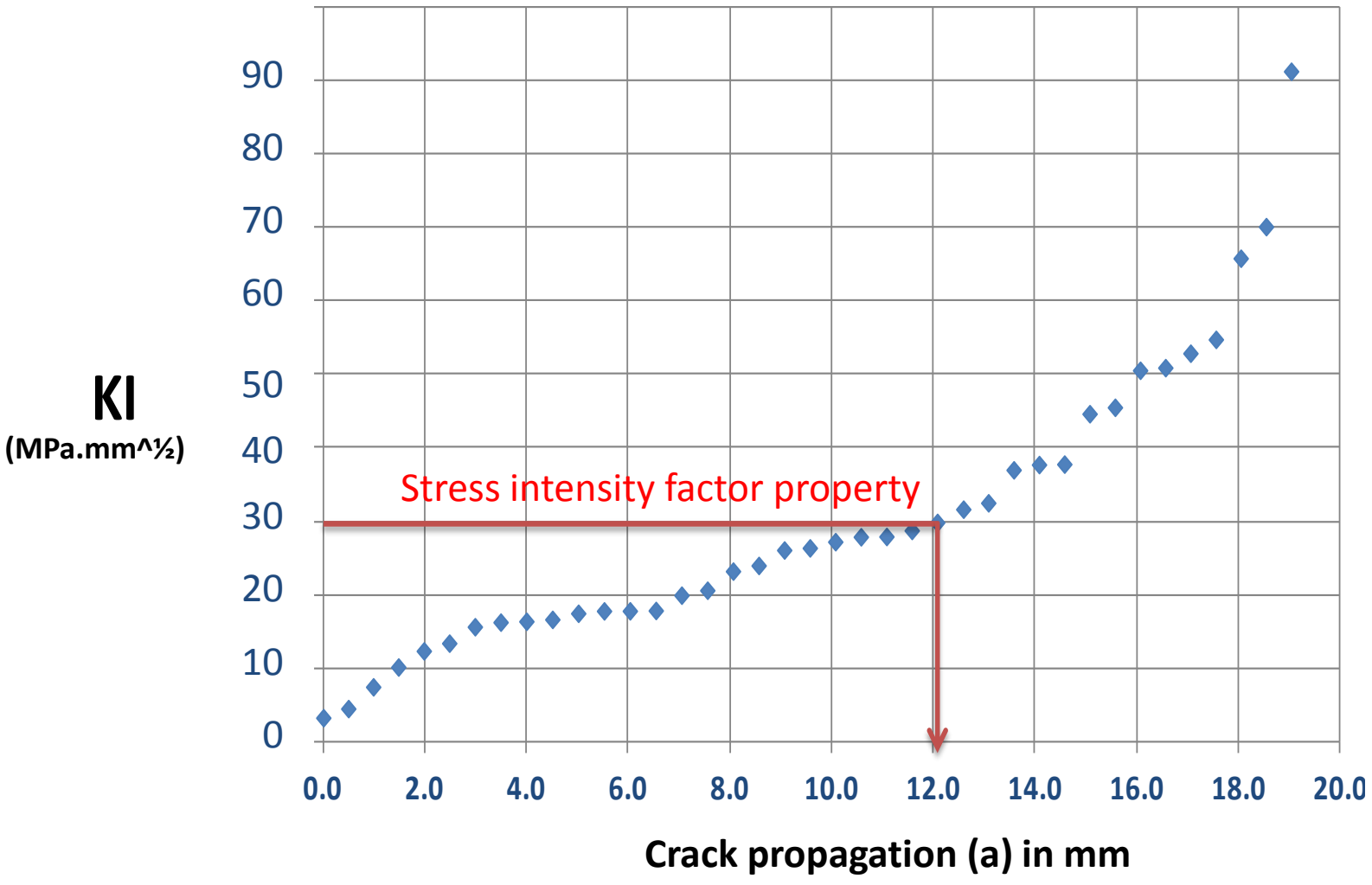


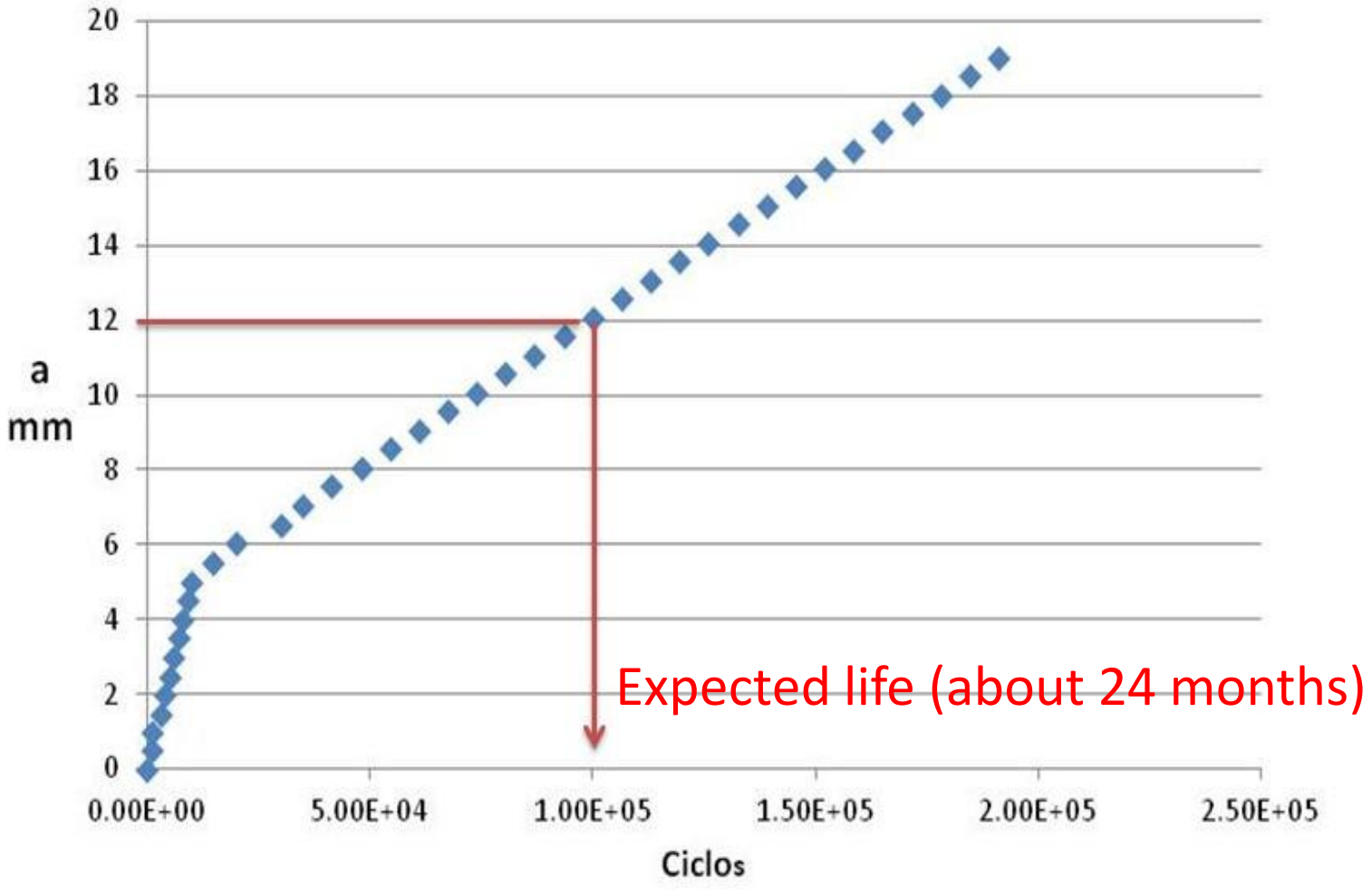
After 6E+4 cicles



After 8E+4 cicles

