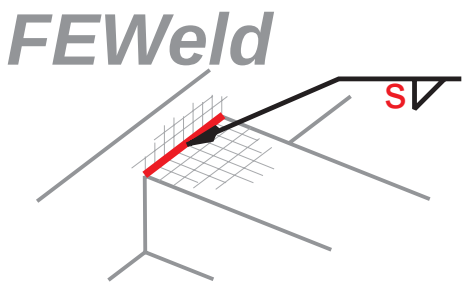
FEWeld

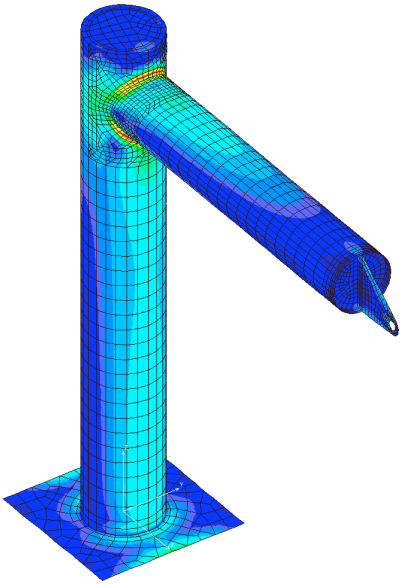


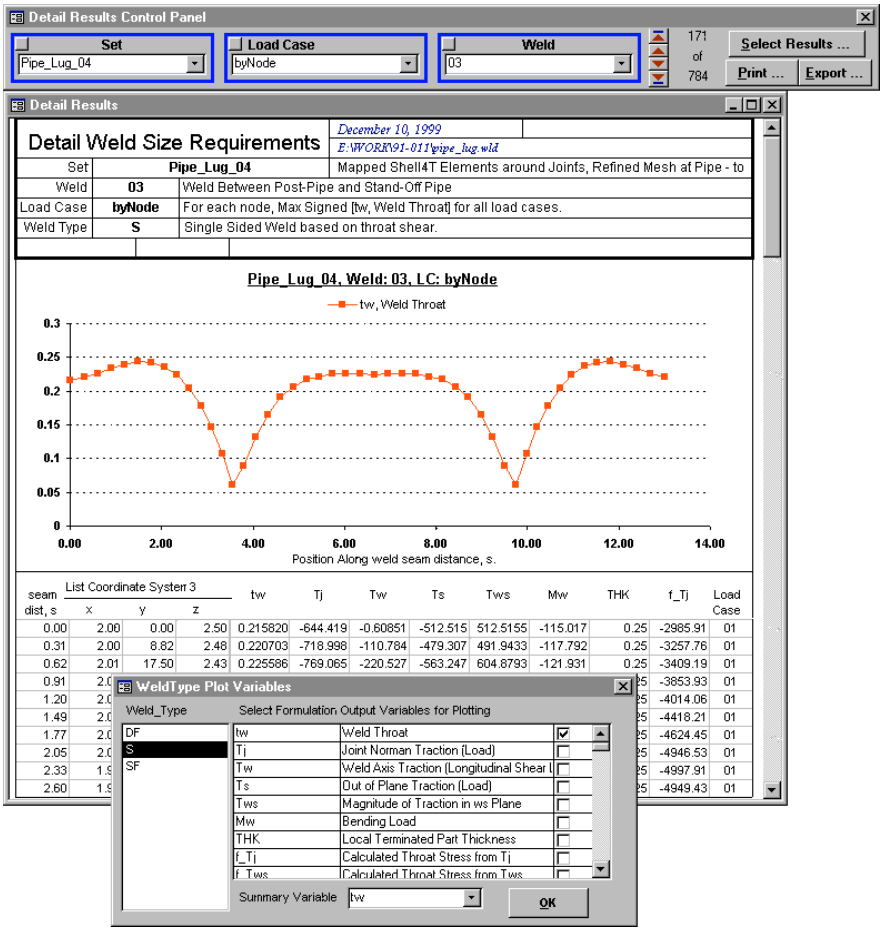
Weld Calculations from FEA

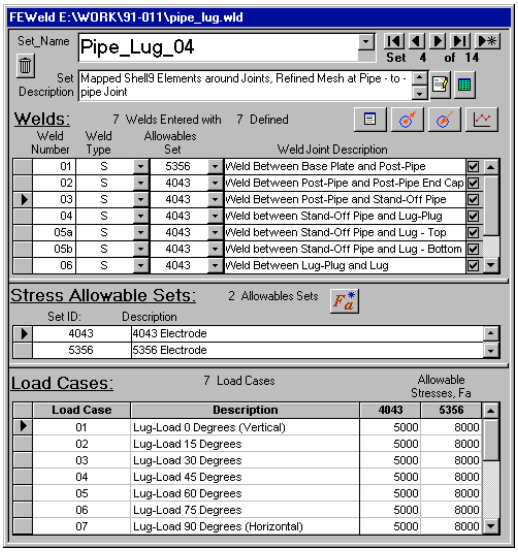
With most fabricated machinery and equipment, the welds play a critical role in the structural resistance to failure. Often, the welds comprise the critical points that determine the capacity of the structure.

FEWeld is a general mathematical tool for calculating weld parameters to meet performance criteria from the results of finite element analysis with shell elements, including your existing solved FEA models. FEWeld calculates and organizes weld size requirements and other design parameters. A database driven GUI manages multiple weldment configurations (corresponding to multiple FEA Models), welds, load cases, and evaluation criteria simply and effectively. The program comes with a standard library formulations for most combinations of Single and Double Sided Fillet and Partial Joint Penetration welds. The formulation library is user extensible with a 'C' like formulation language that will optimize weld design parameters given an objective such as minimizing weld volume and constraints such as allowable throat stress. The formulation is evaluated at each node of a weld for each load case with the local load and stress data available in the local weld joint coordinate system. The calculation results are easily browsed as plots along the joint length for each configuration-weld-load case, or as the worst case across all load cases. Professional summary reports are also generated. FEWeld is fast and easy to use.

FEWeld is implemented for Ansys and Cosmos on Windows NT, 95, 98, 2000, XP, VISTA, and 7 - 32 and 64 Bit.







