

FRANC3D Training Workshop: Part 10

SIF History & Fatigue Life

August - 2026

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Workshop Agenda

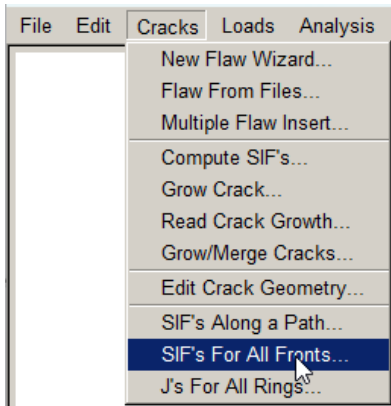
- Part 1: Introduction to Fatigue and Damage Tolerance
- Part 2: Introduction to Fracture Mechanics Analysis
- Part 3: Introduction to FRANC3D
- Part 4: FRANC3D User Interface
- Part 5: Finite Element (FE) Model Import
- Part 6: Crack Insertion
- Part 7: Static Crack Analysis & SIF Computation
- Part 8: SIFs from FE Analysis
- Part 9: Crack Growth
- **Part 10: SIF History & Fatigue Life**
- Part 11: Miscellaneous Topics

SIF History & Fatigue Life

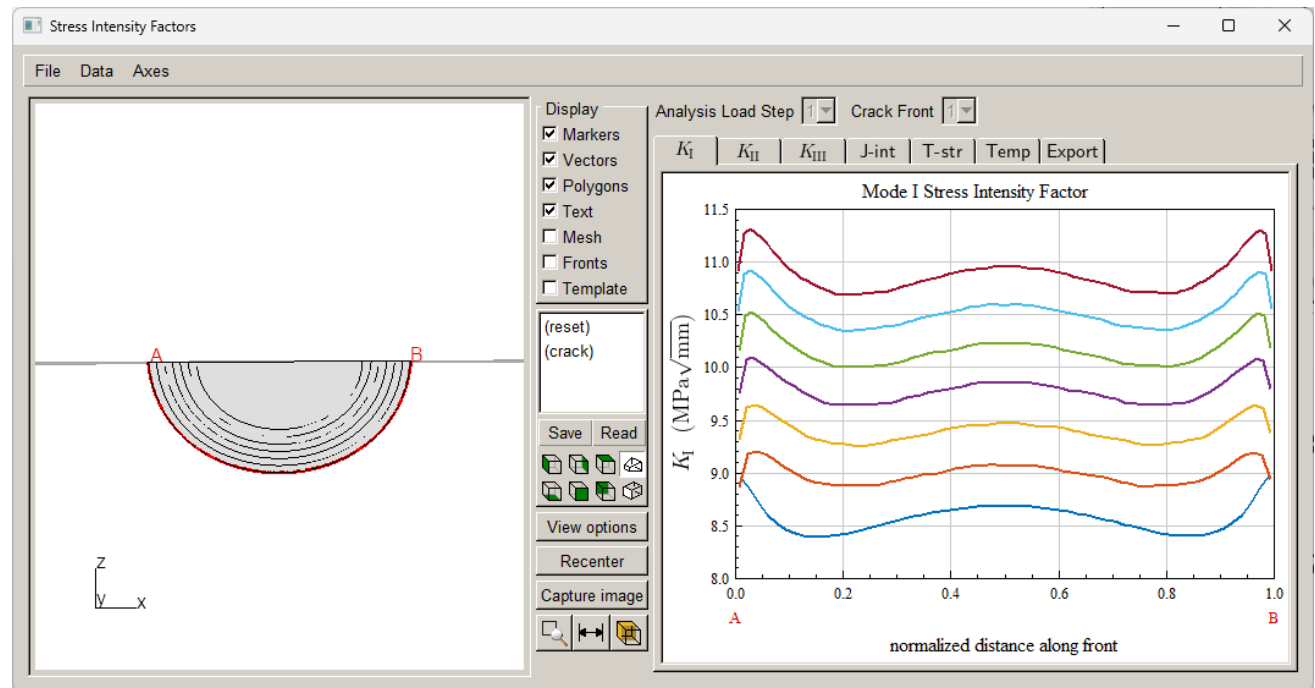
- SIF History
- SIFs Along a Path & Defining a Path
- Computing fatigue life
 - Conventional Single (DOF) Path Approach
 - Multiple Degree of Freedom Approach
- Fatigue Life Predictions User Interface
- Demo: SIF History and Fatigue Life

SIF For All Fronts

- from **Cracks** menu, choose SIFs For All Fronts



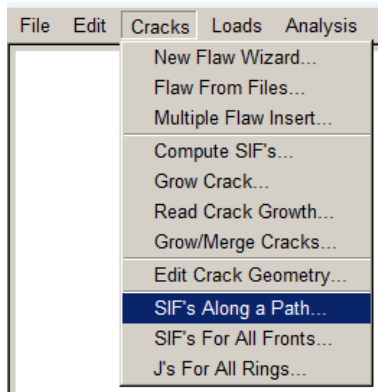
Plot (and export)
SIF values along all
crack fronts.



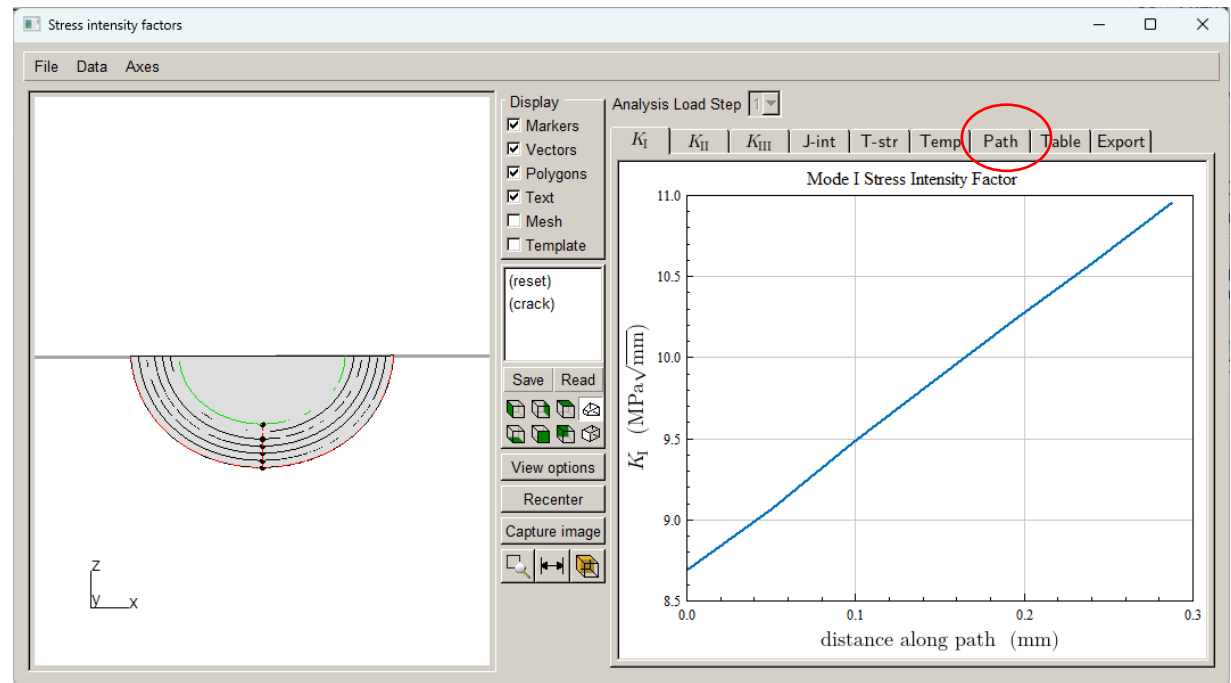
SIFs Along a Path

Using a FRANC3D simulation with more than one step of crack growth

- from **Cracks** menu, choose **SIFs Along a Path**



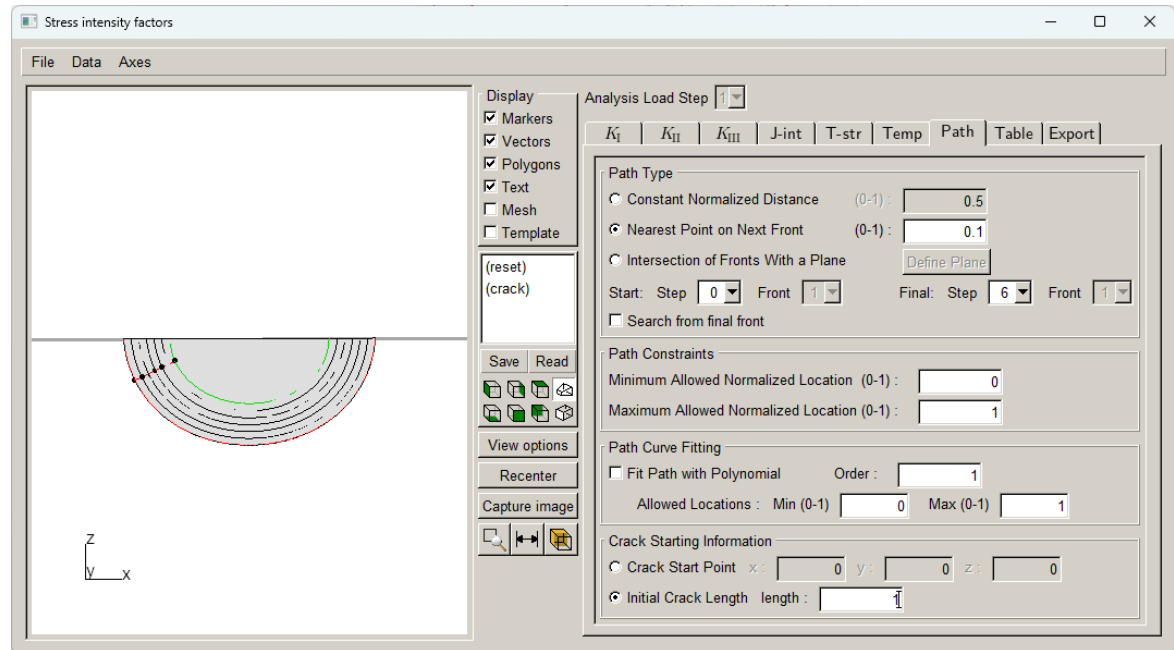
Click on Path to change the path



Defining a Path

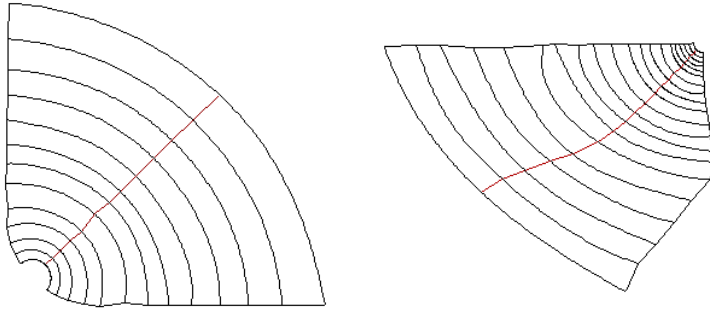
Defining a path requires defining:

- Path type
- Path constraints
- Path curve fitting
- Crack starting point

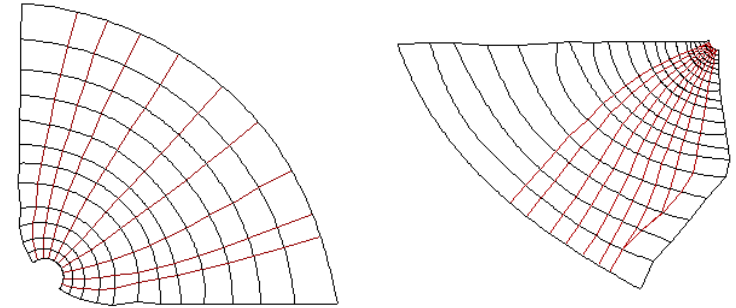


Path Type

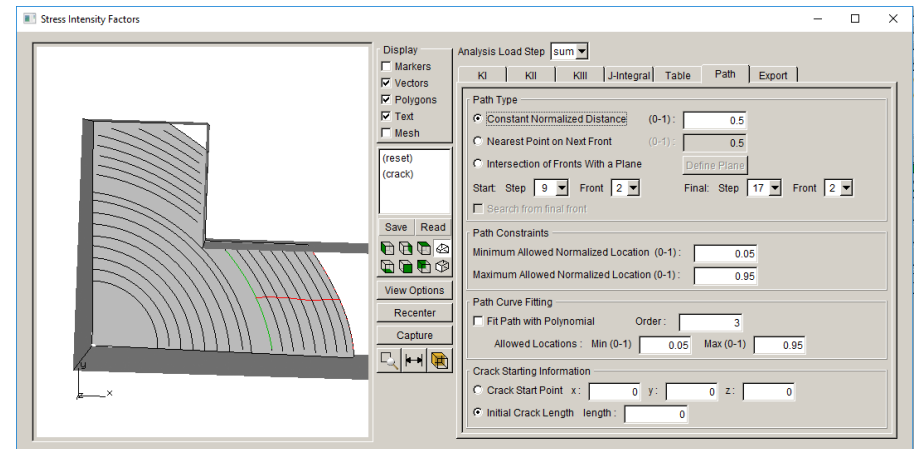
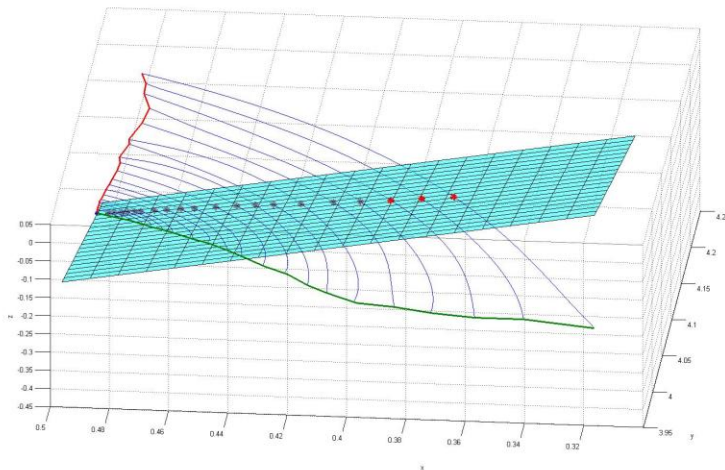
Constant Normalized Distance



Nearest Point on Next Front



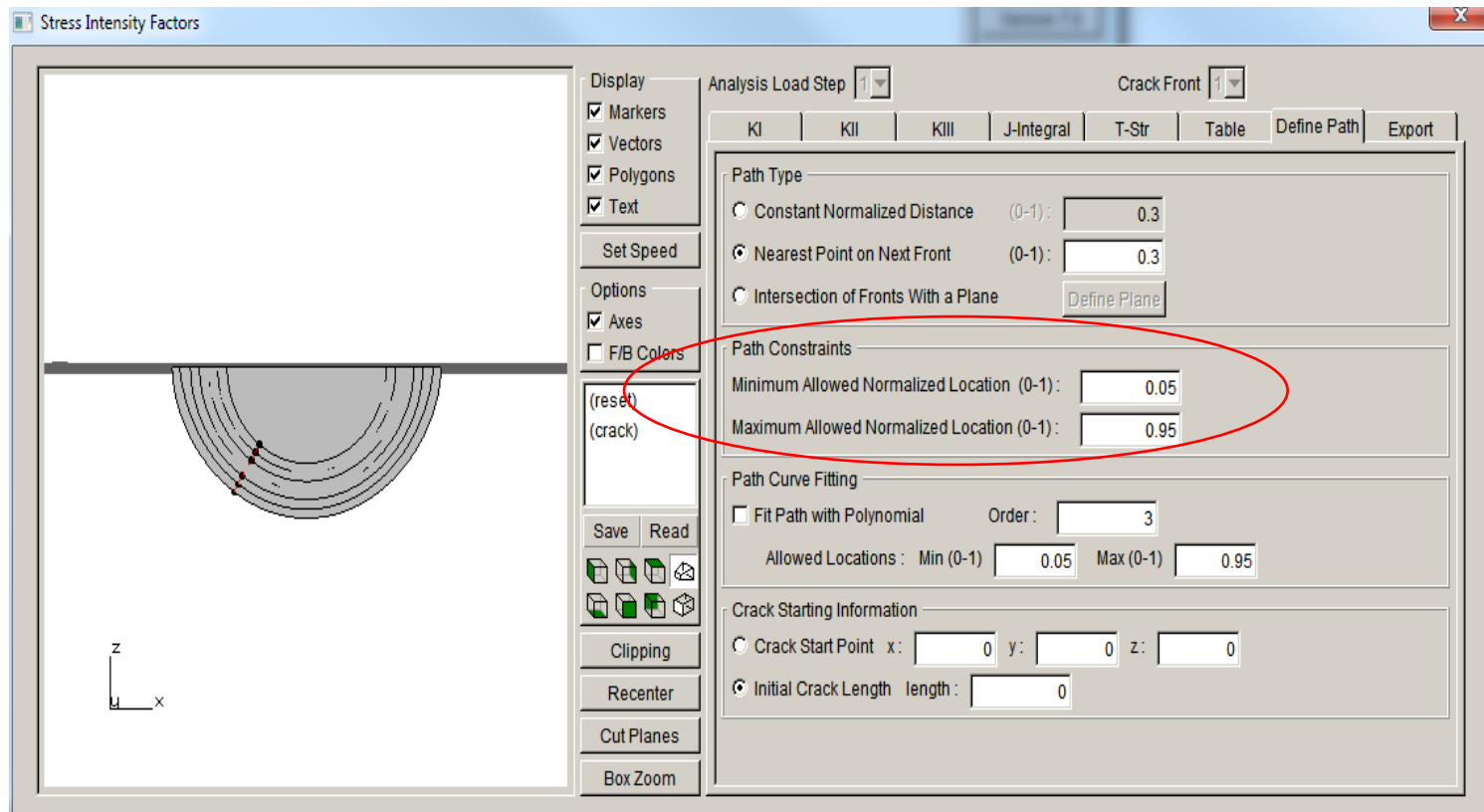
Intersection of Fronts with a Plane



For crack fronts that might split, merge, or disappear, there is the option to specify both the starting and ending crack step number and the crack front number, if there is more than one front

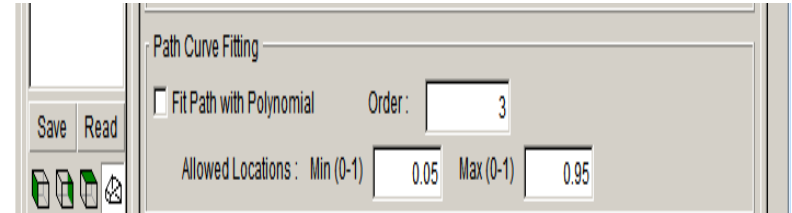
Path Constraints

- There is a user-settable threshold that prevents the computed paths from getting too close to the free surfaces where the accuracy of the computed stress intensity factors is questionable.
- The user can set both the minimum and maximum thresholds.

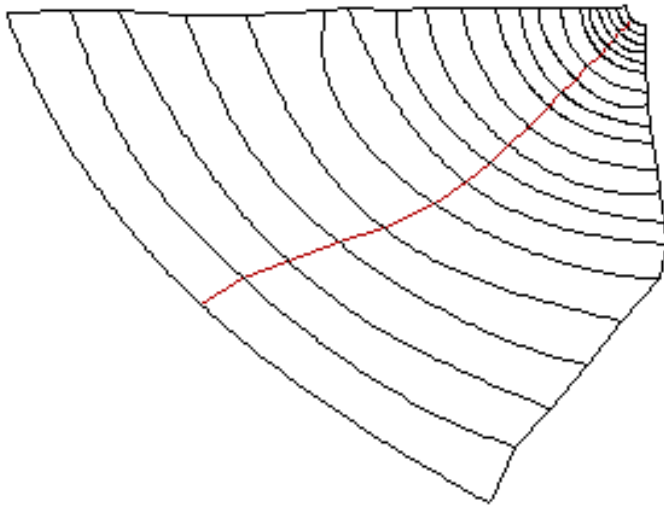


Path Curve Fitting

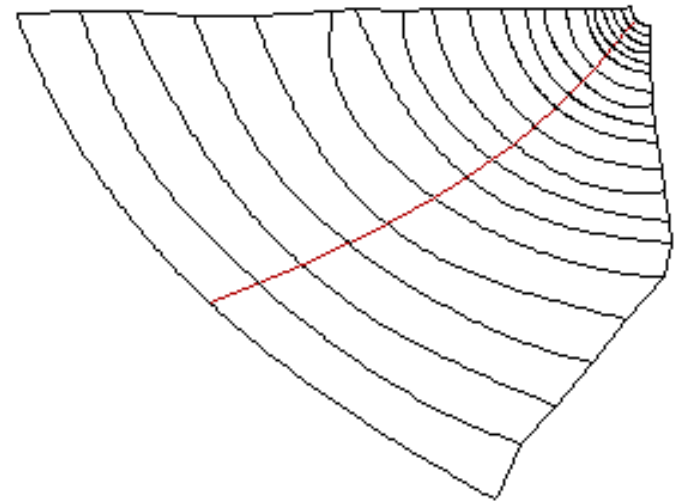
Path curve fitting provides a best fit, in a least-squares sense, through the path



Before path curve fitting

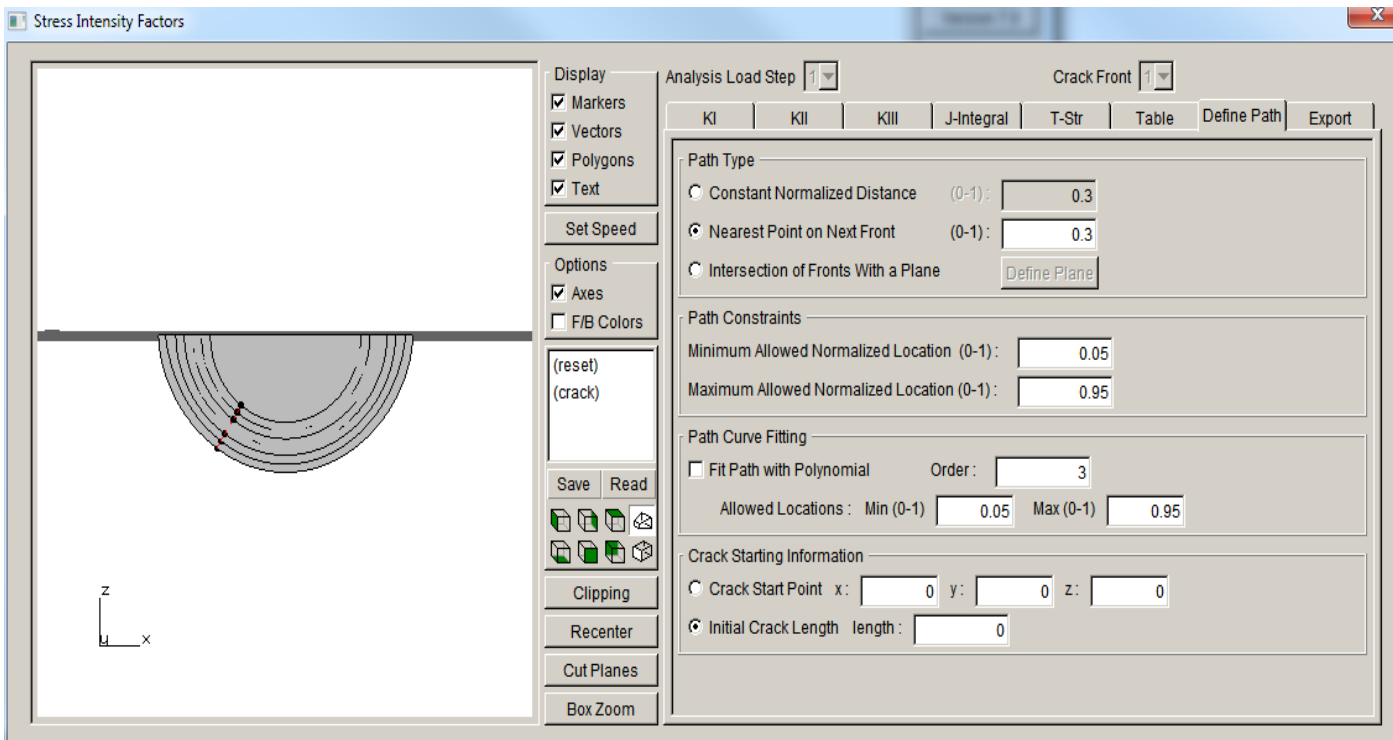


After path curve fitting



Crack Starting Point

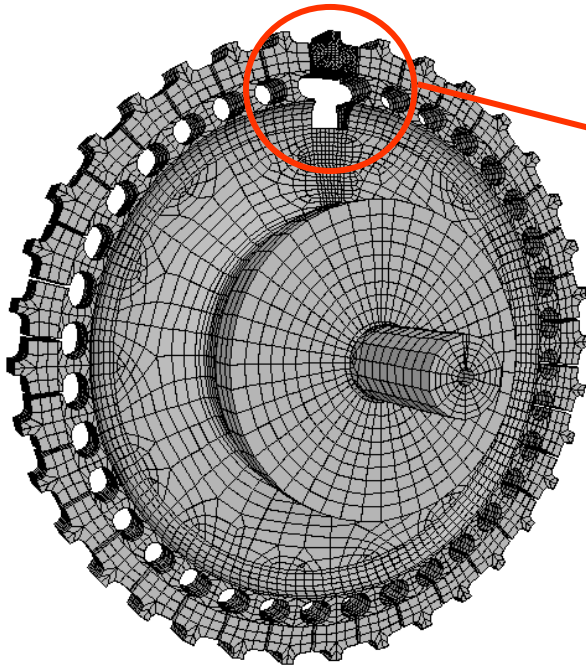
- The crack starting information has two options:
 - Crack start point
 - Initial crack length
- Setting either of these provides a starting point for computing the total crack path length