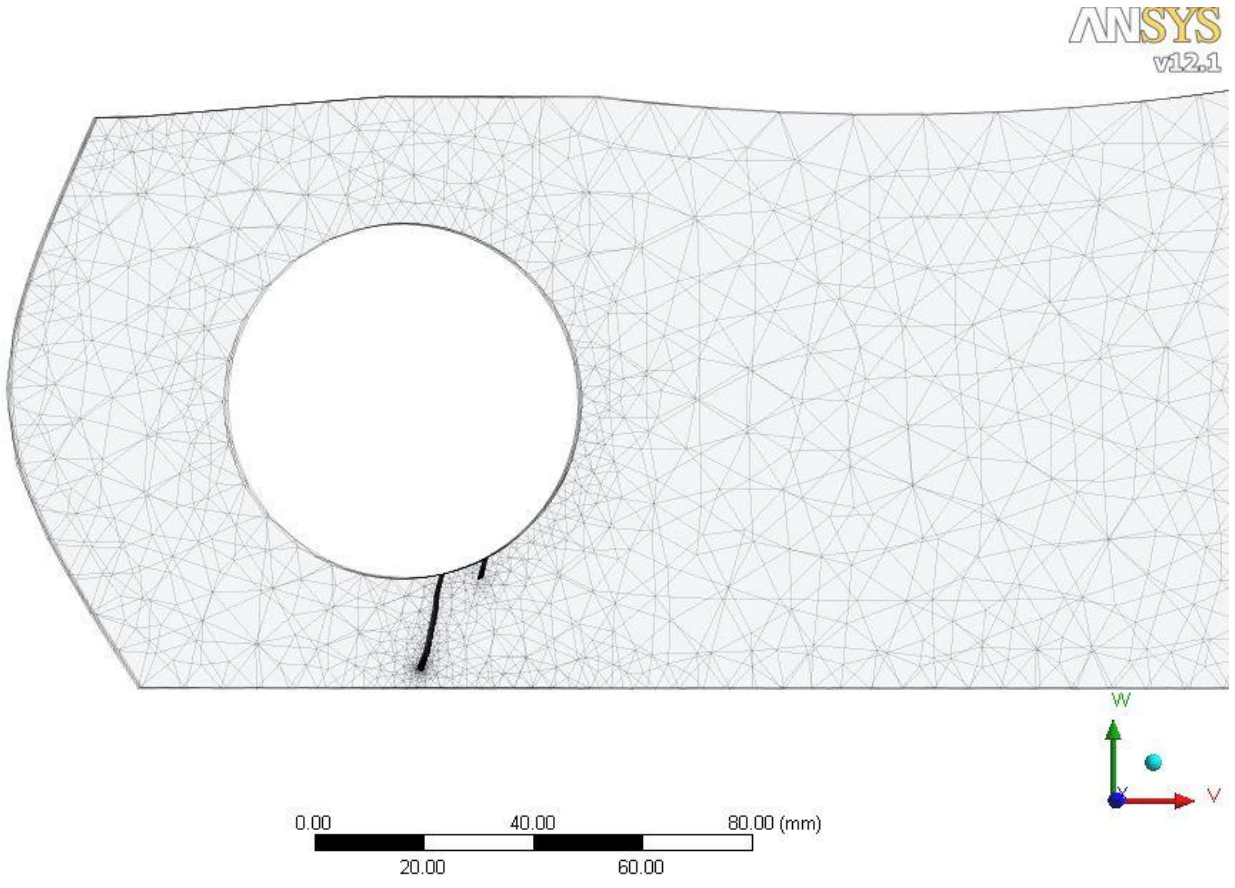

B: Static Structural (ANSYS)
Safety Factor
Type: Safety Factor
Time: 0
06/10/2012 04:51 p.m.
15 Max
10
5
0.22351 Min
ANSYS
v12.1
0.000
0.045
0.090 (m)
0.022
0.068
Zona de Crecimiento de Grieta
Zona de Fractura Súbita
Labio a 45 grados por esfuerzo cortante

