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

*magnus.gustafsson@edrmedeso.com*

# Engineering Simulation Software & Knowledge

## ”Perfect Engineering”

- ANSYS Channel Partner for Nordic
- 800+ Customers
- 70+ employees
- Support, Training & Services
- www.edrmedeso.com

# Saxat från “Svetsen” #2 2016
# Färdplan för fogningsbranschen 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.


EDR™ MEDESO

# Background

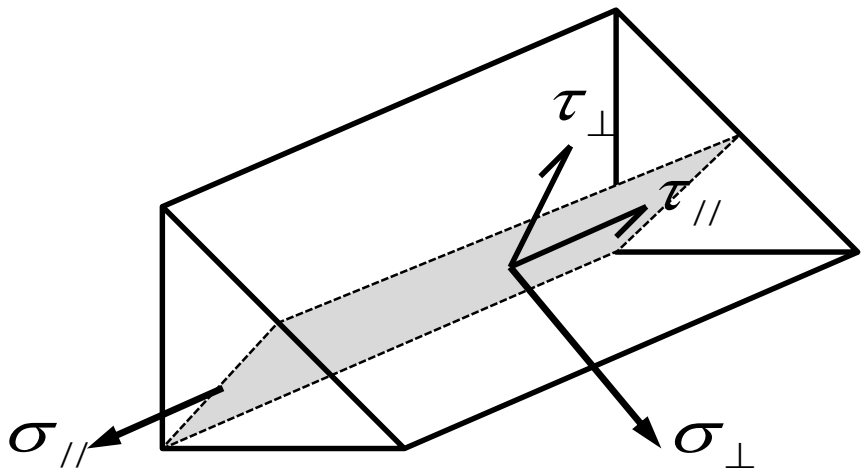
- Welded structures are common in “heavy duty” structures and the need to evaluate according to specific codes is important.
- To asses the weld strength the load distribution of the structure has to be evaluated in on order to get the forces on each weld segment.
- One example of code is the Eurocode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


EDR™ MEDESO

# 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 tress 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

<u>Directional method:</u>

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

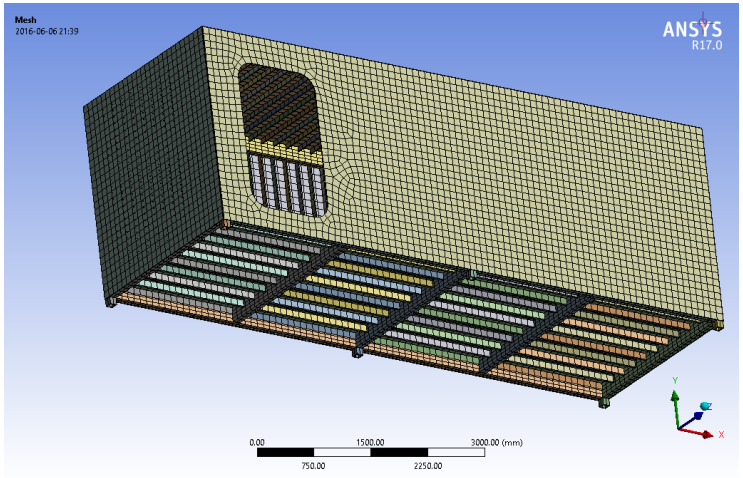
The weld seam is assumed to have sufficient strength if both conditions below are fulfilled:

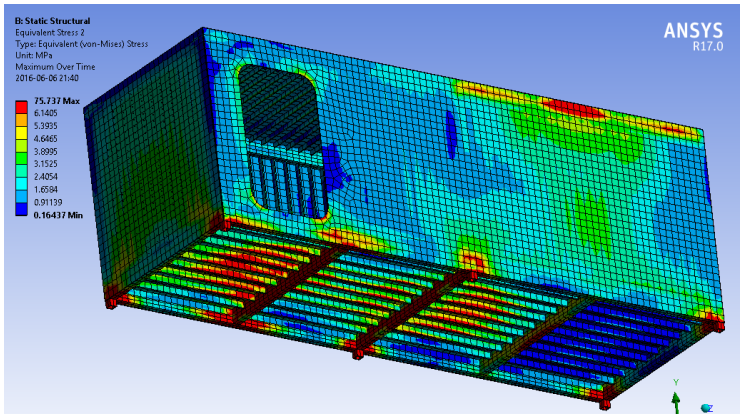
$$\sqrt{\sigma_{\perp}^2 + 3\times\left(\tau_{\perp}^2 + \tau_{//}^2\right)} \leq \frac{f_u}{\beta_w \times \gamma_{M2}} \quad \text{and} \quad \sigma_{\perp} \leq \frac{0.9\times f_u}{\gamma_{M2}}$$

