

BAMpF Workshop 2022

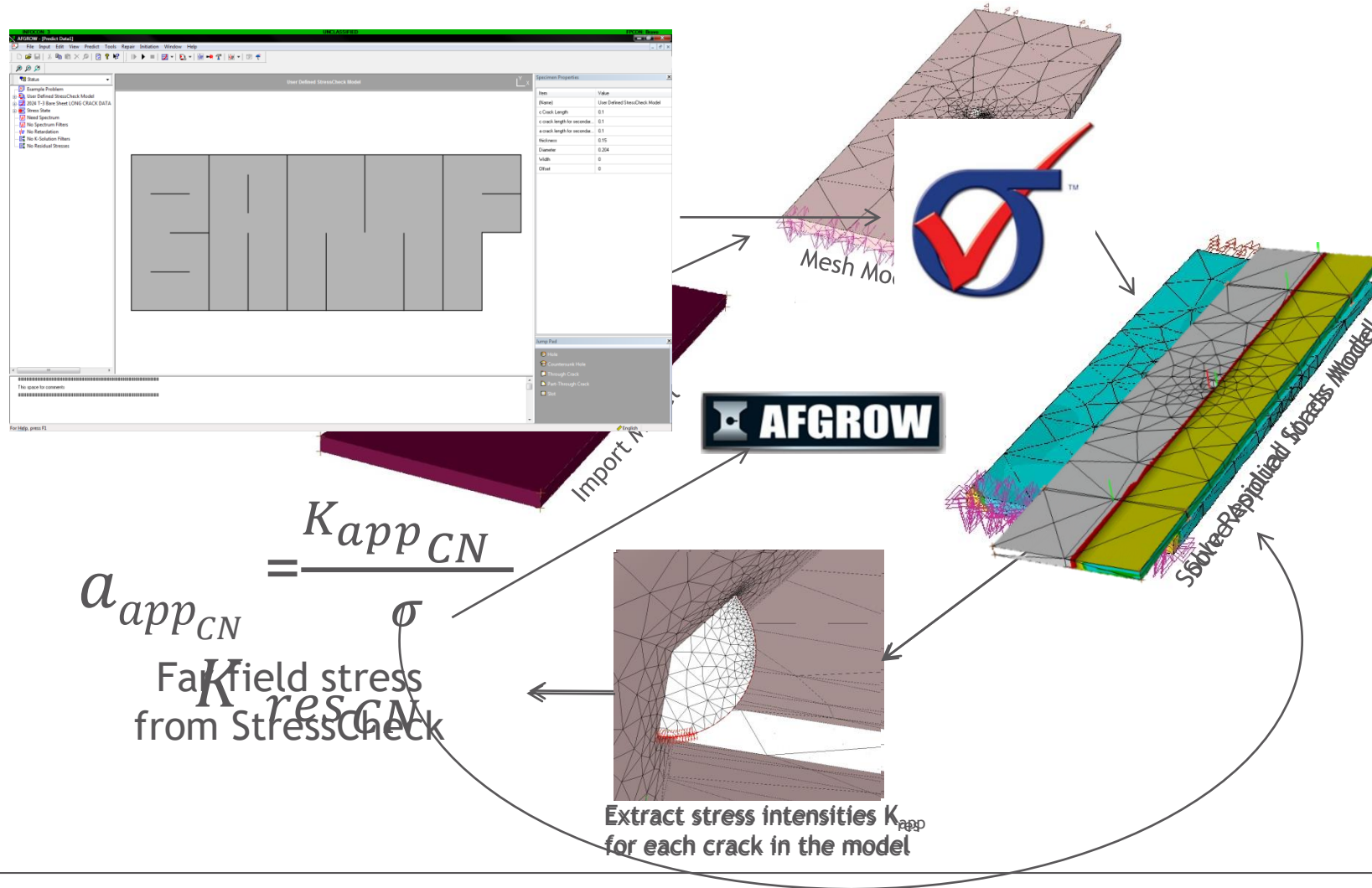
September 14

Overview: What is BAMpF?



