

# New efficient method for weld strength evaluation according to Eurocode 3 using finite element method in ANSYS Mechanical

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# Saxat från “Svetsen” #2 2016

## Färdplan för fogningsbranschen [www.svets.se/fardplan](http://www.svets.se/fardplan)

**Mål 3** Öka användningen av simuleringsstöd och moderna verktyg för konstruktion och beredning av svetsade och sammanfogade produkter

...

Kunskapsnivån måste höjas inom konstruktion och beredning för att nya förbättrade tillverkningsprocesser ska kunna utnyttjas optimalt.

### Initiativ

- Utbilda verksamma konstruktörer och stärka högskoleutbildningen inom konstruktion och beredning av svetsade och fogade produkter.
- Öka användningen av simuleringsstöd, beräkningsverktyg för konstruktion och verktyg för beredning av svetsade och sammanfogade produkter.
- Ge särskilt stöd till små företag att öka användningen av dessa verktyg.



Svetsning och fognings-  
teknik är nyckeltekniker  
för många av landets  
industriföretag. Svets-  
ningen är ojämförligt  
störst av dessa och en  
central och betydelsefull  
faktor för fortsatt fram-  
gång för svensk industri.

En färdplan för vår bransch är en förutsättning för att  
svetsning och fogningsbranschen ska kunna utvecklas och  
bli en konkurrenskraftig del av den svenska ekonomin. Den  
ska ge en tydlig bild av branschens utmaningar och möjligheter  
och vara en vägledning för de beslut som ska fattas för att  
färdplanen ska kunna uppnås.

Den svenska svets- och fogningsbranschen har en lång och  
rik historia. Den har varit en viktig del av den svenska  
ekonomin och har bidragit till den svenska tekniska  
kunskapsutvecklingen. Den har också varit en viktig  
del av den svenska exporten.

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# Background

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- Welded structures are common in “heavy duty” structures and the need to evaluate according to specific codes is important.
- To assess the weld strength the load distribution of the structure has to be evaluated in order to get the forces on each weld segment.
- One example of code is the Eurocode 3.

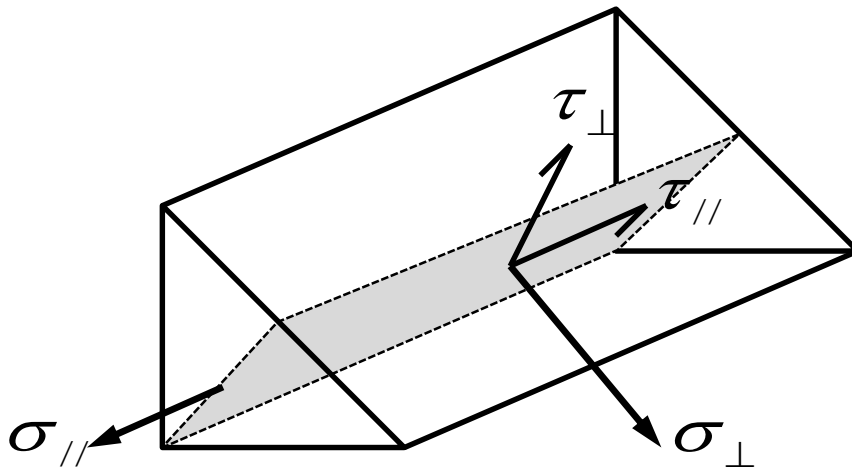


# Eurocode 3 weld assessment due to static loads



## Directional method:

A uniform distribution of stress is assumed on the throat section of the weld, leading to the normal stresses and shear stresses shown below:



$\sigma_{\perp}$  = normal stress perpendicular to weld throat plane

$\sigma_{//}$  = normal stress parallel to weld axis

$\tau_{\perp}$  = shear stress in plane, perpendicular to weld axis

$\tau_{//}$  = shear stress in plane, parallel to weld axis

# Eurocode 3 weld assessment due to static loads



## Directional method:

The stress component  $\sigma_{//}$  is not considered in calculations of weld resistance

The weld seam is assumed to have sufficient strength if both conditions below are fulfilled:

$$\sqrt{\sigma_{\perp}^2 + 3 \times (\tau_{\perp}^2 + \tau_{//}^2)} \leq \frac{f_u}{\beta_w \times \gamma_{M2}} \quad \text{and} \quad \sigma_{\perp} \leq \frac{0.9 \times f_u}{\gamma_{M2}}$$