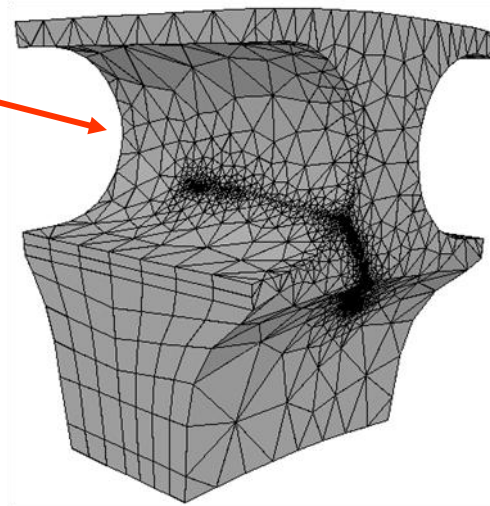
Computing fatigue life

- **Conventional Single (DOF) Path Approach**
- **Multiple Degree of Freedom Approach**

After 22 Steps of Growth

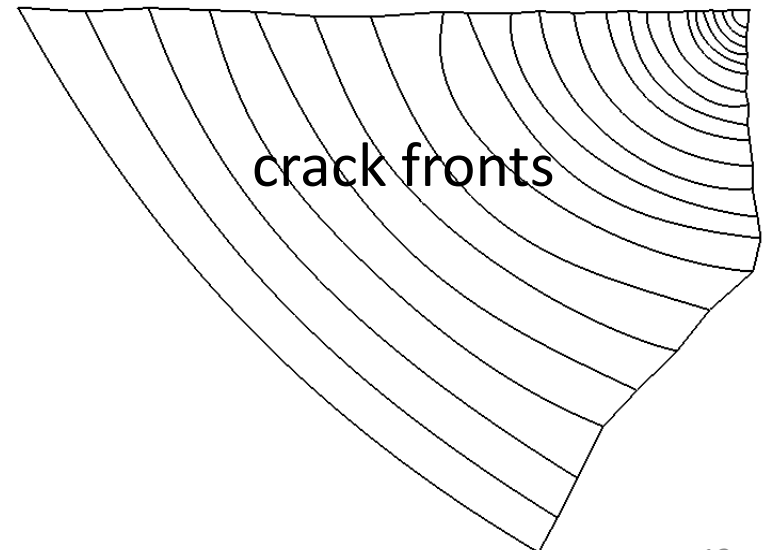
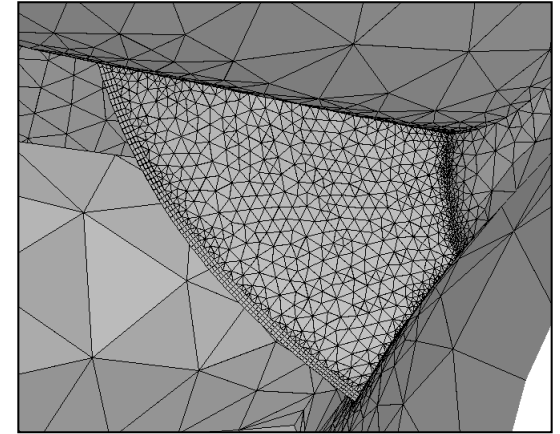


Minidisk



Portion of model
contains crack

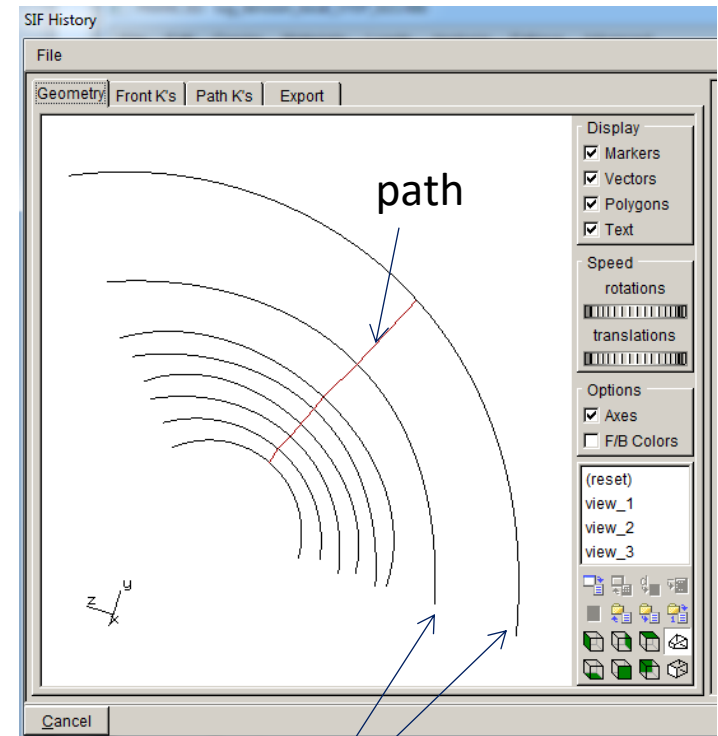
Crack mesh at step 22



How does one make a fatigue life prediction based on this simulation?

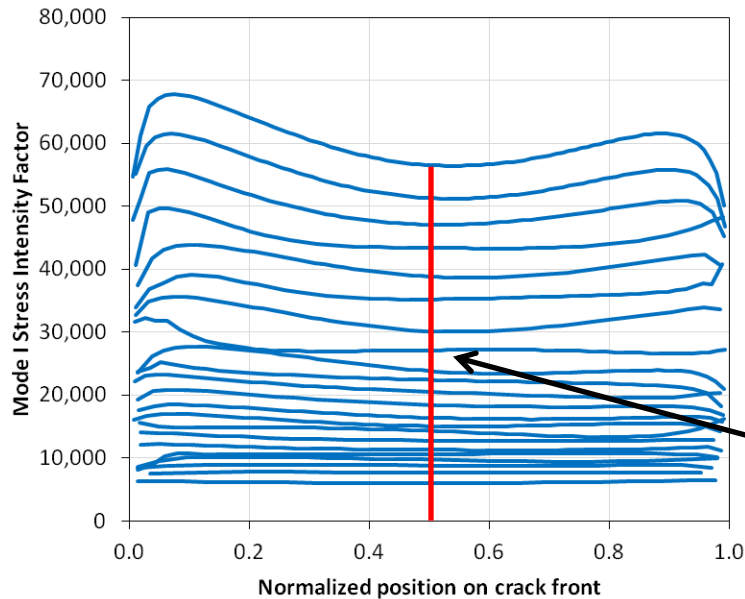
Conventional Single (DOF) Path Approach

- Computing fatigue life (or propagation cycles) involves:
 - Crack insertion and growth
 - Extraction of SIF history for all points on all crack fronts
 - Defining a path
 - through the crack fronts
 - and computing the SIF (K_I , K_{II} & K_{III}) and length along the path
- Integration using the SIF along the path, the path length, and crack growth rate data or model



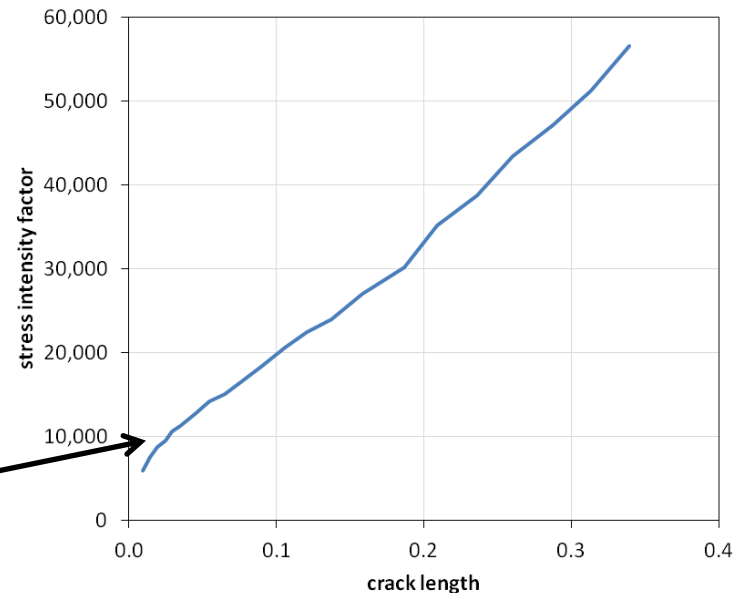
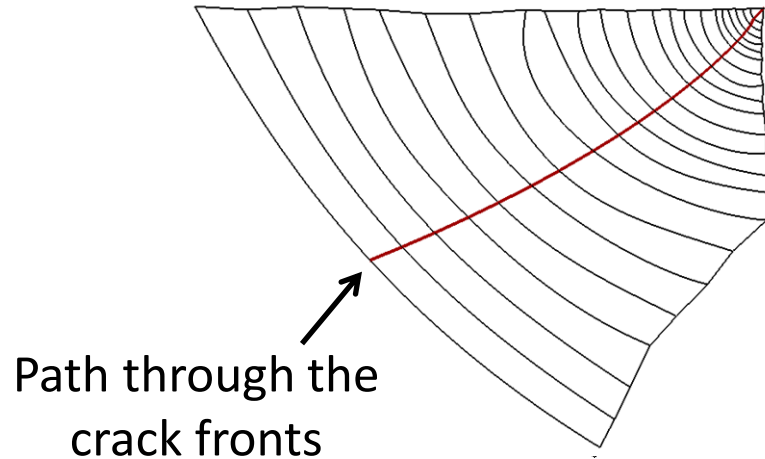
crack fronts

Reducing SIF (K) Data to a Single DOF



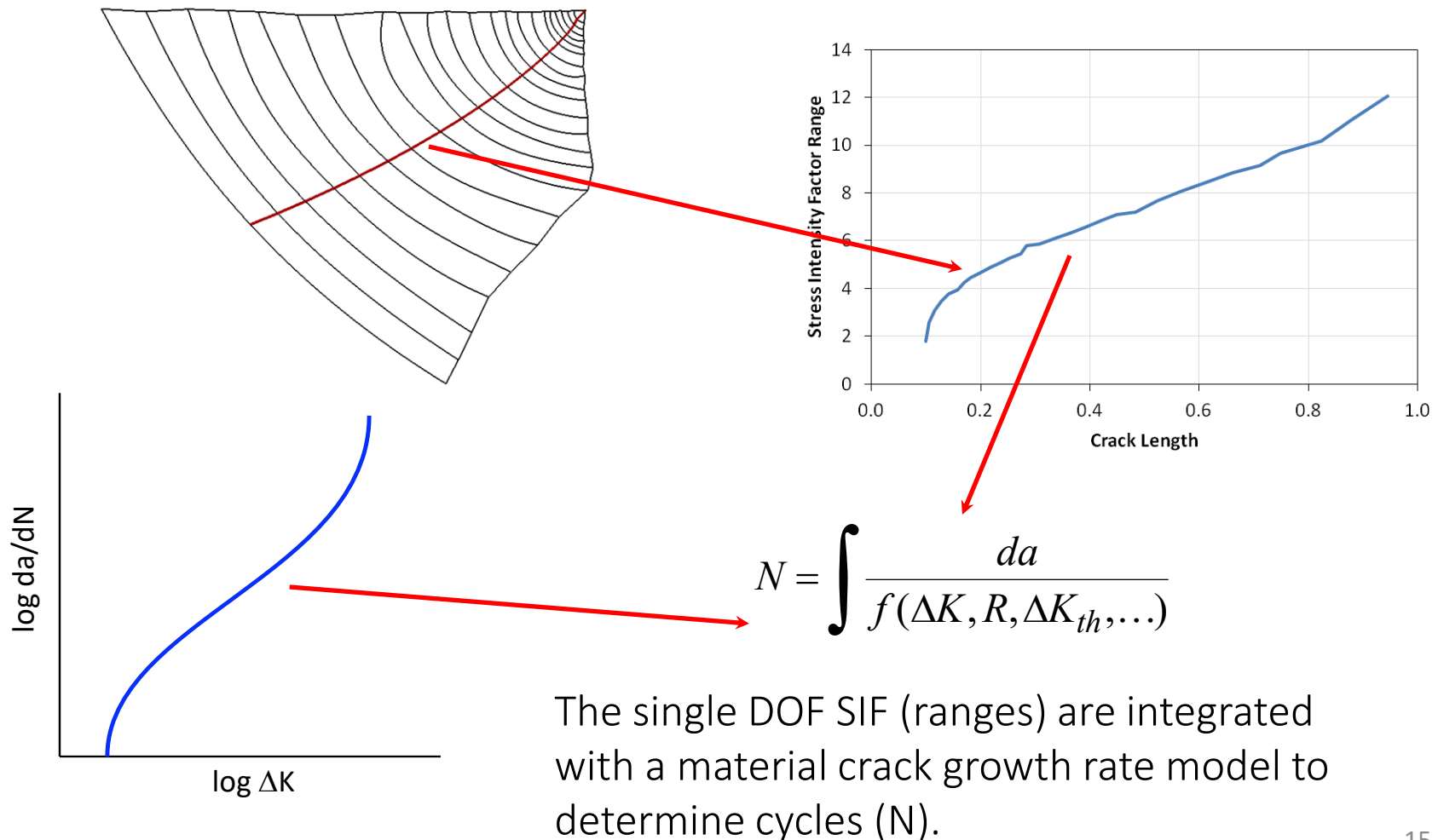
Crack growth simulation yields SIF distributions along each crack front for all crack steps.

