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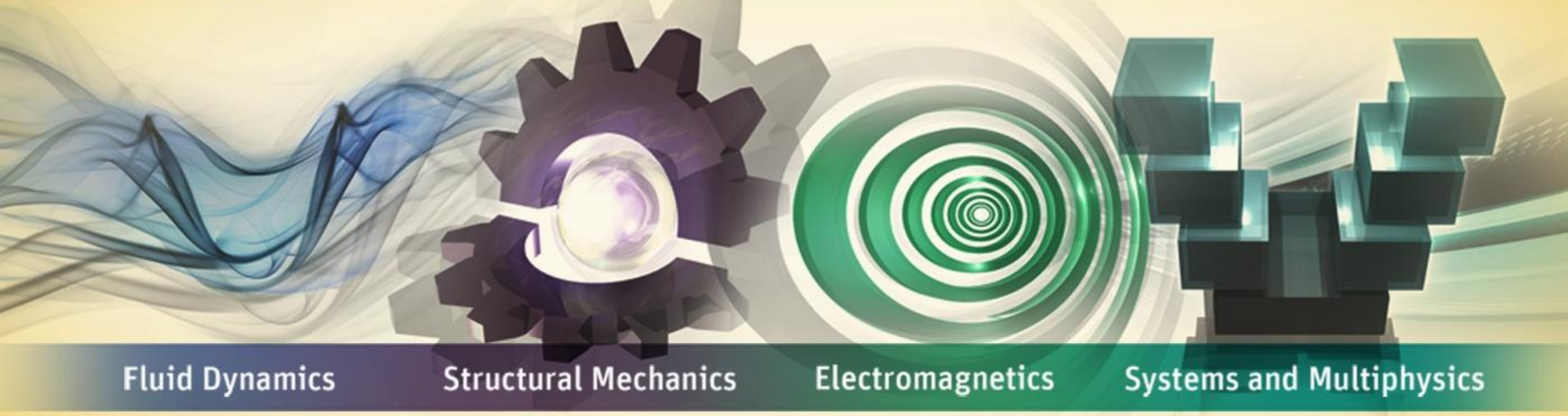
Weld Sizing:

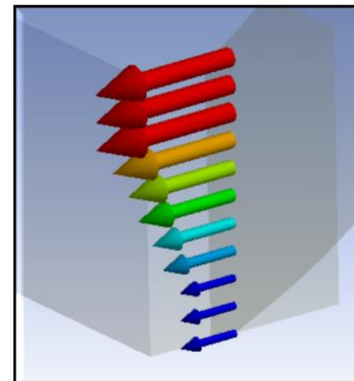
Using ACT for Robust Customization



Rod Scholl   Epsilon FEA, LLC

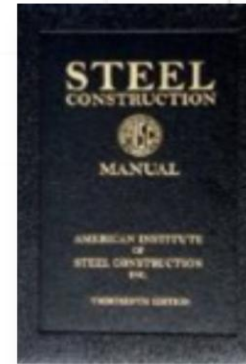
Weld Sizing:
Using ACT for Robust Customization

1. Weld Sizing – Historical Context
2. Customization – From APDL to ACT
3. The Weld Extension Details
   - Geometric Intelligence
   - Determining Required Weld Size
   - Plotting Results
   - Level of Effort



  June 15, 2013

Weld Sizing: Historical Context



Weld Sizing often controlled by standards:

AISC (American Institute of Steel Construction)

AWS (American Welding Society)

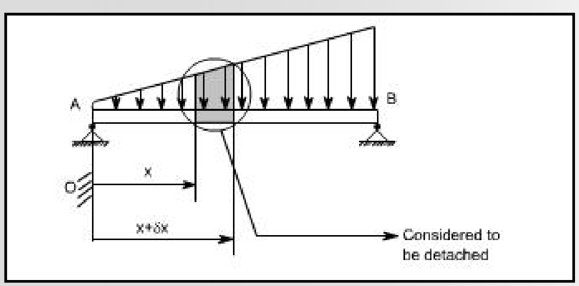
ASME Boiler Pressure Vessel Code (BPVC)

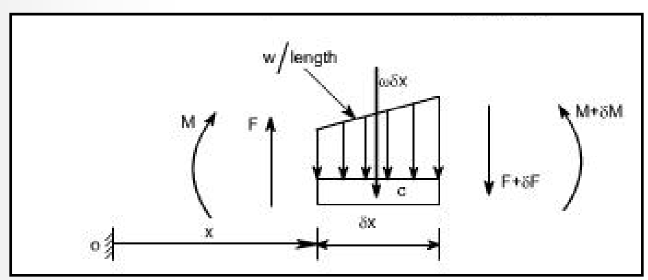
IIW (International Institute of Welding)