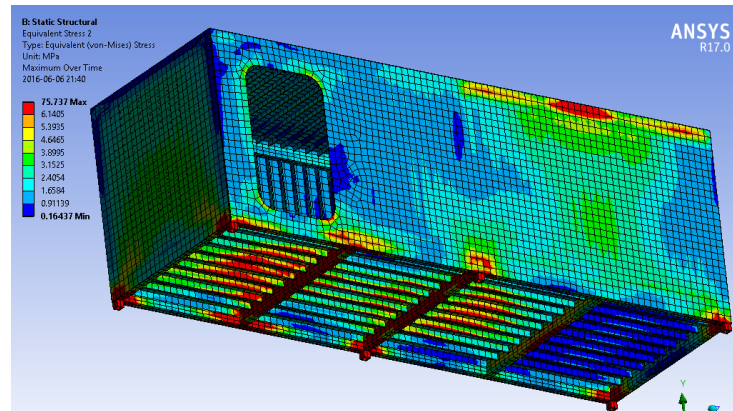
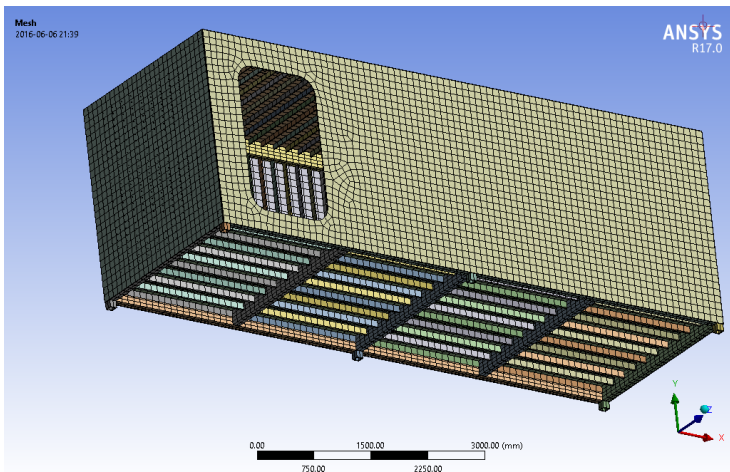
$f_u$  = nominal ultimate tensile strength

$\beta_w$  = correlation factor for material according to table 4.1

$\gamma_{M2}$  = partial safety factor for joints.  $\gamma_{M2} = 1.25$  for welded connections

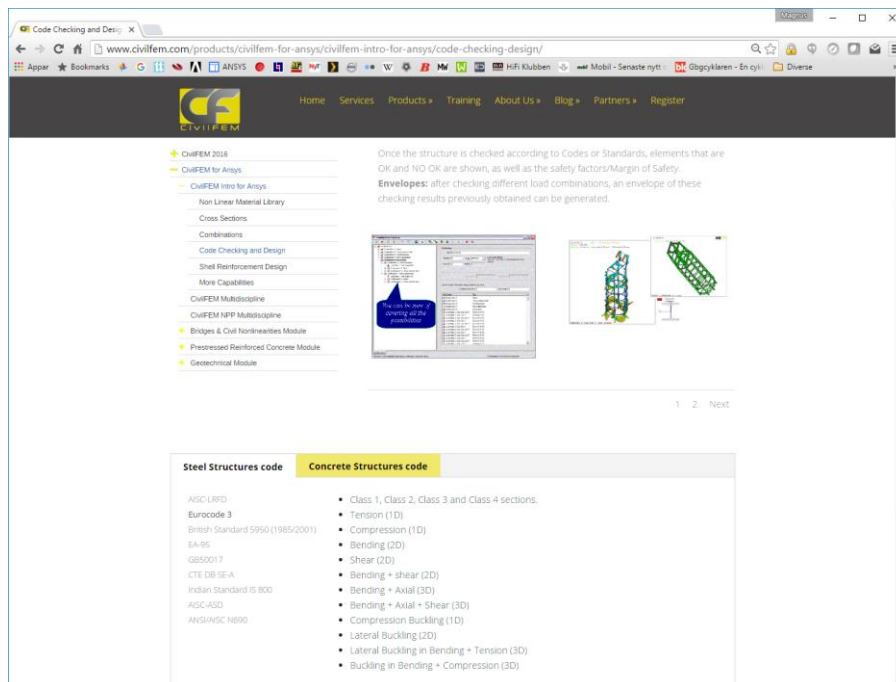
# FE analysis of welded structures

- With FEM the “correct” load distribution can be derived even for very complex geometry and multiple load cases. However evaluation of a FE models according to weld codes are a tedious and time consuming work involving extraction of section forces in local coordinate systems and safety factor calculation or dimensioning of each weld throat thickness.
- This sample container has ~1000 fillet welds and three load cases to evaluate. Which weld and load case is critical?