Single degree of freedom (DOF) "K vs a" curve

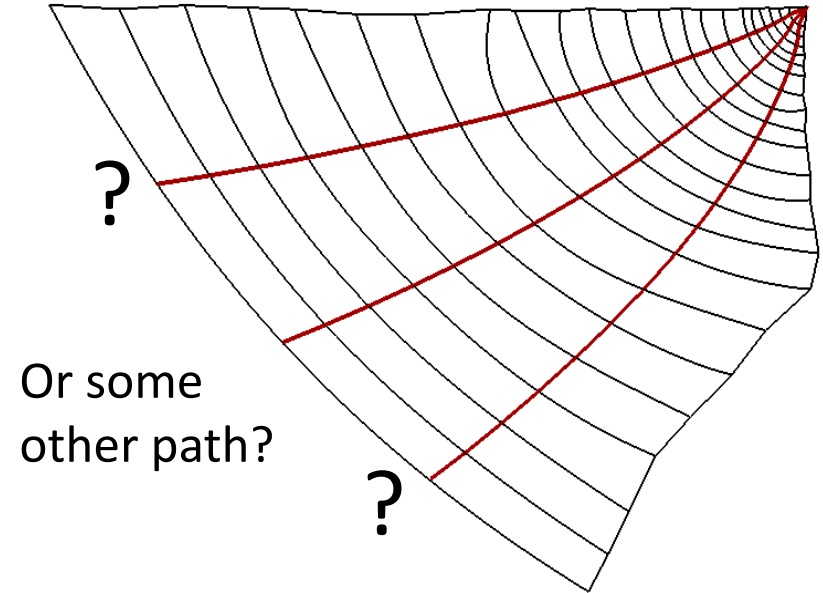
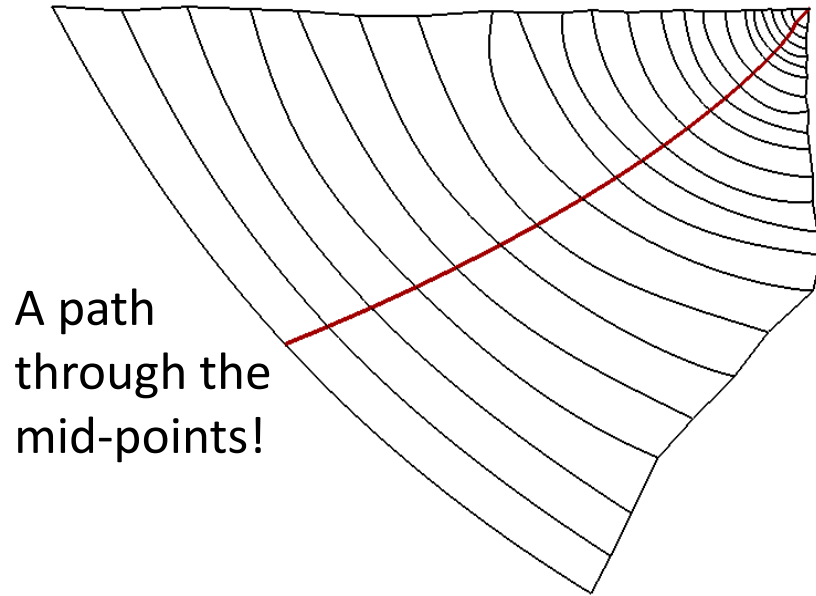


Conventional Lifing with FRANC3D Results

- A path is defined through the crack fronts that effectively reduces the full 3D results to a single DOF model.

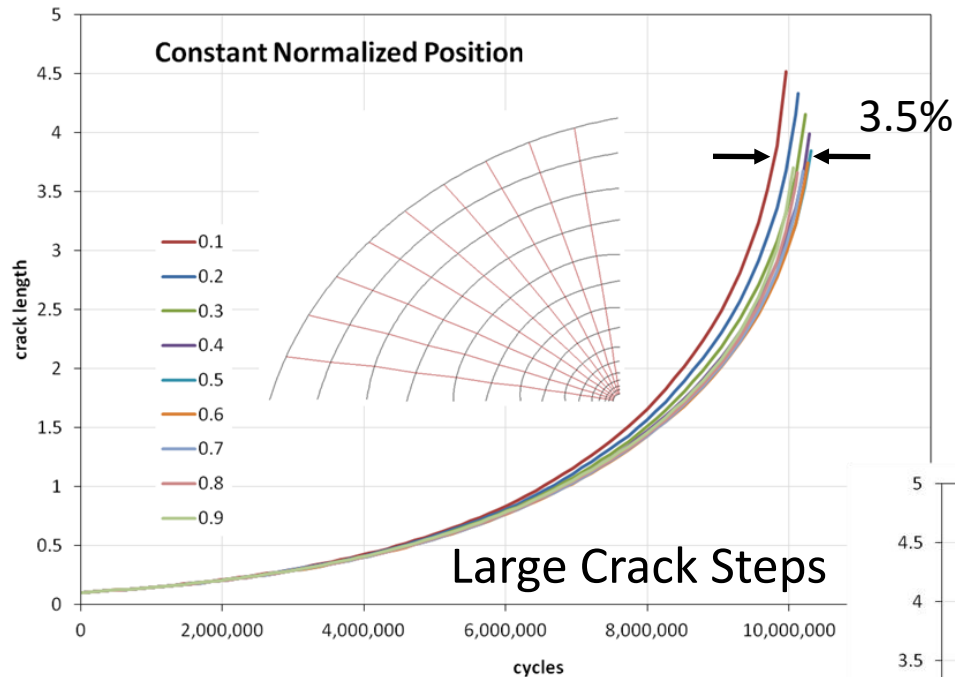


Determining a Single DOF Path(s)

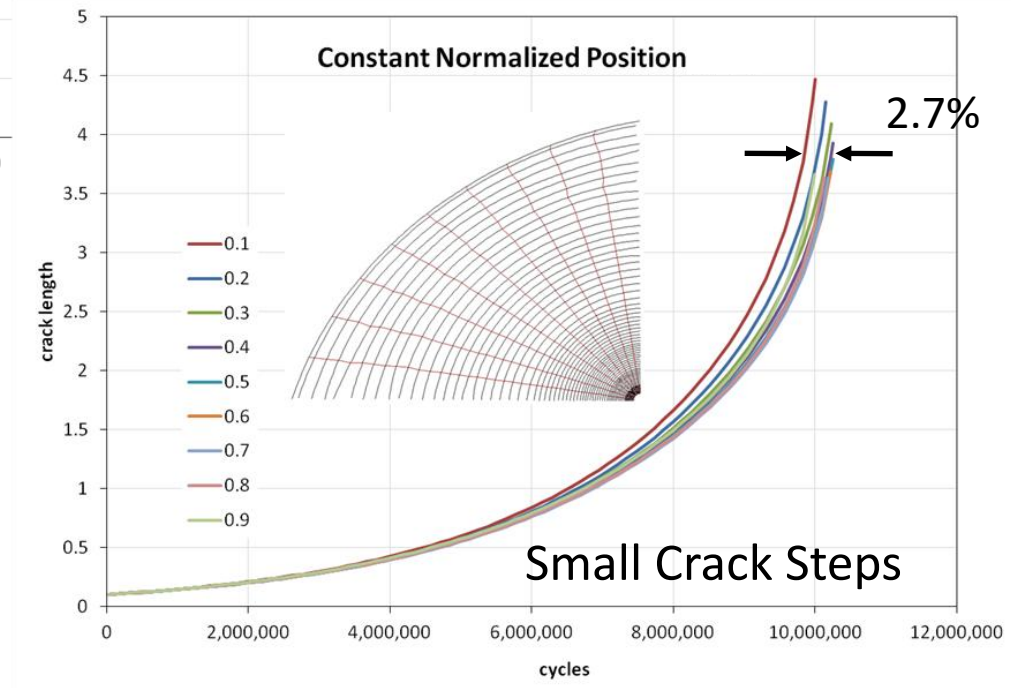


How should one pick the single DOF path, and how does this affect the predicted fatigue life?

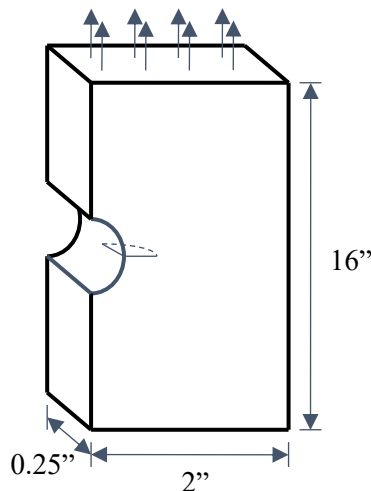
Life Predictions For Different Paths



- Different paths provide different number of cycles; could extract an average or mean and standard deviation.

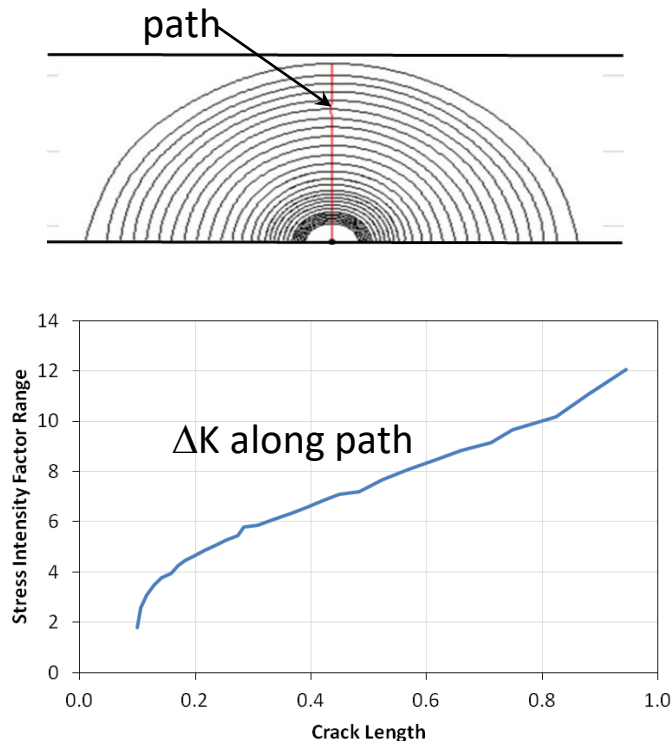


Example:
corner crack
in a plate
under
tension

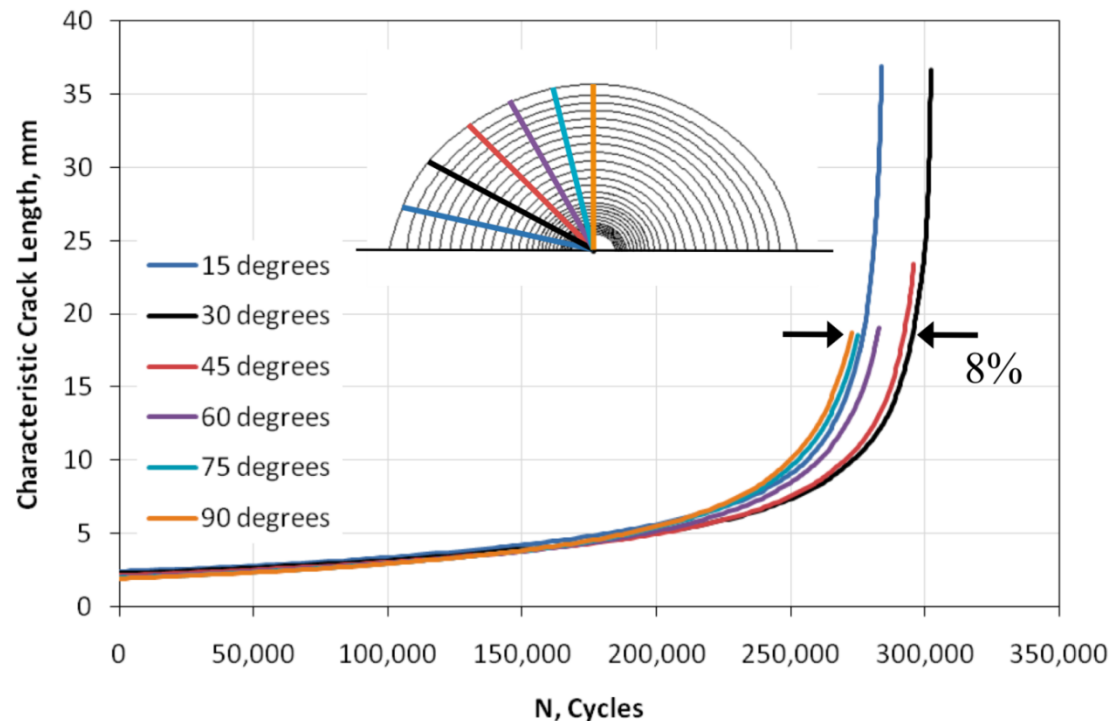


Single DOF Life Predictions

- The least accurate SIFs are computed on the specimen surface; so we choose a path where SIFs are more accurate.