$f_u$ = 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

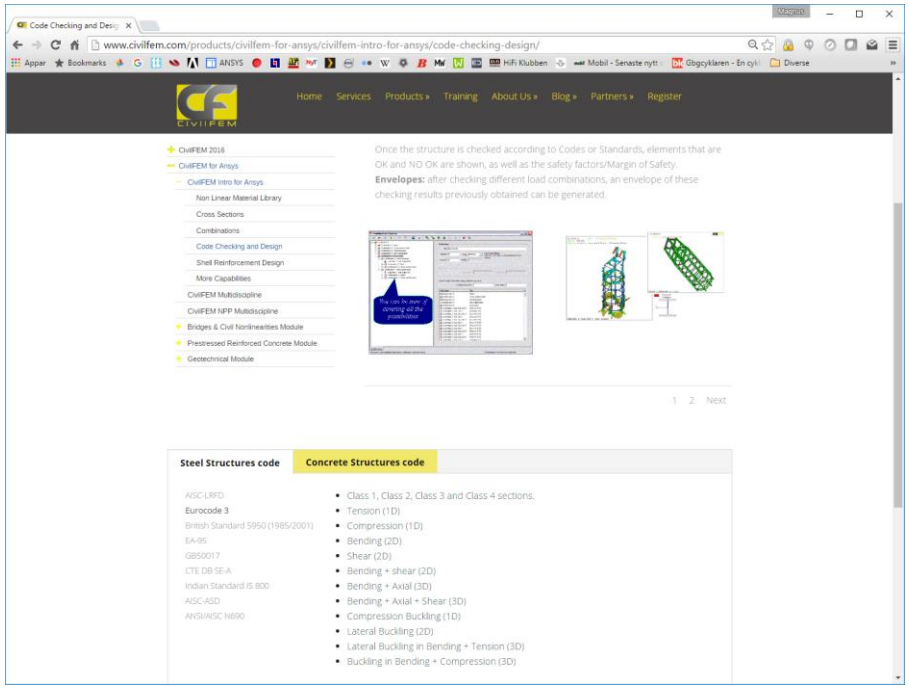
- With FEM the “correct” load distribution can be derived even for very complex geometry and multiple load cases. However evaluation of a FE models according to weld codes are a tedious and time consuming work involving extraction of section forces in local coordinate systems and safety factor calculation 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