# Current limitations of FE analysis of welded structures

- The evaluation according to specific codes are usually not included in general purpose programs such as ANSYS.
- Code check is available in e.g. Civil FEM but not for weld connections.
- The possibility to optimize a welded structure is therefore limited.





# A new solution in ANSYS



- ANSYS has opened up for third party developers to create apps that integrate into ANSYS products such as Mechanical, Design Modeler, Design Xplorer, Meshing etc.
- With apps you can create e.g. custom loads and post processing objects like any standard ANSYS function.
- ANSYS has a market place for apps, both free and paid.  
EDRMedeso is a big contributor

A screenshot of the ANSYS ACT Application Store interface. The interface displays a grid of application cards. Each card includes an icon, the app name, version, target application, and a brief description. The "Weld Strength 17.0" app by EDR Medeso is highlighted with a red circle. The "Weld Strength 17.0" app card shows the EDR Medeso logo and an "Info" button. Other apps visible include "UPF", "View Controls 17", "Virtual.PYXIS 17", "Wind Tunnel Design 17.0", and "Windkessel 17.0". The ANSYS logo is also present on several cards.

App Name	Version	Target Application	Description	Contributor
UPF	Version: 170.4	Mechanical	Allow for the use of User Programmable Features (UPF) within Workbench	ANSYS
View Controls 17	Version: 170.1	Mechanical	Control easily rotating angle and model view and print title on the screen in Mechanical	TAE SUNG S&E, INC.
Virtual.PYXIS 17	Version: 170.1.2	Mechanical	Topology optimization to create innovative components with minimum weight, maximum stiffness or maximum vibration frequency	ESSS
Weld Strength 17.0	Version: 170.5	Mechanical	Post-processing tool to evaluate weld strength according to Eurocode 3 for fillet and butt welds. All types of FE-models can be used: shell/solid, contact/multi-body, with or without weld geometry	EDR MEDESO
Wind Tunnel Design 17.0	Version: 170.1	AIM	Enable simulation of aerodynamic effects on components through a virtual wind tunnel	ANSYS
Windkessel 17.0	Version: 170.1	Fluent	Couple 2- and 3-element Windkessel models to hemodynamics simulations, allowing for realistic and customizable boundary conditions using Fluent	ANSYS





# Weld Strength by EDRMedeso



- Weld strength according to Eurocode 3 or user criteria
- Easy to identify your all welds in one result object
- Set the weld throat thickness or let ANSYS calculate the minimum weld throat thickness
- Contour plots and detailed results listing for each edge in the weld selection

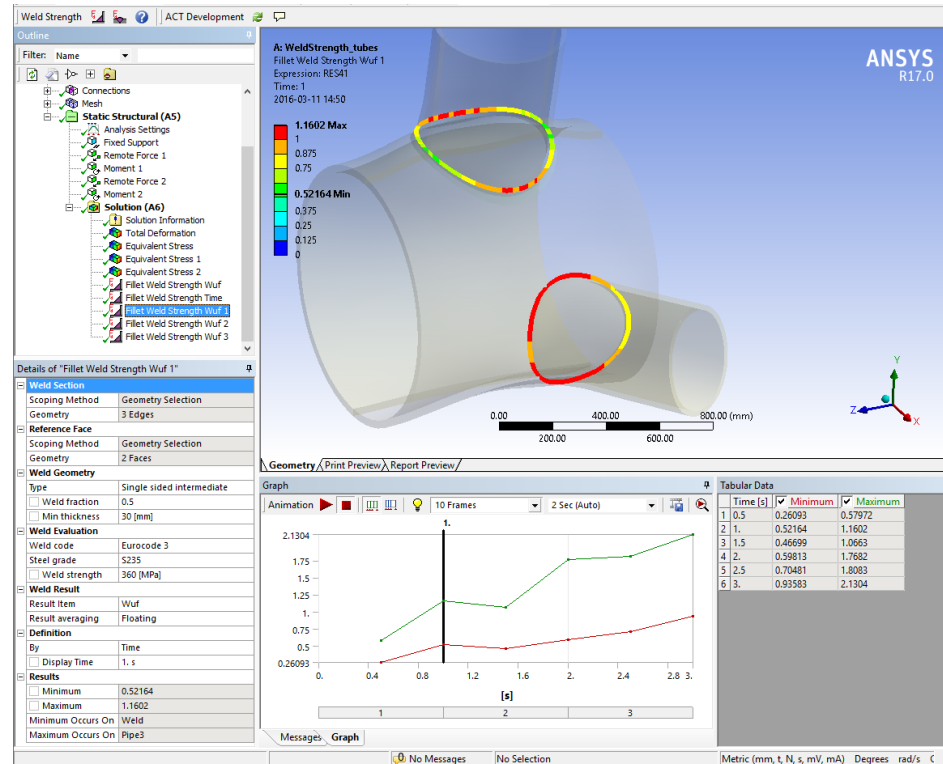
D:\Magnus\ANSYS\ACT\_HeavyDuty\HeavyDuty2\_files\dp0\SYS-2\MECH\Weld\_Strength\_1.lis - Notepad++

```

1 Static Structural
2 Weld Strength
3 Result time: 3
4 Sect Id |Seqv_avg |SX_avg |Sx_avg |Wuf_max |a_min |FX |FY |FZ
5 | | [MPa] | [MPa] | [-] | [-] | [mm] | [aolu] | [aolu] | [aolu]
6 -----
7 176 409.0 163.2 1.136 0.668 30 1.5287e+06 3.9512e+06 3.9831e+06
8 178 408.4 162.0 1.135 0.698 30 1.5055e+06 3.9680e+06 3.9652e+06
9 199 277.8 93.5 0.772 1.123 30 1.2215e+06 4.9999e+06 3.9807e+06
10

