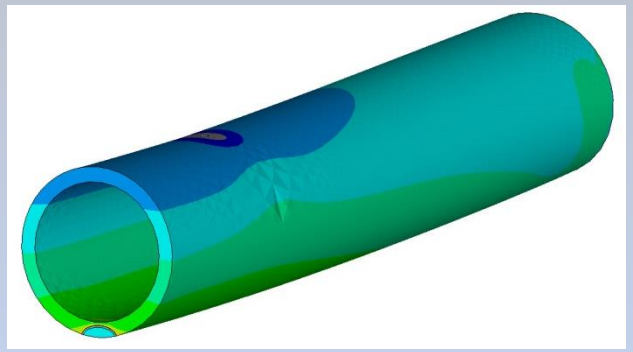
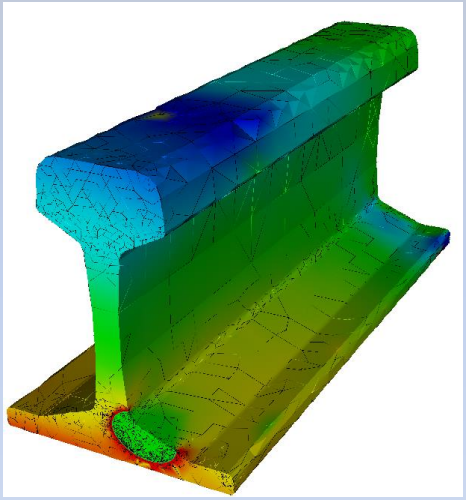
NUMERICAL SIMULATION OF THREE-DIMENSIONAL MODE-I CRACK PROPAGATION USING FCPAS: FIRST SET OF PRACTICAL CASE STUDIES





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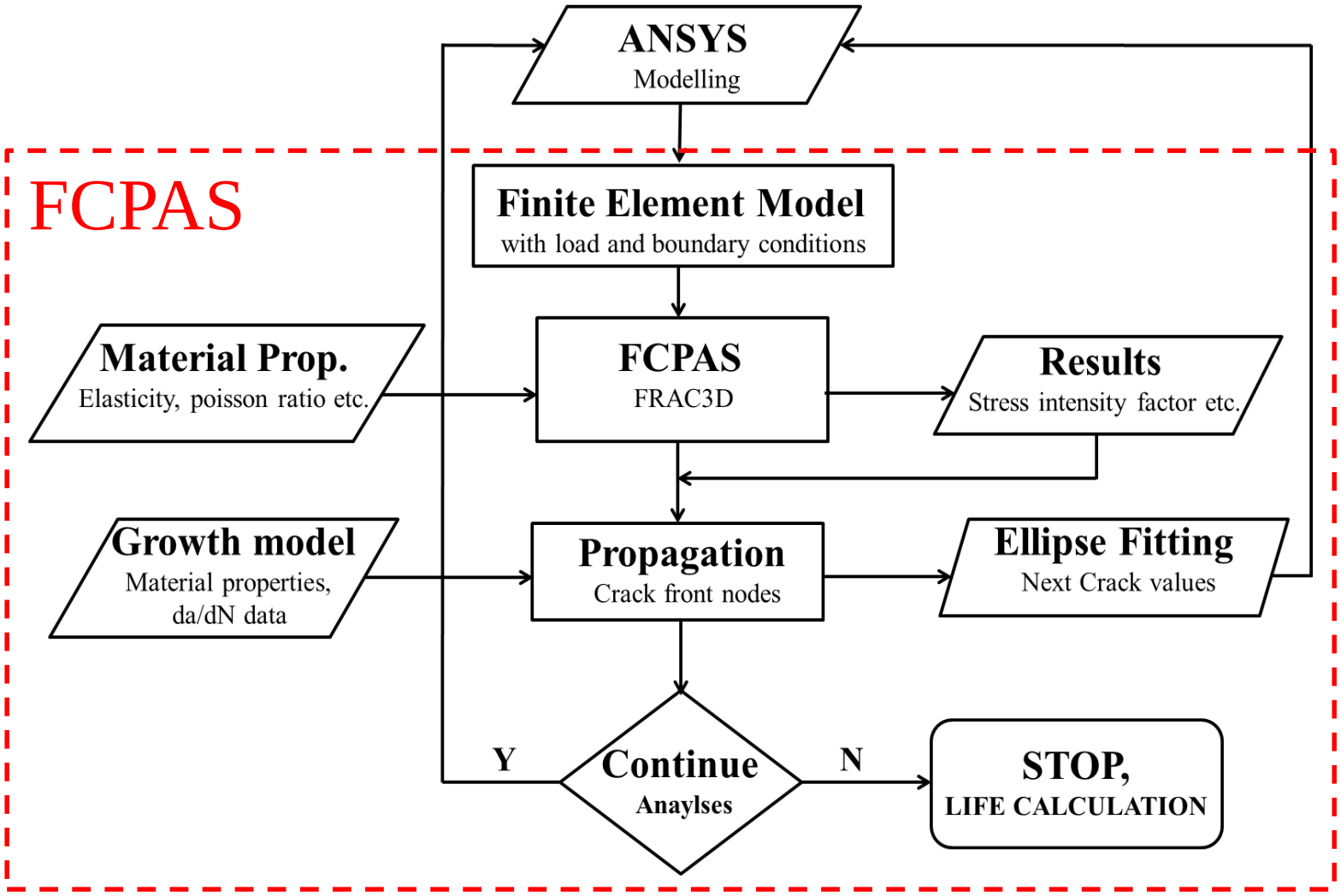
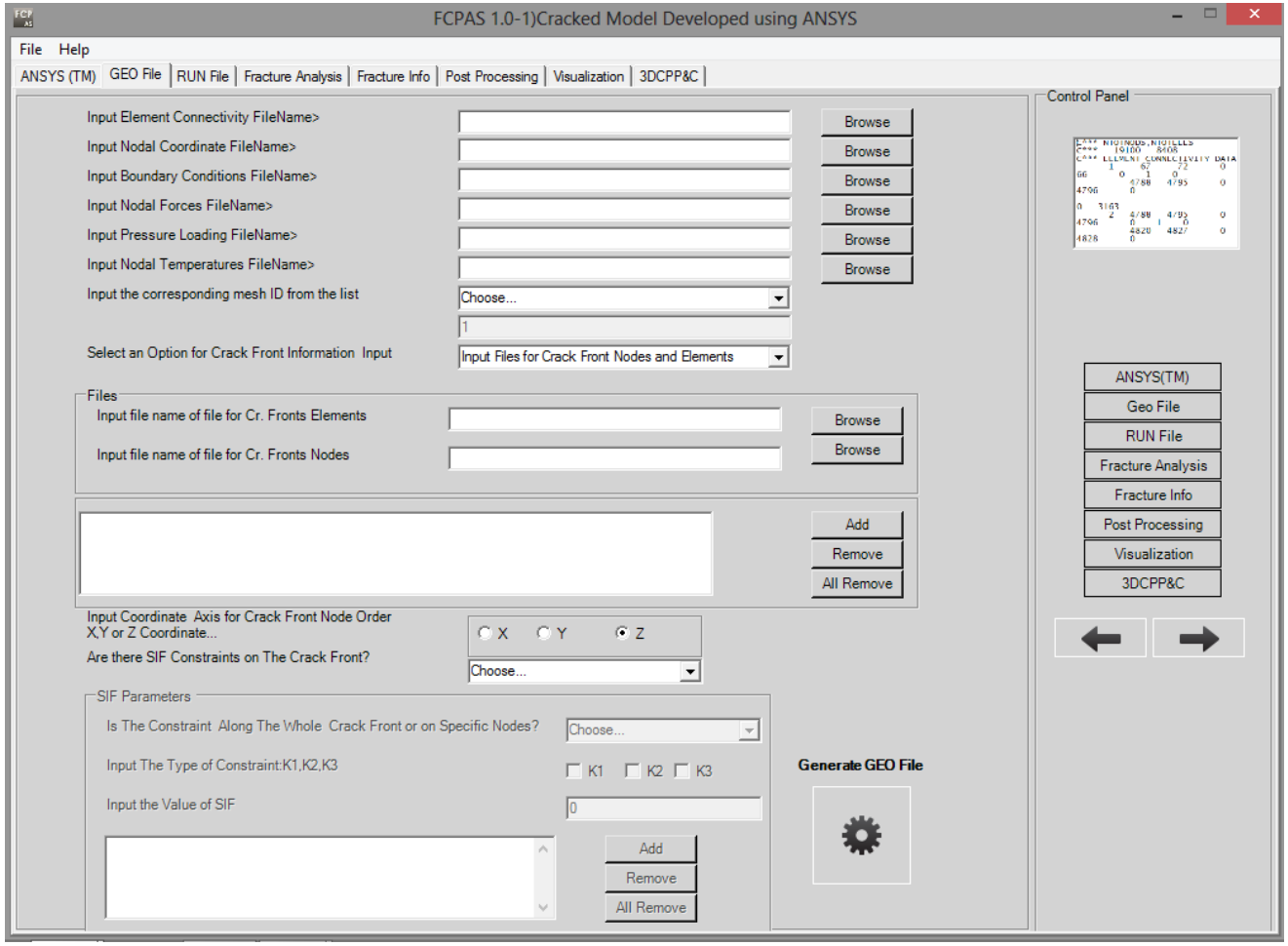
Outline