Broad Application for Multi-point Fatigue

Overview: BAMpF Process Flow



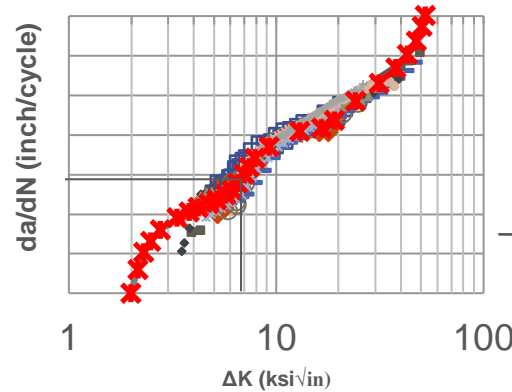
Overview: BAMpF Process Flow

$$K_{min_{CN}} = a_{app_{CN}} \sigma_{min} + K_{res_{CN}}$$

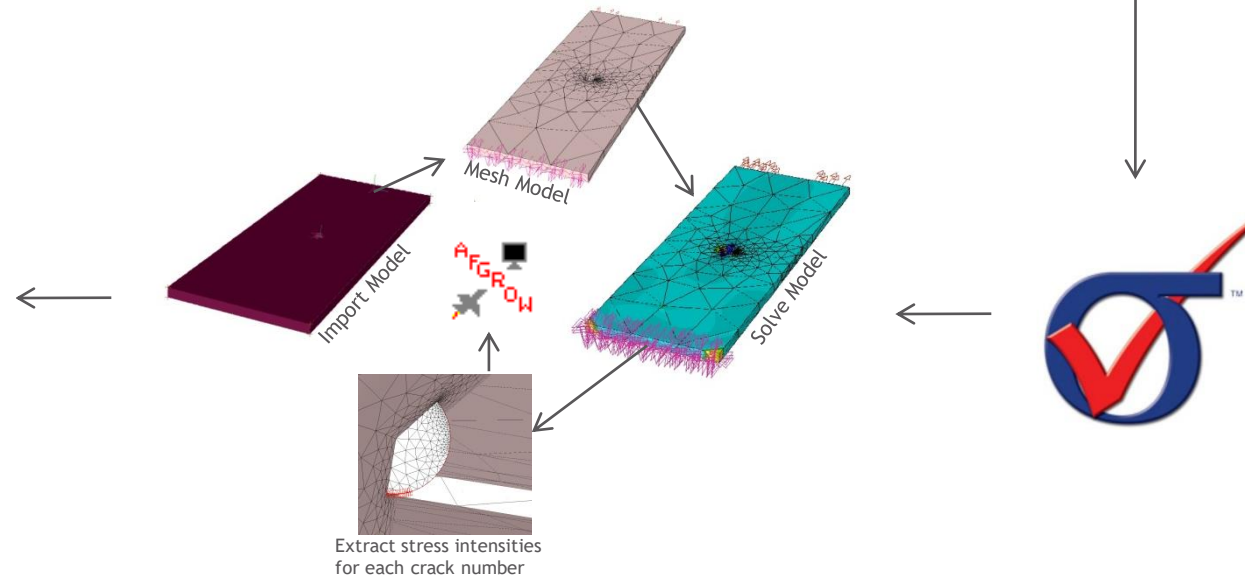
$$K_{max_{CN}} = a_{app_{CN}} \sigma_{max} + K_{res_{CN}}$$

Where $\sigma_{min/max}$ is the AFGROW spectrum stress

$$R_{CN} = K_{min_{CN}} / K_{max_{CN}}$$



→ New Crack Lengths



BAMpF Current State

- ❑ Operational with new releases of StressCheck™ 11.1 and AFGROW 5.4
- ❑ Windows 10/64 bit compatible
- ❑ Full utilization of StressCheck™ software suite
 - Complex load cases (via sets)
 - Contact solutions
 - Residual stresses
 - Bearing loads
- ❑ Full utilization of AFGROW crack growth capabilities
 - Spectrum capabilities
 - Load interaction models
- ❑ Functional API
 - Updated code with significant enhancements
 - Easy integration with in-house FCG codes
 - Process of USAF Approved Software List underway

Proposed Feature List from 2021 Workshop

<u>Feature</u>	<u>Description</u>
Multi-Channel Loading	Solve for multiple loading scenarios
Integration with other FE tools	Ansys, NX (Funding Sources Phase 2 landing gear, A-10)
K extrapolation	Extrapolate K to radius of 0 using two different K extractions
Multi-Crack Auto-Coalescence	(MCAC) When crack fronts intersect-automatically coalesce cracks
3-D crack growth	Crack turning, out of plane crack growth
Restart Analysis	Utilizing Extraction folder restart at last analysis point
Pause Analysis for UI	Allows user to pause an analysis to update the start.scw file
Custom Output files	Use a customizable .ini file to allow the user to tailor output files
Crack front splitting	When the crack front splits into multiple cracks
Retardation Tracking	Build the framework for appropriate Retardation tracking and restarting
BAMpF Training Class	Provide a multi-day training class to discuss all things BAMpF
BAMpF Error Handling Checks	Provide more details on BAMpF Failures
Updated Model Creator	Update the model creator to work with SC10.5 and SC11
Post-processor review GUI	Create executable to review previous BAMpF Analyses
Run ready .PAR files	Allow code to make exceptions on adding parameters already in the parameter file
Stop Crashing Excel	BAMpF Crashes cause excel hanging in background
Restarting BAMpF in VA	Restart at specific cycle in the spectrum with appropriate Retardation
BAMpF ASL	Get BAMpF on the approved software list
AFGROW Crashes with Dax	When Opening a DAX while plug-in is running AFGROW/BAMpF Crashes

Sept 2021-Sept 2022

Reported Bugs

BAMpF Reported Bugs

□ Jake Warner

- StressCheck meshing issues
 - Mesh refinement
 - Mesh failures
- Set Selection Errors
- “Your output format is confusing and sucks”
- New API if no RS Kapp/1000 was applied to Krs
- Formula is not applied if it starts with a numeric

□ Renan Ribeiro

- Excel Macro issue
 - Run AFGROW as Admin
- Midnight Stopping of AFGROW/BAMpF
 - Related to Hill Engineering RMM software

□ Casey Scott

- Point pinning on surface in contact model
- GUI pulls data from hanging excel file into plots