```

Normal text file length: 701 lines: 10 Ln: 1 Col: 1 Sel: 0|0 Dos/Windows UTF-8 w/o BOM INS





# Weld Strength Usage

- Build the FE-model as normal. All types of elements and connections are supported (see next slide)
- Insert the “Fillet weld” or “Butt weld” results object
- Define weld section, geometry, evaluation, result item, result averaging and time step.
- Solve the model and review the results.

The screenshot shows the ANSYS Mechanical Enterprise PrepPost interface. The top toolbar includes a 'Weld Strength' icon, which is highlighted with a red box. Below the toolbar, the 'Details of "Fillet Weld Strength Wuf 1"' panel is visible, showing various configuration options for the weld strength analysis. The panel is divided into several sections: Weld Section, Reference Face, Weld Geometry, Weld Evaluation, Weld Result, Definition, and Results. Each section contains specific parameters and values for the analysis.

**Weld Strength**

**Details of "Fillet Weld Strength Wuf 1"**

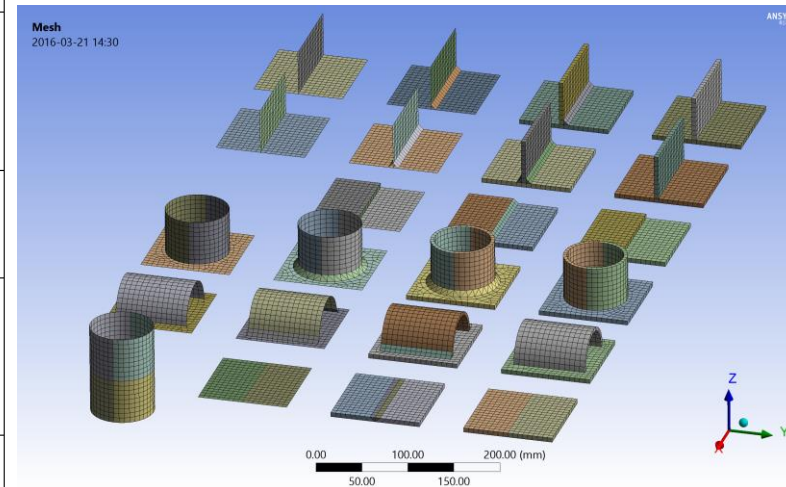
- Weld Section**
  - Scoping Method: Geometry Selection
  - Geometry: 3 Edges
- Reference Face**
  - Scoping Method: Geometry Selection
  - Geometry: 2 Faces
- Weld Geometry**
  - Type: Single sided intermediate
  - ☐ Weld fraction: 0.5
  - ☐ Min thickness: 30 [mm]
- Weld Evaluation**
  - Weld code: Eurocode 3
  - Steel grade: S235
  - ☐ Weld strength: 360 [MPa]
- Weld Result**
  - Result Item: Wuf
  - Result averaging: Floating
- Definition**
  - By: Time
  - ☐ Display Time: 1. s
- Results**
  - ☐ Minimum: 0.52164
  - ☐ Maximum: 1.1602
  - Minimum Occurs On: Weld
  - Maximum Occurs On: Pipe3



