# FINITE ELEMENT MODELING OF GROWING MULTIPLE THREE-DIMENSIONAL CRACKS UNDER





FCPAS







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# Outline

□ FCPAS Standard and Additional Crack Propagation GUI

□ Used Tools and Methods for Ellipse Fitting

□ Used Tools and Methods for Plotting Analysis Results

□ Fracture Analyses of Attachment Lugs for Single and Two Cracks Cases

Fracture and Crack Propagation Analyses of 2024 Al Alloy Multiple Crack Specimen and

7050 Al Alloy Specimen with Two Surface Crack

- Problem Description
- Finite Element Fracture Models
- Stress Intensity Factor Solutions
- Crack Propagation Analyses
- SIF Results
- Comparison with Results in Literature
- Crack Profiles and Stress Contours

□ Summary and Conclusions

## **FCPAS GUI**

#### **FCPAS Standard GUI**

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#### FCPAS Additional Crack Propagation GUI



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### **How FCPAS Works For Multiple Cracks?**



### **New Ellipse Fitting Method: Automated Excel Solver**



Automated Excel File by VBA Macro Code

### **New Ellipse Fitting Method: Automated Excel Solver**



Ellipse\_Fit.xlsm Work Flow Scheme

# **Automated Plotting Tool: Flash\_Plot**

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#### Flash\_Plot.xlsm main page

Automated Excel File by VBA Macro Code

## **Automated Plotting Tool: Flash\_Plot**



Crack\_Profiles, K\_Graph and a-N Graph pages of Flash\_Plot.xlsm

#### Multiple Crack Containing Attachment Lug - Problem Description



\* R. RIGBY and M. H. ALIABADI, Stress intensity factors for cracks at attachment lugs, Engineering Failure Analysis, Vol. 4, No. 2, 1997, pp. 133, 146 9

### **Multiple Crack Containing Attachment Lug – Results**



\* R. RIGBY and M. H. ALIABADI, Stress intensity factors for cracks at attachment lugs, Engineering Failure Analysis, Vol. 4, No. 2, 1997, pp. 133, 146 10

### **Specimen with Two Surface Crack - Problem Description**



Symmetric and Full Model of Multiple Crack Specimen

\* J.T. Tan and B.K. Chen , A new method for modelling the coalescence and growth of two coplanar short cracks of varying lengths in AA7050-T7451 aluminium alloy, International Journal of Fatigue, Vol. 49, 2012, pp 73–80

### **Specimen with Two Surface Crack – FE Model**



FE Model and Crack Develop Steps

#### **Specimen with Two Surface Crack - Results**



\* J.T. Tan and B.K. Chen , A new method for modelling the coalescence and growth of two coplanar short cracks of varying lengths in AA7050-T7451 aluminium alloy, International Journal of Fatigue, Vol. 49, 2012, pp 73–80

### **Multiple Crack Specimen - Problem Description**



#### Double Symmetric Finite Element Model of Multiple Crack Specimen

Nishimura, T., Noguchi, Y., and Uchimoto, T., "Damage Tolerance Analysis of Multiple-Site Cracks Emanating from Hole Array," Journal of Testing and Evaluation, JTEVA, Vol. 18, No. 6, Nov. 1990, pp. 401-407

### **Finite Element Fracture Models**



Finite Element Model of Multiple Crack Specimen



Stress Intensity Factor Solutions of Interacting Multiple Cracks within FCPAS

16



Life calculation comparison for 4-crack specimen (a-N data from 1st crack)

Life Calculation Results of Interacting Multiple Cracks From FCPAS Analyses

Nishimura, T., Noguchi, Y., and Uchimoto, T., "Damage Tolerance Analysis of Multiple-Site Cracks Emanating from Hole Array," Journal of Testing and Evaluation, JTEVA, Vol. 18, No. 6, Nov. 1990, pp. 401-407



Life calculation comparison for 8-crack specimen (a-N data from 1st crack)

Life Calculation Results of Interacting Multiple Cracks From FCPAS Analyses

Nishimura, T., Noguchi, Y., and Uchimoto, T., "Damage Tolerance Analysis of Multiple-Site Cracks Emanating from Hole Array," Journal of Testing and Evaluation, JTEVA, Vol. 18, No. 6, Nov. 1990, pp. 401-407



Crack Profiles From Crack Propagation Analyses within FCPAS

### **Displacements and Stress Contours**



**Corner Crack** 



8-crack specimen (through the thickness crack)



Close-up view of through the thickness crack

High Stresses Exist Along Crack Fronts

# **Summary and Conclusions**

FCPAS - Fracture and Crack Propagation Analysis System – is applied to variety of three-dimensional

multiple fracture and crack propagation problems.

- Enriched finite elements used in FCPAS allow computation of SIFs and simulation of crack growth in threedimensional multiple crack containing structures accurately and efficiently
  - ✓ No special mesh and post-processing needed
  - ✓ FCPAS (Fracture and Crack Propagation Analysis System) currently automated multiple crack growth simulations in specimens under different loading and boundary conditions
- Fracture and Crack Propagation Analyses of Multiple Crack Containing Specimens and Attachment Lugs
  - ✓ 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

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