American Welding Society
The Strength of Welding

Historically sized with hand-calcs

- Geared toward beams more than irregular geometry
- Commonly uses Loads (<u>Force and Moments</u>)
  - Not stresses

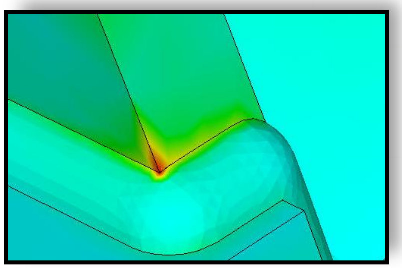




FEA Models Increasingly Available

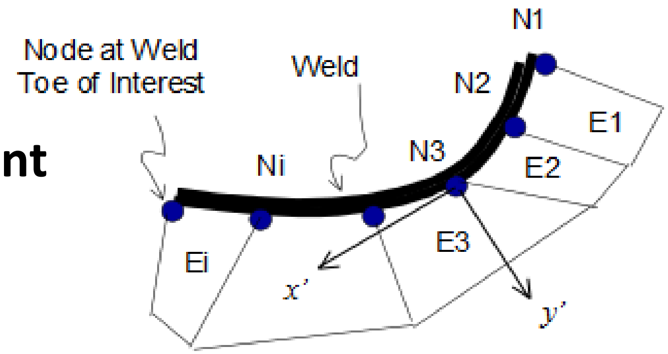
FEA results are too localized

- Singularities & Stress concentrations



"Hot-spot stress" Methods

1. Expects explicitly modeled size/geometry & requires nodes at toe
   - Must iterate on weld size
   - Some methods expect shell models
2. Geared toward fatigue failure at toe
3. Is predictive, not specification-compliant



Verity Method (Battelle, 2006)

- Integrated into FE-Safe and Hypermesh
- Has the three limitations above
- Is insensitive to mesh density and has better correlation/acceptance

Each company uses different specs, approaches, and methods!

Weld Sizing: Design for Manufacture

Welding Manufacturing Costs are often nontrivial

- Never-ending squeeze on labor/materials
- Cost of FEA continues to fall (relative to build-and-test)
  - High cycle fatigue usually not testable at system level
- Margins added on top of Safety Factors
  - Weld process has huge variability
  - Indeterminate physical material properties
  - Residual stresses
  - Weld length/flaw count adds statistical factor
  - Statically indeterminate loading (not a simple beam)
    - *This portion of overdesign can be mitigated using FEA*

Customization: From APDL to ACT

The Power of Customization

- Cost benefits
  - Automation usually has large ROI
- Quality Benefits
  - Standardization/Codification of Design Process
- Individual Benefits
  - Increasing individual contribution over time

The Risks of Customization

- Obsolescence (ANSYS development always adding features)
- Version Repair / Upkeep / Training & Documentation

Customization: From APDL to ACT

APDL (ANSYS Parametric Design Language)

– Scripting in APDL has been viable bridge (snippets)

Journaling / Scripting in Workbench allows for task automation

– *DO loop functionality for repetitive tasks
– Log File allows a low initial learning investment
– Limited interaction with numerical model/results

ACT (ANSYS Customization Toolkit) – New!

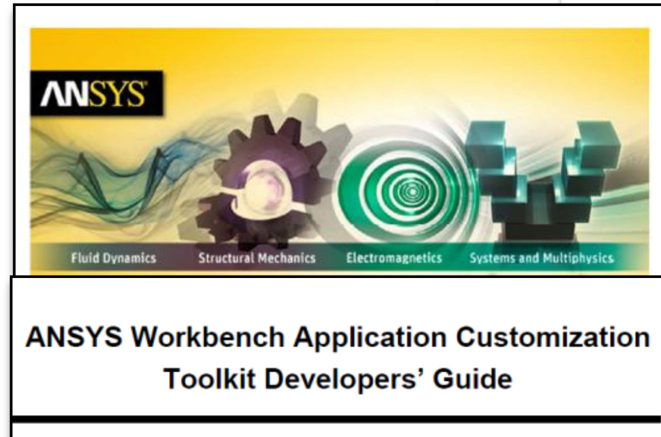
– Full access and manipulation of the model / matrices via API's
– Can encapsulate legacy APDL scripts with low investment
– Object Oriented! (Python)
– ANSYS inc. committed to long term support
– Expanding Library of Free Extensions (some open source)

Downloads at the customer portal of *http://support.ANSYS.com*

ACT Released at 14.5

- **Manageable learning curve**
  - ***Python*** **is within many graduates' skill sets**
    - ***(Yes, we're getting old)***
  - **Developers' guide from ANSYS**
  - **Training is available**
  - **Basic Tool to browse Workbench API's**
- **Extension can call uncompiled APDL scripts**
  - **Do what you can in Python -- put the rest in APDL**
  - **Incrementally learn Python**
  - **Edit APDL without ACT license!**
- **Robust Unit inputs**
- **You get to make your own button icon**

  …which is fun.