# Weld Strength Pictorial guide

Table of valid weld geometries and their Type, Weld section and Reference Face

Shell model (no weld elements)	Shell model (weld elements)	Solid model (weld elements)	Solid model (no weld elements)
Type: Single sided	Type: Single sided	Type: Single sided	Type: Single sided
Type: Double sided	Type: Double sided	Type: Single sided	Type: Double sided
	Type: Single sided	Type: Single sided	Type: Single sided
Type: Single sided	Type: Single sided	Type: Single sided	Type: Single sided
Type: Single sided	Type: Single sided	Type: Single sided	Type: Single sided
Type: Butt weld	Type: Butt weld	Type: Butt weld	Type: Butt weld





# Weld Strength Results

- In the solution folder, a result summary text file for each result object is created with the same name as the result object. See example below:

Static Structural

Fillet Weld Strength Contact Solid Weld

Result time: 1

Weld Type: Single sided

Weld Code: Eurocode 3

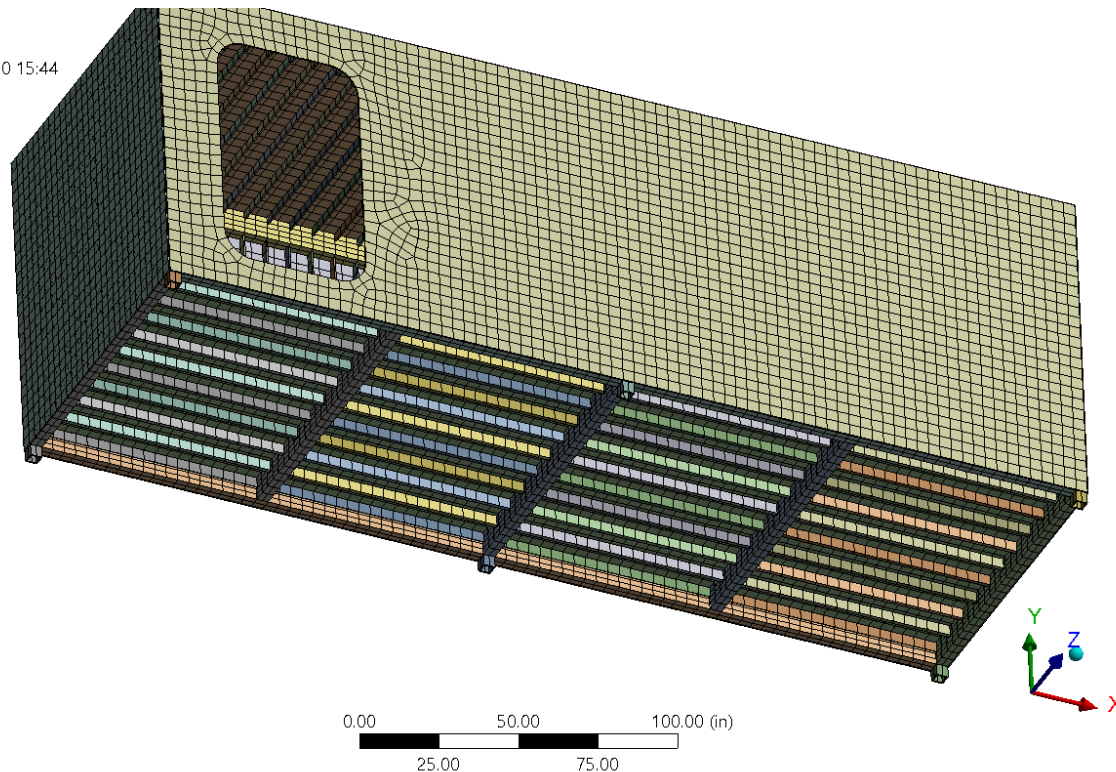
Sect Id	Seqv_avg   [MPa]	Snorm_avg   [MPa]	Wuf_avg   [-]	Wuf_max   [-]	a_min   [mm]	FX (radial)   [N]	FY (parall)   [N]	FZ (axial)   [N]
388	113.3	62.5	0.482	0.500	3	5.7712e+03	4.2131e-05	2.4986e+04
192	141.6	62.5	0.603	0.625	3	5.7713e+03	4.9157e-05	2.4986e+04