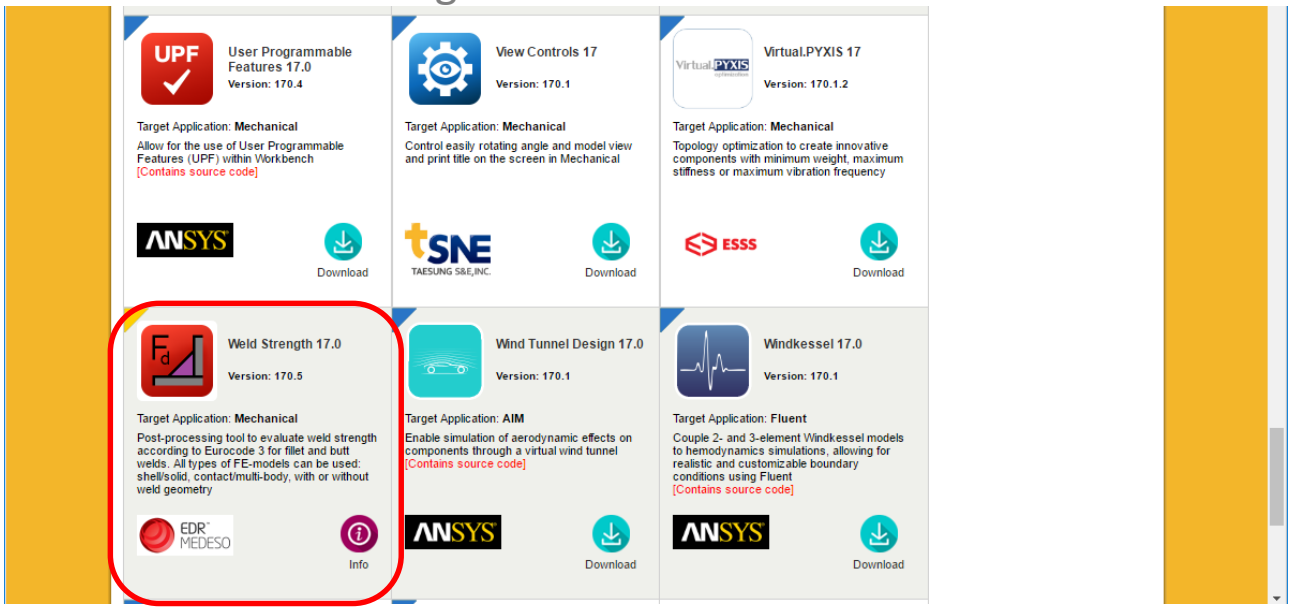
- The evaluation according to specific codes are usually not included in general purpose programs such as ANSYS.
- Code check is available in e.g. Civil FEM but not for weld connections.
- The possibility to optimize a welded structure is therefore limited.




EDR™ MEDESO

# A new solution in ANSYS

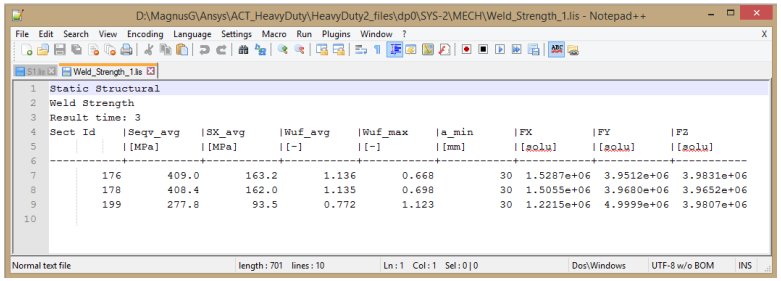

- ANSYS has opened up for third party developers to create apps that integrate into ANSYS products such as Mechanical, Design Modeler, Design Xplorer, Meshing etc.
- With apps you can create e.g. custom loads and post processing objects like any standard ANSYS function.
- ANSYS has a market place for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

