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

FCP AI	FCPAS 1.0-1)Cracked Model Developed using ANSYS	X
File Help		
ANSYS (TM) GEO File RUN File Fracture Analysis Fracture in	rro Post Processing Visualization 3UCPP&C	Control Panel
Input Element Connectivity FileName>	Browse	
Input Nodal Coordinate FileName>	Browse	CANA INTOTINUUS, NTOTELLS CANA DIDIOD 8008 CANA ELEVENT CONNECTIVITY DATA
Input Boundary Conditions FileName>	Browse	66 0 0 01 0 ⁷² 0 4788 4795 0 4796 0
Input Nodal Forces FileName>	Browse	0 3163 2 4/88 4/95 0 4796 0 1 0
Input Pressure Loading FileName>	Browse	4828 0 4827 0
Input Nodal Temperatures FileName>	Browse	
Input the corresponding mesh ID from the list	Choose	
	1	
Select an Option for Crack Front Information Input	Input Files for Crack Front Nodes and Elements	
Files		ANSYS(TM)
Input file name of file for Cr. Fronts Elements	Browse	Geo File
Input file name of file for Cr. Fronts Nodes	Browse	RUN File
		Fracture Analysis
		Fracture Info
	Add	Post Processing
	Remove	Visualization
	All Remove	3DCPP&C
Input Coordinate Axis for Crack Front Node Order X,Y or Z Coordinate	C X C Y C Z	
Are there SIF Constraints on The Crack Front?	Choose	
SIF Parameters		
Is The Constraint Along The Whole Crack Front or	r on Specific Nodes? Choose	
Input The Type of Constraint:K1,K2,K3	☐ K1 ☐ K2 ☐ K3 Generate GEO File	
Input the Value of SIF	0	
	Add 👯	
	Remove	
	V All Remove	

FCPAS GUI – RUN File Tab

On Material properties step;

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

E FCPAS 1.0-1)Cracked Model Developed using ANSYS	- 🗆 🗙		
File Help ANSYS (TM) GEO File RUN File Fracture Analysis Fracture Info Post Processing Visualization 3DCPP&C			
Run File Name without ".run" Analysis Type Image: Solver Type Frontal • PCG Tolerance> Number of different material in the model 1 Ex Ey Saterial Properties Number of different material in the model 1 Ex Ey Ez Gxy Gyz Gxz Number of different material in the model 1 Ex Ey Ez Gyz Gyz Gyz Gyz Gyz Gyz Gyz Gyz B Orthotropic Elasto Plastic FGM Properties(E(x)=E0.exp(βx), Nu(x)=Nu0.exp(n,x), Alpha(x)=Alpha0.exp(w.x))) β n w Is Material1 FGM? Is Material2 FGM? Is Material3 FGM?	Consort and 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 30000000 0 300000 0 1 1 1 1 1 1 1 0 30000 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1<		
Image: Dop You Have Other Tied DDF Sets How many DOF do you have? How many nodes 1 Node number and direction 1 Image: X mode in the image in	Fracture Info Post Processing Visualization 3DCPP&C Generate RUN File		
Input Uirection Cosines of Grav, Loading 111 Direction (wrt Global Coord. Sys.) 111 Second on Axis 111 Image: I	*		

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





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



PROBLEM STUDIES: Surface crack in a powerplant pipe



**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





Simulation results



^{10,000} ^{20,000} ^{Number of Cycles} ^{40,000} ^{50,000} ^{60,000} ^{**}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

PROBLEM STUDIES: Helicopter Lift Frame



**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



Stress contours and deformed shape



Helicopter lift frame result and comparation



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.

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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).