Sect Id:	Weld Section edge "reference_id". (Use selection information on an edge with Beta options)
Seqv_avg:	Average equivalent stress of the whole weld section, $\sigma_{Eqv} = \sqrt{\sigma_{\perp}^2 + 3 \times (\tau_{\perp}^2 + \tau_{\parallel}^2)}$
Snorm_avg:	Average normal stress of the whole weld section, $\sigma_{\perp}$
Wuf_avg:	Average weld utilization factor of the whole weld based on total load and weld area.
Wuf_max:	Maximum weld utilization factor along the weld based on local moving average.
a_min:	Calculated minimum needed weld throat thickness to fulfil $Wuf < 1$ . This value is calculated from the section average and may differ compared to the floating average thickness results.
FX:	Shear force normal or radial to the weld section reference face (listed in solution unit, e.g. [N])
FY:	Shear force parallel or tangential to the weld section (listed in solution unit, e.g. [N])
FZ:	In plane axial force perpendicular to the weld section (listed in solution unit, e.g. [N])

# DEMO Model

- Container, 210 parts, double sided welds, 920 weld segments
- Three load steps (acceleration loads), solution time 70 sec (small model)

**Mesh**  
2016-08-10 15:44

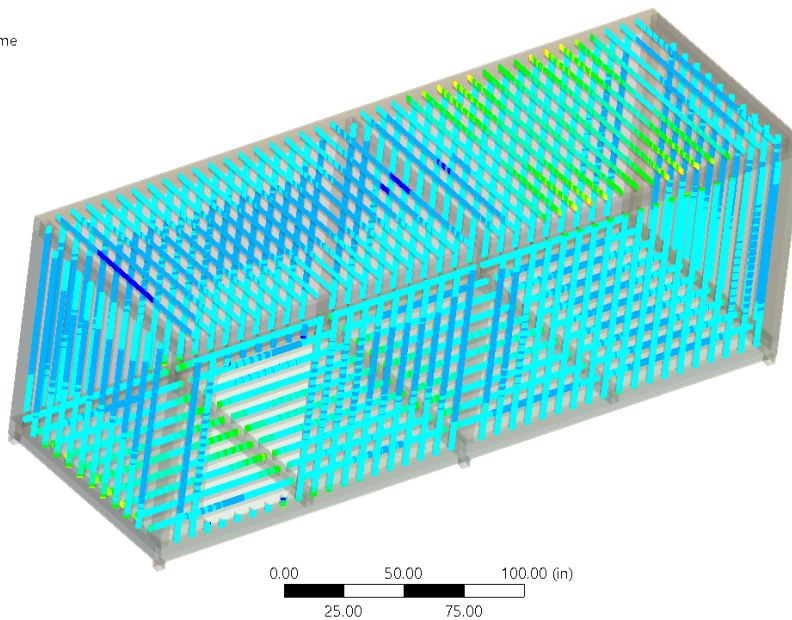
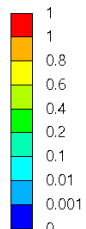




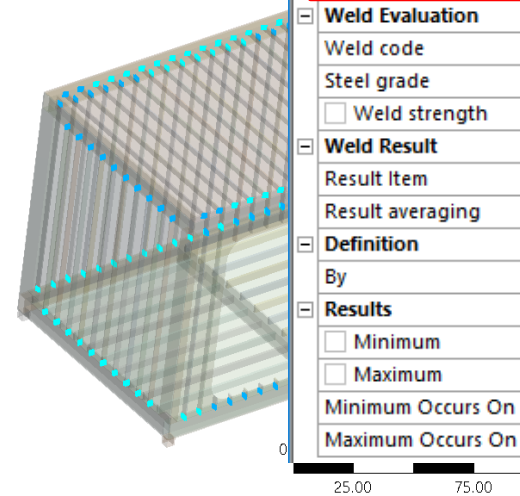
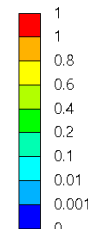
# DEMO Model results

- Weld utilization ratio along the welds.
- The model fulfils the weld criteria, utilization less than one.
- Optimize weld size and intermediate weld fraction

**B: Static Structural**  
Weld beams long  
Expression: RES51  
Maximum Over Time  
Max: 0.87556  
Min: 0  
2016-08-10 15:45



**B: Static Structural**  
Weld beam short  
Expression: RES111  
Maximum Over Time  
Max: 0.35199  
Min: 0.0020375  
2016-08-10 15:45