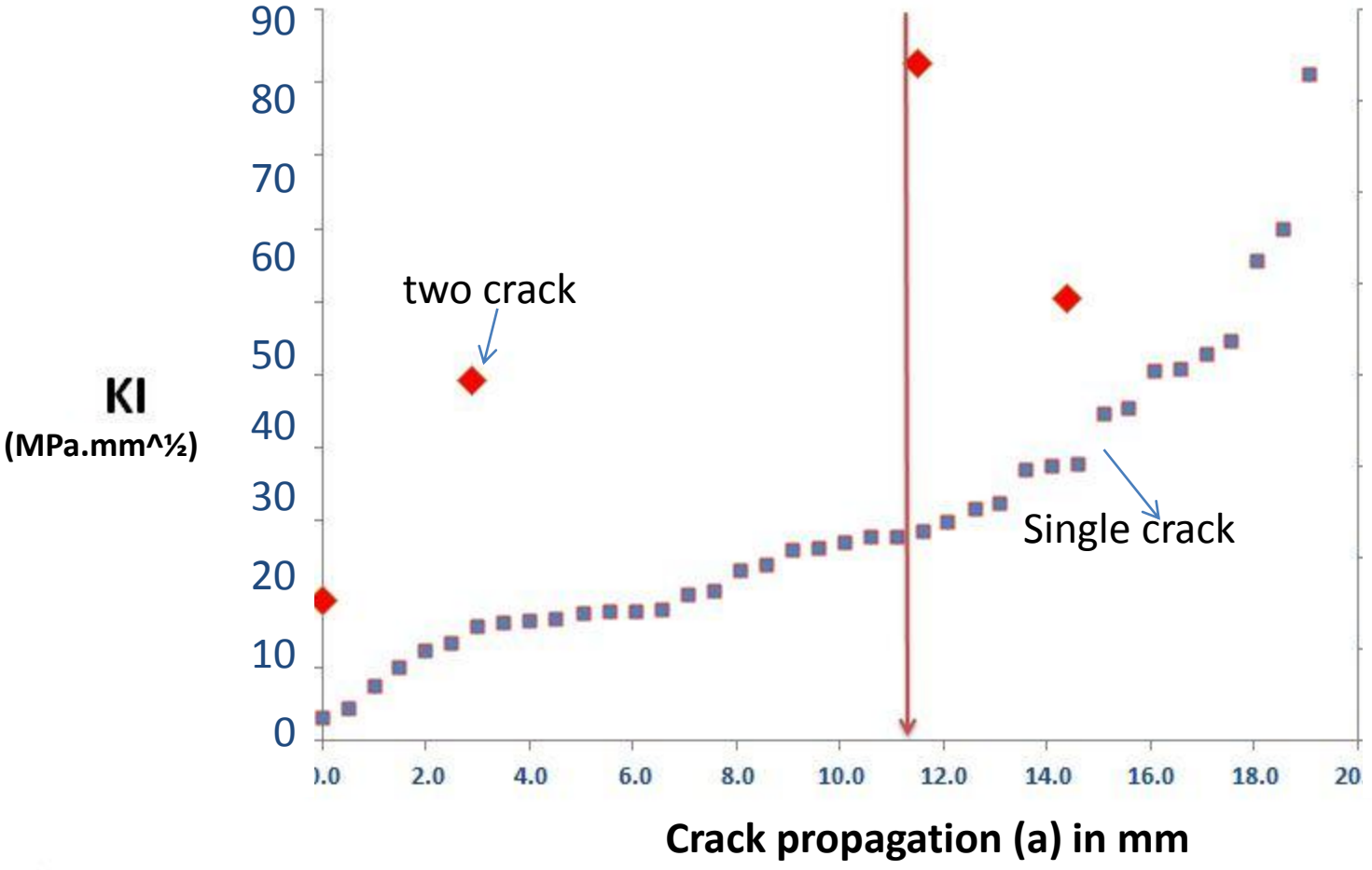

KI
(MPa.mm^½)
90
80
70
60
50
40
30
20
10
0
Stress intensity factor property
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Crack propagation (a) in mm