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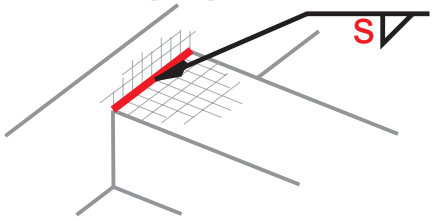
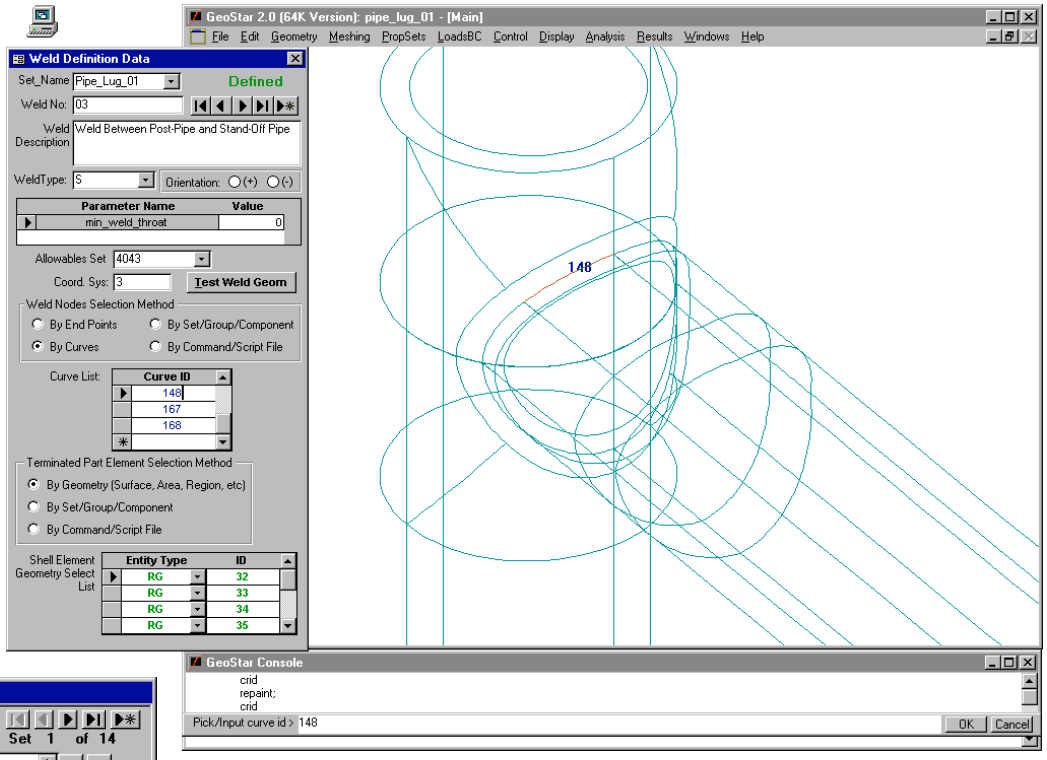
FEWeld

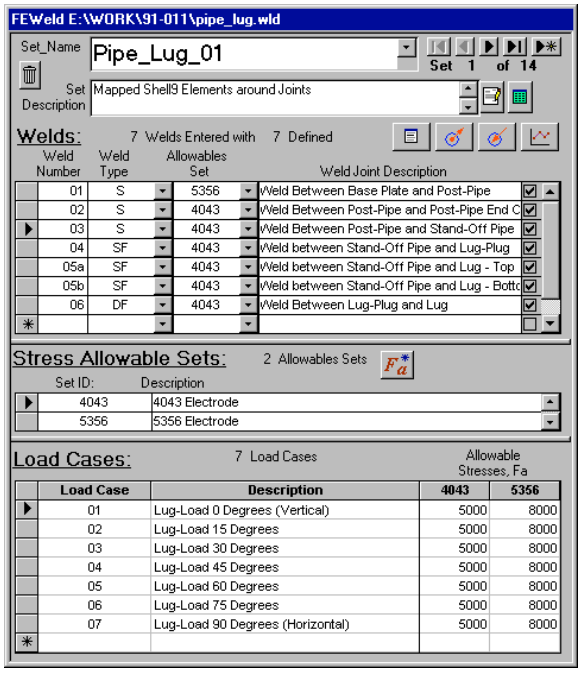


Weld Calculations from FEA

Weld Configuration Definition

Each Weld Set within a FEWeld file contains the definition of the configuration: Welds, Load Cases, and Stress Allowables. The Weld Definitions include the Weld Number, a Weld Formulation, a Stress Allowable Set, and a specification for the weld in the FEA Model. This FEA Model definition includes the weld joint nodes, selectable by associated Curves|Lines or Component|Group|Selection Set; and terminated part element selection by associated Areas|Surface|Regions or Component|Group|Selection Set. The Load Case Definitions include Load Case Numbers and a stress allowable value for each stress allowable set.

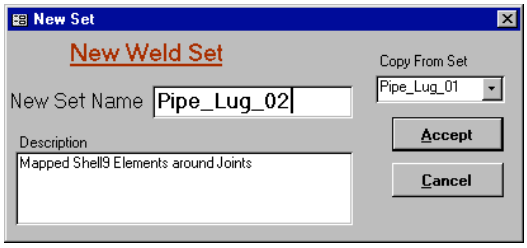




Above: Interactive specification of weld joint nodes and terminated part elements in Cosmos.

Left: The Weld Set Main Window. Contains the basic definition of the Weld Set: Welds, Load Cases, and Stress Allowables. Also displays definition status information.

Below: New weld sets can be defined as duplicates of existing weld sets to avoid effort duplication for definition of similar configurations.



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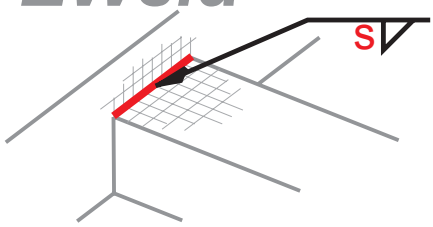
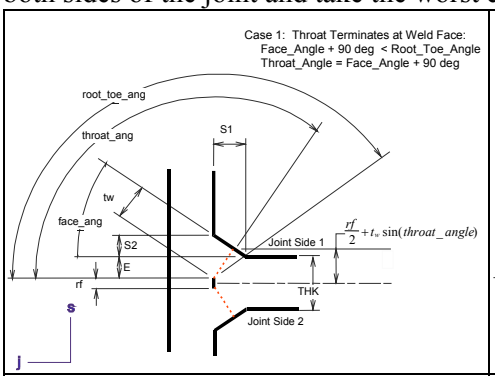