□ Matt McSwiggen

- 180° and 360° cracks do not grow properly
 - Fixed minor bugs in new API

□ Brian Boeke

- Contact does not match hand calcs

Release date Spring 2022

BAMpF 8.1 FEATURES

Features






- BAMpF architectural redesign**
 - Revamped output format
 - Restart analysis
 - Run ready PAR files
 - Improved crash handling
 - BAMpF and StressCheck logging
 - BAMpF API
- Post-analysis review GUI**
- Model creator**
- AFGROW patch for multiple dax opening**
- StressCheck 11.1 updating meshing capability**

BAMpF Architectural Redesign










- ❑ In 2020 it became clear that we were out growing the engineer who learned VB.net on this project
- ❑ The redesign allowed us to:
 - Optimize code
 - Remove work arounds that have been patched in current versions of SC and AFGROW
 - Develop a working API
 - Introduce logging features to aide in debugging
 - Allow for a more interactive GUI
 - Streamline updates and feature requests
- ❑ Beta versions have been distributed and is currently undergoing testing
 - AFGROW
 - API enabled

BAMpF Architectural Redesign

☐ Revamped output format



















	IFF_RR_contact_v4_SC	8/10/2022 7:54 AM	File folder	
	IFF_RR_contact_v4_SC.dax	8/9/2022 2:10 PM	Problem Definition	17 KB
	iff_rr_contact_v4_sc.out	8/6/2022 6:09 AM	OUT File	2,839 KB
	iff_rr_contact_v4_sc.pl2	8/6/2022 6:09 AM	PL2 File	24 KB
	IFF_RR_contact_v4_SC.scp	8/4/2022 3:42 PM	StressCheck SCP file	8,370 KB

Extraction Values folder now is name of StressCheck Model

	IFF_RR_contact_v4_SC_Start.scp	8/10/2022 7:54 AM	StressCheck SCP file	8,370 KB
	AfterExtraction.scp	8/10/2022 7:53 AM	StressCheck SCP file	20,669 KB
	AddedExtraction.scp	8/10/2022 7:53 AM	StressCheck SCP file	22,224 KB
	Excel	8/24/2022 10:51 AM	File folder	
	par_files	8/8/2022 2:44 PM	File folder	
	Kextract	8/8/2022 2:44 PM	File folder	
	logs	8/8/2022 2:44 PM	File folder	
	Images	8/8/2022 2:44 PM	File folder	
	Beachmarks	8/8/2022 2:44 PM	File folder	