Ansys.AAP.PublicAPIs.Selection Namespace

Declaration Syntax

namespace Ansys.AAP.PublicAPIs.Selection

Table 1: Members

ISelectionInfo	SelectionInfo class
ISelectionMgr	ISelectionMgr Interface
SelectionTypeEnum	SelectionTypeEnum enumerator

ISelectionInfo

SelectionInfo class

Declaration Syntax

public interface ISelectionInfo

Table 2: Members

Property	Id	Gets or sets the ID of this ISelectionInfo object.
Property	Ids	Gets or sets selected IDs.
Property	Name	Gets or sets the name of this ISelectionInfo object.
Property	SelectionType	Gets or sets the selection type.

The Weld Extension

The Weld Extension has four steps

1. **Pass surface selection and results to Mechanical APDL**
   - **Required because we are including an APDL core**
   - **Mechanical will launch Mechanical APDL in background**
2. **Intelligent Geometry Recognition**
3. **Load/Stress Calculation**

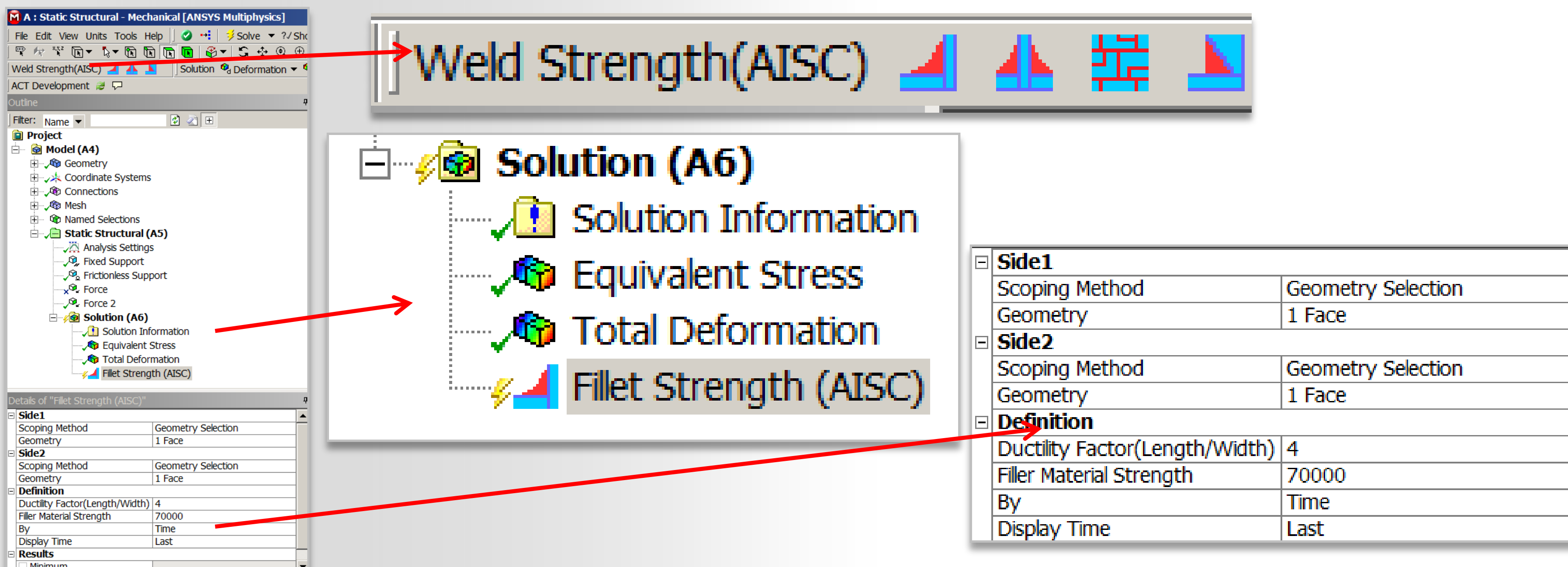
This is the challenging part (steps 2–3)