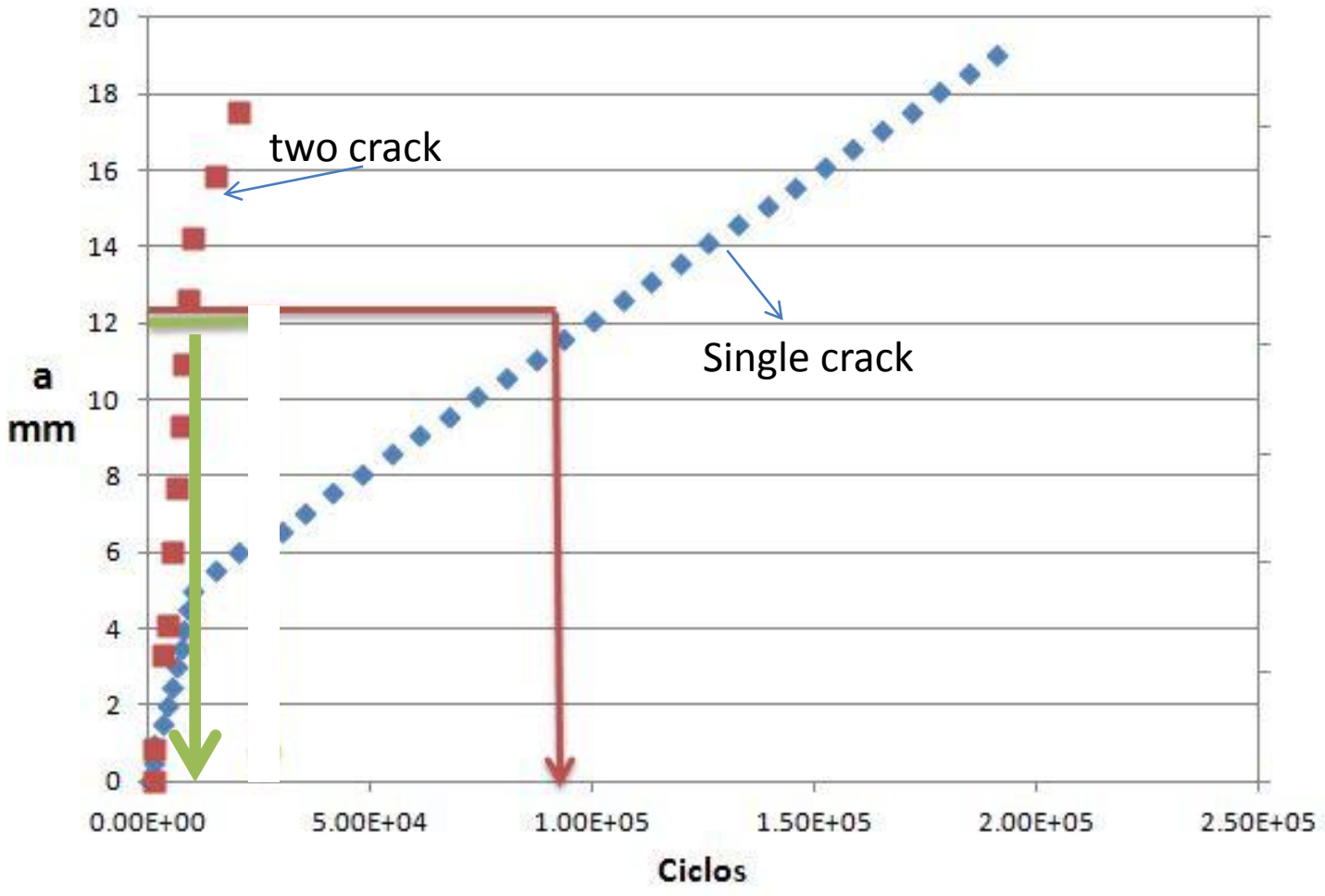

20
18
16
14
12
10
8
6
4
2
0
a
mm
0.00E+00
5.00E+04
1.00E+05
1.50E+05
2.00E+05
2.50E+05
Ciclos
Expected life (about 24 months)