## Details of "Weld beams long"

<b>Weld Section</b>	
Scoping Method	Named Selection
Named Selection	weld_beams_long_edge
<b>Reference Face</b>	
Scoping Method	Named Selection
Named Selection	weld_beams_long_face
<b>Weld Geometry</b>	
Type	Double sided intermediate
<input type="checkbox"/> Weld fraction	0.4
<input type="checkbox"/> Min thickness	3 [mm]
<b>Weld Evaluation</b>	
Weld code	Eurocode 3
Steel grade	S235
<input type="checkbox"/> Weld strength	360 [MPa]
<b>Weld Result</b>	
Result Item	Wuf
Result averaging	Floating
<b>Definition</b>	
By	Maximum Over Time
<b>Results</b>	
<input type="checkbox"/> Minimum	0.
<input type="checkbox"/> Maximum	0.87556
Minimum Occurs On	Solid
Maximum Occurs On	Solid

---

# Manual vs. Automated post processing

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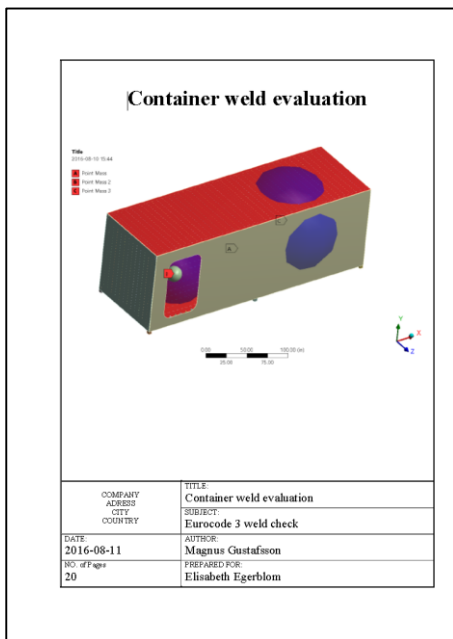
- Demo model with 920 segments and three load cases.
- Manual work to evaluate utilization for one weld segment, ~5 min, total ~80 h!
  - Define a local coordinate system at the weld segment
  - Define a force probe to list section forces, for each load step
  - Export force list e.g. MS Excel to evaluate weld utilization, for each load step
  - Post process a BIG list of data and keep track naming of weld segments, type, size etc.
- Automated workflow, ~5 minutes in total.
  - Define components of weld sections, weld seems of equivalent size and type  
Can be more than 100 segments in a weld section
  - Define results object and set weld type, strength, size.
  - Evaluate weld utilization, forces, minimum throat size as contour plots
  - Extract results from result listing for reporting





# Report Generator by EDRMedeso

- Extract and create a report can be done in minutes using the Report Generator
- The report is a “one to one” image of the analysis.
- No copy/paste errors or time consuming layout work.
- If model is updated with new loads or properties the report is generated in seconds!



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Eurocode 3 weld check		
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EDRMedeso Report Generator V10.3

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Container weld evaluation  
Eurocode 3 weld check

Date: 2016-08-11

## 5. Static Structural

### 5.1. Analysis Settings

Table 6 Time steps summary

Step	Time Step	Time Step	Defined By	Carry Over	Initial	Minimum	Maximum
1	0	0.000	Program Controlled	N/A	N/A	N/A	N/A
2	0	0.000	Program Controlled	N/A	N/A	N/A	N/A
3	0	0.000	Program Controlled	N/A	N/A	N/A	N/A

Table 7 Analysis settings summary

Property	Value
Solver Type	Program Controlled
Weak Springs	Off
Large Deformation	False
Finite Rotations	False
Solver Units	Consistent (N)

### 5.2. Acceleration

#### At Study Structural

Time: 0 to 1 sec  
Frequency: 0.0 to 10.0 Hz

Acceleration: 0.000 m/s<sup>2</sup>  
Components: 0.0, 0.0, 0.0 m/s<sup>2</sup>

A 3D model of a mechanical component, possibly a container or a structural part, shown in a perspective view. The model is light gray with a green rectangular feature on the front face. A yellow arrow points to a specific location on the top surface. A coordinate system (X, Y, Z) is shown in the bottom right corner, with X pointing right, Y pointing up, and Z pointing out of the page. A scale bar at the bottom indicates dimensions in millimeters (mm) and inches (in).