Updated models can be found in the analysis results folder

Updates to the *start.scp file can be accessed on a restart

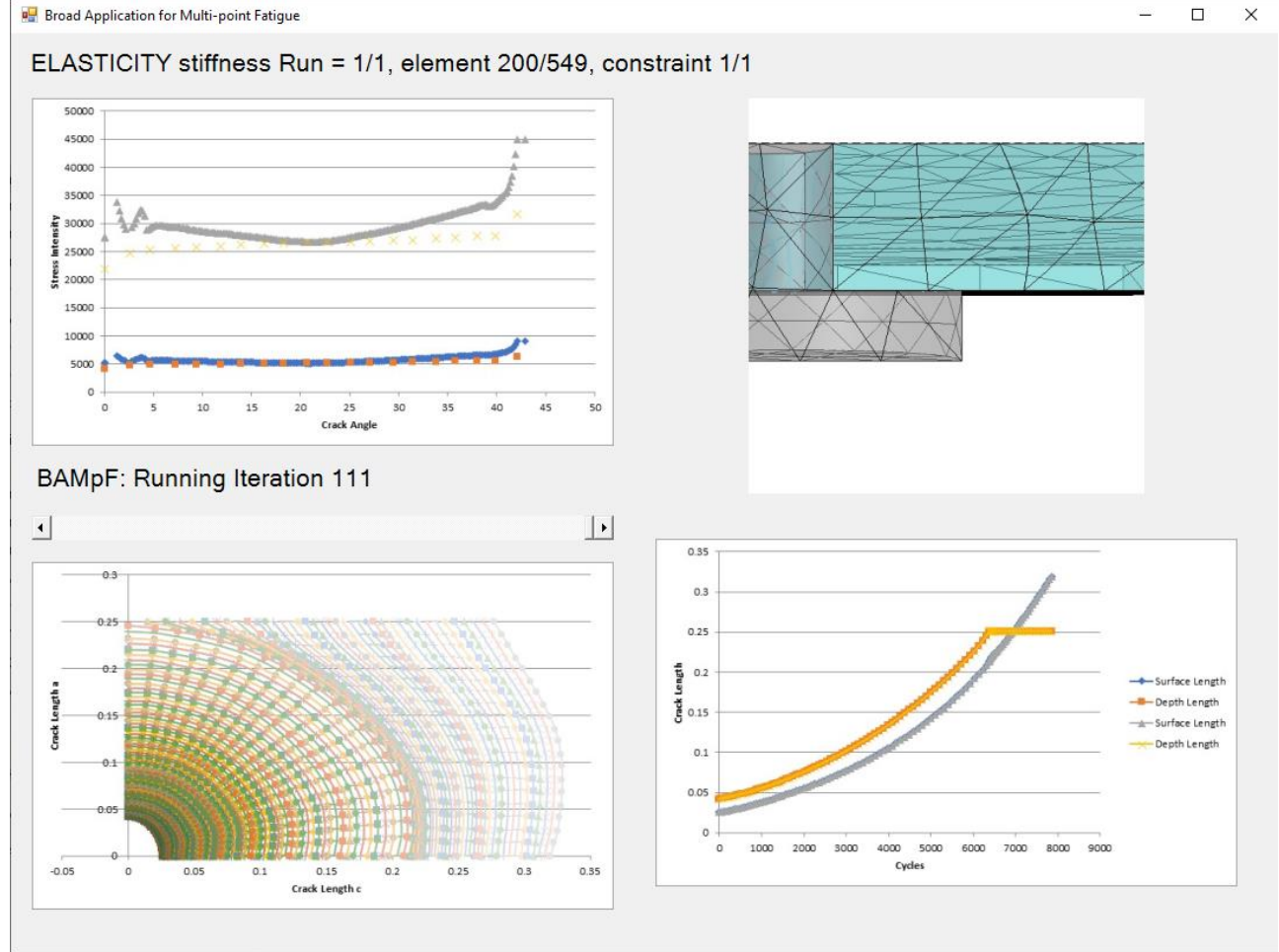
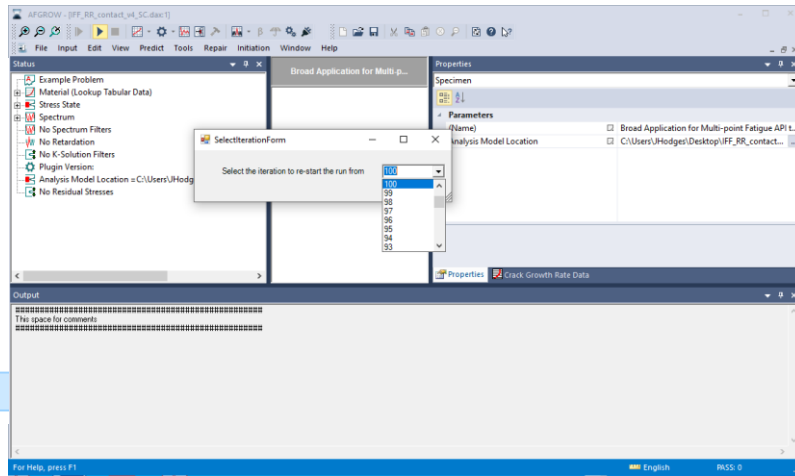
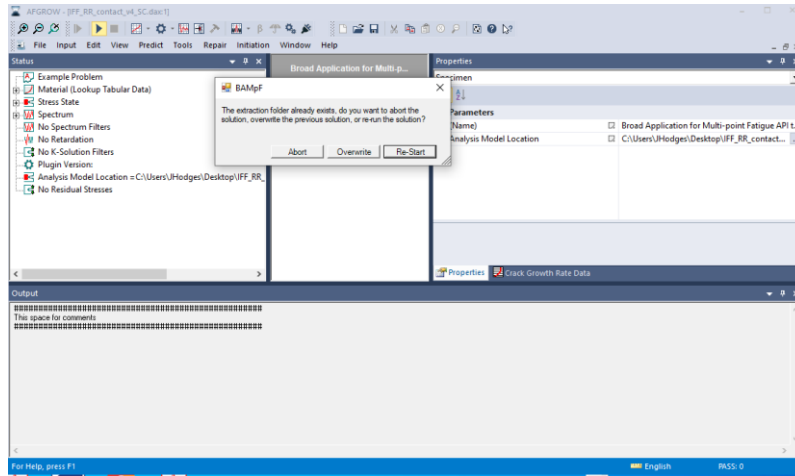
-  IFF_RR_contact_v4_Excel_120.xlsx
-  IFF_RR_contact_v4_Excel_119.xlsx
-  IFF_RR_contact_v4_Excel_118.xlsx
-  IFF_RR_contact_v4_Excel_117.xlsx
-  IFF_RR_contact_v4_Excel_116.xlsx
-  IFF_RR_contact_v4_Excel_115.xlsx
-  IFF_RR_contact_v4_Excel_114.xlsx
-  IFF_RR_contact_v4_Excel_113.xlsx
-  IFF_RR_contact_v4_Excel_112.xlsx
-  IFF_RR_contact_v4_Excel_111.xlsx
-  IFF_RR_contact_v4_Excel_110.xlsx
-  IFF_RR_contact_v4_Excel_109.xlsx
-  IFF_RR_contact_v4_Excel_108.xlsx
-  IFF_RR_contact_v4_Excel_107.xlsx
-  IFF_RR_contact_v4_Excel_106.xlsx
-  IFF_RR_contact_v4_Excel_105.xlsx
-  BAMpFLog.txt
-  StressCheckLog.txt

BAMpF Architectural Redesign

Restart analysis

- IFF_RR_contact_v4_SC
- IFF_RR_contact_v4_SC.dax
- iff_rr_contact_v4_sc.out
- iff_rr_contact_v4_sc.pl2
- IFF_RR_contact_v4_SC.scp

- Beachmarks
- Excel
- Images
- Kextract
- logs
- par_files
- AddedExtraction.scp
- AfterExtraction.scp
- IFF_RR_contact_v4_SC_Start.scp