- Fracture and Crack Propagation Analysis System(FCPAS)
  - *Work Flow Scheme*
  - *Modelling*
  - *Frac3D solving*
  - *Ellipse fitting-next crack prediction*
- Problem studies
  - *Rail problem*
  - *Power Plant Pipe problem*
  - *Helicopter lift frame problem*
- Summary and Conclusions
- Acknowledgements

Work Flow Scheme of FCPAS



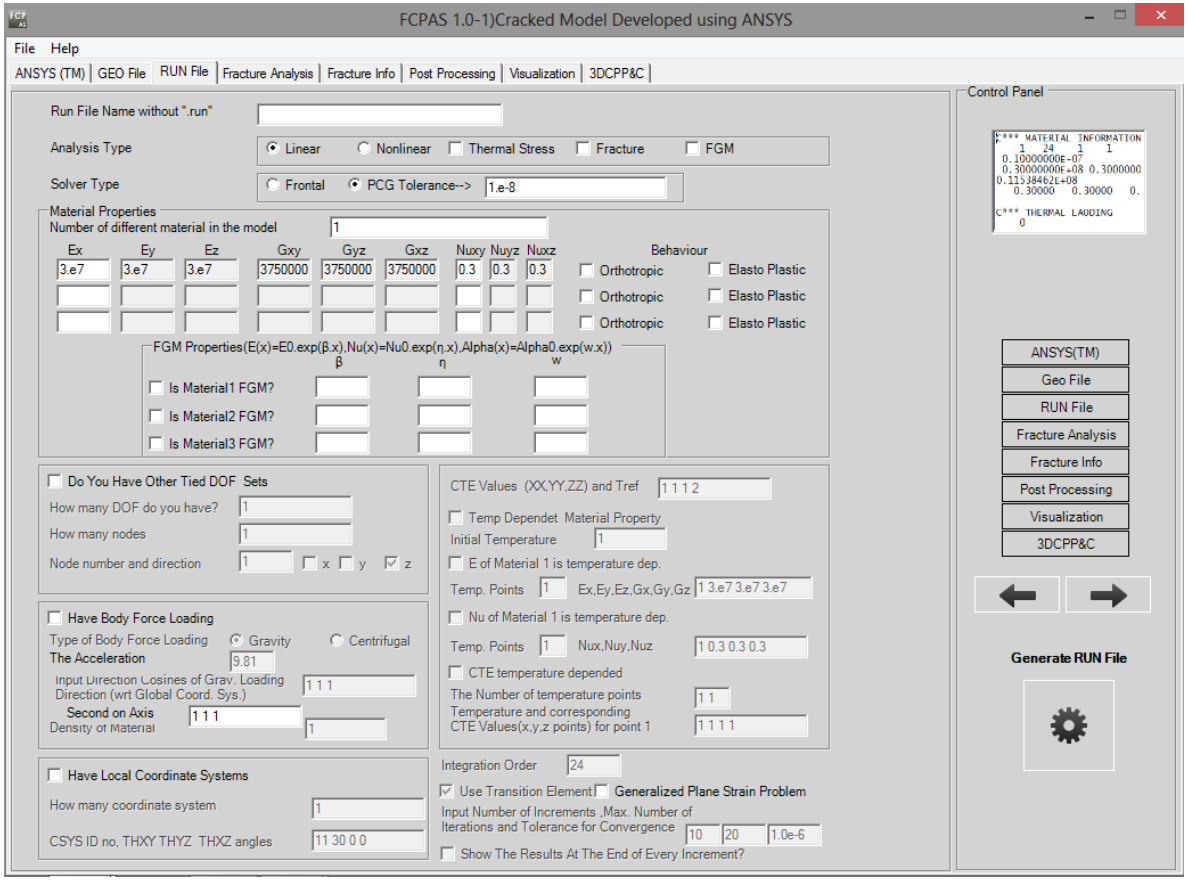
FCPAS GUI – GEO File Tab



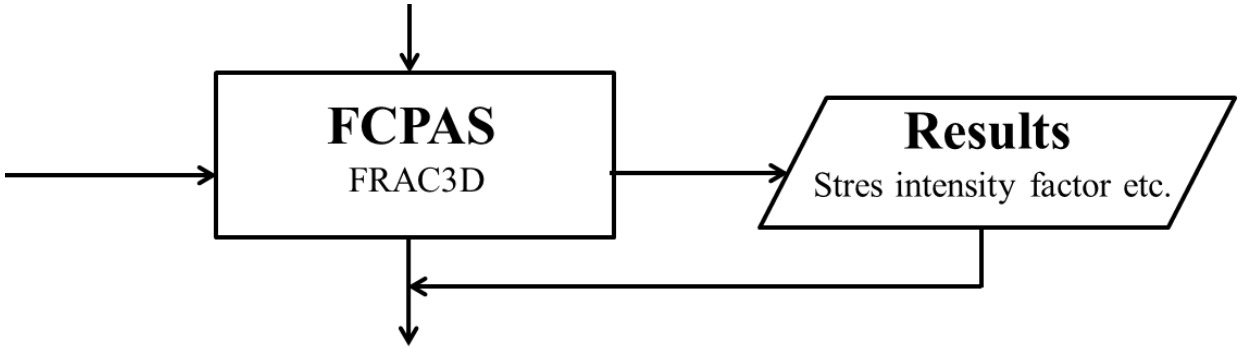
FCPAS GUI – RUN File Tab

On Material properties step;

- Converting material properties in **FCPAS** for Frac3D
  - *Material properties input by **FCPAS GUI***

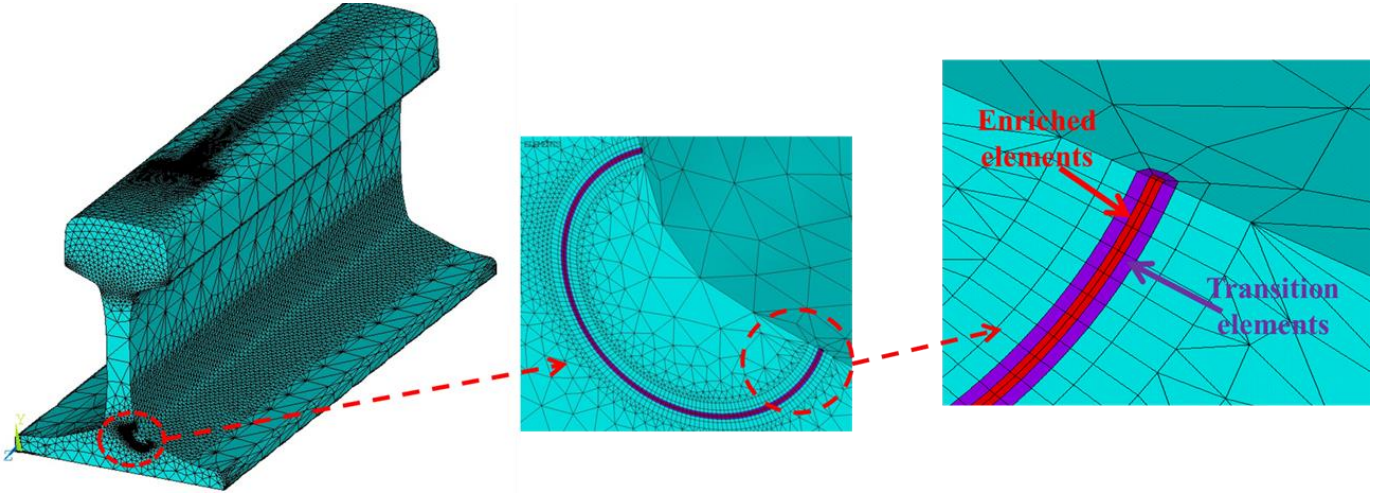


FCPAS Solution Step

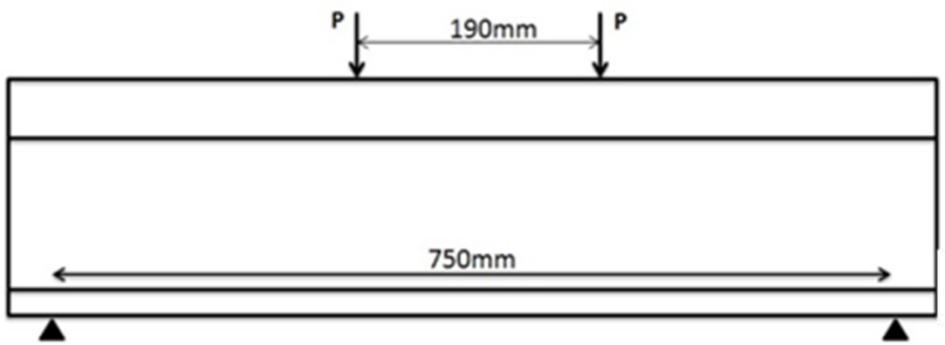


On these steps ;