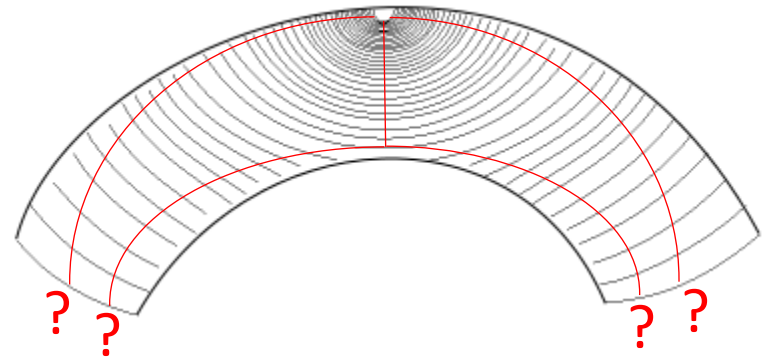


- Comparison of life predictions using SIFs evaluated along six different paths shows a significant variation.



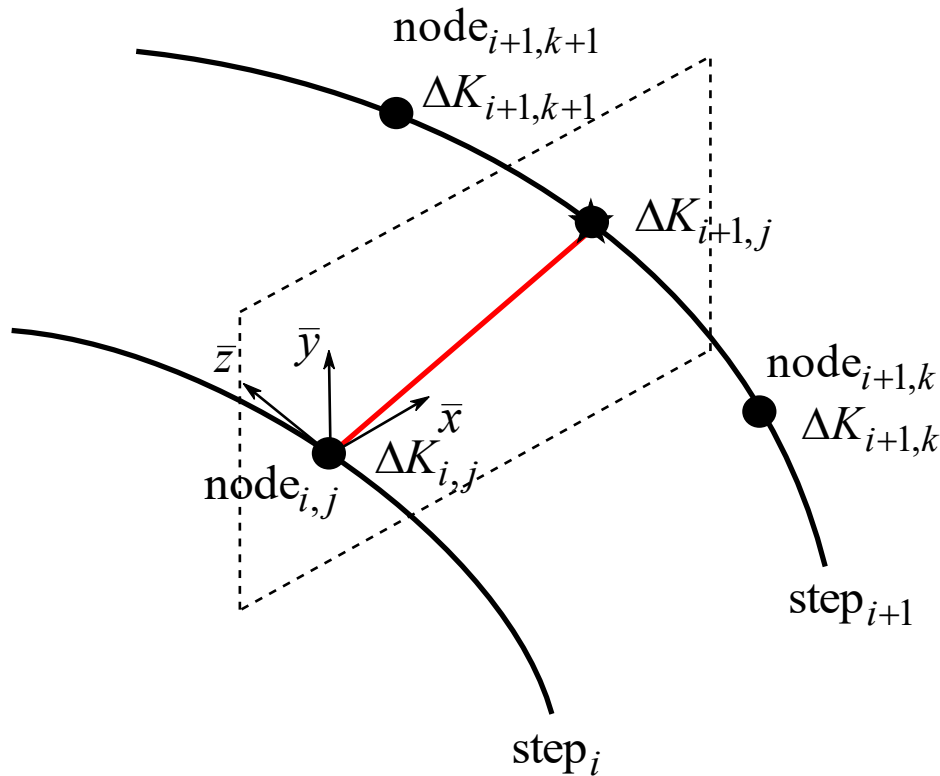
Problems With the Single DOF Approach

- Defining an appropriate single path becomes difficult for a more complex crack geometry
- Defining a single path requires subjective engineering judgment leading to non-objective life predictions
- Difficult to automate path selection
- Uses only a small amount of the available SIF information
- Can not easily correlate cycles with the observed or measured crack lengths on the specimen surface



For many “real world” models, a single path cannot intersect all crack fronts so multiple paths need to be evaluated.

Multiple/Variable DOF Approach



For all nodes on crack front i

1. Project perpendicular to the crack-front to find the intersection with the next crack front $i+1$
2. Interpolate to find DK at the projected intersection
3. Assume a linear variation in the DK's going from step i to step $i+1$ and integrate to find the cycles ($N_{i,j}$)
4. Average the computed cycles for all crack front nodes to obtain one value for cycles required to grow from crack front i to crack front $i+1$

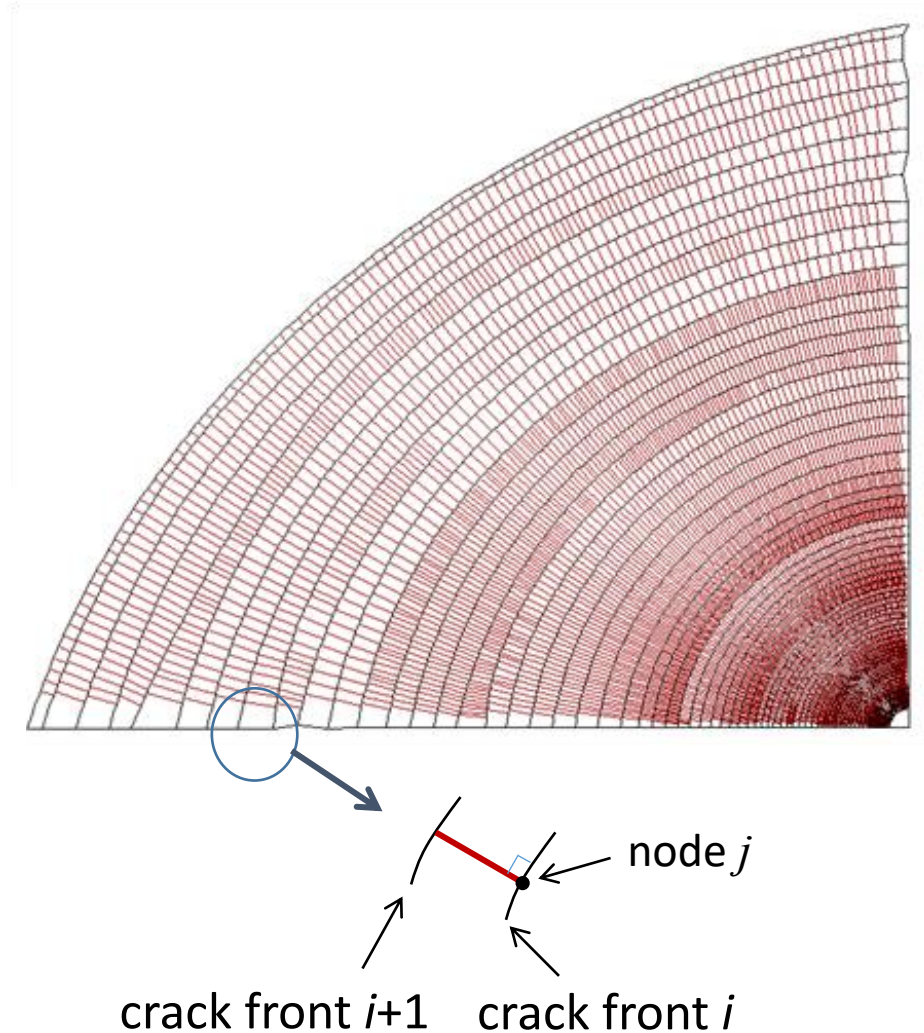
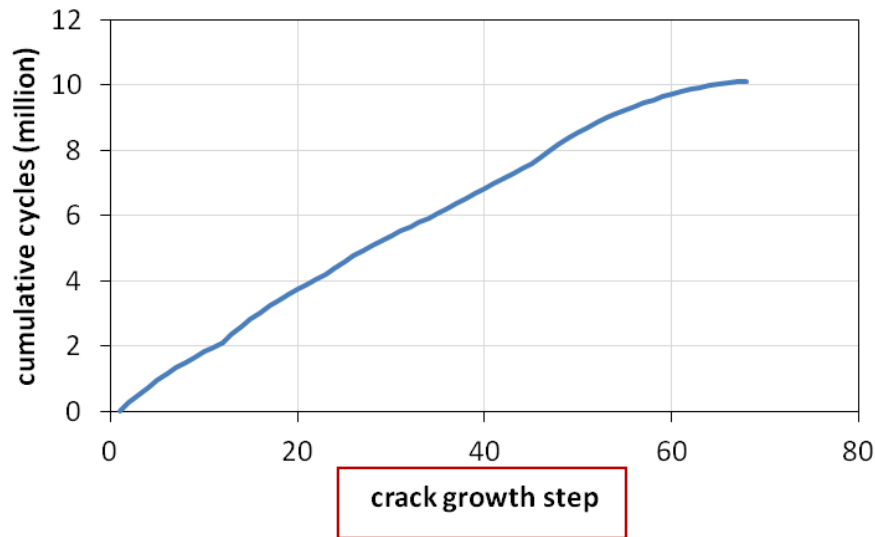
$$N_{i,j} = \int_0^{\Delta a} \frac{da}{f(\Delta \bar{K}, R, \dots)}$$

where $\Delta \bar{K} = \Delta K_{i,j} + \frac{a}{\Delta a} (\Delta K_{i+1,j} - \Delta K_{i,j})$

$$N_{i \rightarrow i+1} = \frac{1}{n} \sum_{j=1}^n N_{i,j}$$

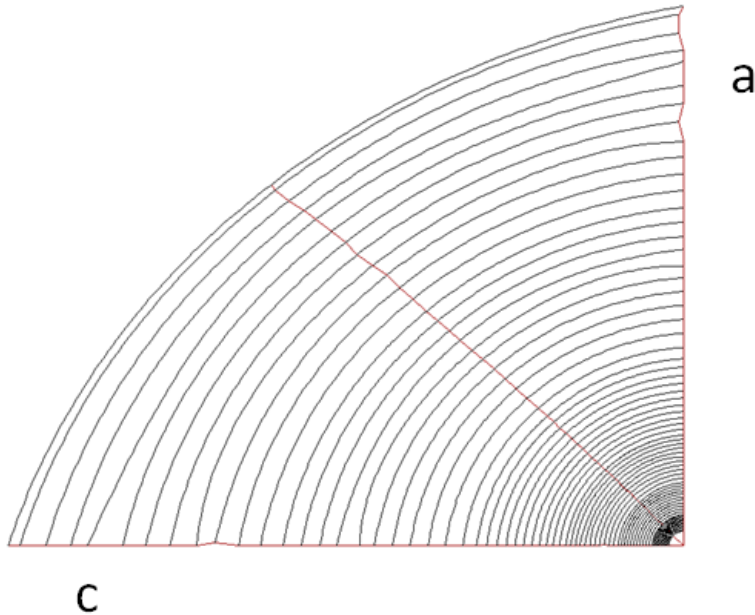
Multiple/Variable DOF Approach

- Compute the number of cycles for all nodes along a crack front
- Compute the average
- Store average cycles versus step of crack growth