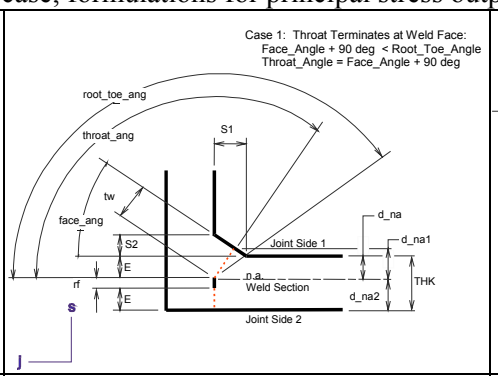
Weld Calculations from FEA

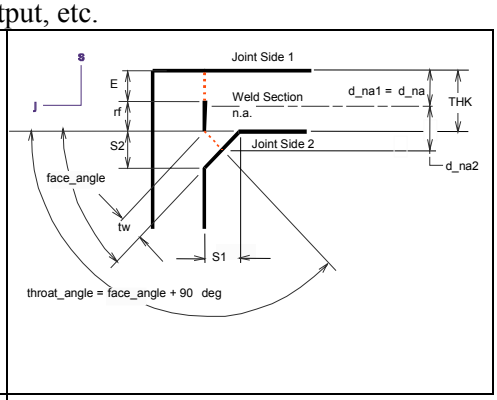
Weld Formulation Library

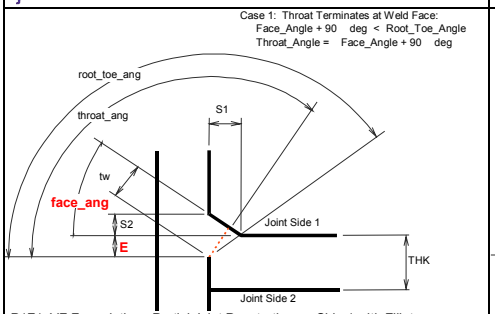
FEWeld ships with a large selection of parametric weld definitions that embody most combinations of Fillet and Partial Joint Penetration Welds. The parameters of these definitions can be solved at each node of the weld joint or input for each weld as part of the weld definition. For example, on some welds, the amount of joint prep will be predefined and the definition will solve for the fillet reinforcement size, while for others both the prep depth and reinforcement size will be variables in the solution to minimize weld volume constrained by the allowable stress.

There are also formulations to apply notch stress concentration factors for bending and for membrane load stresses on both sides of the joint and take the worst case; formulations for principal stress output, etc.

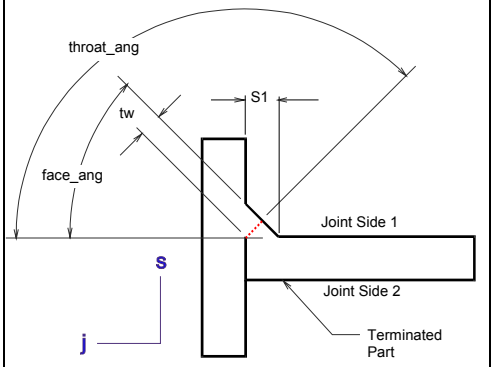


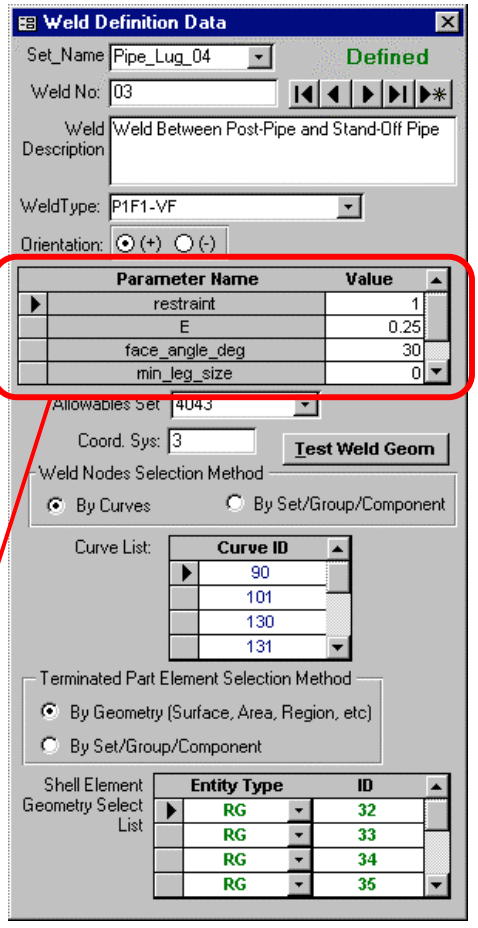


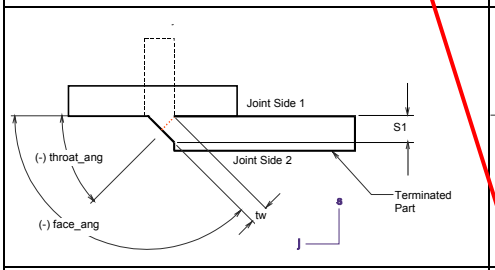


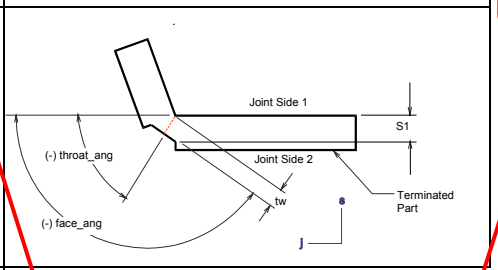


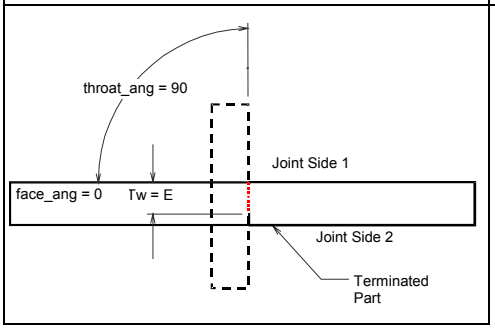
P1F1_VF Formulation: Partial Joint Penetration on Side 1 with Fillet Reinforcement. Groove size & Fillet Face angle fixed (weld parameters), fillet size calculated (VF – Variable Fillet) to minimize weld volume and keep throat shear below allowable.











Weld Formulation
Parametric Weld
Definition Variables

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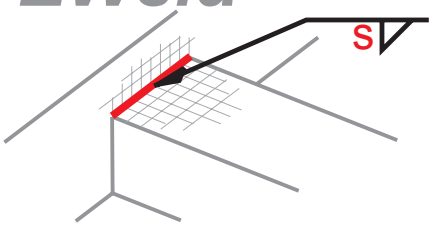
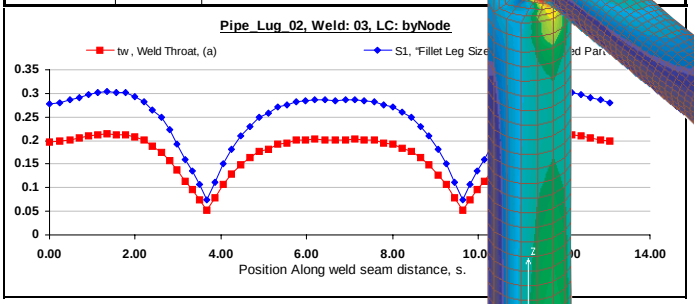


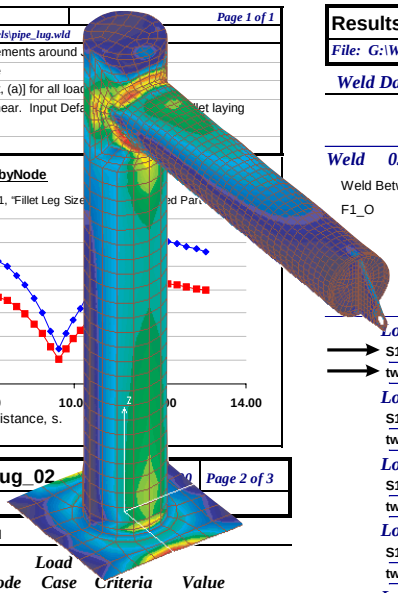
Weld Calculations from FEA

Results Presentation

FEWeld provides a variety of result reports with varying degrees of detail. The most distilled is the 'Results By Weld' report that presents the single worst case nodal value for each summarized weld parameter across all nodes and evaluation conditions (load cases). The 'Results By Load Case' report provides the worst case nodal value for each load case of each weld for each summarized weld parameter, identifying the load case with the worst value. Finally, charting of nodal weld results traversing the weld is available.