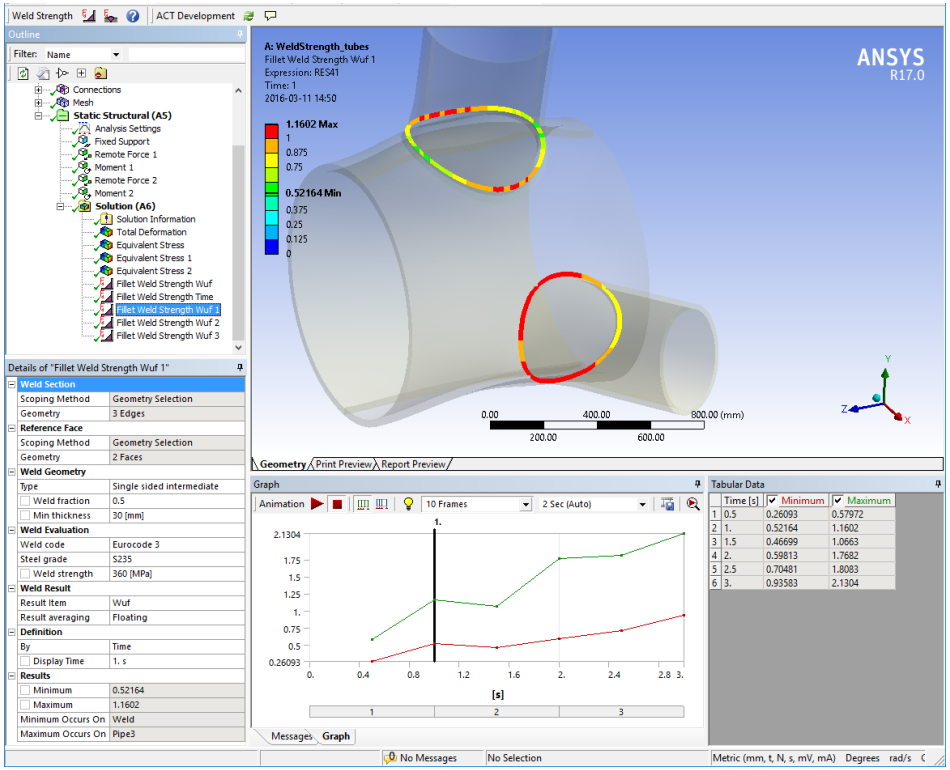



EDR™ MEDESO

# Weld Strength by EDRMedeso

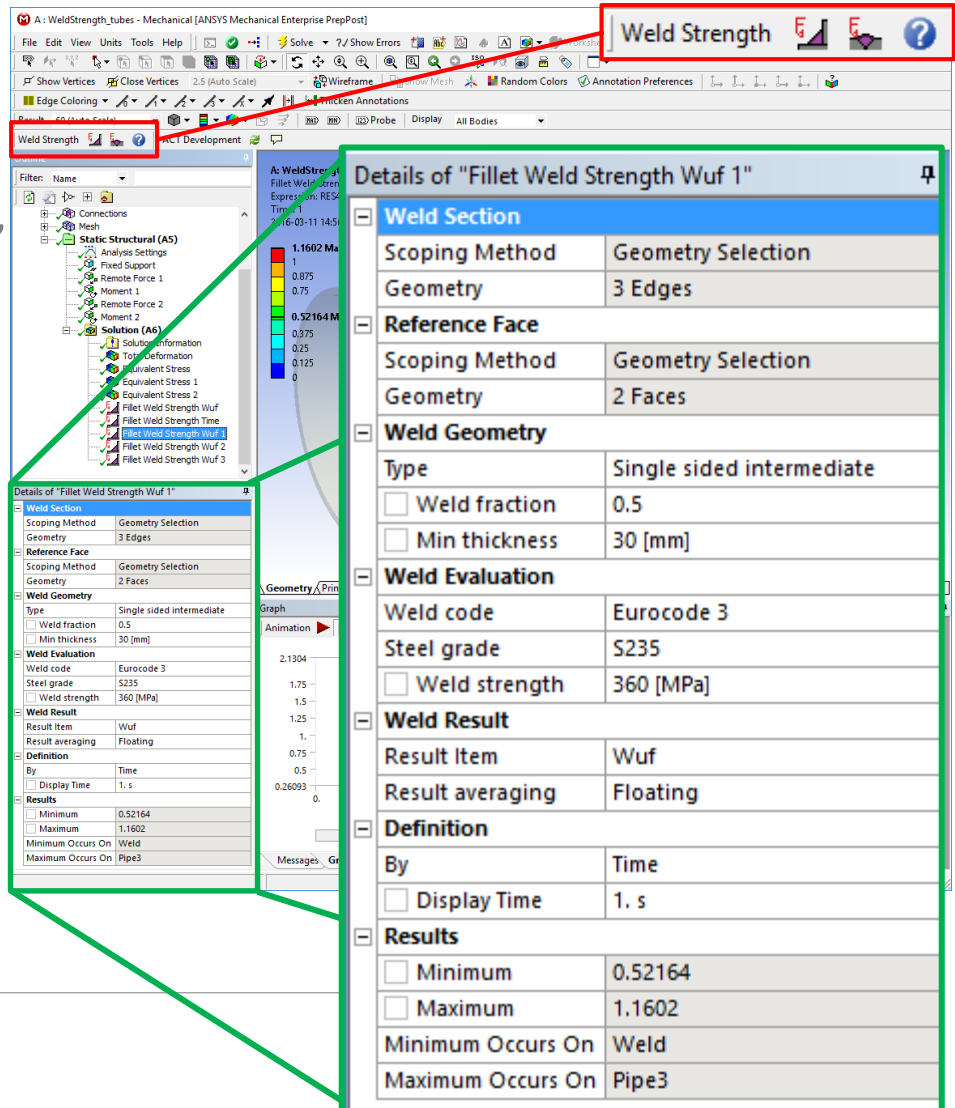
- Weld strength according to  Eurocode 3 or user criteria
- Easy to identify your all welds in one result object
- Set the weld throat thickness or let ANSYS calculate the minimum weld throat thickness
- Contour plots and detailed results listing for each edge in the weld selection