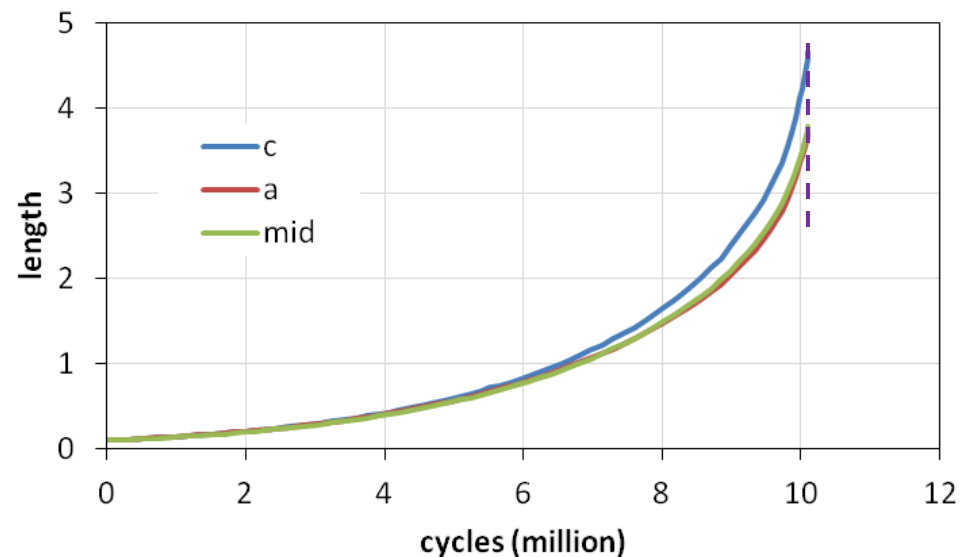


Multiple/Variable DOF Approach

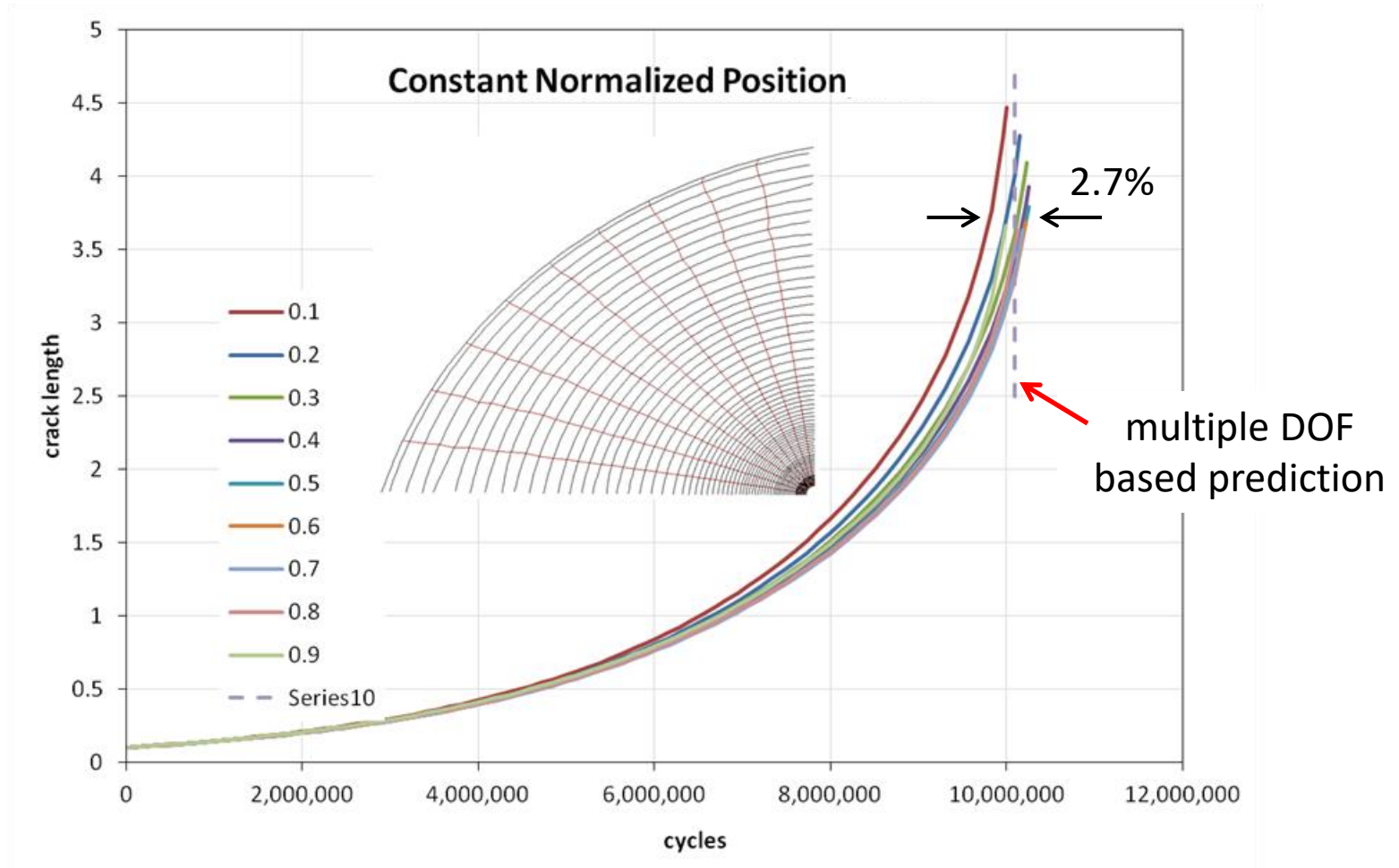
- Life curves can be generated for different paths, and the number of cycles will be consistent.



Can even plot cycles versus crack length for a path on the surface where computed SIFs are not usually accurate.

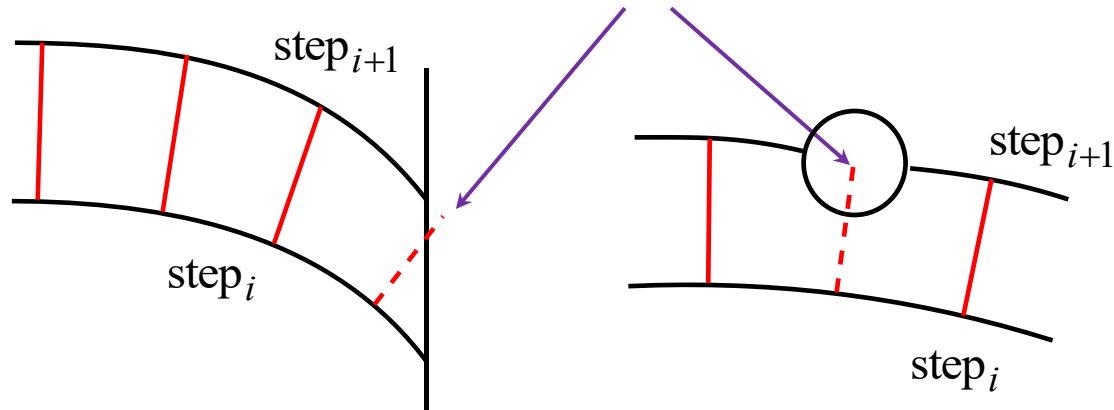


Compare to Single DOF Predictions

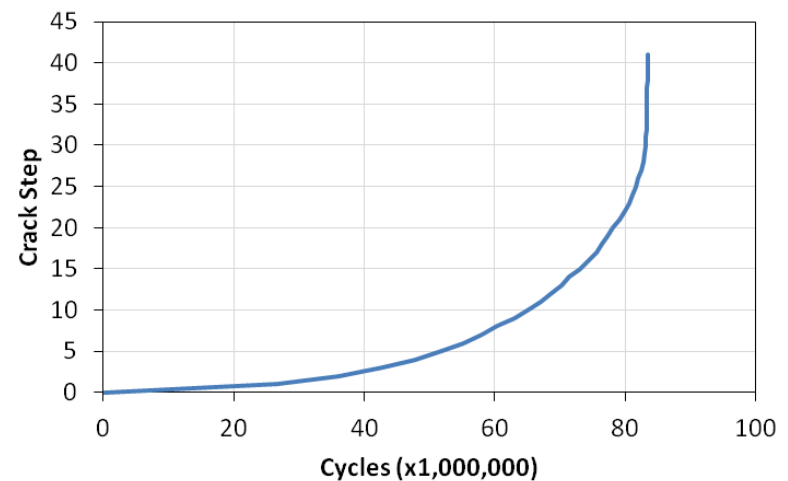
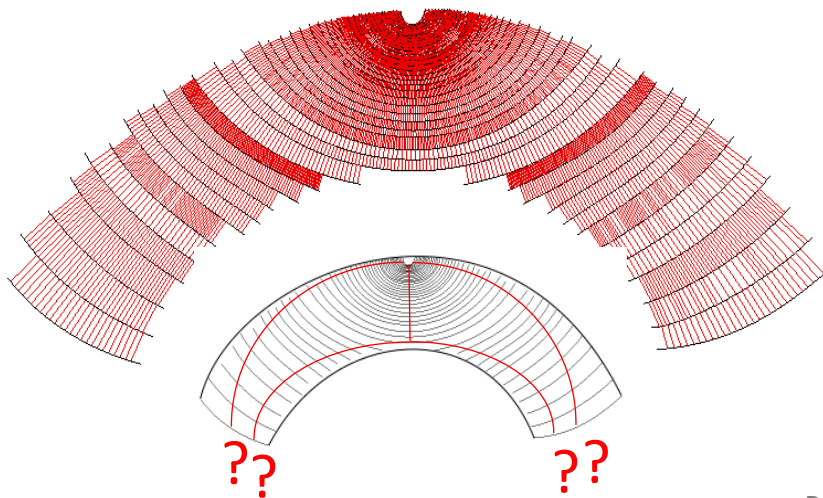


Benefits of Multiple/Variable DOF Approach

- Ignores cases where a projected point cannot be found

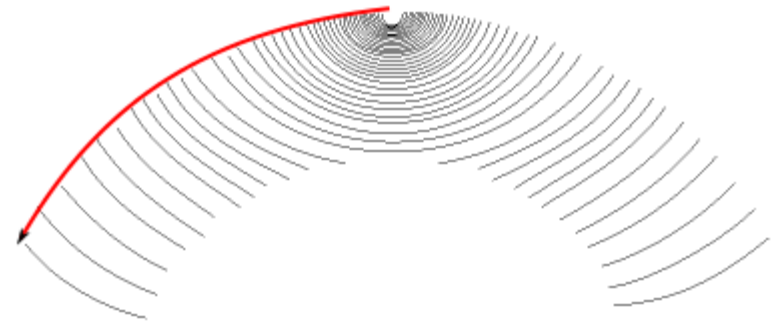
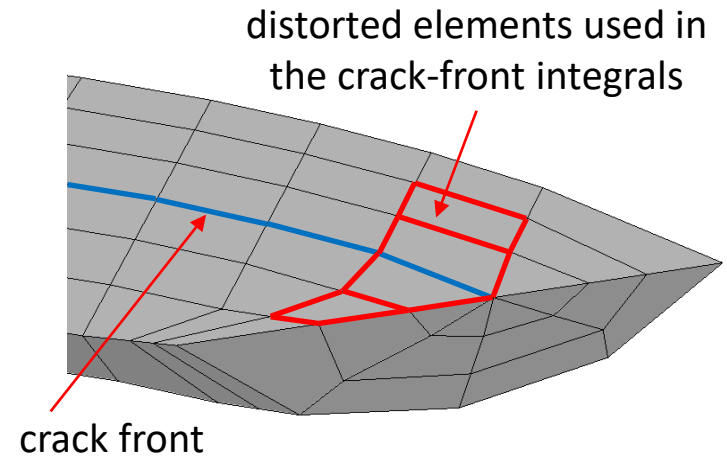


- Generates a unique cycle count for each crack front.