Detail Weld Results	June 04, 2000	Page 1 of 1
	G:\Work\91-011\Models\pipe_lug.wld	
Set	Pipe_Lug_02	Mapped Shell8 Elements around J
Weld	03	Weld Between Post-Pipe and Stand-Off Pipe
Load Case	byNode	For each node, Max Signed [tw, Weld Throat, (a)] for all load
Weld Type	F1_o	Single Sided Fillet Weld Based on Throat Shear. Input Defa… let laying Outside of terminated part surfaces.





Results Summary by Weld for Set: Pipe_Lug_02		Page 2 of 3
File: G:\Work\91-011\Models\pipe_lug.wld		

Weld Data: Weld_Count 7 entered with 7 Calculated

			Allowable Stress	Node	Load Case	Criteria	Value
Weld 01	Weld Between Base Plate and Post-Pipe						
F1_O	Single Sided Fillet Weld Based on Throat Shear. Input Defaults for 90 degree fillet laying Outside of terminated part surfaces.	Sa_Set_No: 5356					
	restraint 1						
	face_angle_deg 45						
	min_leg_size 0						
S1	"Fillet Leg Size (z) on Terminated P		8000	5631	04	Max Signed	.218
tw	Weld Throat, (a)		8000	5631	04	Max Signed	.154
Weld 02	Weld Between Post-Pipe and Post-Pipe End Cap						
F1_O	Single Sided Fillet Weld Based on Throat Shear. Input Defaults for 90 degree fillet laying Outside of terminated part surfaces.	Sa_Set_No: 4043					
	restraint 1						
	face_angle_deg 45						
	min_leg_size 0						
S1	"Fillet Leg Size (z) on Terminated P		5000	7147	01	Max Signed	.146
tw	Weld Throat, (a)		5000	7147	01	Max Signed	.104
Weld 03	Weld Between Post-Pipe and Stand-Off Pipe						
F1_O	Single Sided Fillet Weld Based on Throat Shear. Input Defaults for 90 degree fillet laying Outside of terminated part surfaces.	Sa_Set_No: 4043					
	restraint 1						
	face_angle_deg 45						
	min_leg_size 0						
S1	"Fillet Leg Size (z) on Terminated P		5000	8808	01	Max Signed	.304
tw	Weld Throat, (a)		5000	8808	01	Max Signed	.215
Weld 04	Weld between Stand-Off Pipe and Lug-Plug						
F1_O	Single Sided Fillet Weld Based on Throat Shear. Input Defaults for 90 degree fillet laying Outside of terminated part surfaces.	Sa_Set_No: 4043					
	restraint 1						
	face_angle_deg 45						
	min_leg_size 0						
S1	"Fillet Leg Size (z) on Terminated P		5000	868	02	Max Signed	.12
tw	Weld Throat, (a)		5000	868	02	Max Signed	.085

Results Summary by LC for Set: Pipe_Lug_02	June 04, 2000	Page 3 of 5
File: G:\Work\91-011\Models\pipe_lug.wld		

Weld Data: Weld_Count 7 entered with 7 Calculated

			Allowable Stress	Node	Criteria	Value
Weld 03	Weld Between Post-Pipe and Stand-Off Pipe					
F1_O	Single Sided Fillet Weld Based on Throat Shear. Input Defaults for 90 degree fillet laying Outside of terminated part surfaces.	Sa_Set_No: 4043				
	restraint 1					
	face_angle_deg 45					
	min_leg_size 0					
Load Case: 01	Lug-Load 0 Degrees (Vertical)					
S1	"Fillet Leg Size (z) on Terminated P		5000	8808	Max Signed	.304
tw	Weld Throat, (a)		5000	8808	Max Signed	.215
Load Case: 02	Lug-Load 15 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	8808	Max Signed	.294
tw	Weld Throat, (a)		5000	8808	Max Signed	.208
Load Case: 03	Lug-Load 30 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	8808	Max Signed	.272
tw	Weld Throat, (a)		5000	8808	Max Signed	.192
Load Case: 04	Lug-Load 45 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	8808	Max Signed	.238
tw	Weld Throat, (a)		5000	8808	Max Signed	.168
Load Case: 05	Lug-Load 60 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	7047	Max Signed	.193
tw	Weld Throat, (a)		5000	7047	Max Signed	.137
Load Case: 06	Lug-Load 75 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	7047	Max Signed	.134
tw	Weld Throat, (a)		5000	7047	Max Signed	.095
Load Case: 07	Lug-Load 90 Degrees (Horizontal)					
S1	"Fillet Leg Size (z) on Terminated P		5000	8791	Max Signed	.097
tw	Weld Throat, (a)		5000	8791	Max Signed	.068
Weld 04	Weld between Stand-Off Pipe and Lug-Plug					
F1_O	Single Sided Fillet Weld Based on Throat Shear. Input Defaults for 90 degree fillet laying Outside of terminated part surfaces.	Sa_Set_No: 4043				
	restraint 1					
	face_angle_deg 45					
	min_leg_size 0					
Load Case: 01	Lug-Load 0 Degrees (Vertical)					
S1	"Fillet Leg Size (z) on Terminated P		5000	868	Max Signed	.117
tw	Weld Throat, (a)		5000	868	Max Signed	.083
Load Case: 02	Lug-Load 15 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	868	Max Signed	.12
tw	Weld Throat, (a)		5000	868	Max Signed	.085
Load Case: 03	Lug-Load 30 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	868	Max Signed	.119
tw	Weld Throat, (a)		5000	868	Max Signed	.084
Load Case: 04	Lug-Load 45 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	868	Max Signed	.113
tw	Weld Throat, (a)		5000	868	Max Signed	.08
Load Case: 05	Lug-Load 60 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	868	Max Signed	.102
tw	Weld Throat, (a)		5000	868	Max Signed	.072
Load Case: 06	Lug-Load 75 Degrees					
S1	"Fillet Leg Size (z) on Terminated P		5000	8647	Max Signed	.095
tw	Weld Throat, (a)		5000	8647	Max Signed	.067
Load Case: 07	Lug-Load 90 Degrees (Horizontal)					
S1	"Fillet Leg Size (z) on Terminated P		5000	8647	Max Signed	.106
tw	Weld Throat, (a)		5000	8647	Max Signed	.075