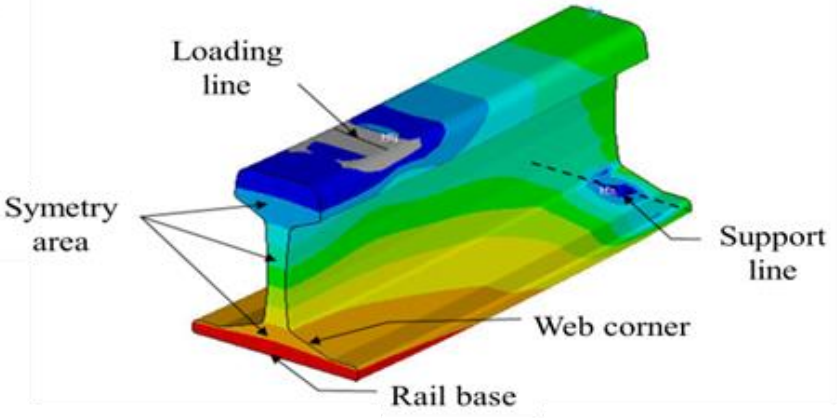
- **FRAC3D** is **FCPAS'** main solver
- **FRAC3D** uses enriched elements to calculate SIFs
- Solving stress intensity factors by **FRAC3D**
- **FRAC3D** outputs are stress and strain data of the model, and crack front SIFs

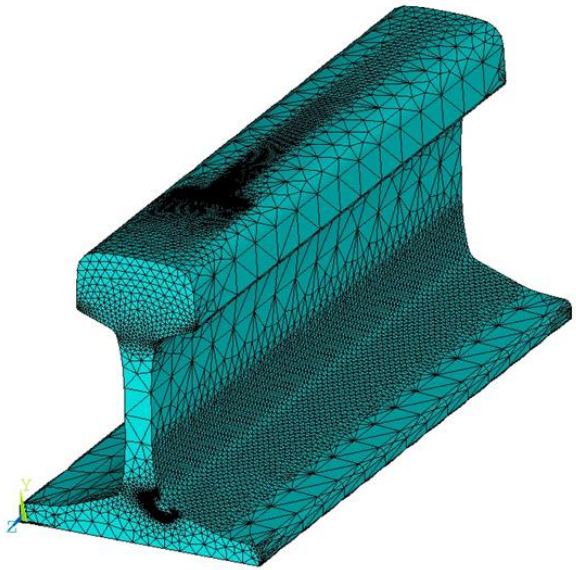


PROBLEM STUDIES: UIC 60 Rail



Four point bending test setup





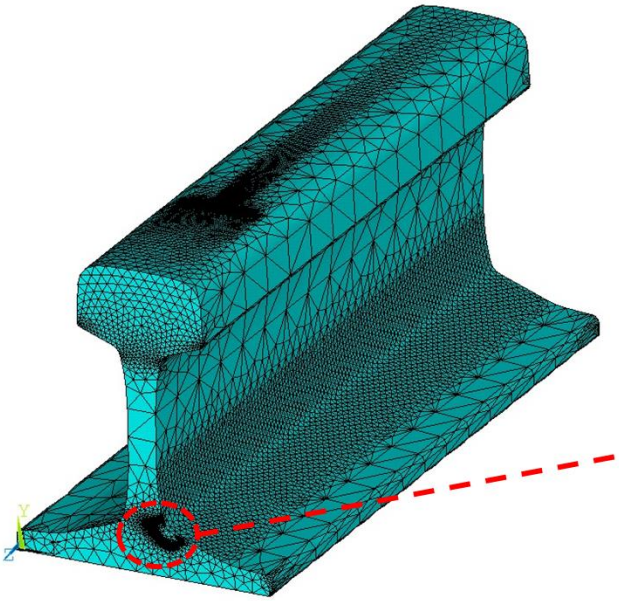
Problem Description

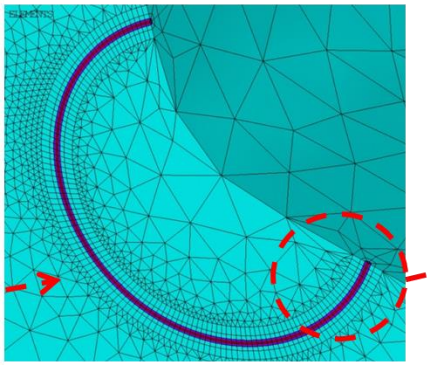
- Four point bending test simulation
- Max load, P=512 kN
- Initial crack on web corner
- Symmetric model
- $C=3.13x10^{-13}$ m=2.63

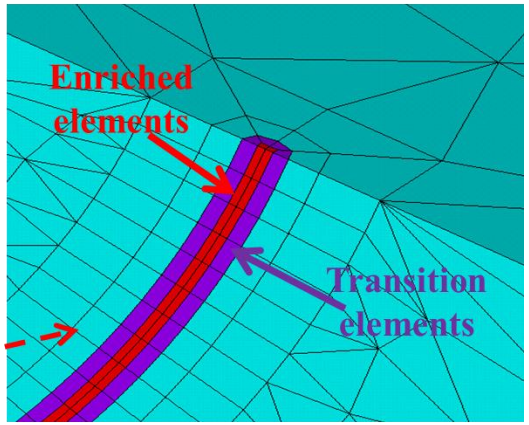
Paris-Erdoğan eguation, $da/dn=C\ (\Delta K)^m$

***Kotsikos, G., Grasso, M. Assessment of Fatigue Cracks in Rails. Procedia Social and Behavioral Sciences, Transport Research Arena – Europe 2012; 48: 1395-1402.*

