

## FEMAP Solid Modeling Workflow

A Seminar for FEMAP and NX Nastran Users Adrian Jensen, PE - Senior Staff Mechanical Engineer Brian Kolb – Staff Mechanical Engineer



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Allen Foulstone Senior Systems Engineer Stratolaunch Systems







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#### 1. WHY WE ARE HERE

All finite element analysts know this experience – take a single piece of solid CAD geometry, auto-mesh it, apply the boundary and analyze the model. It will be quick, easy and you think you will have some results ready to document in time to leave the office at a reasonable hour... and then the model crashes and the goose chase begins. Sometimes the simplest analysis projects can suck up a ridiculous amount of time.

In this technical seminar, we want to get back to the basics and talk about why it's not always so basic. This presentation will walk through the standard analysis workflow from geometry to stress results and take a look at some of the common pitfalls. Along the way, we will share with you some of our time saving techniques. We will be working with solid geometry and tetrahedral meshes as we explore geometry preparation, mesh quality, model verification tools and finally, some recommended post-processing practices.

#### Analysis Workflow:

- Geometry
- Material
- Property
- Mesh Sizing
- Meshing
- Loads
- Constraints
- Analyze



#### 2018

#### 1.1 LET'S START WITH FEMAP PREFERENCES

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A nice feature added for Femap 11.3 is the ability to configure a dynamic zoom and rotation around your cursor location instead of the center of your screen or view center.

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#### **2. GEOMETRY**

#### *File > Import > Geometry*

Note the scale factor (39.37 in/meter). The scale factor can be controlled after import via *Modify > Scale > Solid*. Consider model scale factor and part scale factor.

Solid Model Read Options					
Title Transmission Housing Ca	asting				
Entity Options					
Geometry Scale Factor	39.37				
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Assembly Options					
Increment Layer 🔽 Increment Color					
<u>O</u> K	Cancel				





#### 2.1 GEOMETRY PREP – DE-FEATURING, SLICING, INSCRIBING AND EMBEDDING

It's best to make modifications to the geometry before moving on to other step in the analysis workflow. Let's take a look at a few ways to prepare the geometry for mesh control and application of boundary conditions.





#### 2.2 PANES, TOOLBARS AND VIEWS: THE JOYS OF CREATING A CUSTOM WORK ENVIRONMENT

Before we get too far, let's talk about view settings... Nobody wants to see magenta in the contour plots.





#### **3. MATERIALS AND PROPERTIES**

Ok, back to it! Create your own materials or pull from the FEMAP libraries. Or, create your own and save it to the material library. Watch out for auto-repeat!

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#### 3.1 BLANKING FROM THE MODEL INFO TREE AND THE VISIBILITY TOOLBOX

There's lots of ways to control what is displayed in FEMAP. We recommend starting with the Model Info Tree and the Visibility Toolbox. Get used to using Ctrl-Q to access Visibility and your FEMAP workflow will be much quicker.



All On

All Off

Selected On

Selected Off

Selected Only

Entity Colors

View Colors

Load View...

Save View...

Reset View

Done

.



#### **3.2 DRAW / ERASE TOOLBAR**

Entity Selection - Select Property(s) to Draw

🖌 to

O Exclude

by 1

Add 
 Remove

ID |

The Draw / Erase toolbar is a useful new tool for navigating your model by selecting Entities to show, or to hide. It's even better once your geometry is already meshed.

**Select by Property** 

+100

Select All

Previous More





#### 4. MESH SIZING

Choose a mesh sizing approach that is appropriate for your geometry and desired element type. In this case, we will be using *Mesh > Mesh Control > Size on Solid*. Note the option for "Multi-Solid Sizing" and how the appearance of your curves and surfaces changes once you have applied mesh sizing. Also pay attention to the message window.

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#### 4.1 WHY DO WE CARE ABOUT TET OR HEX?

We'll skip the lecture about good mesh / bad mesh and just get to the point about why hexing is has some advantages:

#### Simply Supported Bending = 12,000



#### Plate with Hole under Uniform Tension $K_t = 3.0$



#### Pros

- Tet is "easy" and for linear analysis hard to justify hex
- Tet provides acceptable linear elastic stress results
- Good Tets = Good Stress (watch Jacobian and Tet Collapse – no free lunch)

#### Cons

- Tet is heavy (to fill a cube: 26 vs. 8 nodes)
- Often unsuitable for material nonlinear analysis
- Can be unwieldy in large models that require normal modes solution (e.g., PSD)



#### 5. MESHING

Choose a meshing method that is appropriate for your geometry and desired element type. For this model, we will be using *Mesh > Geometry > Solids*. Just like mesh sizing, the defaults are the recommended starting point but take some time to look at the options and the corresponding help section. It's really quite useful and it will save time in the long run. As always, pay attention to the message window; there's good information there.





#### 2018

#### 5.1 TETRAHEDRAL MESHING FUNDAMENTALS - HOW IT WORKS

Everybody does it the same: (i) surfaces are meshed with three-node triangular elements (FEMAP plot-only), (ii) the surface mesh is "sealed" (nodes at edges are merged and elements are checked) and (iii) the surface mesh is submitted to the solid tet mesher.

In this example, we have done things simply not too much cleanup or geometry prep. But what happens when you have to deal with a beast like this?