BAMpF Architectural Redesign

❑ Run ready PAR files

- Previous versions of BAMpF required modifications to files if a .par file was loaded
 - Delete boundary layer parameters and K extraction parameters in your SCP
 - Delete formulas in SC 10.5 from the par file that causes errors in the import
- New version of BAMpF can load a par file and run
 - Boundary layer parameters are updated if they exist in the file
 - RS equation bug in SC has been updated

❑ Improved crash handling

- Update code to properly close Excel and StressCheck programs upon a BAMpF “crash”
 - Should reduce the hanging excel files
 - Should reduce tied up StressCheck licenses
- Crash handling does not work when killed through task manager

BAMpF Architectural Redesign

❑ BAMpF and StressCheck logging

- Logging files have been created that provide details of critical BAMpF functions
- Levels of BAMpF Logging can be changed by using a user built parameter BAMpF_Debug
 - 0= Verbose –very detailed information for debugging
 - 1=Debug –general information for debugging
 - 2=Information –general information regarding program function
 - **3=Warning –items that can potentially cause problems**
 - 4=Error –error information given during a run
 - 5=Fatal –information about program crashes
- StressCheck Logging provides details regarding warnings and errors in StressCheck
 - This provides great detail on the issues that arise inside StressCheck

BAMpF Architectural Redesign

❑ BAMpF and StressCheck logging

```

BAMpFLog.txt - Notepad
File Edit Format View Help
[16:09:13 INF] {"Source Context":"StressCheck"} : Preparing model CRACKFACE for out of body spline operations
[16:09:14 INF] {"Source Context":"StressCheck"} : SymCrackFlag for Crack 0 is false. updating crack face
[16:09:14 INF] {"Source Context":"StressCheck"} : Updating region
[16:09:15 INF] {"Source Context": ".updateCrackPoints"} : Update crack points
[16:09:15 INF] {"Source Context":"StressCheck.updateCrackParameters"} : Updating crack parameters
[16:09:16 WRN] {"Source Context":"StressCheck Log"} : NOTE: NOTE: 10.0-170703 - 10.0-170703
[16:09:16 INF] {"Source Context":"BAMpFGUI.BAMpFGUI_FormClosing"} : Form Closing. Raising the Shutdown Event.
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Shutting down BAMpF
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Removing StressCheck Events
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Removed StressCheck Events
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Removing Excel Events
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Removed Excel Events
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Shutting down StressCheck
[16:09:16 INF] {"Source Context":"StressCheck"} : Closing SC App
[16:09:16 WRN] {"Source Context":"StressCheck"} : StressCheck not Closed, Killing the StressCheck Process
[16:09:16 INF] {"Source Context":"BAMpFAPI"} : Shutting down Excel
[16:09:16 ERR] {"Source Context":"BAMpFAPI"} : StressCheck Error occurred. Shutting down BAMpF
APIDevelopment.StressCheckInteractionException: Critical error assigning parameter C1Px20 ---> System.Runtime.InteropServices.Marshal.ThrowExceptionForHR(Exception hr)
   at ESRD.StressCheck.Core._IDualStressDoc.ParameterAssign(String parameter_name, Double Value, Boolean Update)
   at APIDevelopment.StressCheck.updateCrackParameters(crackParameters newCrack) in C:\Users\JHodges\Documents\BAMpF C
--- End of inner exception stack trace ---
   at APIDevelopment.StressCheck.updateCrackParameters(crackParameters newCrack) in C:\Users\JHodges\Documents\BAMpF C
   at APIDevelopment.BAMpFAPI.runBAMpFPredictionKArray(Double Max_FCGS_Stress, Double Stress_Multiplication_Factor, Boolean
[16:09:16 INF] {"Source Context":"BAMpFGUI.Form1_Disposed"} : Form Closed.
[16:09:17 ERR] {"Source Context":"BAMpFGUI.SetStressCheckMessage"} : Error invoking SetStressCheckMessage
  
```

```

StressCheckLog.txt - Notepad
File Edit Format View Help
description. There must be at least one curve and one
surface selected.
[16:06:56 INF] {"Source Context":"StressCheckLog"} : Status: RUNNING
Run : 1

[16:06:56 INF] {"Source Context":"StressCheckLog"} : Status: RUNNING
Run : 1

[16:08:12 INF] {"Source Context":"StressCheckLog"} : Status: COMPLETE
Run : 1

[16:08:12 INF] {"Source Context":"StressCheckLog"} : Status: COMPLETE
Run : 1

[16:08:12 INF] {"Source Context":"StressCheckLog"} : Status: COMPLETE
Run : 1

[16:08:12 INF] {"Source Context":"StressCheckLog"} : Status: COMPLETE
Run : 1

[16:08:12 INF] {"Source Context":"StressCheckLog"} : Status: COMPLETE
Run : 1

[16:09:01 WRN] {"Source Context":"StressCheckLog"} : ERROR: Invalid 2D crack
description. There must be at least one active curve selected.
[16:09:01 WRN] {"Source Context":"StressCheckLog"} : ERROR: Invalid 2D crack
description. There must be at least one active curve selected.
[16:09:16 WRN] {"Source Context":"StressCheckLog"} : NOTE: NOTE: 10.0-170703 -
10.0-170703
  