4. **Pass results back to WB and Plot**

Step 1: Pass Selection and Results

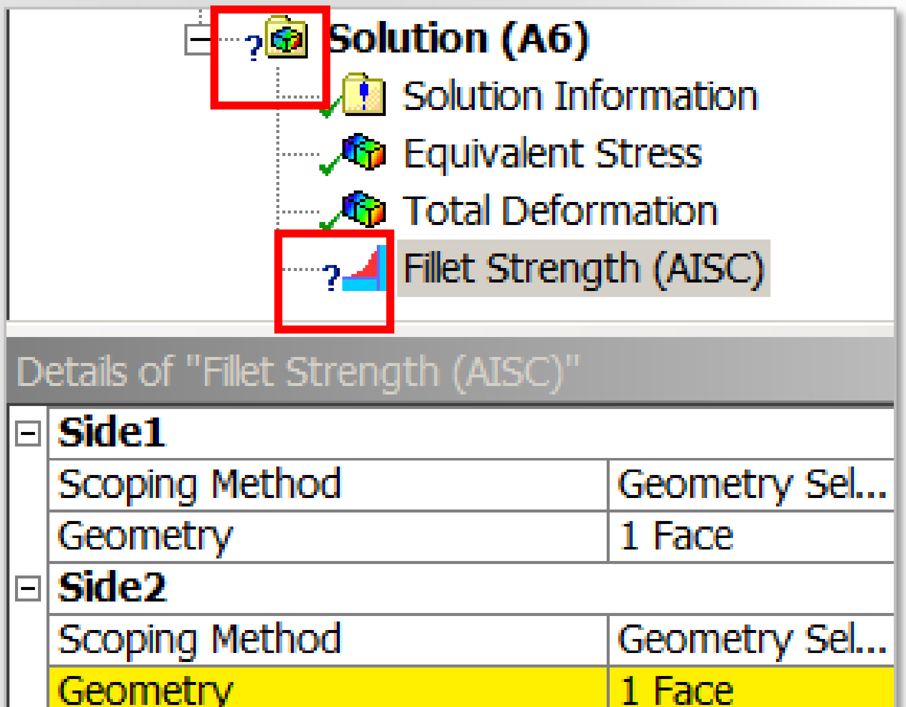
Pass surface selection and results to Mechanical APDL

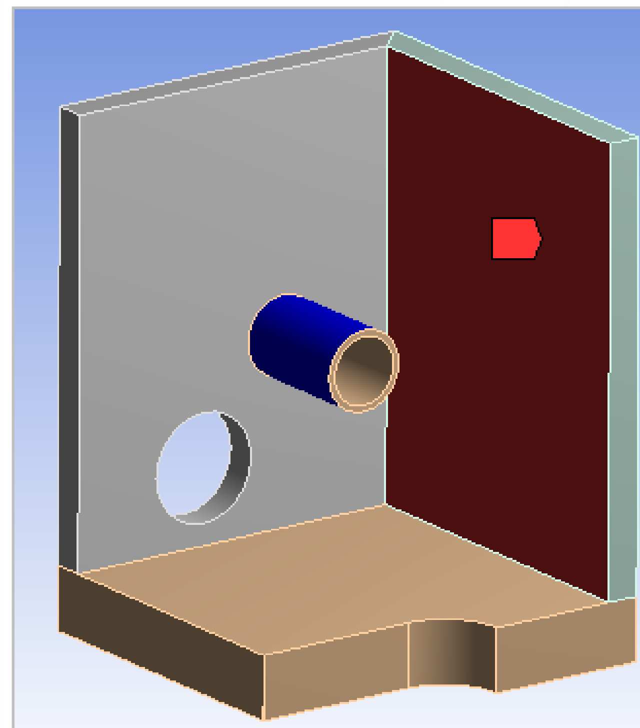
1. This is simple (once you get the hang of it)
    - Can enforce scoping to one type(s) of geometry
    - In our case, it is restricted to two surfaces
    - Enter other data in details window (as dropdown or variable)