#### 5.2 How to IMPROVE THE QUALITY OF YOUR TET MESH

- Pick a part and then start with a reasonable mesh size
- Read the messages and think a bit
- Investigate to see if it seems reasonable
- Try *Mesh > Geometry Preparation*
- What is it doing in the background?
  - Trimming and splitting
  - Features suppression
  - Boundary surfaces and composite curves
- Check Mesh Quality.









#### 5.3 TROUBLESHOOTING BAD GEOMETRY - BRUTE FORCE TET MESHING

- Try to be systematic
- Look at mesh identify the geometric features that lead to bad mesh
- Play with the changes generated by Geometry Preparation
- Sometimes, Geometry Preparations creates unwanted changes. Protect these regions with groups.
- Modify the mesh sizing and geometry using the Meshing Toolbox
- Use plot-only elements to test model changes quickly
- Try Geometry > Solid > Cleanup



No magic bullet - No perfect system – Still jobs for simulation engineers 🙂



#### 6. BOUNDARY CONDITIONS

Let's apply loads and constraints to geometric features. FEMAP will identify certain features and allow for advanced boundary conditions (e.g., cylindrical constraints or bearing loads).





#### 2018

#### 6.1 **APPLICATION PROGRAMMING INTERFACE (API)**

Over the years, we have saved our clients hundreds of thousands of dollars using FEMAP's API to expedite project work.

#### Unique Load Applications



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7 Lower Vessel Shell Property Number	102512	0					A	diust fo	r Horizo	ntal Seisr	nic Analysis			
8 Bottom Head Under Jacket Property Number	101712	0						.,						
9 Bottom Head Under Jacket Property Number	101513	0												
10														
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13 Outer PJM Shell Property Number (in fluid)	302073	0												
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18 Concrete Density	0.0752	0.000194819				Thi	ckness t	o Surfa	e	Jet Jue	Midplan	e	5 10	
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20														
21	Volume (in^3)	Weight (lbf)	Mass (lbm)	Density										
22 Total Vessel Volume	30,441,914	1648429.64	4270.54											
23 Total PJM Cluster w/ Supports	3,/11,4/2	200976.21	520.66											
24 Vessei Liquid	20,750,442	144/455.45	3749.88											
26 PJM Cluster (Displaced Fluid Volume)	3,481,951				1									
27 PJM Liquid (Volume)	2,805,225	151902.93	393.53	(lbm/in^2)										
28 PJM Liquid (Surface Area)	181,239			0.002171333										
29 PJM Cluster Concrete (Volume)	676,686	50886.79	131.83											
30 PJM Cluster Concrete (Surface Area)	17,873			0.007375828										
31 PJM Cluster NSM (Liquid+Concrete)		202789.72	525.36											
22														
33 Horizontal PJM Cluster Supports (Displaced Fluid Volume)	136,669													
34 Vertical PJM Cluster Supports (Displaced Fluid Volume)	92,852													
35 Vertical PJM Cluster Supports Concrete (Volume)	92,852	6982.47	18.09	(lbm/in)										
36 Vertical PJM Cluster Supports Concrete (Length)	180			0.10049612										
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#### Driving FEMAP via Excel



#### 7. ANALYZE

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#### 7.1 WHEN WORKING WITH TETS, USE THE ITERATIVE SOLVER

When working with a model dominated by tet10 elements, one should use the iterative solver to reduce solve time.

NASTRAN Executive and Solution Options	X				
Solver					
Direct Output To C:\scratch					
Base Filename for Analyze (Blank to Match Model)					
Additional Command Line					
Executive Control	MSC/MD Nastran Version				
Problem ID	Ver 2001     Ver 2004 or later				
Sol <u>u</u> tion Override	O Previous Versions				
Max <u>T</u> ime (in minutes)	Solution Ontions				
Diagnostics	Iterative Solver				
System Cells					
Estandad Emma Managara	<u>N</u> umber of Processors				
Extended Error Messages	Solver Memory (Mb 0=Auto) 0				
Extended Solution Status Monitoring					
Restart Control					
Save Databases for Restart					
Read Onl	y Restart				
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Version Starting Sub	case				
Manual Control					
Skip Standard Executive Control	Etart Text (Off) End / DMAP Text (Off)				
Prev Next Scratch Files	<u>O</u> K Cancel				



#### 8. POST PROCESSING

Post Processing Toolbox (Contour, Deform)





#### 8.1 JUST A QUICK NOTE ABOUT STRESSES



Stress Flows

Stress (2D) in an isotropic solid can be described using the Airy Function that satisfies the *Biharmonic Equation:* 

$$rac{\partial^4 \phi}{\partial x^4} + 2 rac{\partial^4 \phi}{\partial x^2 \partial y^2} + rac{\partial^4 \phi}{\partial y^4} = 0$$

Stresses around holes have stress concentrations of -1 and +3 under pure tension and +4 under pure shear





Images courtesy of www.FractureMechanics.org



#### 8.2 FREE BODY DIAGRAM (FBD): WHAT EVERY SIMULATION ENGINEER TRULY LOVES





#### AND NOW A WORD FROM OUR SPONSORS

# Thank You

Predictive Engineering is located in Portland, OR





## PredictiveEngineering.com