```

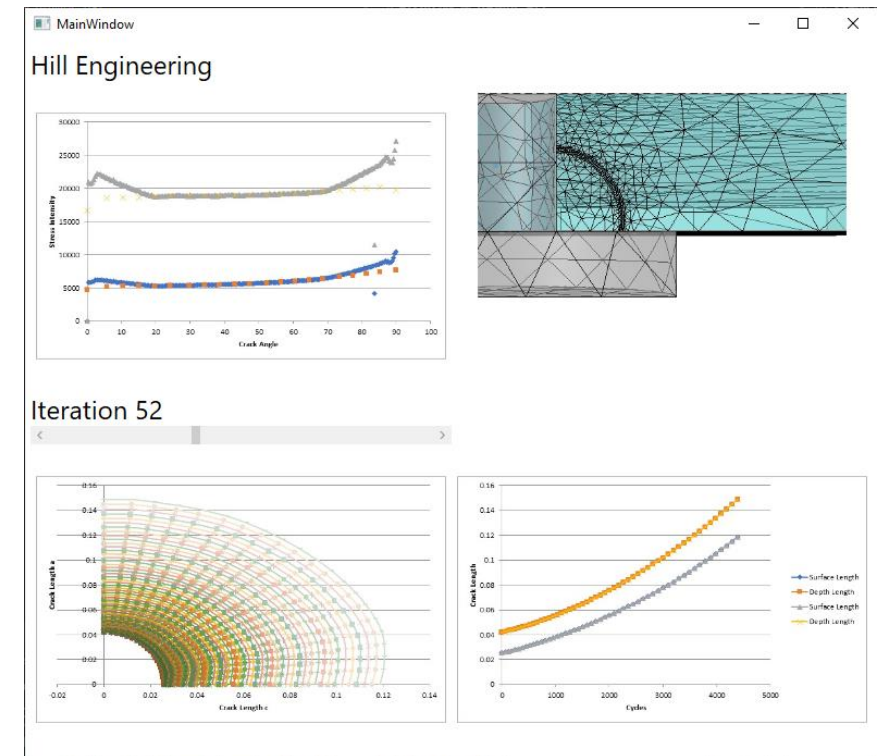
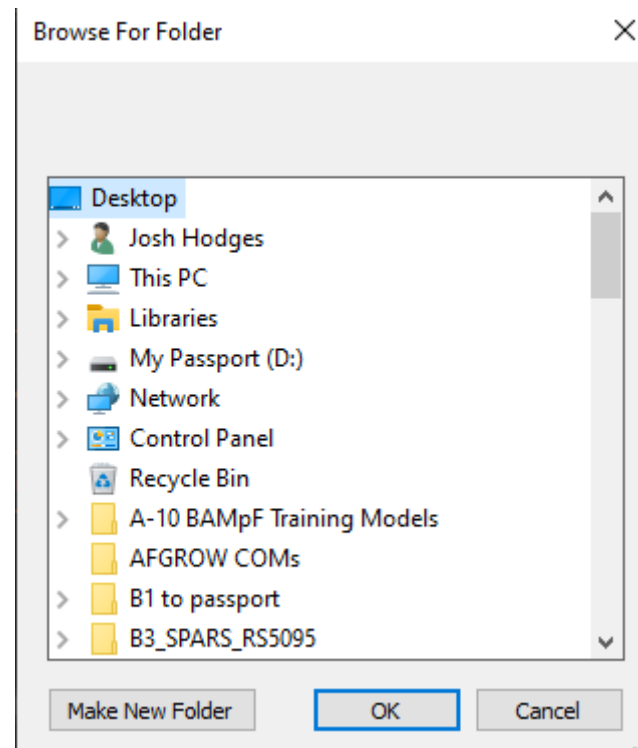
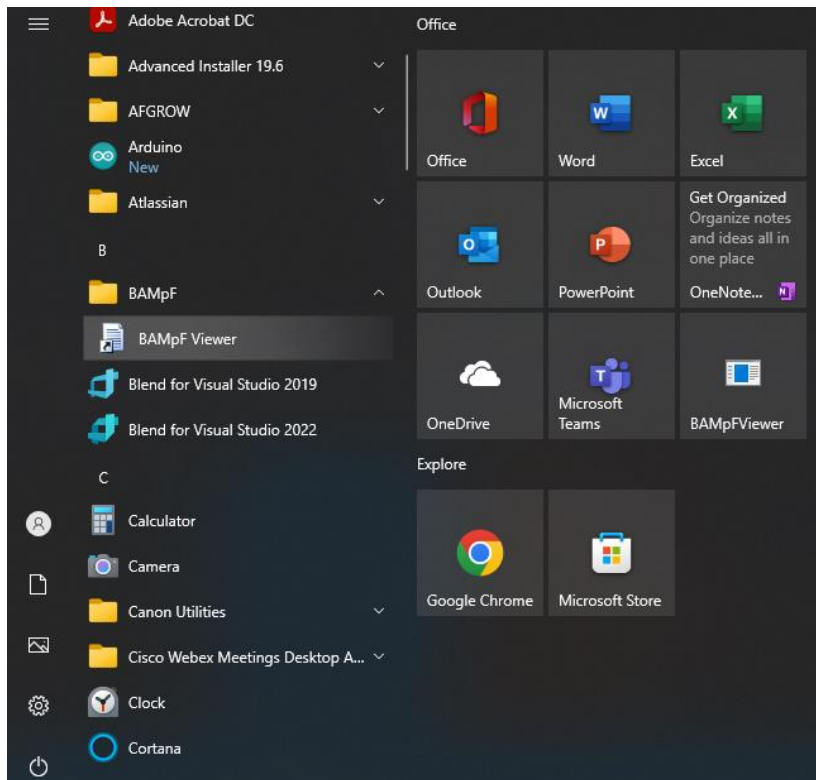
BAMpF Architectural Redesign