Step 1: Pass Selection and Results, cont'd

Enforce error checking to prevent incompatible choices



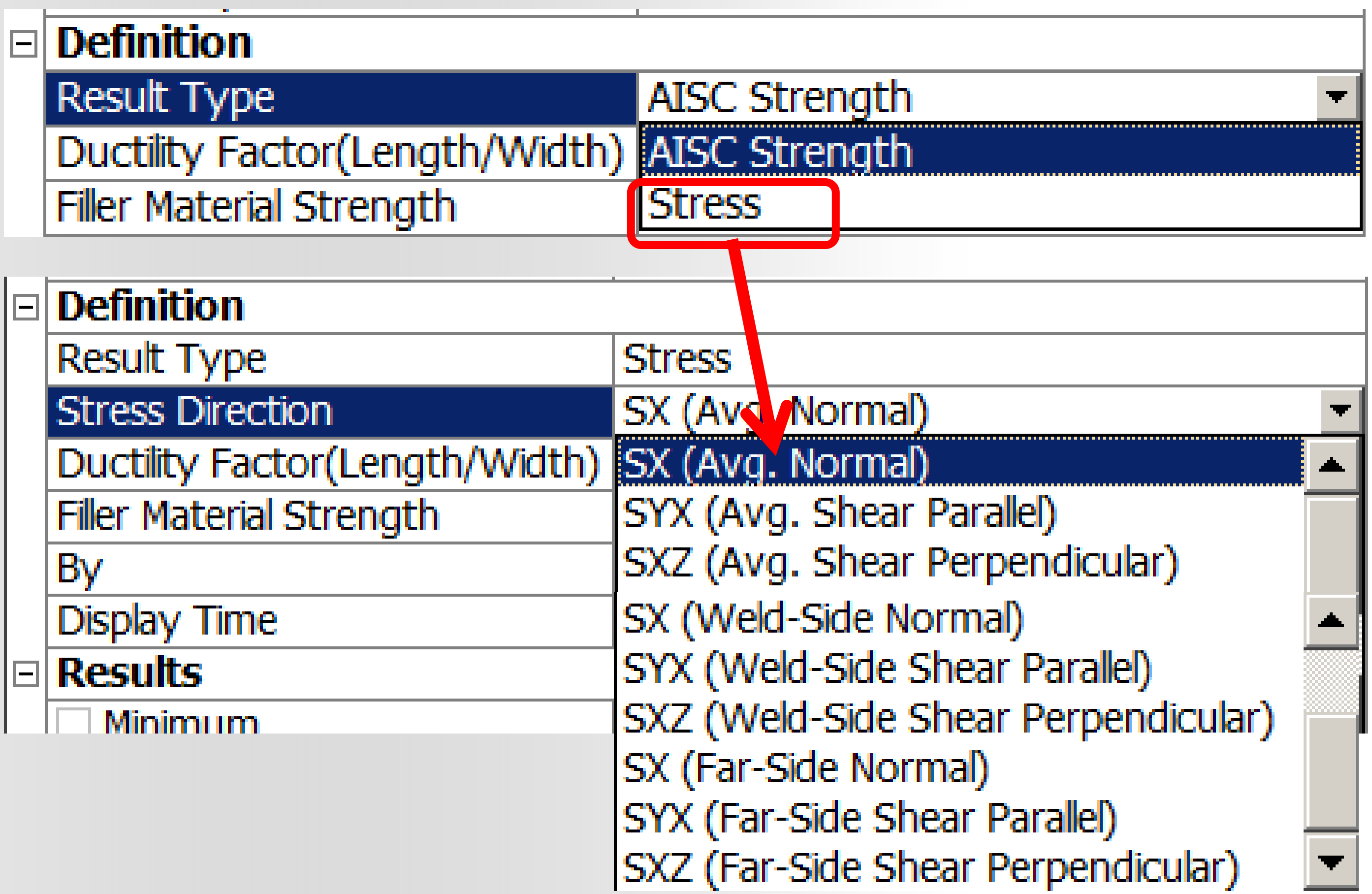


No Intersection!

Step 1: Pass Selection and Results, cont'd

Plot weld size requirement per AISC Strength

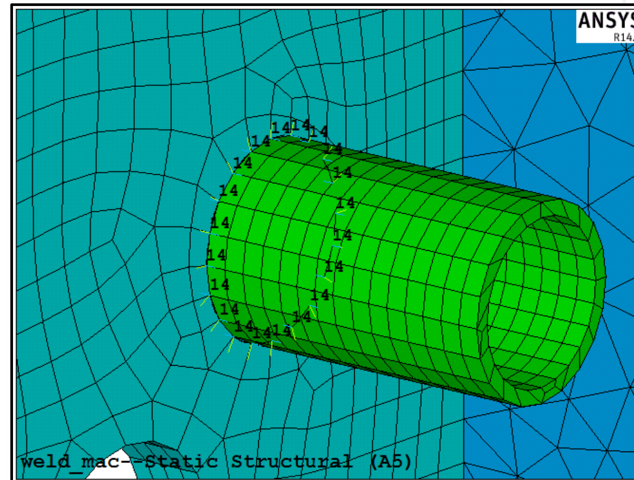
Or plot the weld stresses in local coordinates



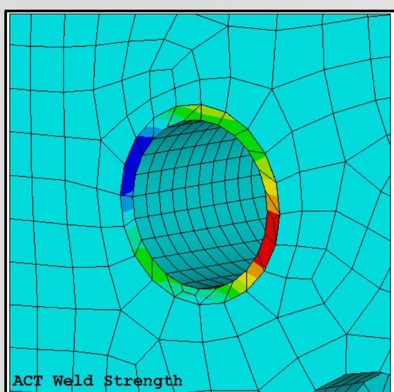
Step 2: Geometry Recognition

Robust Geometry Recognition

- Using APDL, determined normal thickness (150 lines of script)
  - Done for each shared node
  - Allows for curved weld joints
  - Allows for varying thickness



- Queries normal and shear stresses
  - On both parent materials
  - On front and back of solid