UIC 60 Rail results

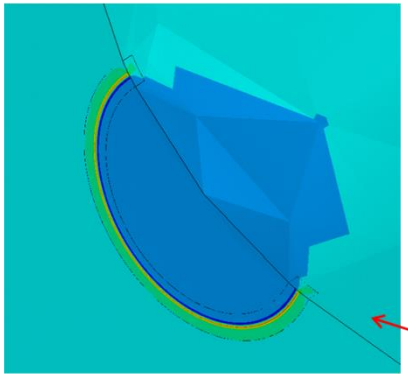


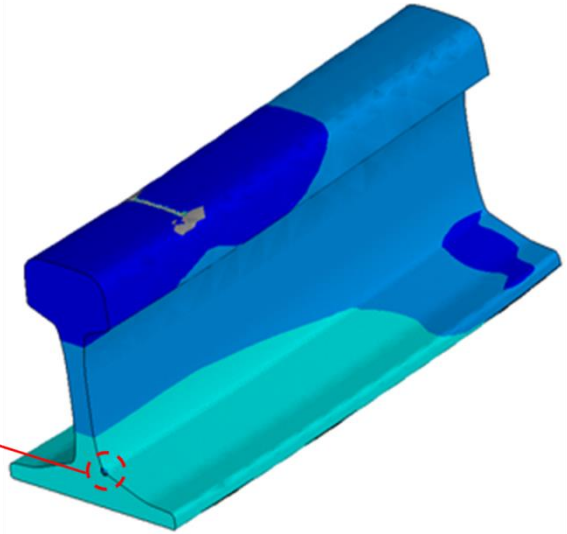




- Enriched element on crack tip
- Transition elements around crack tip elements

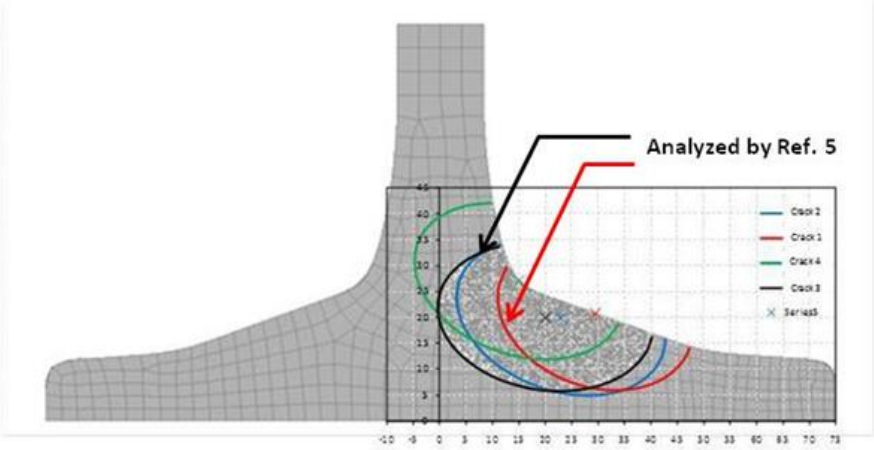
- Max. Stress on crack front

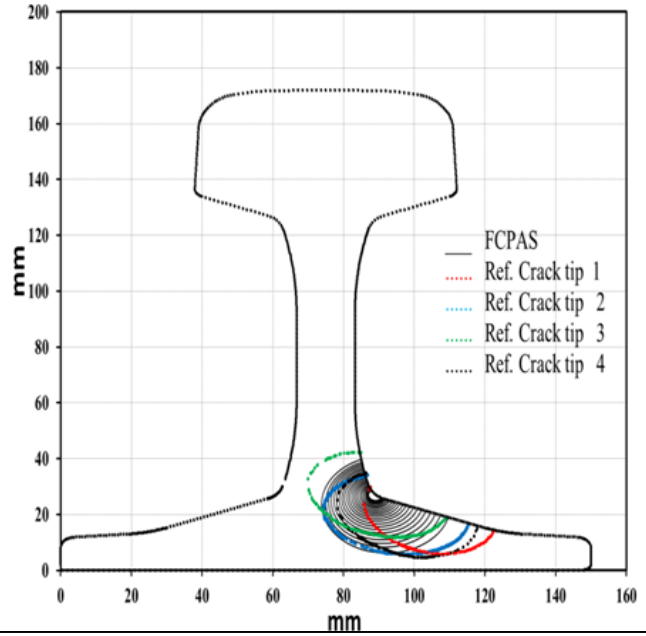


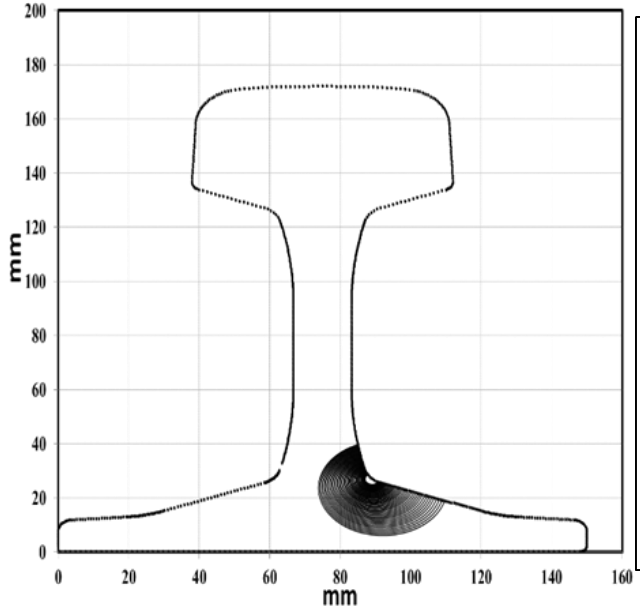


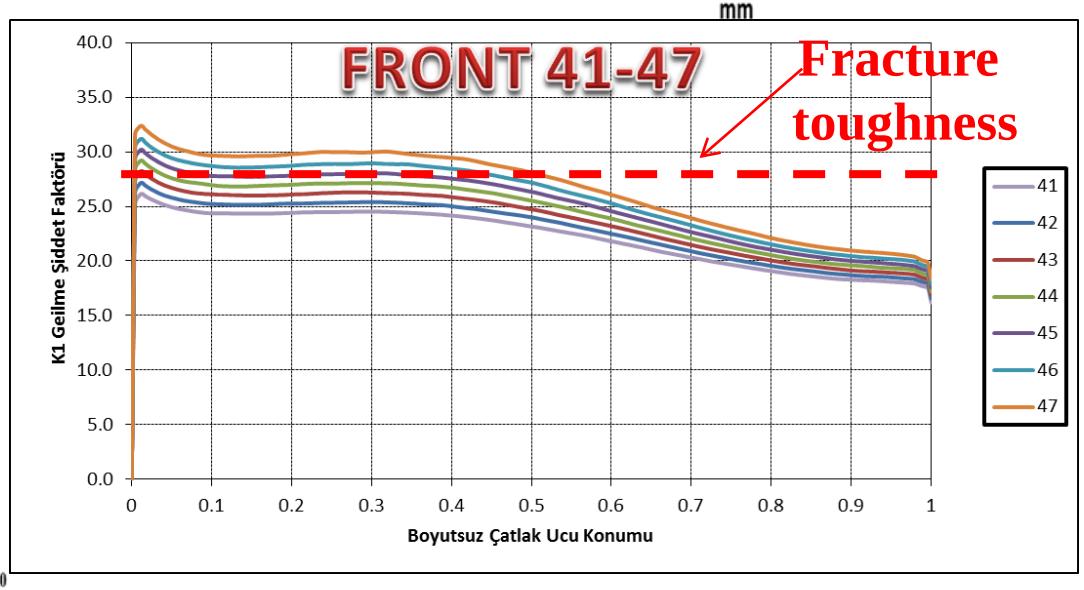
UIC 60 Rail results

Crack configuration **

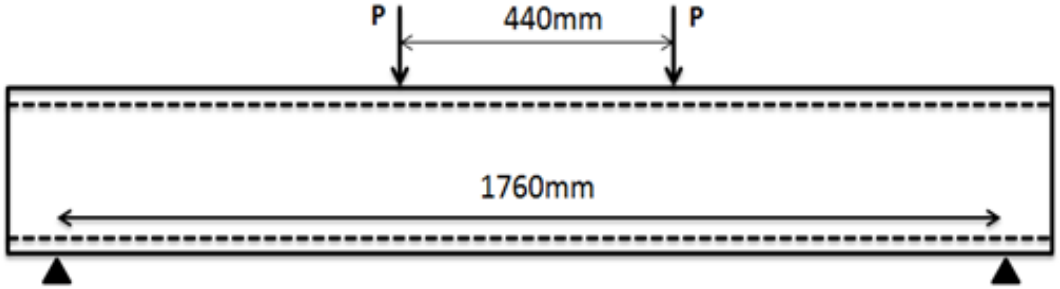








PROBLEM STUDIES: Surface crack in a powerplant pipe

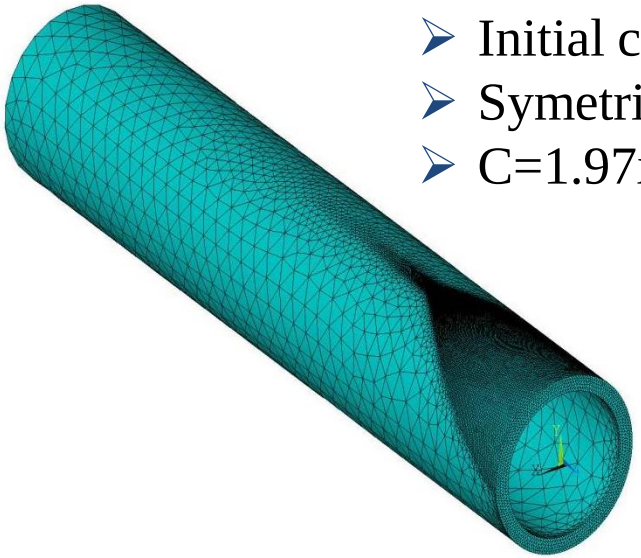


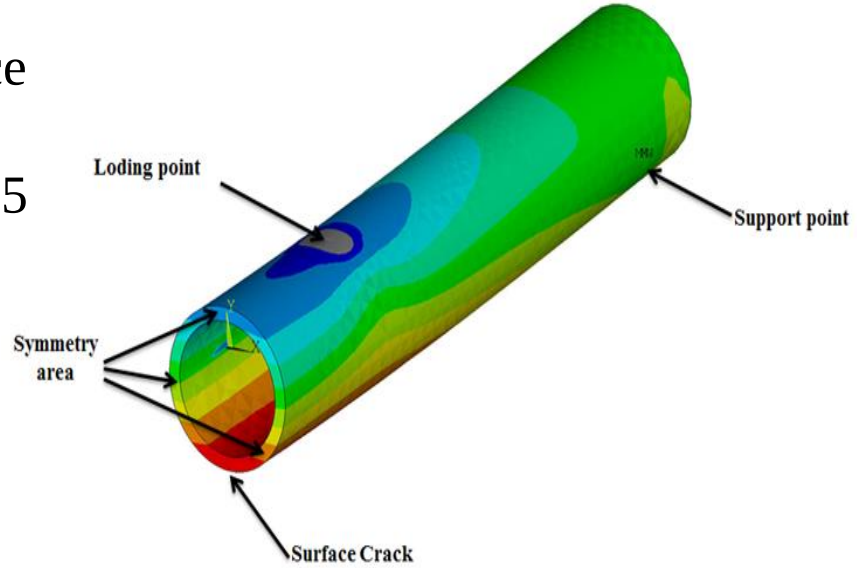
Problem Description

- Four point bending test simulation
- Max load, P=185 kN
- Initial crack on surface
- Symetric model
- C=1.97x10^{-12} , m=3.95