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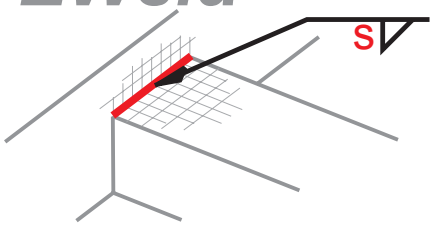
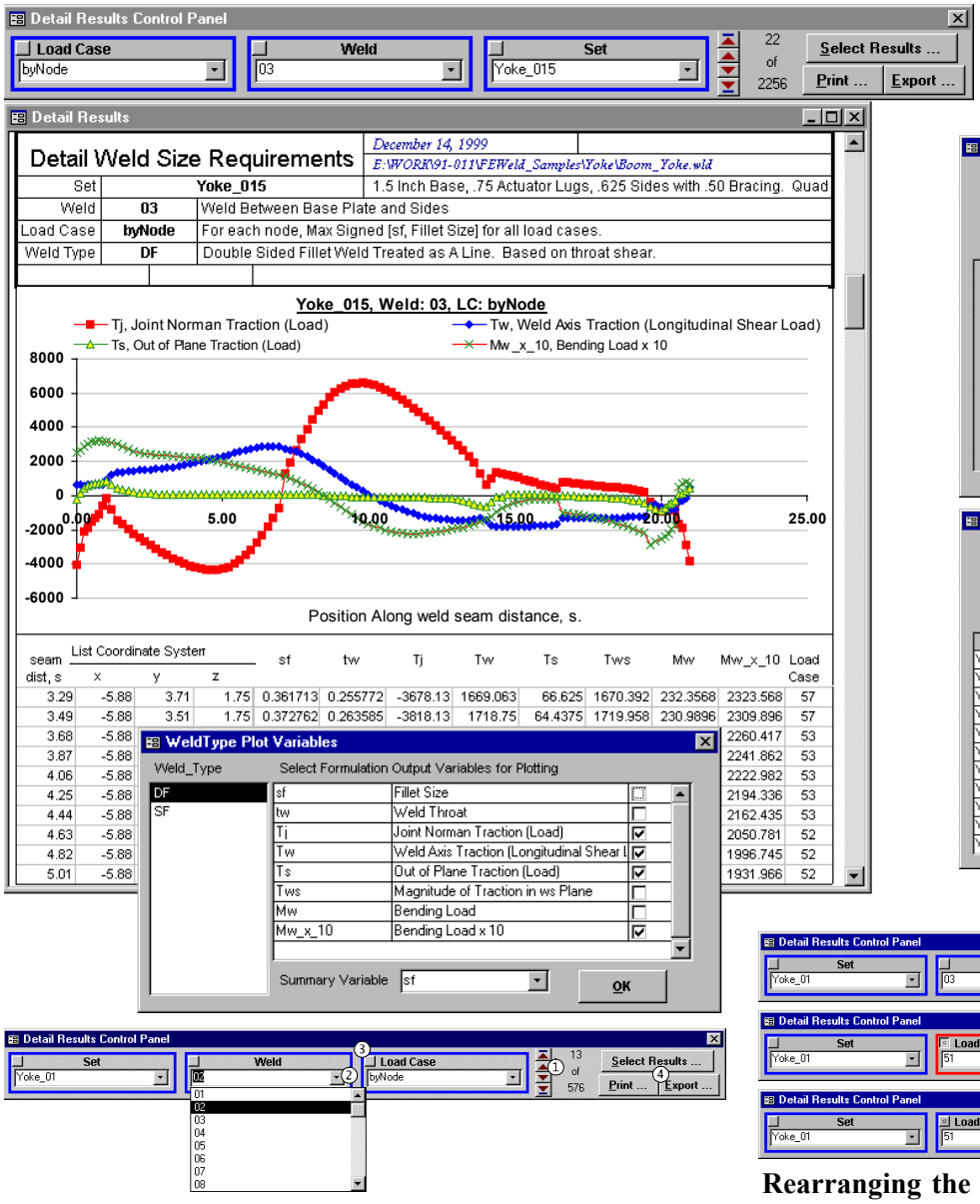
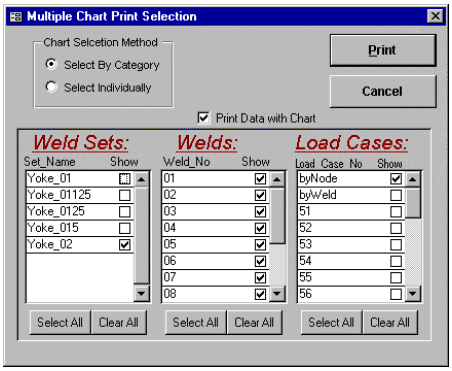


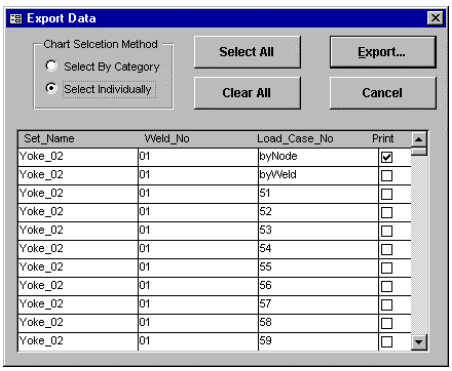
Weld Calculations from FEA

Detail Results Review

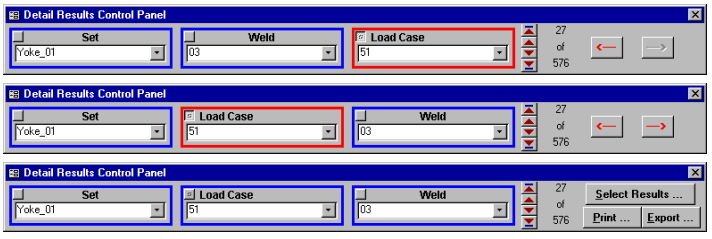
All of the stored outputs from the weld formulation are available for plotting for each Weld_Set, Weld_No, Load_Case combination, as well as plotting byNode. ByNode is a pseudo load case that plots, for a given weld in a given weld set, the maximum or minimum value across all load cases at each node for a selected formulation summary variable. The plots can be batch printed with or without data listings and the data can be batch exported. The plots themselves can be directly copied and pasted as a windows metafile, bitmap, or graph object into your favorite documentation application.







The Detail Results Control Panel: The Detail results control panel drives the Detail Results Plots. Specific Results Sets (Weld_Set, Weld_No, Load_Case) can be directly accessed, or the results can be viewed sequentially.



Rearranging the Display Sequence: The plot sequence can be rearranged to sequence through Weld Sets, Welds, and Load Cases in any order.