□ BAMpF API

- The BAMpF API makes available 3 functions that can be used to connect with in house CG engines
- It provides the capability to create unique solutions with readily available tools
- `bampf.configureBAMpFRun(Model Name, Model Path, StressCheck Visible, Log Level)`
 - Initializes BAMpF Model opening StressCheck and getting BAMpF Parameters
- `bampf.runBAMpFPredictionKArray(MaxStress, SMF, Life in Hours, Delta P, Life)`
 - Runs the full BAMpF solution for crack growth codes that have the Karray feature implemented
- `bampf.runBAMpFPrediction(MaxStress, SMF, Life in Hours, Delta P, Life)`
 - Runs the classic BAMpF solution
- Can utilize the API with excel to perform studies on variable growth rates

Post-analysis review GUI

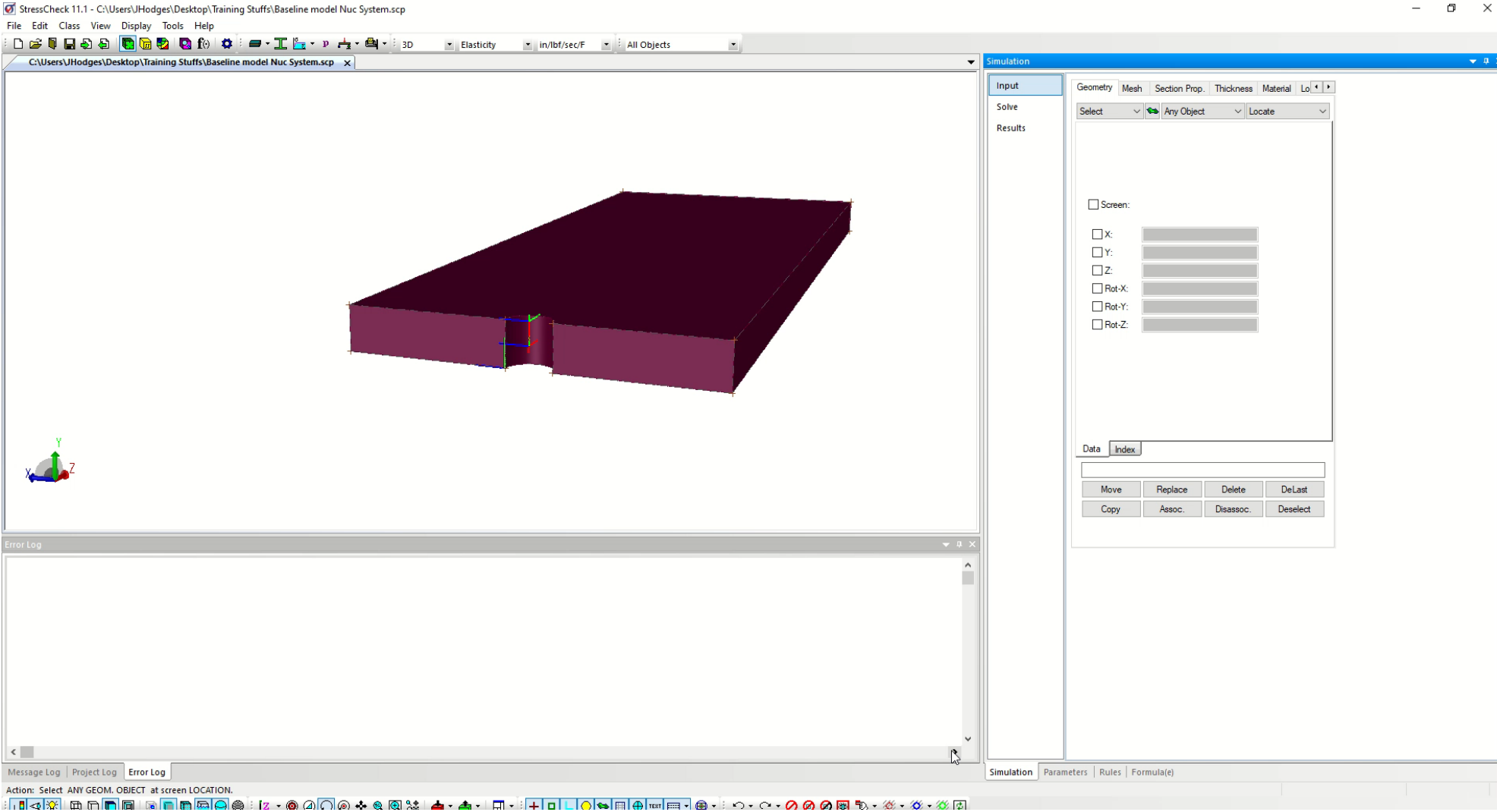
- ❑ The BAMpF Viewer GUI was created to quickly review old BAMpF analyses
- ❑ It can be accessed through the Program Folders in the BAMpF Folder
- ❑ It allows the user to cycle through iterations to interrogate the model