Paris-Erdoğan eguation

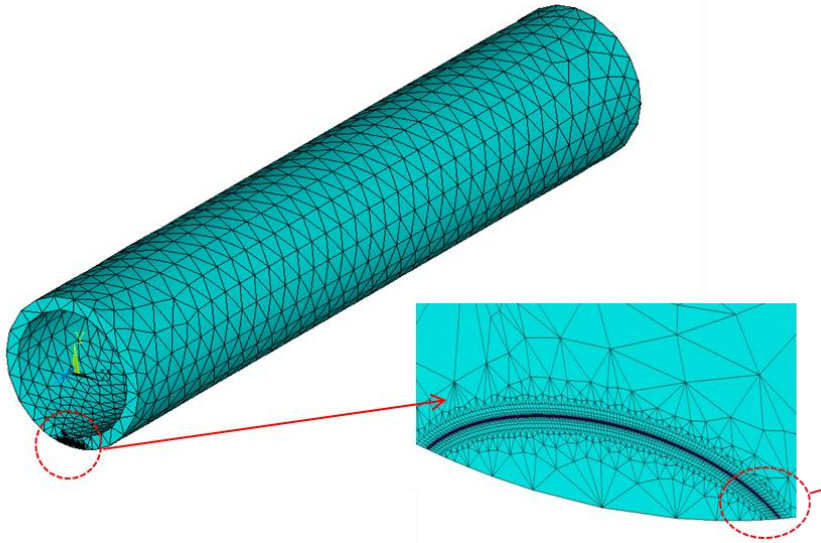
$da/dn=C\ (\Delta K)^m$

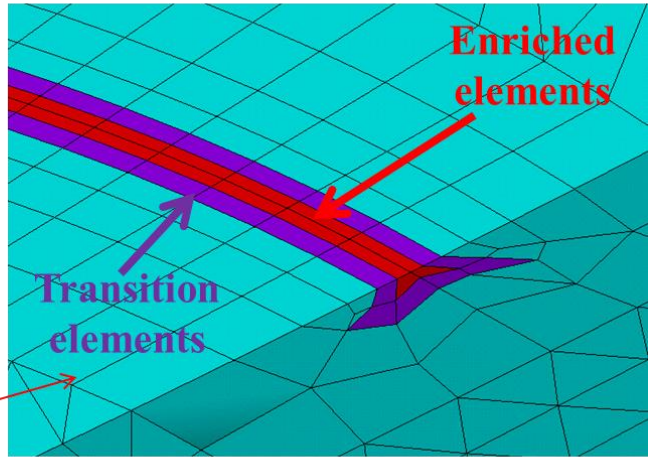




**Punit Arora, Singh PK., Bhasin V, Vaze K.K.,. Ghosh A.K,. Pukazhendhi D.M, Gandhi P. ,Raghava G., Predictions for fatigue crack growth life of cracked pipes and pipe welds using RMS SIF approach and experimental validation. International Journal of Pressure Vessels and Piping –India 2011;88: 384-394

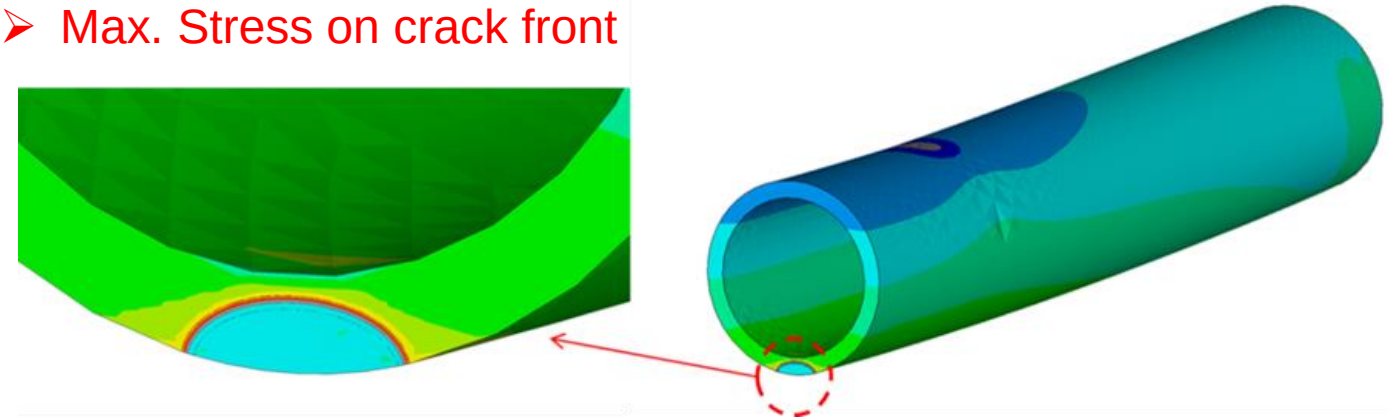
Details of the Finite elemet Fractura model



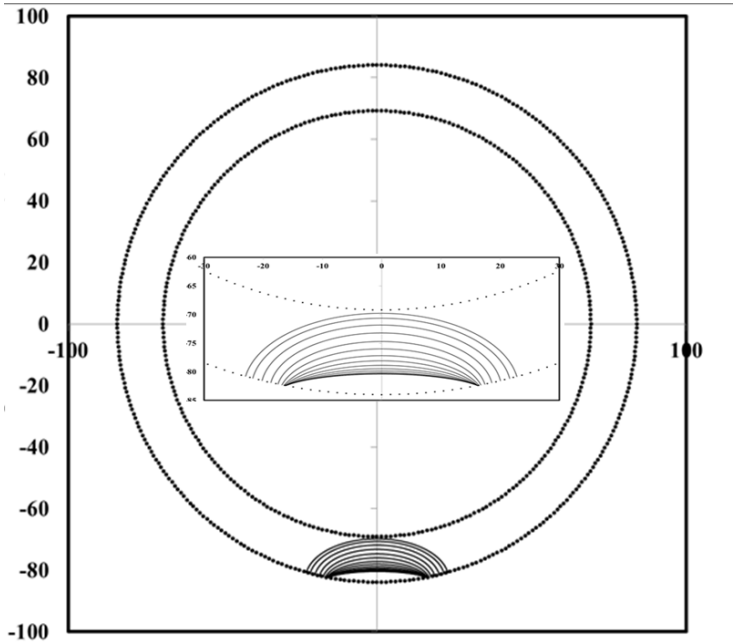


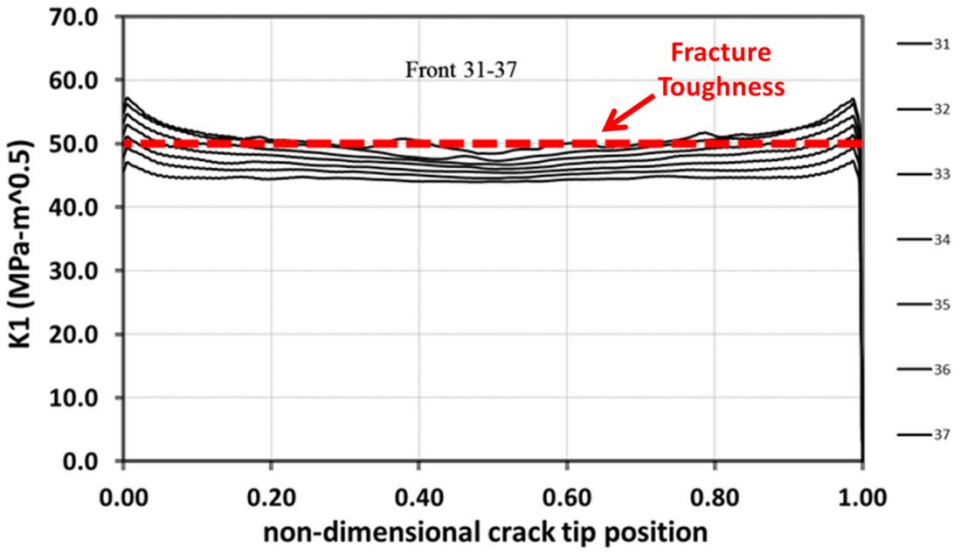
- Enriched element on crack tip
- Transition elements around crack tip elements