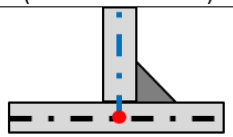
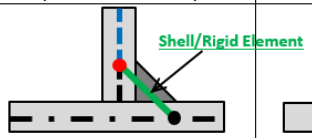
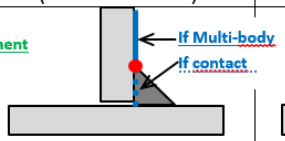
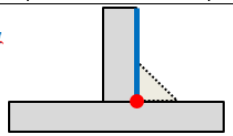
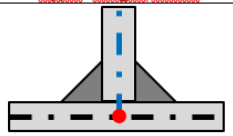
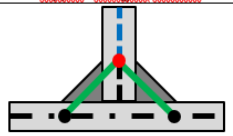
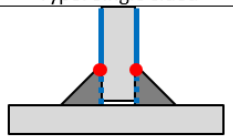
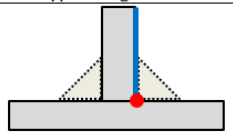
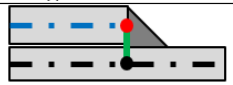
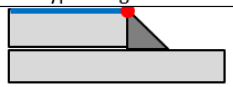
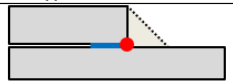
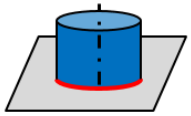
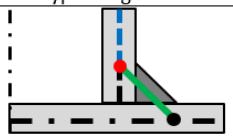
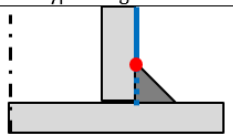
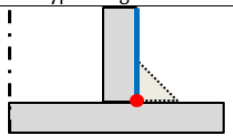
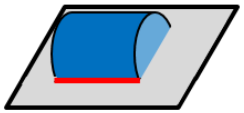
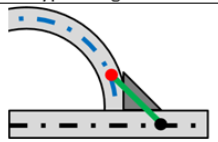
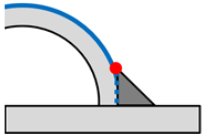
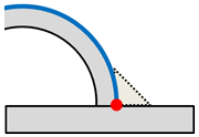
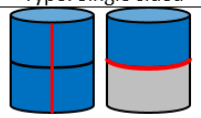
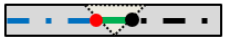
# Weld Strength Usage

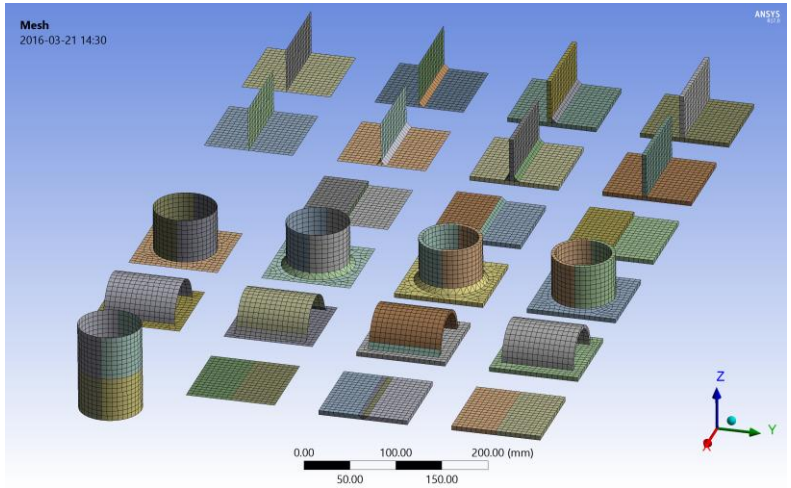
- Build the FE-model as normal. All types of elements and connections are supported (see next slide)
- Insert the “Fillet weld” or “Butt weld” results object
- Define weld section, geometry, evaluation, result item, result averaging and time step.
- Solve the model and review the results.