Model Creator

- ❑ The model creator was designed to correctly and efficiently enter a crack in the model
- ❑ Due to modifications in StressChecks Parasolid models the model creator wasn't stable
- ❑ Updates have been made to increase stability and increase appropriate set creation
- ❑ **Crack geometry**
 - Circular flaw with defined number of points
 - Points directly from a table
 - Points from a table interpolated and respaced (Creation of cracks from Marker Bands)
- ❑ **Set creation is done through selection sets and should always be checked**
- ❑ **Model must be un-meshed and a nucleation system set is required**

Model Creator



StressCheck 11.1 Updated Meshing Capability

- With the update of SC11.1 new meshing functionality has been released
- Meshing capability is available to BAMpF users but is turned off by default
- To perform automatic meshing in SC the user can create a boundary set called **CRACK#** that selects both the crack face and the crack front
- BAMpF_MixedMesh turns on the wedge to tet conversion in SC11.1
- If nothing is done BAMpF will utilize its normal boundary layer meshing routine until the new mesh enhancements have been interrogated
- Mesh enhancements and other SC features can be found at <https://www.esrd.com/stresscheck-v11-1-released/>

StressCheck 11.1 Updated Meshing Capability

Geometry Mesh Section Prop. Thickness Material Lo

Create Mesh Boundary Layer

MeshSim ,4001.Bnd. Layer.Select.Active.CRACKFRONT1

Active

Enable All

Ratio: 5.263157894736842e-02

Layers: 2.000000000000000e+00

Inner Thickness: 1.205180477125024e-03

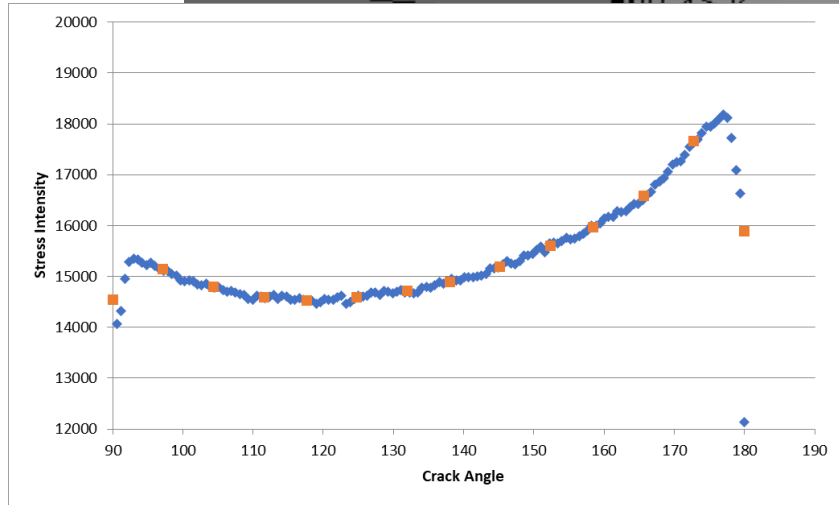
Total Thickness: 2.410360954250049e-03

Side: Both Sides

Mixed Mesh

Shrink To Fit

20383 Elements



Geometry Mesh Section Prop. Thickness Material Lo

Create Mesh Crack Front

MeshSim , 1.Global , .Active.SET28

Active

Automatic Values

Ratio: 6.25000e-02

Curvature D/H: 2.53570e-02

Layers: 4

Inner Radius: 2.52863e-05

Outer Radius: 7.49223e-03

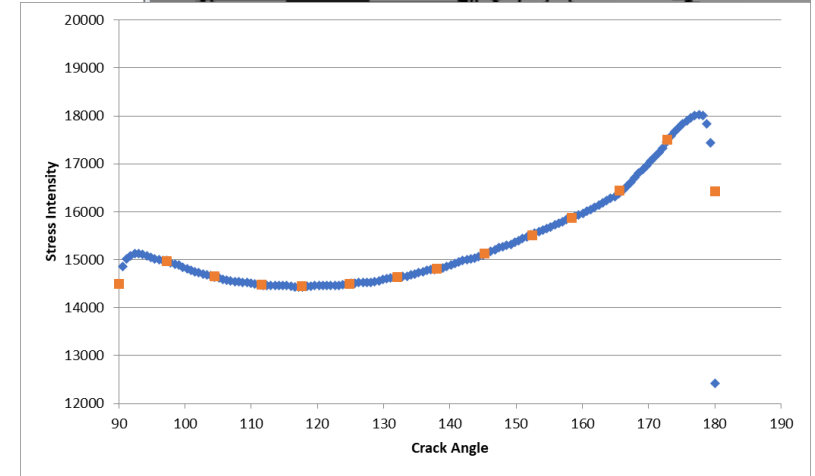
Mixed Mesh

Integration Layer

Grade Toward Ends

Reset

21529 Elements



BAMpF Approved Software List

- The process for getting BAMpF on the ASL has been initiated!!!
- No more backdoor solutions to get the .dll registered
- Submitted paper work in June 2022, expect a response no later than June 2027!!!



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Restart Analysis	Utilizing Extraction folder restart at last analysis point
Failure Criteria	Implement some sort of failure criteria, beyond all points reaching K critical (Warner 2022)

Special Thanks