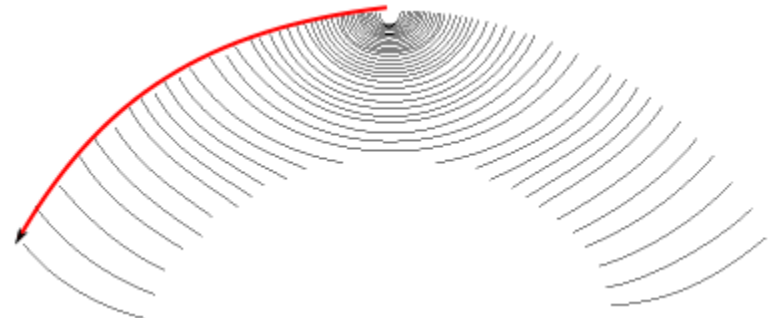
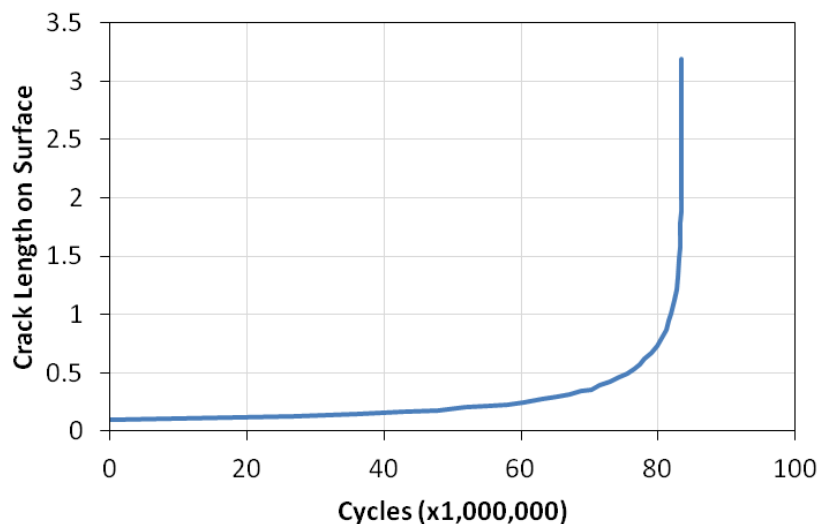
Benefits of Multiple/Variable DOF Approach

- Avoids SIFs computed at surface, which are unreliable because:
 - plane strain conditions do not hold locally, and
 - crack front elements can be highly distorted
- Cycles for each crack step include information from the entire crack front.
- Generate accurate predictions of cycles versus surface breaking crack length even if we cannot compute accurate stress intensity factors at surface breaking points.



Summary

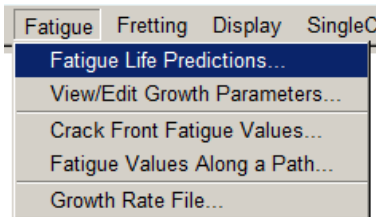
- Multiple variable DOF approach provides objective life predictions
- Uses all or most of the available SIF data
- Easily automated
- Easily negotiates complex crack shapes
- Generate a versus N curves on surfaces (where computed SIFs are usually inaccurate)



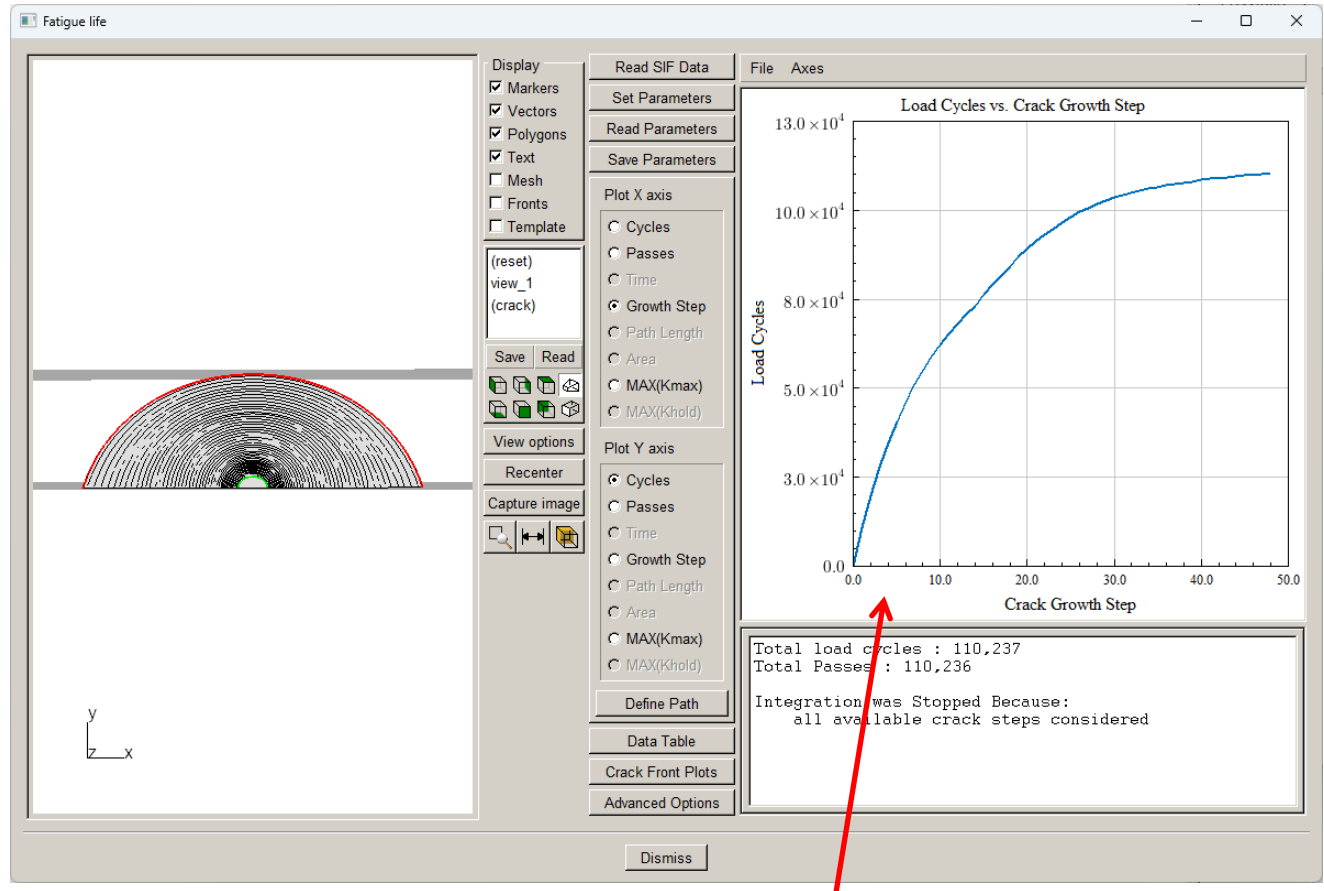
Fatigue Life Predictions Dialog

Fatigue Life Dialog

- The Fatigue Life dialog allows the user to compute fatigue cycles



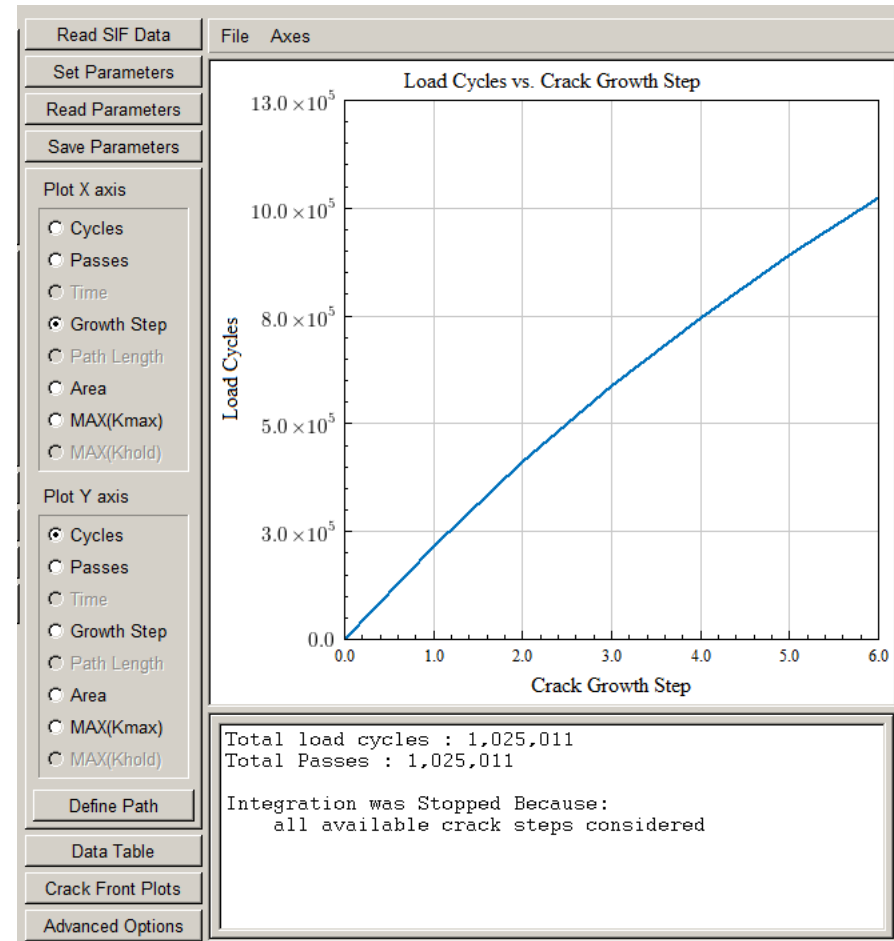
Crack display



Display plots of cycles or time

Fatigue Life Dialog

- If crack growth was done using a subcritical growth model, the parameters are already defined and the right-side pane will show a plot of cycles versus crack step
- **Read SIF Data** button: allows the reading of crack fatigue data (.fcg file) that includes SIF history
- **Set Parameters** button: Leads to the definition of the crack growth rate model
- **Read Parameters** button: Allows one to read a previously saved crack growth rate model from a file (.cgp file)
- **Save Parameters** button: Allows one to save the current crack growth model data to a file (.cgp file)
- **Plotting**: Allow the plotting of either cycles or time
 - Growth Step
 - Relative Variance: displays the standard deviation in the computed data
 - Path: Allows the user to define a Path
- **Data Table** button: Displays whatever data is currently active, in tabular form; it can be **exported** to a .txt file



Fatigue Life Dialog

- Defining a Path

The screenshot displays the 'Fatigue life' dialog box with the 'Path' tab selected. The 'Path' tab includes a 'Display' section with checkboxes for Markers, Vectors, Polygons, Text, Mesh, Fronts, and Template. Below these are buttons for (reset), view_1 (crack), Save, Read, View options, Recenter, and Capture image. The 'Path Type' section has three radio buttons: Constant Normalized Distance (0-1) : 0.5, Nearest Point on Next Front (0-1) : 0.5, and Intersection of Fronts With a Plane (Define Plane). The 'Start' and 'Final' sections show Step 0 and Front 1, and Step 6 and Front 1 respectively. The 'Path Constraints' section has Minimum Allowed Normalized Location (0-1) : 0 and Maximum Allowed Normalized Location (0-1) : 1. The 'Path Curve Fitting' section has a checkbox for Fit Path with Polynomial (Order : 1) and Allowed Locations : Min (0-1) : 0 and Max (0-1) : 1. The 'Crack Starting Information' section has a checkbox for Crack Start Point (x : 0, y : 0, z : 0) and a checkbox for Initial Crack Length (length : 1). The 'Define Path' button is highlighted with a red circle. The 'Read SIF Data' section has buttons for Read Parameters, Save Parameters, and a 'Define Path' button. The 'Plot X axis' section has radio buttons for Cycles, Passes, Time, Growth Step, Path Length, Area, MAX(Kmax), and MAX(Khold). The 'Plot Y axis' section has radio buttons for Cycles, Passes, Time, Growth Step, Path Length, Area, MAX(Kmax), and MAX(Khold). The 'File' section has buttons for Data table, Crack Front Plots, and Advanced Options. The 'Dismiss' button is at the bottom. The 'Graph' section shows a plot of Load Cycles vs. Crack Growth Step. The y-axis is labeled 'Load Cycles' and ranges from 0.0 to 13.0 x 10^4. The x-axis is labeled 'Crack Growth Step' and ranges from 0.0 to 50.0. The plot shows a blue curve that starts at (0,0) and increases, leveling off around 11.0 x 10^4. Below the plot, the text reads: 'Total load cycles : 110,237', 'Total Passes : 110,236', and 'Integration was Stopped Because: all available crack steps considered'.