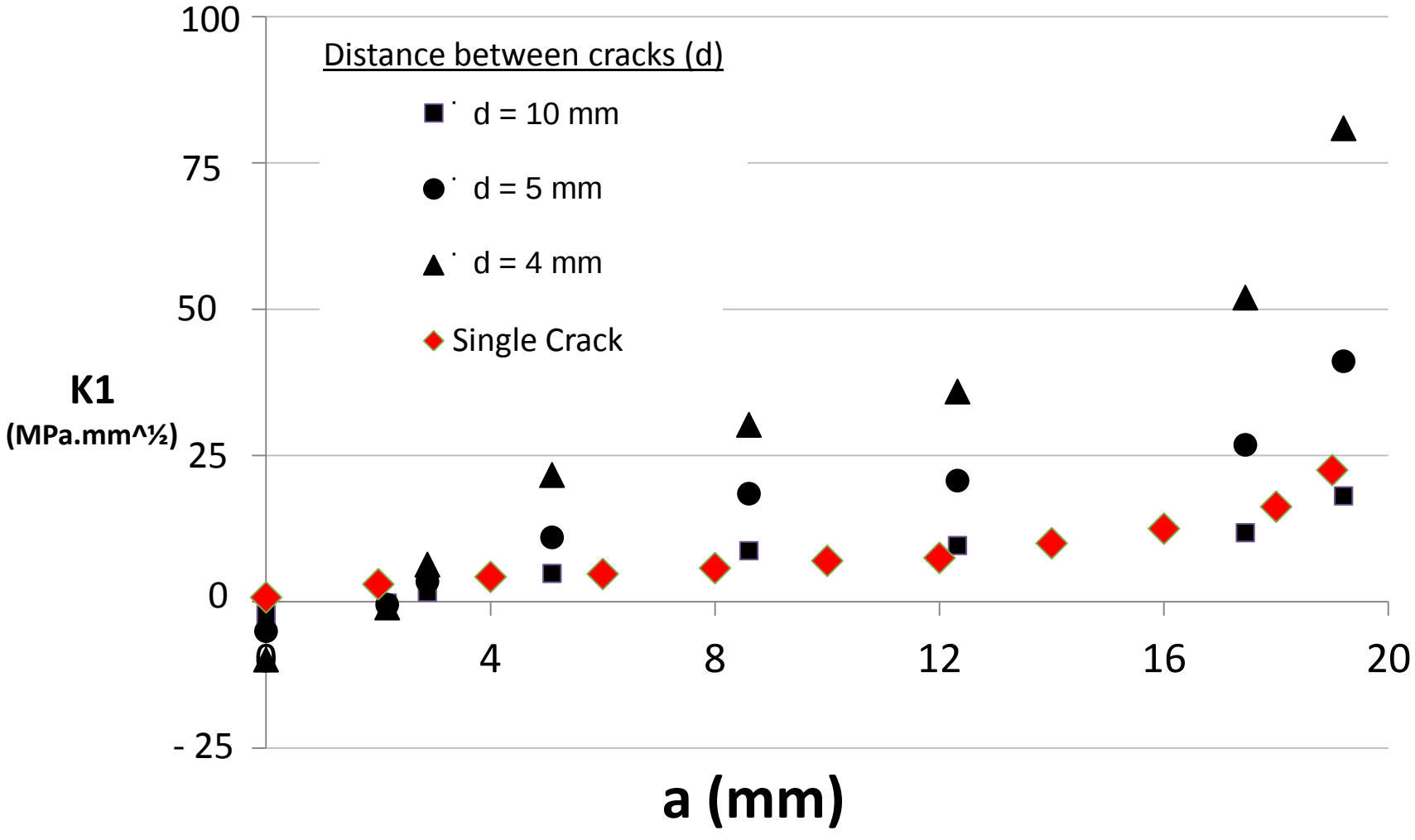
Outline

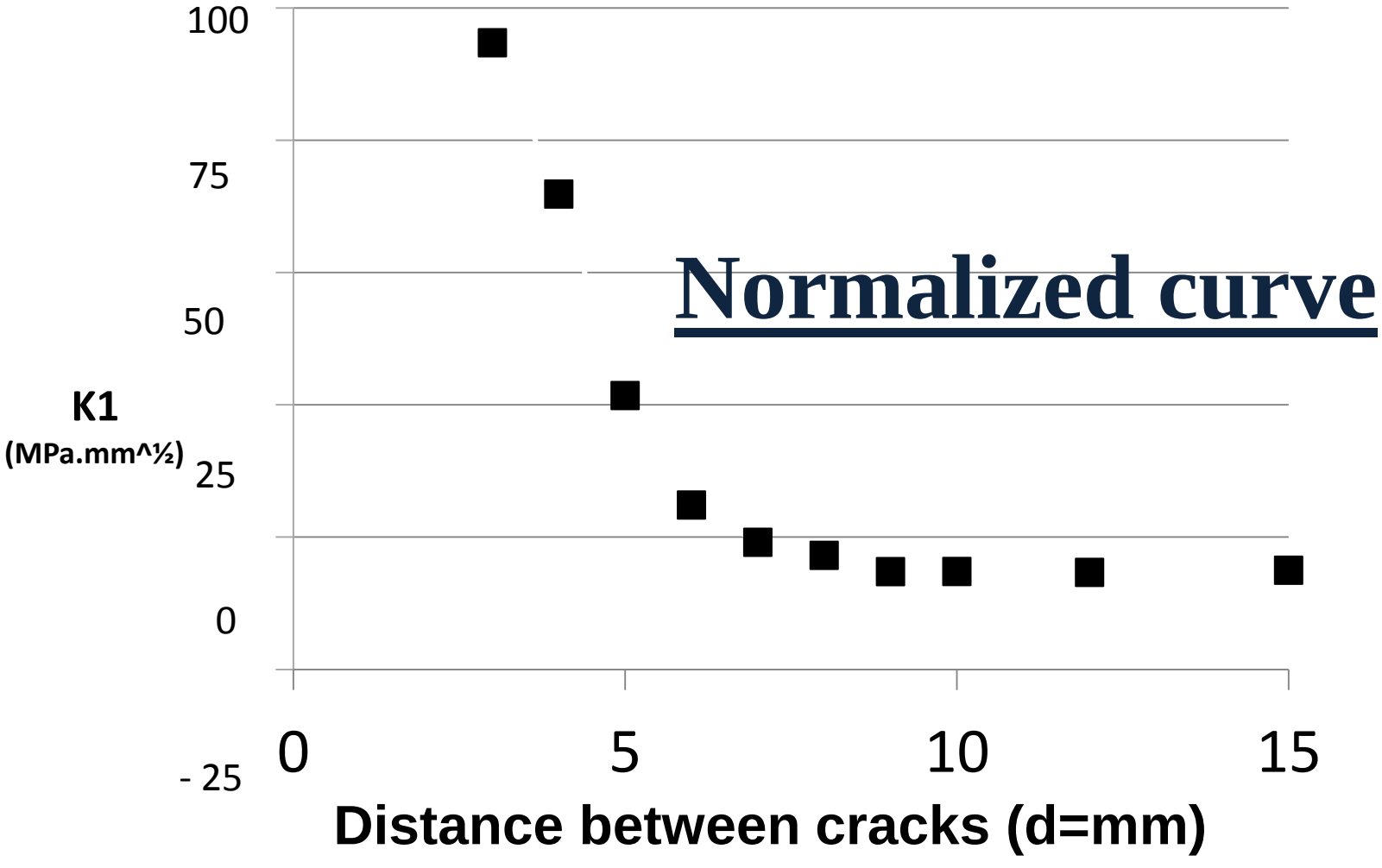
1. Introduction
2. Modeling of the crack propagation mechanism
3. Application to real structures
4. Analysis of single cracks
5. Analysis of multiple cracks
6. Conclusions


ANSYS
v12.1
W
V
0.00
40.00
80.00 (mm)
20.00
60.00


KI
(MPa.mm^½)
90
80
70
60
50
40
30
20
10
0
two crack
Single crack
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Crack propagation (a) in mm


20
18
16
14
12
10
8
6
4
2
0
a
mm
two crack
Single crack
0.00E+00
5.00E+04
1.00E+05
1.50E+05
2.00E+05
2.50E+05
Ciclos


Distance between cracks (d)
d = 10 mm
d = 5 mm
d = 4 mm
Single Crack
K1
(MPa.mm^½)
100
75
50
25
0
- 25
4
8
12
16
20
a (mm)


100
75
50
25
0
- 25
K1
(MPa.mm^½)
0
5
10
15
Distance between cracks (d=mm)
Normalized curve

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

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

Doctor Adan Vega Saenz

Technological University of Panama
www.lepum.utp.ac.pa
Email: adan.vega@utp.ac.pa
Phone: (507) 60198076 / 560-3095