Figure 16 Acceleration

Table 8 Acceleration, Global Coordinate System

Time (sec)	mm/s <sup>2</sup>	mm/s <sup>2</sup>	mm/s <sup>2</sup>	mm/s <sup>2</sup>	mm/s <sup>2</sup>	mm/s <sup>2</sup>
0	0.000	0.000	0.000	0.000	0.000	0.000
1	8610.000	0.000	0.000	0.000	0.000	0.000
2	0.000	8610.000	0.000	0.000	0.000	0.000
3	0.000	0.000	8610.000	0.000	0.000	0.000

EE330-3m Report, December 5/10 3

- 14 -

EDRMedeso Report Generator V10.3

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Container weld evaluation  
Eurocode 3 weld check

Date: 2016-08-11

## 6.4. Weld beams long

### At Study Structural

Welds  
Weld type: Double sided intermediate  
Weld fraction: 0.4  
Min thickness: 3 mm  
Weld code: Eurocode 3  
Steel grade: S235

0.0  
0.001  
0.002  
0.003  
0.004  
0.005  
0.006  
0.007  
0.008  
0.009  
0.010

0.00 10.00 100.00 (m)

Figure 21. Weld beams long

Table 9. Weld beams long property list

Property	Value
Weld type	Double sided intermediate
Weld fraction	0.4
Min thickness	3 mm
Weld code	Eurocode 3
Steel grade	S235
Weld strength	360 MPa
Weld result	Full
Weld as	Erasing



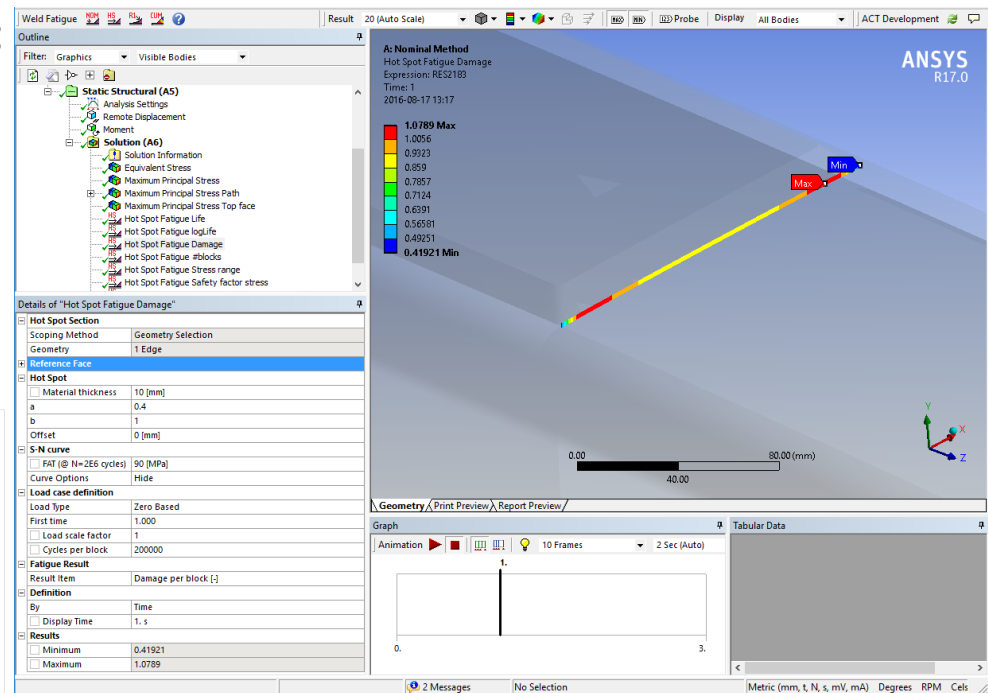
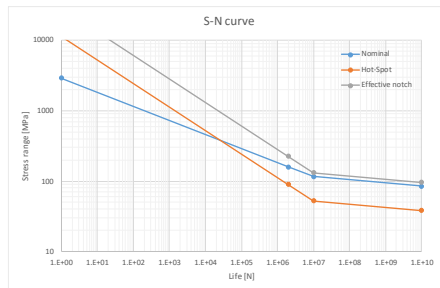
# Future outlook:



# Weld Fatigue



- A corresponding Weld Fatigue app is in development for release later this fall based on the book: “Recommendations for Fatigue Design of Welded Joints and Components” by: A.F. Hobbacher, International Institute of Welding
- The app will support the methods:
  - Nominal
  - Hot Spot
  - Effective notch



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# Conclusions

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- The use of ANSYS together with the Weld Strength and Report Generator app is a winning combination.
- **Speed up 10X.** Weld evaluation and reporting done in minutes instead of weeks. Free up time for the engineer to do more analyses and deliver reports instantly in order to take correct decisions faster.
- **Quality Assurance.** Report content matches the actual FE-model, makes for a valid third party reviewing. No copy/paste errors or wrong images.
- **Traceability.** Easy to document the development of a product and make new report revisions when there are new prerequisites. The documentation is automatically saved in the ANSYS project.
- **Process integration.** Use company specific report templates.
- **Simplicity.** Easy to use ANSYS Mechanical GUI.

**THANK YOU!**

Magnus Gustafsson

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