Path

Display

- ☒ Markers
- ☒ Vectors
- ☒ Polygons
- ☒ Text
- ☐ Mesh
- ☐ Fronts
- ☐ Template

(reset)
view_1 (crack)

Save Read

View options

Recenter

Capture image

Path Type

- ☐ Constant Normalized Distance (0-1) : 0.5
- ☒ Nearest Point on Next Front (0-1) : 0.5
- ☐ Intersection of Fronts With a Plane (Define Plane)

Start: Step 0 Front 1 Final: Step 6 Front 1

☐ Search from final front

Path Constraints

Minimum Allowed Normalized Location (0-1) : 0

Maximum Allowed Normalized Location (0-1) : 1

Path Curve Fitting

☐ Fit Path with Polynomial Order : 1

Allowed Locations : Min (0-1) : 0 Max (0-1) : 1

Crack Starting Information

- ☐ Crack Start Point x : 0 y : 0 z : 0
- ☒ Initial Crack Length length : 1

Define Path

Data table

Crack Front Plots

Advanced Options

Dismiss

Load Cycles vs. Crack Growth Step

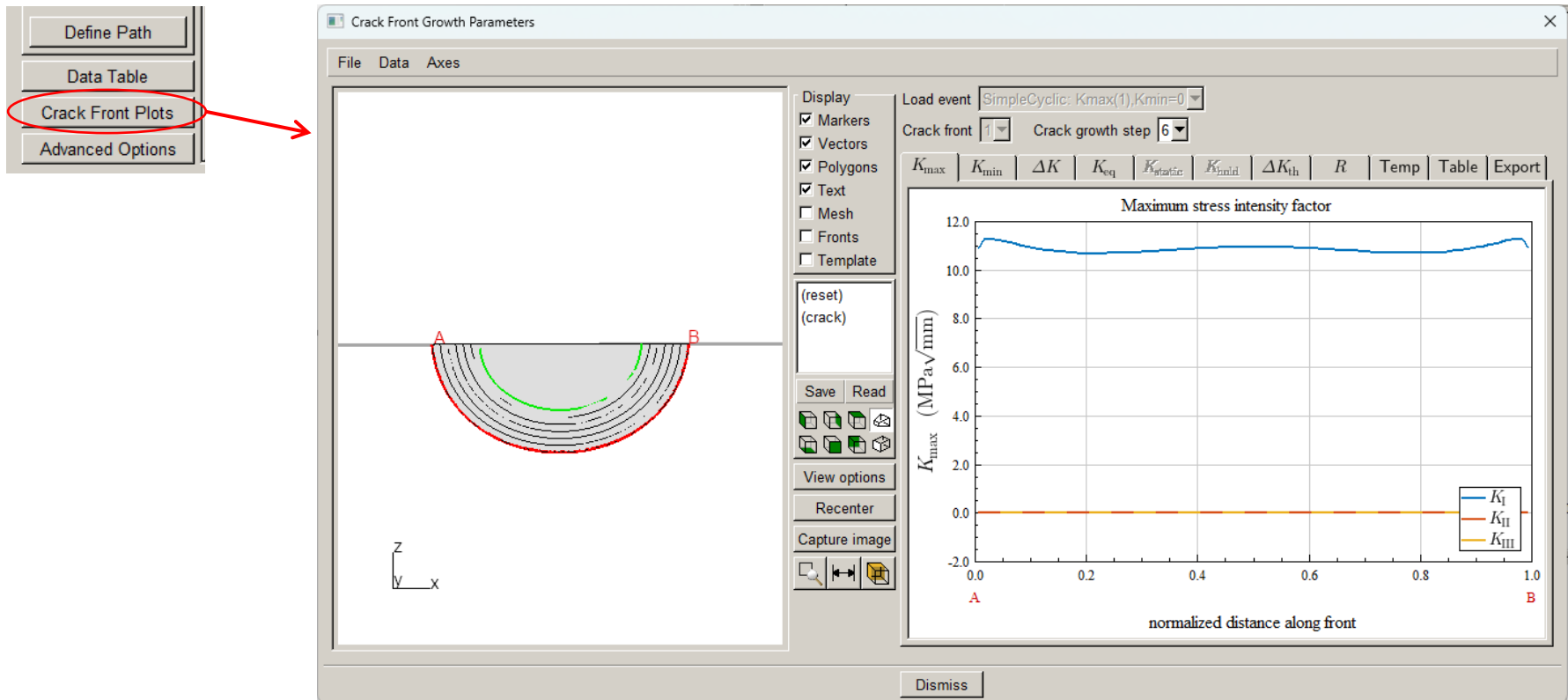
Load Cycles

Crack Growth Step

Total load cycles : 110,237
Total Passes : 110,236
Integration was Stopped Because:
all available crack steps considered

Fatigue Life Dialog

- Crack Front Plots
 - display K_{max} , K_{min} , ΔK , K_{eq} , K_{static} , K_{hold} , R , and Temp for each crack front and for each growth step

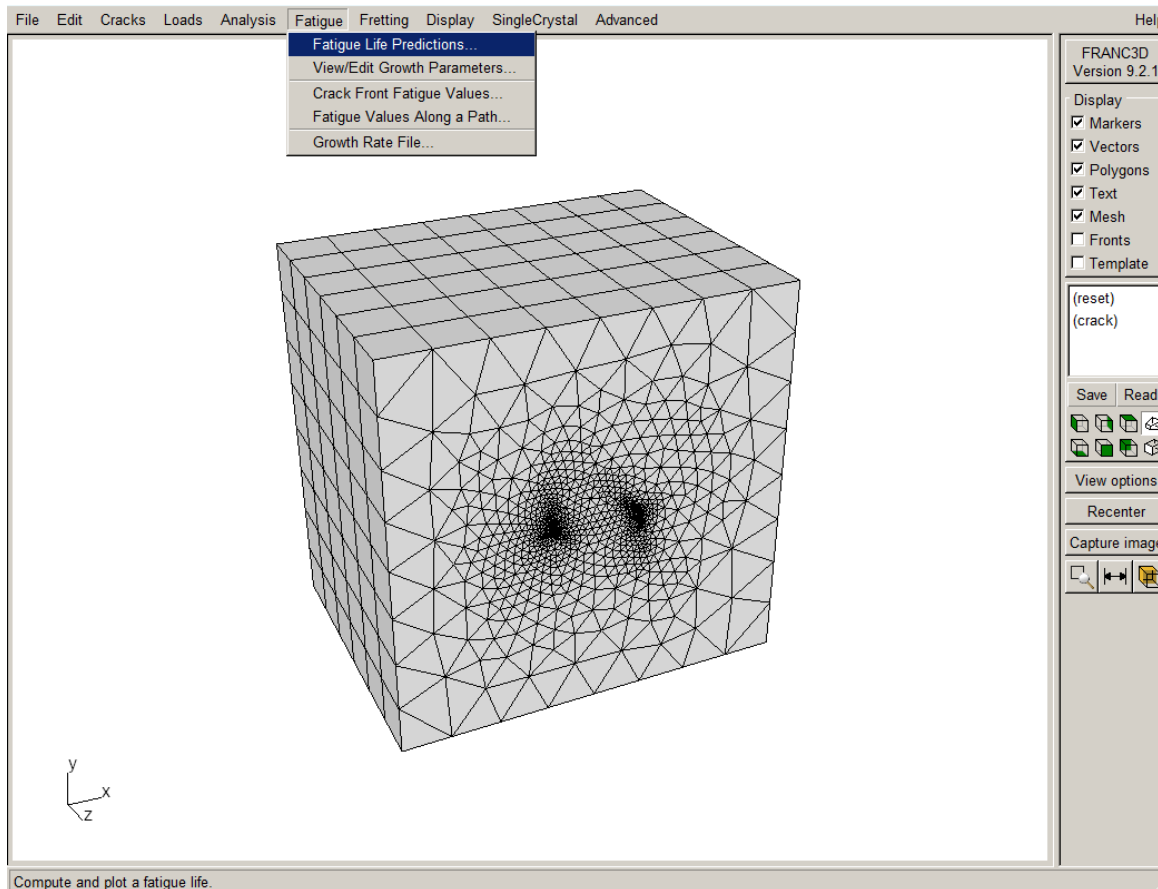


Demo/Hands On (Homework): SIF History and Fatigue Life

FRANC3D Tutorial 1 – Fatigue Life Predictions

From the FRANC3D menu, select **Fatigue**
→ **Fatigue Life Predictions**

Assuming crack growth
was performed



FRANC3D Tutorial 1 – Fatigue Life Predictions

Load Schedule

Schedule:

- SimpleCyclic: Kmax(1.0),Kmin=0

Buttons: Add, Delete, Duplicate, Up, Down, Left, Right

Load Steps: Repeat | Temperature | Time | Static | Other

Load event repeat count:

- ☐ Repeat count: 1
- ☒ Repeat FOREVER

Buttons: Cancel, Accept

Cyclic Loading Growth Model

Paris growth model:

$$da / dN = C \Delta K^n$$

Model Label (Optional):

Description (Optional):

Units: stress: MPa length: mm temp: C time: sec

	C	n	DKth	Kc
1	1e-10	3	1	100

Buttons: Cancel, Back, Next

Growth Parameters

Units used in FE model: stress: MPa length: mm temp: C time: sec

Crack Growth Load Schedule:

Buttons: New Schedule, Read From File, Wizard, View/Edit, Save To File

Crack Growth Rate Model:

Buttons: New Model, Read From File, View/Edit da/dN, View/Edit da/dt, Save To File

Mixed-mode equivalent K:

☒ $K^{equiv} = K_I$ ☐ $K^{equiv} = \sqrt{K_I^2 + (\gamma_{II} K_{II})^2 + (\gamma_{III} K_{III})^2}$

γ_{II} : 0 γ_{III} : 0

sign: ☒ from K_I ☐ from K_{II} ☐ from K_{III} ☐ always positive ☐ always negative

Effective Delta K:

☒ $\Delta K_{eff} = K_{max} - K_{min}$ ☐ $\Delta K_{eff} = K_{max} - \max(K_{min}, 0)$

☐ Use load interaction model

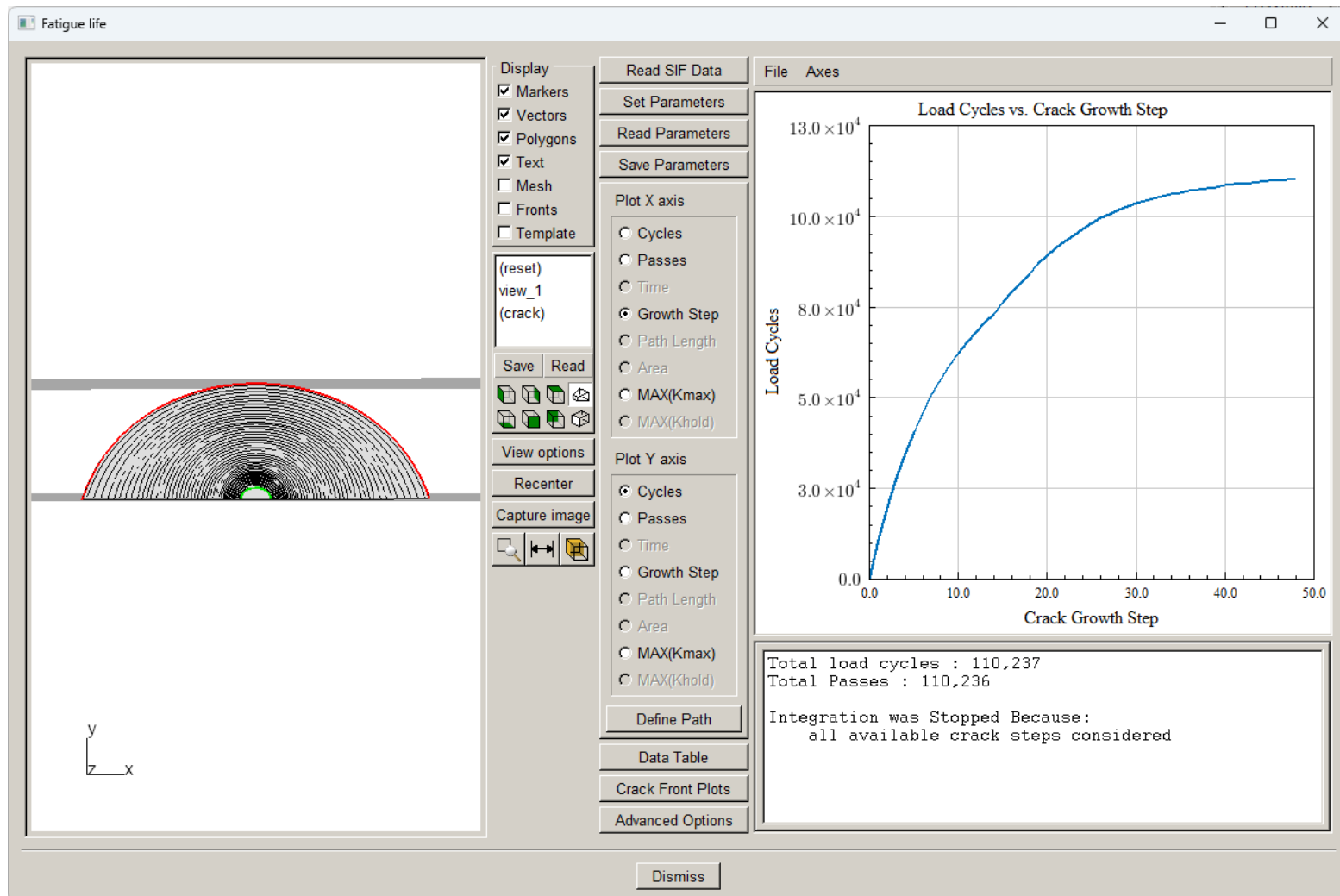
Integration Options:

☒ Accelerated counting ☐ Constant K for time integration

Buttons: Cancel, Accept

FRANC3D Tutorial 1 – Fatigue Life Predictions

Fatigue life dialog showing Cycles vs Crack Growth Step



End Part 10