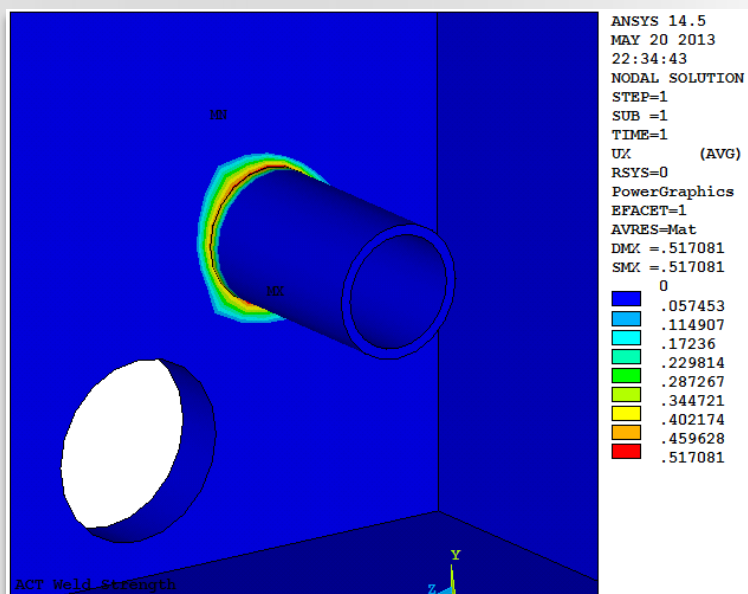



```
*do,jcount,1,ncount
!builds stress array in individual CS's
        CS,CS_max,0,storenum(jcount),nxaxisA(jcount),nyaxisA(jcount)
        rsys,CS_max
        *get,normstress(jcount),node,storenum(jcount),s,y
        *get,shearijstress(jcount),node,storenum(jcount),s,xy
        *get,shearikstress(jcount),node,storenum(jcount),s,yz
        *get,oppnormstress(jcount),node,storeopp(jcount),s,y
        *get,oppshearijstress(jcount),node,storeopp(jcount),s,xy
        *get,oppshearikstress(jcount),node,storeopp(jcount),s,yz
*enddo
```


Step 3: Averaging Stresses

Averaged along length 4X the thickness (100 lines of script)

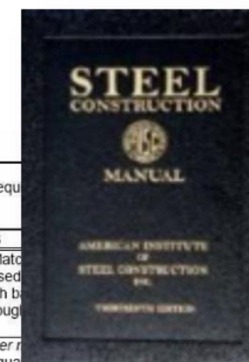
- One of many methods to account for ductility
- Determined minimum Weld Size (25 lines of script)
  - Used AISC method, Chapter J, Table J2.5
  - Different extensions/calc's for each weld type: double fillet, PJP, etc.



Available Strength of Welded Joints

Load Type and Direction Relative to Weld Axis	Pertinent Metal	Φ and Ω	Nominal Strength (F_{BM} or F_w)	Effective Area (A_{BM} or A_w)	Requ…
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal				Matc… used with b… toug…
Compression Normal to weld axis	Strength of the joint is controlled by the base metal				Filler r… equa… less than matching *filler metal* is permitted.
Tension or Compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				*Filler metal* with a strength level equal to or less than matching *filler metal* is permitted
Shear	Strength of the joint is controlled by the base metal				Matching *filler metal* shall be used. [c]

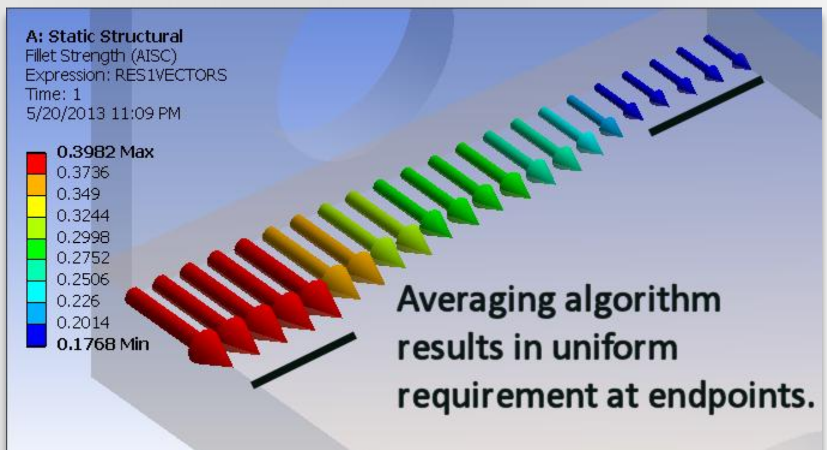
(Part of Table J2.5 AISC 2005)