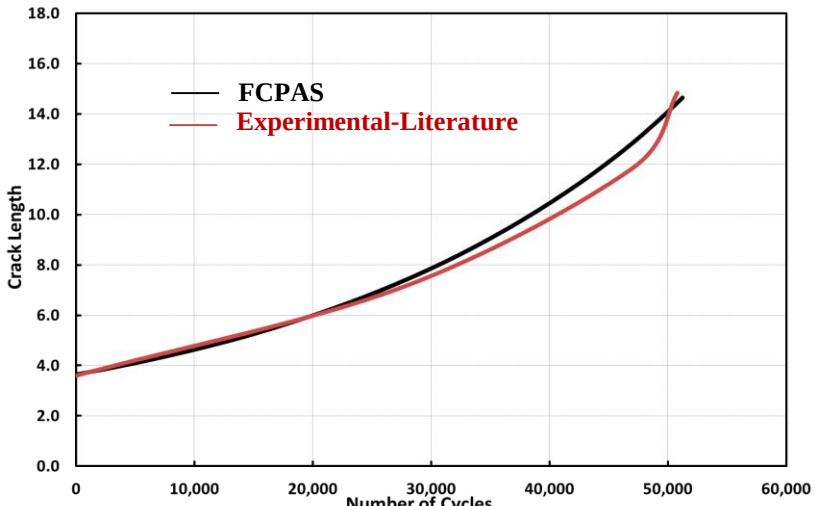
- Max. Stress on crack front

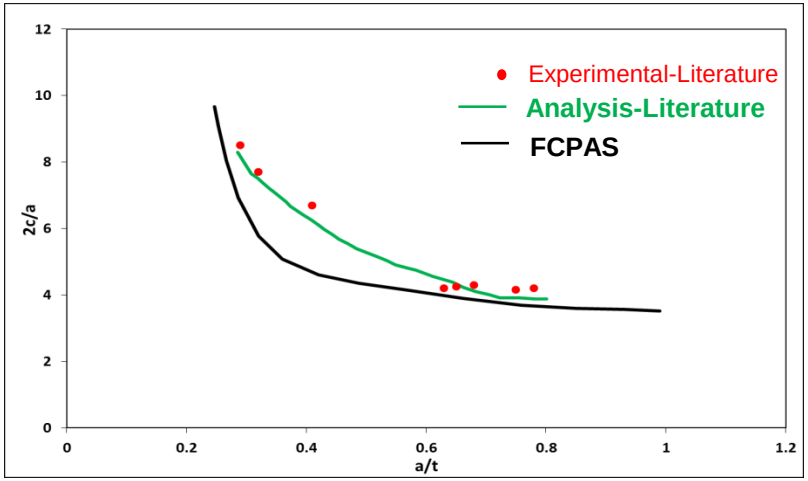


Simulation results









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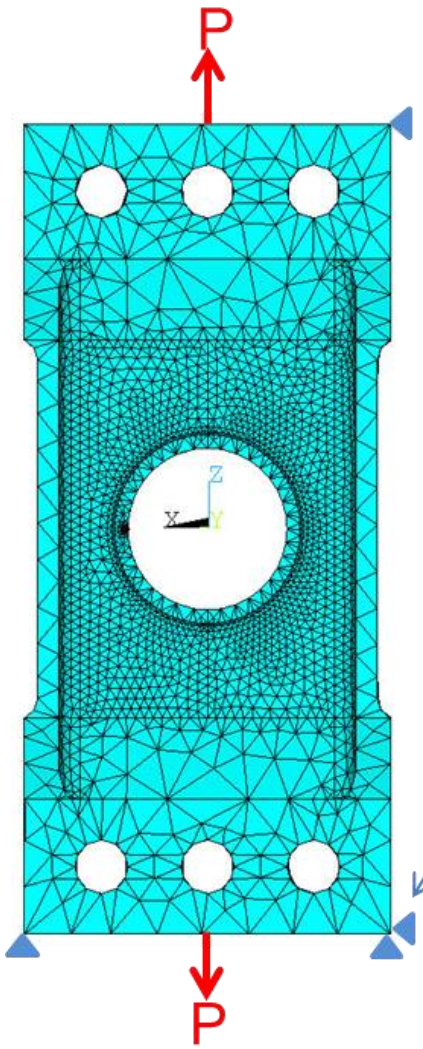
PROBLEM STUDIES: Helicopter Lift Frame



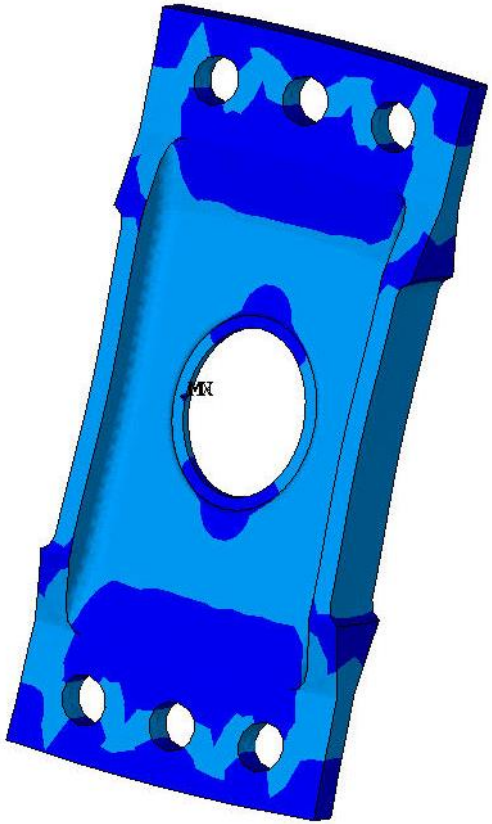
Support point

Problem Description

- Fatigue under tensile loading
- Initial crack on corner
- Full model
- C=1.95x10^{-6}, m=1.95