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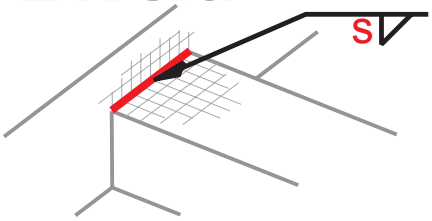
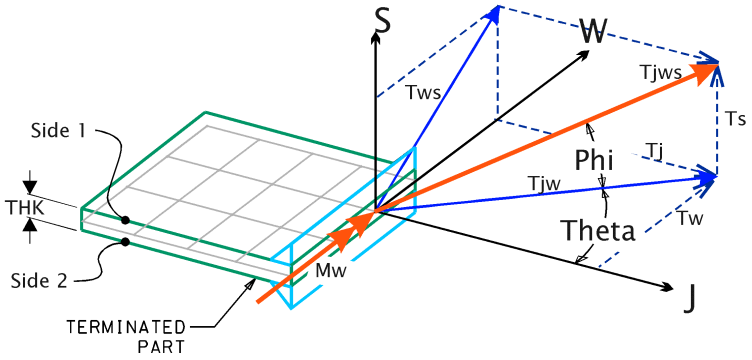


Weld Calculations from FEA

User Weld Formulations

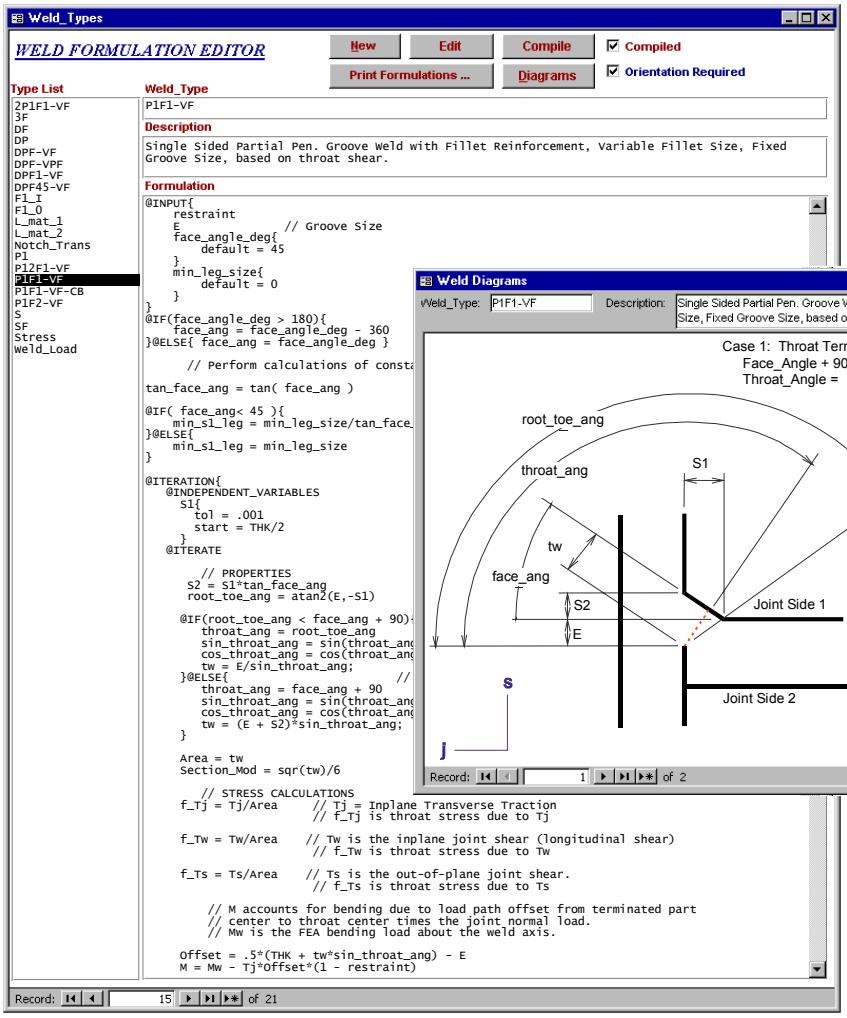
All weld calculations and results generation in FEWeld are defined in the *Weld Formulation*. The Weld Formulation is a mathematical algorithm that performs calculations at each node of each weld joint for each load case from the local loads and/or stresses in the local weld joint coordinate system, the local part thickness, and the evaluation criteria.

While FEWeld provides a library of formulations that will cover many design cases, additional formulations can be written for special situations or to modify the library formulations.



Features

- Simplified 'C' like programming syntax with C and C++ style comments.
- Input variable definitions that are definition parameters for each weld using that formulation. For example, *min_weld_size* or *skew_angle*.
- Iteration construct: Robust constrained goal searching with single and multiple independent variables.
- Outputs with descriptions for post processing.
- Optional summary data for Outputs: max or min signed or unsigned summaries store summary data: *ByNode* - worst case (max or min) load case for each node of each weld, used for xy-plots; *ByLC* - worst case node of each weld for each load case; and *ByWeld* - worst case nodal value for each weld across all load cases.
- Weld Orientation: Can account for weld elemental orientation to get load sense transformed into the weld joint coordinate system correctly.
- Wide variety of stress, load, criteria, and geometry data are available as global variables.
- Large set of arithmetic, trigonometric, and conditional functions built in.



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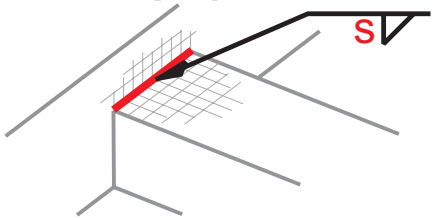
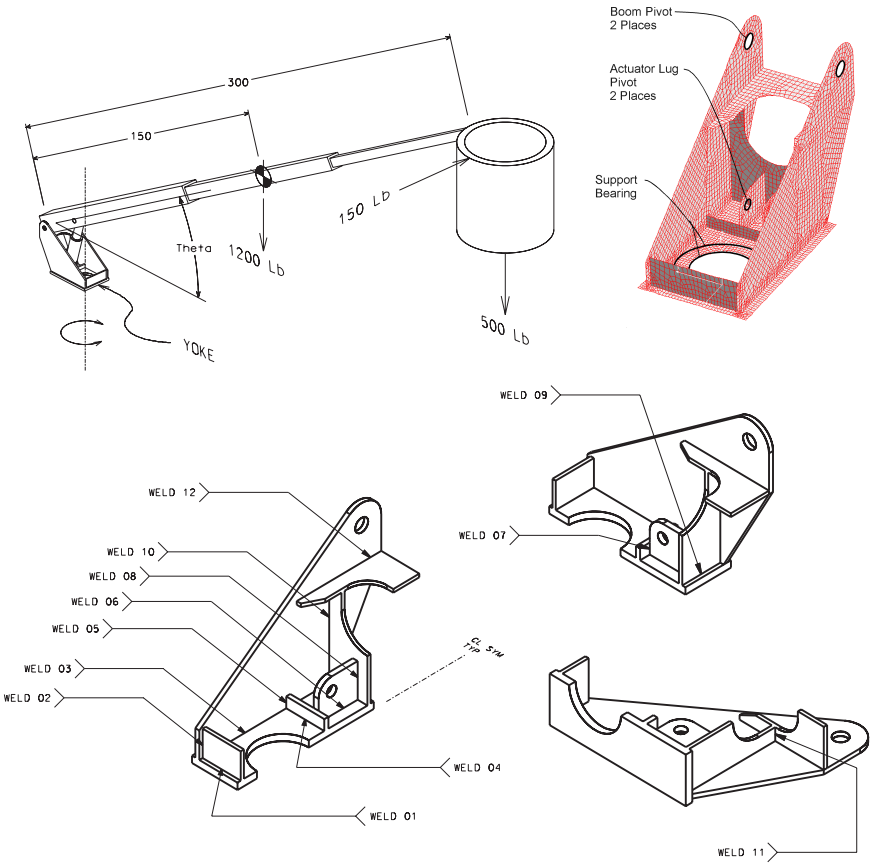


Weld Calculations from FEA

Evaluation of Welds with FEA

Finite element analysis (FEA) has become a practical method of Predicting stresses and deflection for loaded structures. FEA accurately Identifies the load path, which can be difficult using classical analysis with Complex structures. FEA shell element models are effective for predicting Loads in weldments fabricated from plate, sheet, structural shapes, and tube.