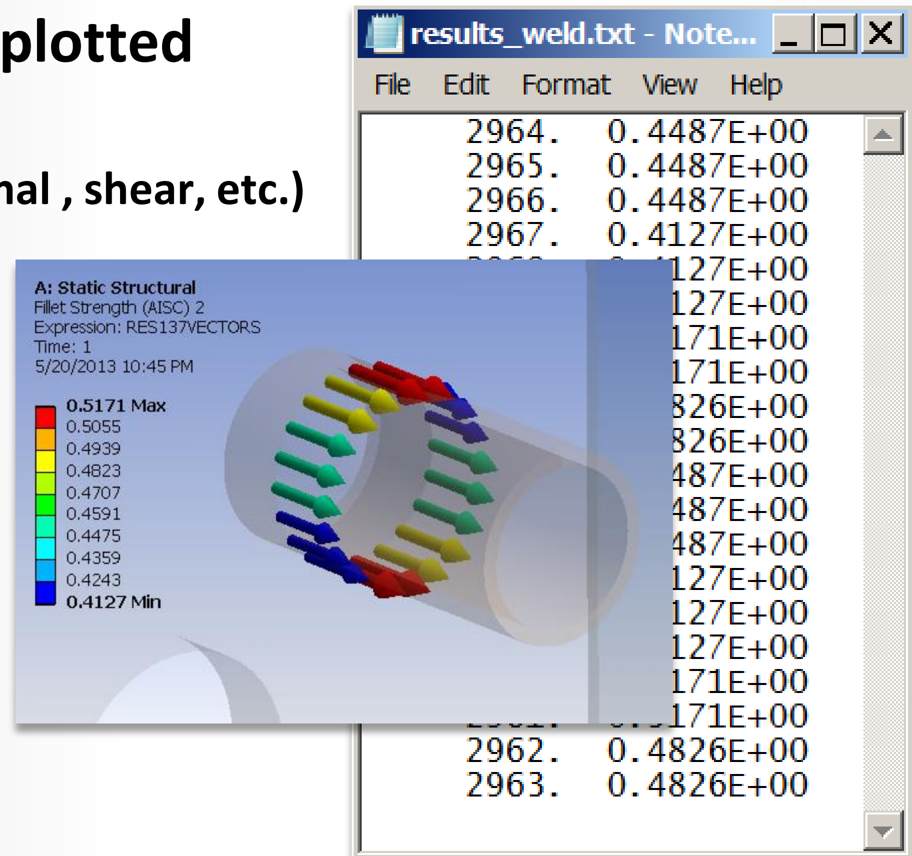


Step 4: Plotting Results

Pass results into Workbench Mechanical for plotting

- Uses ascii text file, written from Mechanical APDL
- Read into Mechanical and plotted
  - Vector style plot chosen
  - Option to plot raw stresses (normal , shear, etc.)

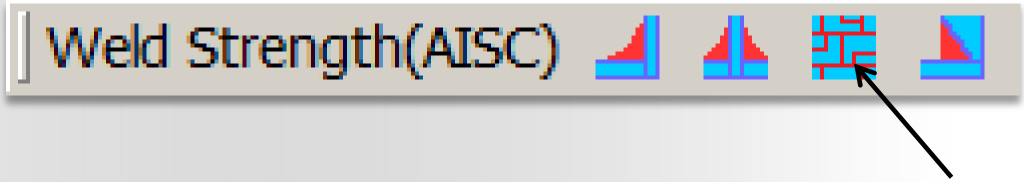




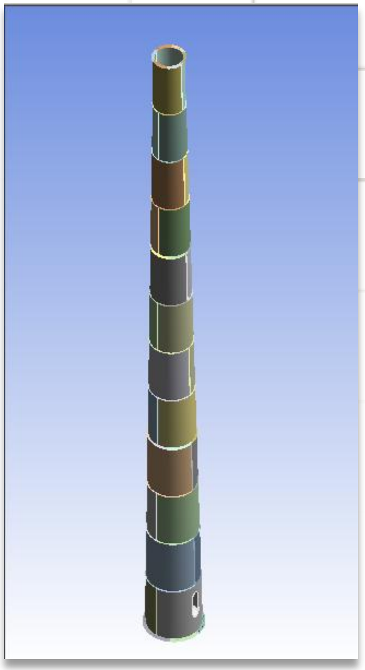
System Level Example:
Wind Turbine Tower

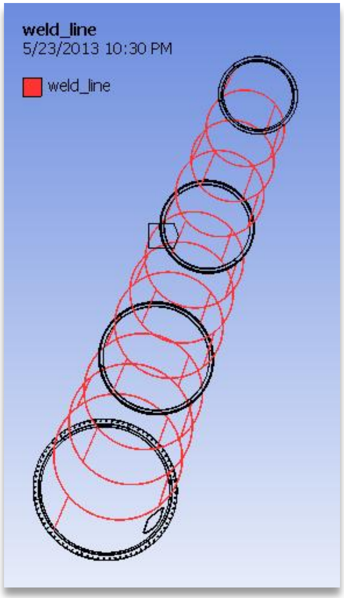
Extend to Large Model

- **Full model used for modal/vibration/seismic**
- **CJP welds expense vs. PJP**
- **Loading**
  - **Tapered cylindrical bending (blade load/moment)**
  - **Wind load varies top to bottom (not linearly)**
  - **Wind load varies circumferentially (drag)**
  - **Not an easy hand-calc**
    - **(differential equation might be an unsolved form)**