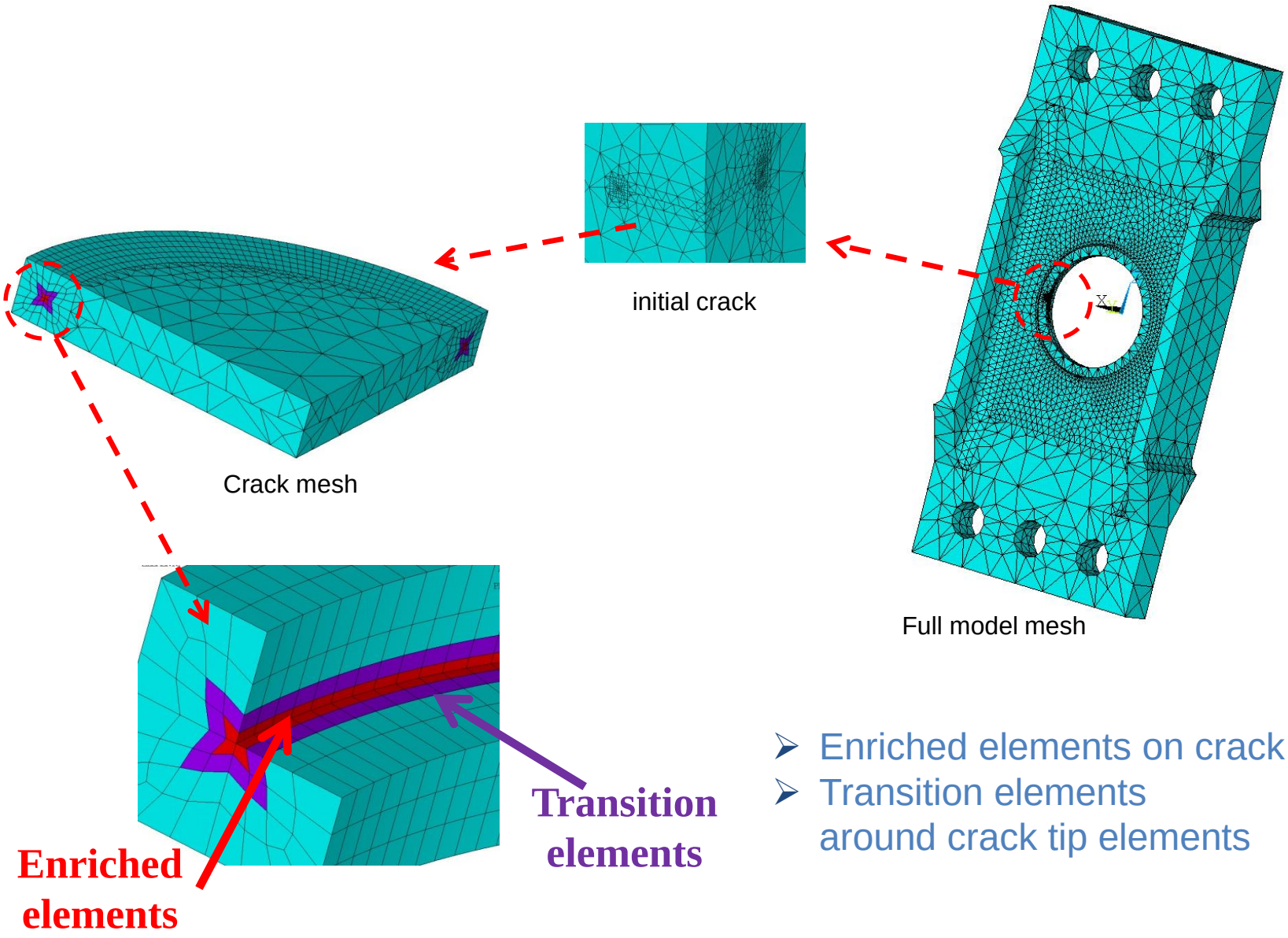
Paris-Erdoğan eguation

$da/dn=C\ (\Delta K)^m$



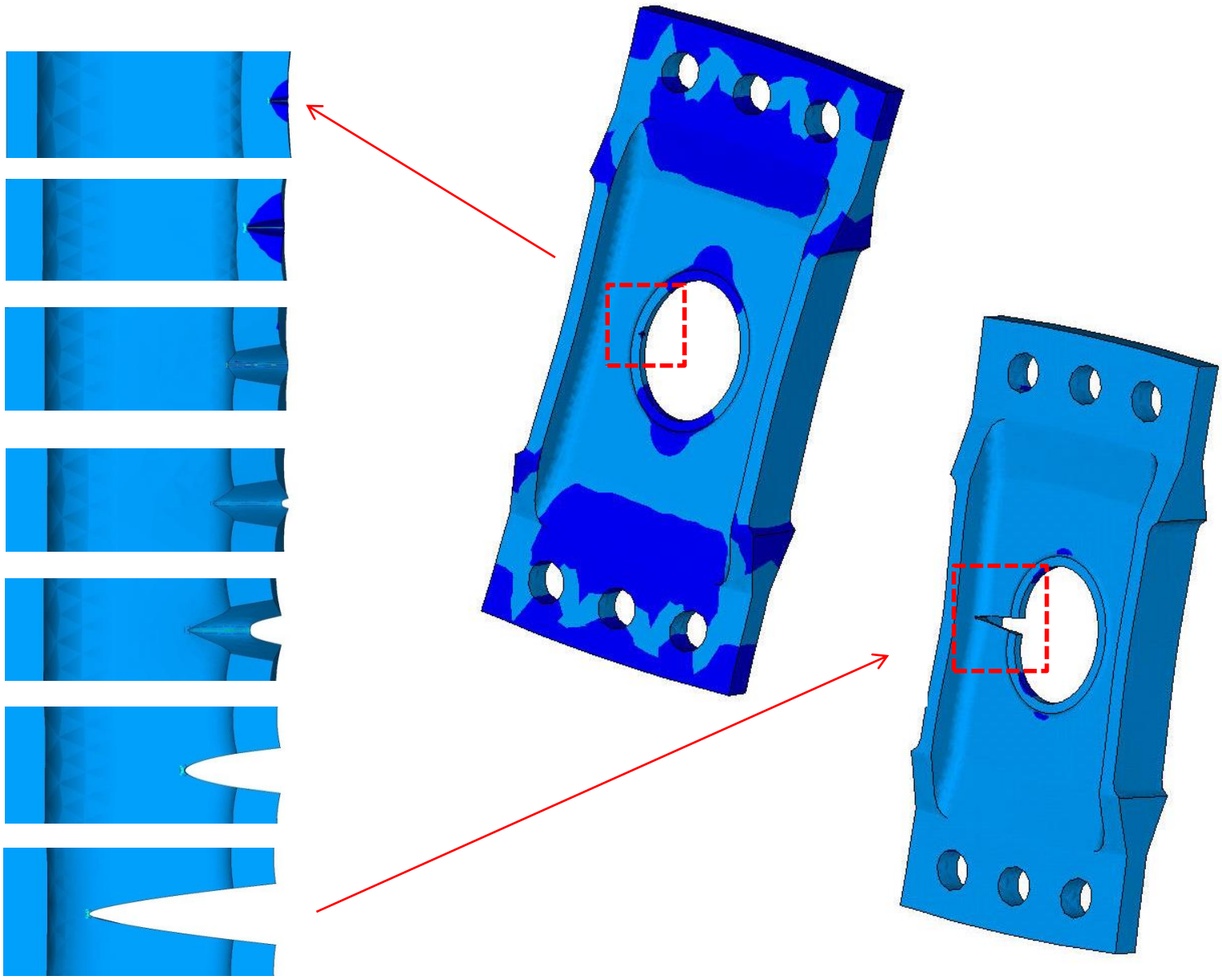
***U.H. Tiong, R. Jones,, Damage tolerance analysis of a helicopter component. International Journal of Fatigue –Australia (2009) 1046–1053*

PROBLEM STUDIES: Helicopter Lift Frame

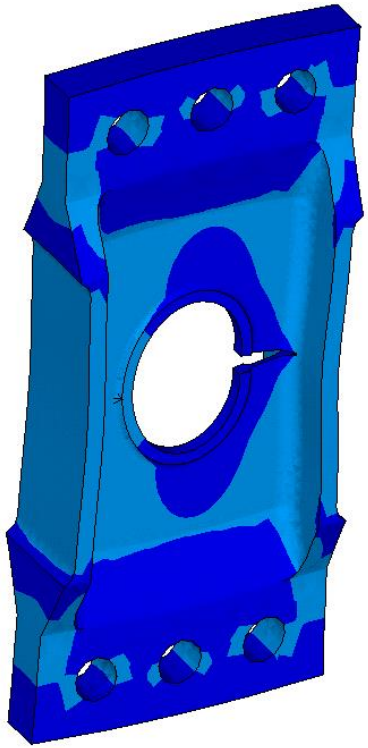


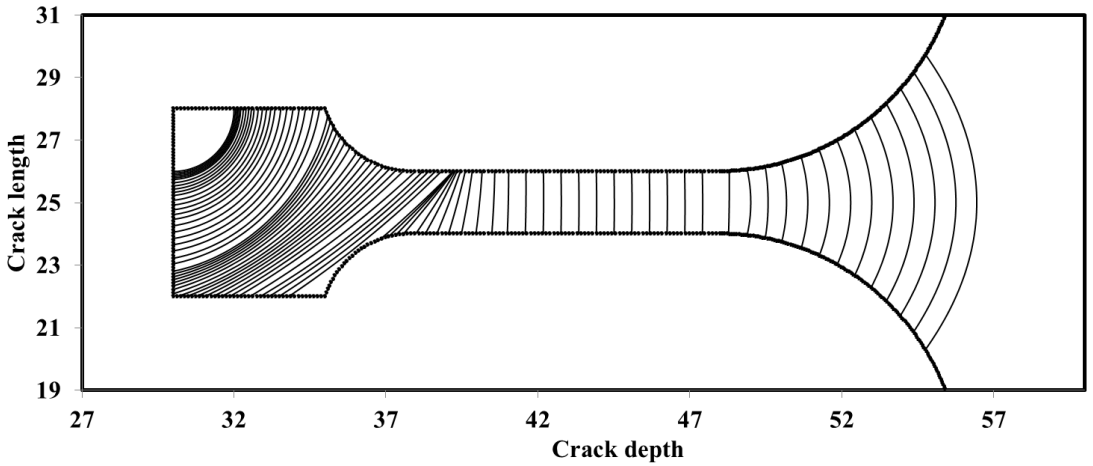
- Enriched elements on crack tips
- Transition elements around crack tip elements

Stress contours and deformed shape

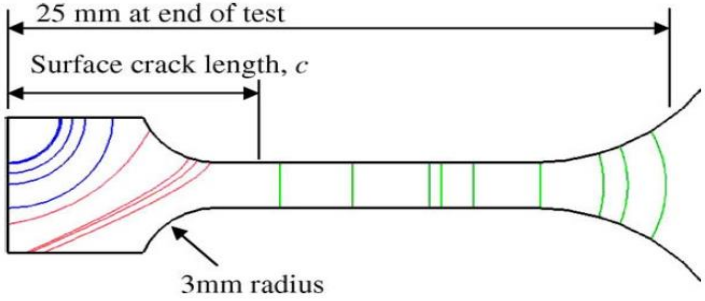


Helicopter lift frame result and comparation

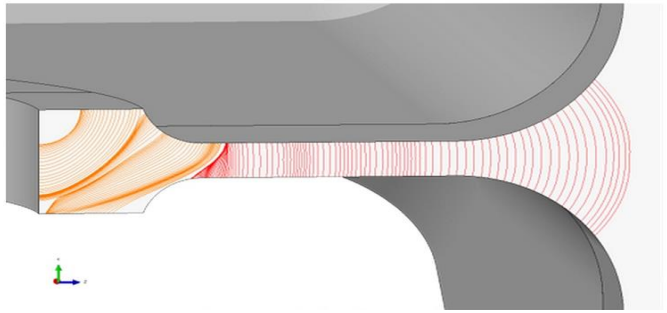




Crack Profiles by FCPAS Simulation



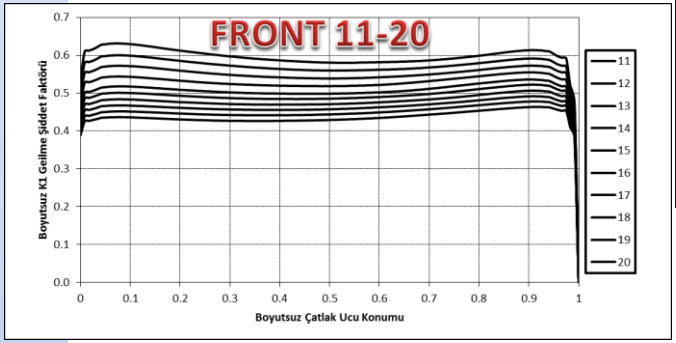
U.H. Tiong, R. Jones,, Damage tolerance analysis of a helicopter component. International Journal of Fatigue –Australia (2009) 1046–1053