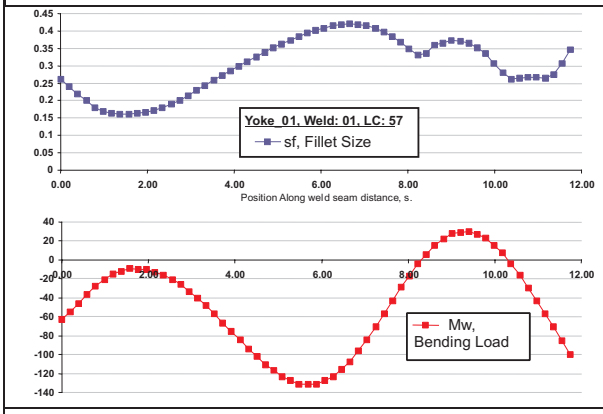
Evaluation of effect of baseplate thickness on weld loads and size requirements for boom yoke



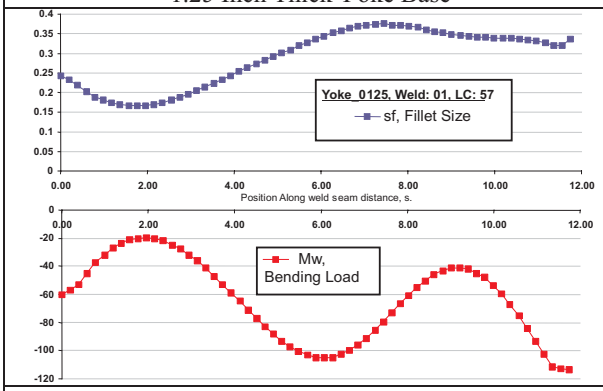
WeldSizeResults

Weld_ No	WeldType	Sa_Set	Description	1Inch Base	1.5Inch Base	2Inch Base
01	SF	Class2	Weld Between Front Stiffener and Base Plate	.421	.366	.402
02	DF	Class1	Weld Between Front Stiffener and LeftSide	.604	.388	.274
03	DF	Class1	Weld Between Base Plate and Sides	.84	.543	.468
04	DF	Class1	Weld between Base Plate and Middle Stiffener	.402	.309	.245
05	DF	Class1	Weld Between Middle Stiffener and Side Plate	1.117	.736	.534
06	DF&SF	Class2	Weld Between Actuater Lug and Base Plate	.25(DF)	.186(DF)	.485(SF)
07	DF	Class1	Weld Between Actuator Lug and Middle Stiffener	.584	.414	.328
08	DF	Class1	Weld Between Actuator Lug and Back Stiffener	.672	.431	.306
09	DF	Class1	Weld Between Back Stiffener and Base Plate	.11	.125	.115
10	DF	Class1	Weld Between Back Stiffener and Side Plate	.122	.091	.08
11	DF	Class1	Weld Between Back Stiffener and Upper Stiffener	.108	.105	.103
12	DF	Class1	Weld Between Upper Stiffener and Side Plate	.399	.258	.196

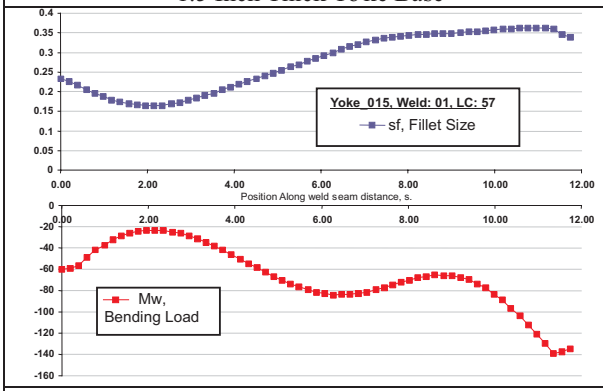
1 Inch Thick Yoke Base



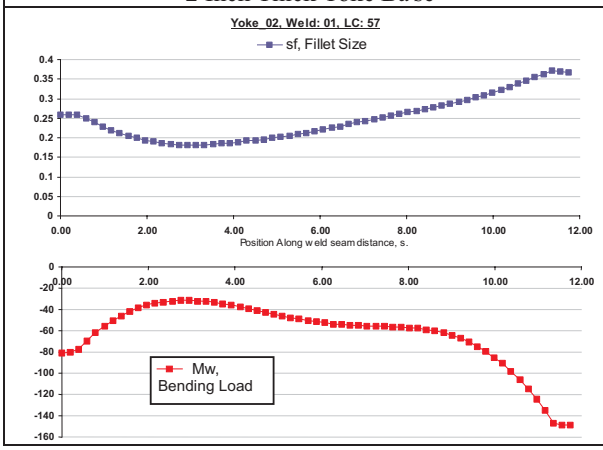
1.25 Inch Thick Yoke Base



1.5 Inch Thick Yoke Base



2 Inch Thick Yoke Base



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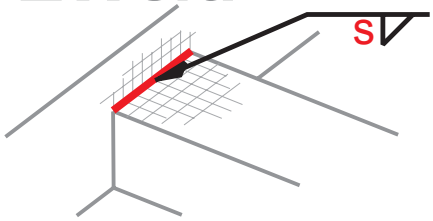
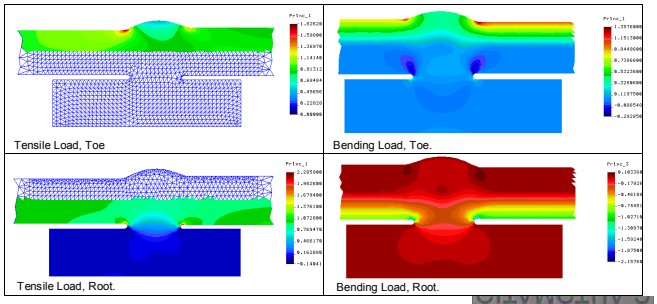
FEWeld



Weld Calculations from FEA

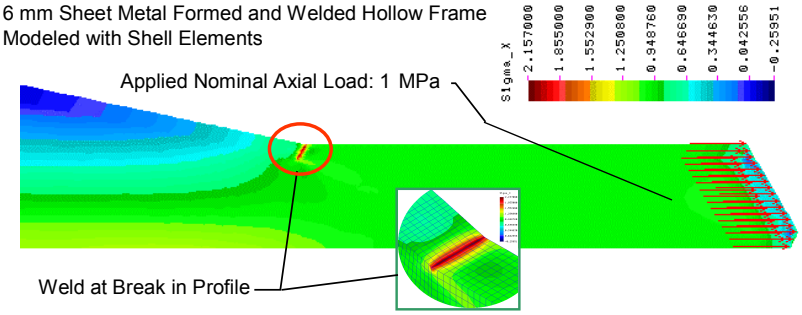
Notch Stress Example

The following example demonstrates combination of geometric weld joint loads with effective notch stress concentration factors to predict the effective notch stress in the structure from the FEA shell element results. The example also illustrates the ease with which new weld formulations are incorporated into the FEWeld environment.