Plot all results (alpha)

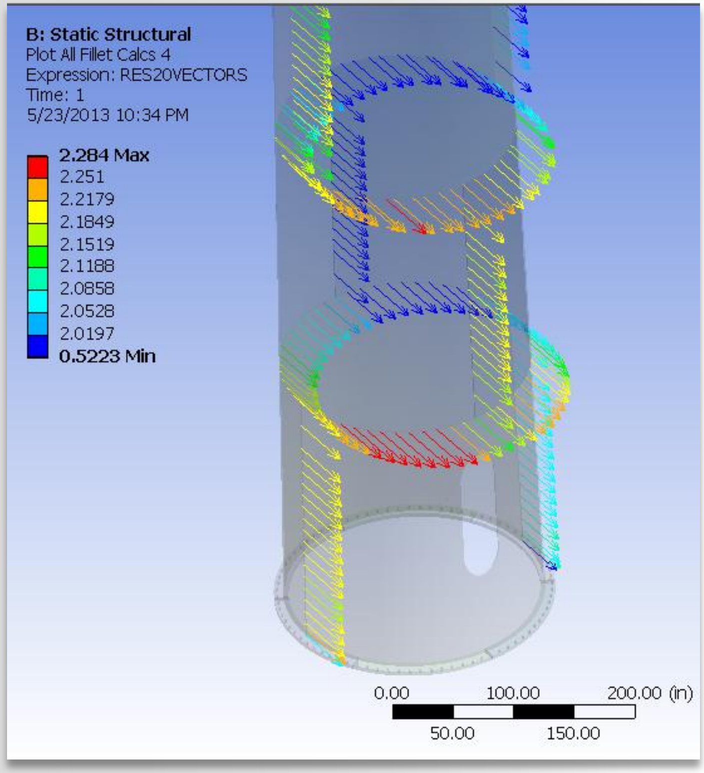


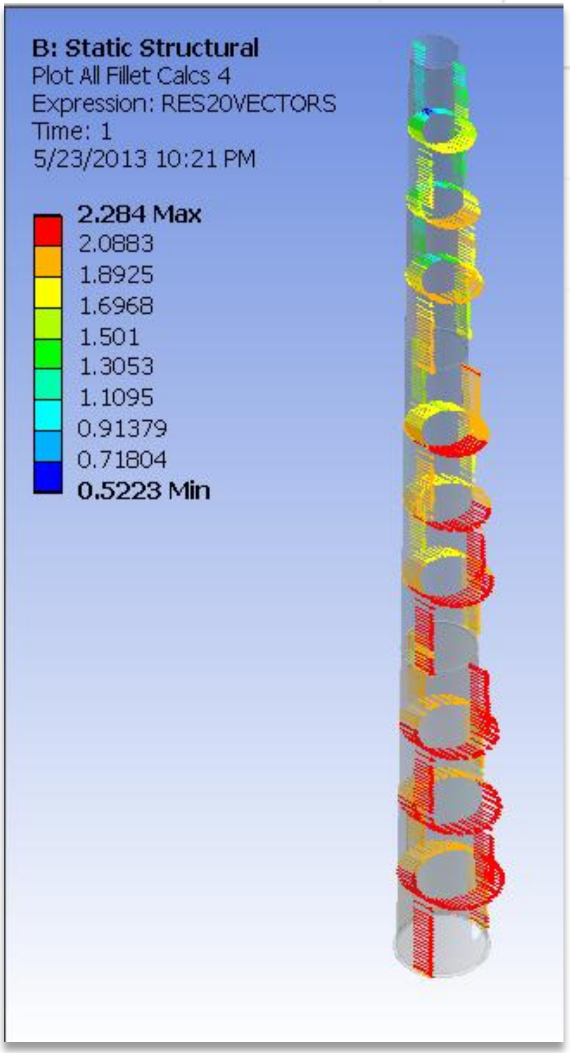


System Level Example:

Wind Turbine Tower

Material is 2" thick, so everything < 2" may have cost savings from PJP welds.





Level of Effort / Q & A

40 hrs -- Reaching (very) Basic Functionality with ACT

- No previous experience with python
- Used training materials, tutorials, and sample files
- It would've been *much* easier/quicker with a mentor or instructor

3 hrs – Later, wrote "Plot all Welds" Extension

- Not user friendly, but functional for me.

80 hrs – Writing the APDL Script

- Could've doubled or halved that depending on topology flexibility

Q & A