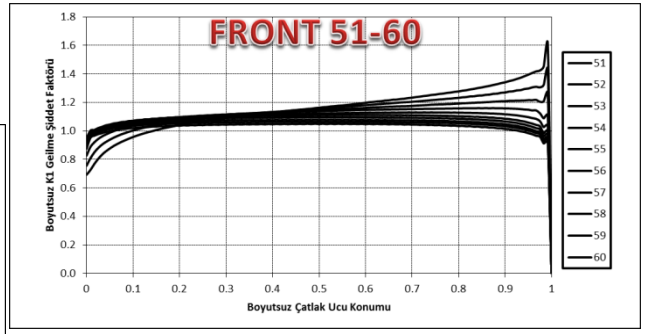


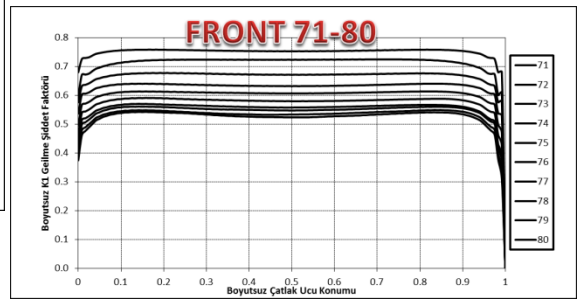
Crack Profiles by ZENCRACK Simulation

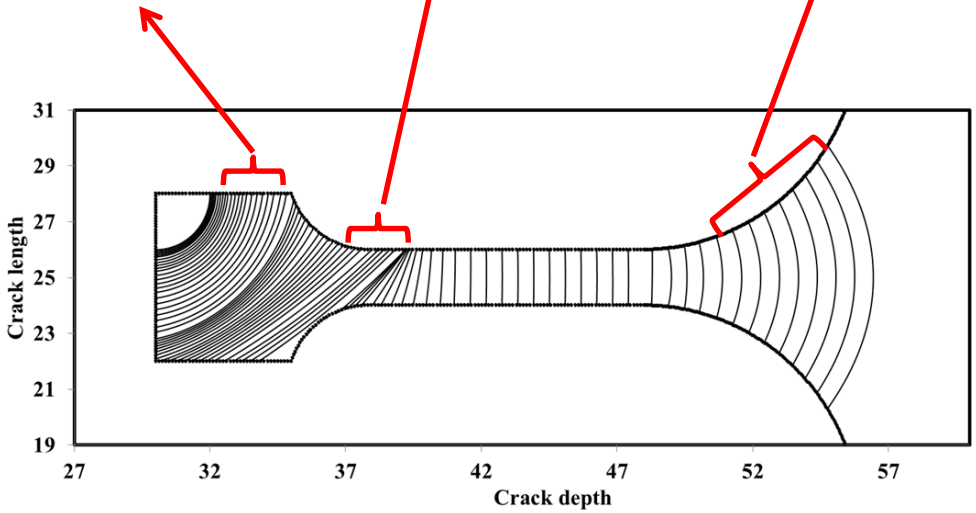
http://www.zentech.co.uk

Helicopter lift frame - SIFs









Summary and Conclusions

- FCPAS programında örnek analizler yapılmıştır
- Litaretürdeki bazı uygulamalar Aynı şartlarda modellenerek Mod-I çatlak ilerleme simulasyonları gerçekleştirilmiştir
- Yapılan analizlerin sonuçları litaratürdeki ve testlerdeki örnekler ile örtüşmektedir
- Bu örtüşme bize FCPAS programının doğruluğunu ve kullanılabilirliğini göstrermektedir

Summary and Conclusions

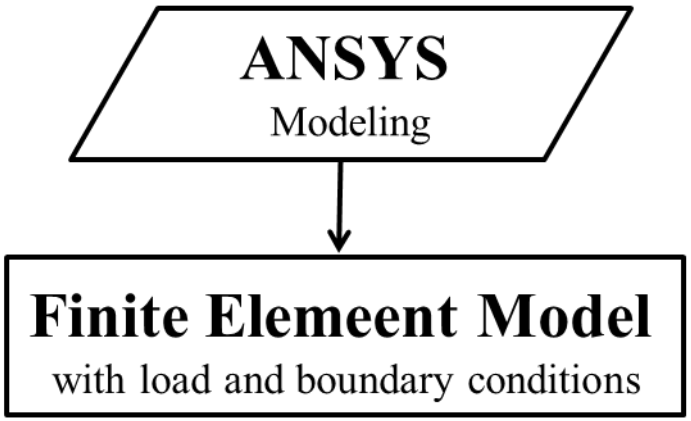
- FCPAS is applied to various mode-I three-dimensional crack propagation problems.
  - UIC 60 rail problem
  - Powerplant pipe
  - Helicopter Lift frame
  - ✓ **Simulations of Mode-I Fatigue Crack propagation have been done**
- Enriched finite elements used in FCPAS allow computation of SIFs and simulation of crack growth in structures accurately and efficiently.
- Some applications from the literature are modeled and crack propagation analyses are done by FCPAS.
  - FCPAS fracture models generated and Stress Intensity Factors (SIFs) are Computed
  - Life calculation results are obtained from FCPAS' crack propagation analyses
  - Life Calculation Results agree well with literature results
- These agreements of results with data from the literature show FCPAS' accuracy for simulation of fatigue crack propagation problems.

Acknowledgements

✓*Authors are thankful to The Scientific and Technological Research Council of Turkey (TUBITAK) for the financial support during FCPAS Project.*

Thank you

FE Model Generation



Within Ansys ;

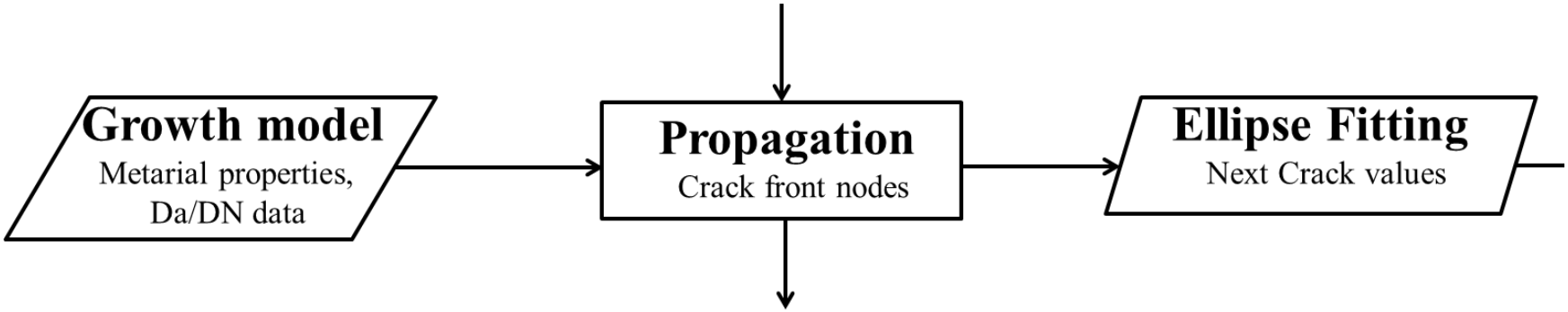
- Modelling of crack containing geometry
- Meshing cracked model
- Output files are *.elis, *.node, *.dlis, *.flis *.sflis, *.crelems and *.crnodes

" * " is your model name
*.elis is element list of the FE model
*.node is list of model nodes
*.dlis is list of model displacementand boundary cond.
*.flis is list of loading force
*.sflis is list of pressure loading
*.crelems is list of crack front elements
*.crnodes is list of crack front nodes

On Finite Element Model Step;

- Reading lists by **FCPAS GUI**
- Converting lists in **FCPAS** for Frac3D (*.geo file is generated)

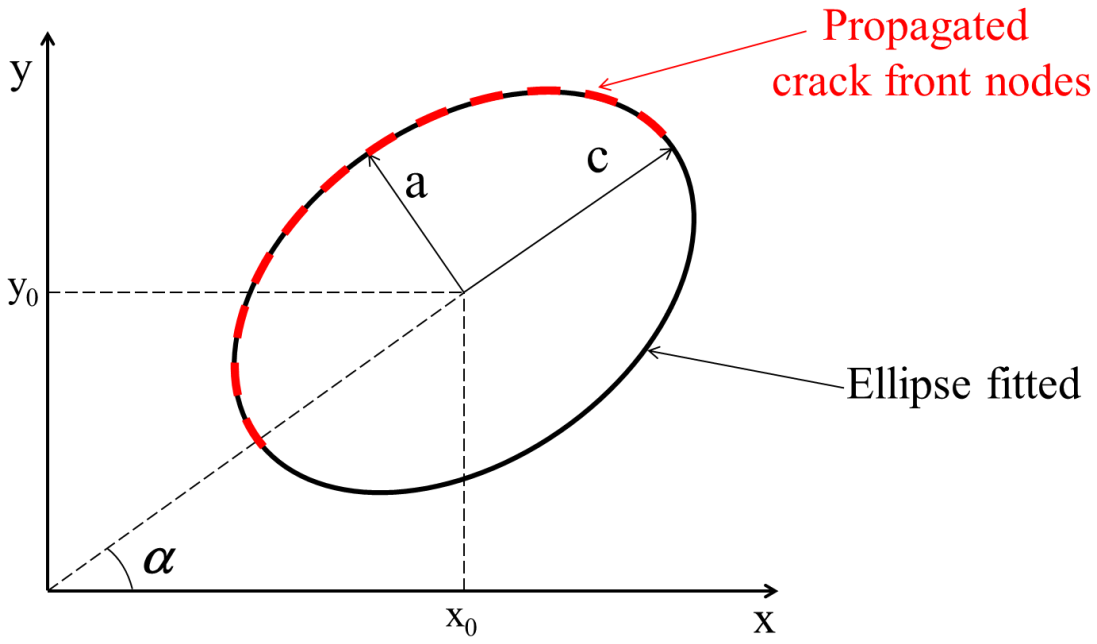
Prediction of Next Profile and Ellipse Fitting



On these steps ;

- Crack front nodes are propagated with **Paris-Erdoğan equation** by **FCPAS** propagation exe (crk_propagation.exe)
- When **FCPAS** propagation exe uses SIF data from **FRAC3D** solution
- Also,it uses da/dN data; C and m constants for Paris Erdoğan equation (these constants can be defined by **FCPAS GUI)**
- Next crack depth (a) and length(c) are found by Ellipse fitting method using propagated nodes

Ellipse Fitting



Ellipse fitting;

- Five parameter ellipse fitting method is used
- These parameters are; depth of crack (a), length of crack (c), x and y coordinates of the center of the fitted ellipse (x0, y0) and the rotation angle of the ellipse's major axis with respect to one of the axes of the global coordinate system (α).