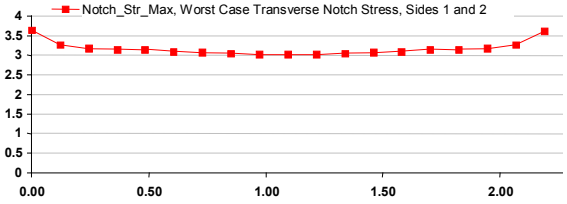
	KTENSION	KBENDING
TOE	1.59	1.36
ROOT	2.45	-2.16

6 mm Sheet Metal Formed and Welded Hollow Frame
Modeled with Shell Elements

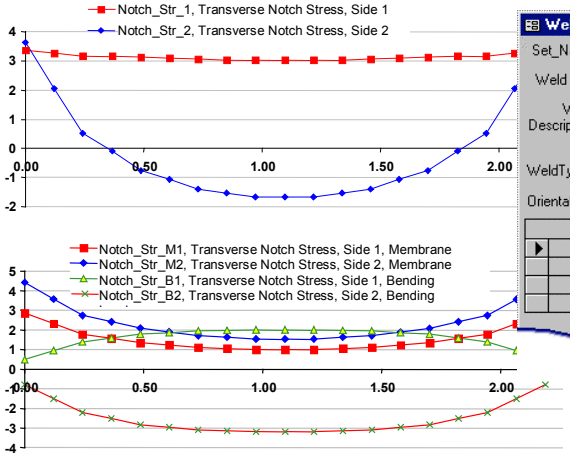


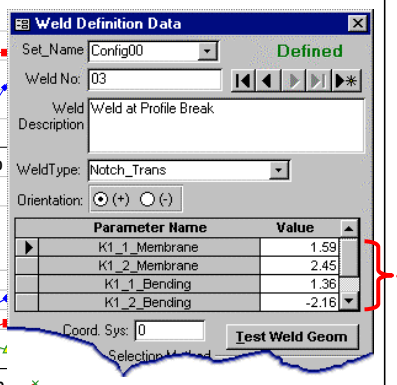
Above is a FEA shell element model of a welded sheet metal structure with applied loading such that the nominal stress is 1.0 Mpa. The predicted structural (geometric effects, not counting the weld notch effect.) stress is 2.16 Mpa at the weld on the outside surface

Left is a plane strain FEA model used to estimate the effective notch stress concentration factors on each side of the joint for both Membrane and Bending Loading. The loading applied was such that the nominal stress in the material without the notch would be 1 MPa.



The combined notch and geometric stresses are shown to the left. To the right is the formulation used for the calculation.





Above shows the match-up between the weld formulation input parameters and weld definitions.

```
/******** COMMENT BLOCK ****
    Name:  Notch_Trans
    Weld Side 1 and 2 Stress Concentration Factors for Membrane
    and Bending Applied to Transverse Geometric Stresses and Added.
    Criteria:
        None, Stress Result with Notch Factors Applied and Returned.
    User Inputs:
        K1_1_Membrane:  Transverse Notch Stress Concentration
                        Factor for Membrane Stresses on Joint Side 1
        K1_2_Membrane:  Transverse Notch Stress Concentration
                        Factor for Membrane Stresses on Joint Side 2
        K1_1_Bending:   Transverse Notch Stress Concentration
                        Factor for Bending Stresses on Joint Side 1
        K1_2_Bending:   Transverse Notch Stress Concentration
                         Factor for Bending Stresses on Joint Side 2
    Calculated Variables:
        Notch_Str_1         - The total Notch Stress on Side 1 due to
                              Transverse Membrane and Bending Loads
        Notch_Str_2         - The total Notch Stress on Side 2 due to
                              Transverse Membrane and Bending Loads
        Notch_Str_Max       - The Maximum of Snotch_1 and Snotch_2
        Notch_Str_M1        - The Notch Stress Due to Transverse
                              Membrane Stresses on Side 1
        Notch_Str_M2        - The Notch Stress Due to Transverse
                              Membrane Stresses on Side 2
        Notch_Str_B1        - The Notch Stress Due to Transverse
                              Bending Stresses on Side 1
        Notch_Str_B2        - The Notch Stress Due to Transverse
                              Bending Stresses on Side 2
        Str_Mem             - The Transverse Membrane Stress
        Str_Bend            - The Transverse Stress Due to Bending
    Joint Types: Any
******** END COMMENT BLOCK *********/
@INPUT{
    K1_1_Membrane
    K1_2_Membrane
    K1_1_Bending
    K1_2_Bending
}
Str_Mem = (Sjj_1 + Sjj_2)/2
Str_Bend = Sjj_1 -  Str_Mem
Notch_Str_M1 = Str_Mem*K1_1_Membrane
Notch_Str_M2 = Str_Mem*K1_2_Membrane
Notch_Str_B1 =  Str_Bend*K1_1_Bending
Notch_Str_B2 =  Str_Bend*K1_2_Bending
Notch_Str_1 = Notch_Str_M1 + Notch_Str_B1
Notch_Str_2 = Notch_Str_M2 + Notch_Str_B2
@IF(Notch_Str_1 >= Notch_Str_2){
    Notch_Str_Max = Notch_Str_1
}@ELSE{
    Notch_Str_Max = Notch_Str_2
}
@STORE{
    Notch_Str_Max{
      description = "Worst Case Transverse Notch Stress, Sides 1 and 2"
      plot
      summarize max unsigned
    }
    Notch_Str_1{
        description = "Transverse Notch Stress, Side 1"
        summarize max unsigned
    }
    Notch_Str_2{
        description = "Transverse Notch Stress, Side 2"
        summarize max unsigned
    }
    Notch_Str_M1{ "Transverse Notch Stress, Side 1, Membrane Load" }
    Notch_Str_M2{ "Transverse Notch Stress, Side 2, Membrane Load" }
    Notch_Str_B1{ "Transverse Notch Stress, Side 1, Bending Load" }
    Notch_Str_B2{ "Transverse Notch Stress, Side 2, Bending Load" }
    Str_Mem{ "Transverse Structural (Geometric) Membrane Stress" }
    Str_Bend{ "Transverse Structural (Geometric) Bending Stress" }
}
```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