# 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 |




EDR™ MEDESO

# 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:

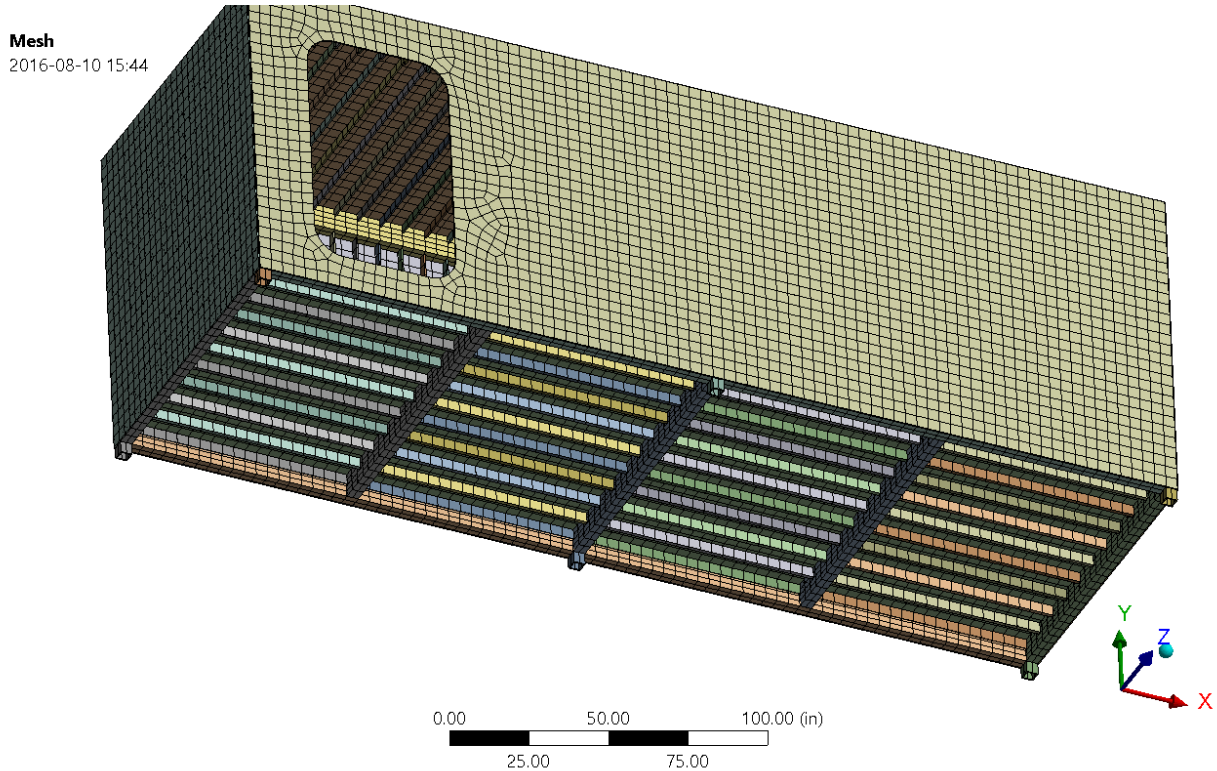
```
Static Structural
Fillet Weld Strength Contact Solid Weld
Result time: 1
Weld Type: Single sided
Weld Code: Eurocode 3
Sect Id  |Seqv_avg   |Snorm_avg  |Wuf_avg    |Wuf_max    |a_min    |FX (radial)|FY (parall)|FZ (axial)
         |[MPa]      |[MPa]      |[-]        |[-]        |[mm]     |[N]        |[N]        |[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, $\sigma_{Eqv} = \sqrt{\sigma_{\perp}^2 + 3\times\left(\tau_{\perp}^2 + \tau_{//}^2\right)}$ |
| 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]) |

EDR™ MEDESO

# DEMO Model

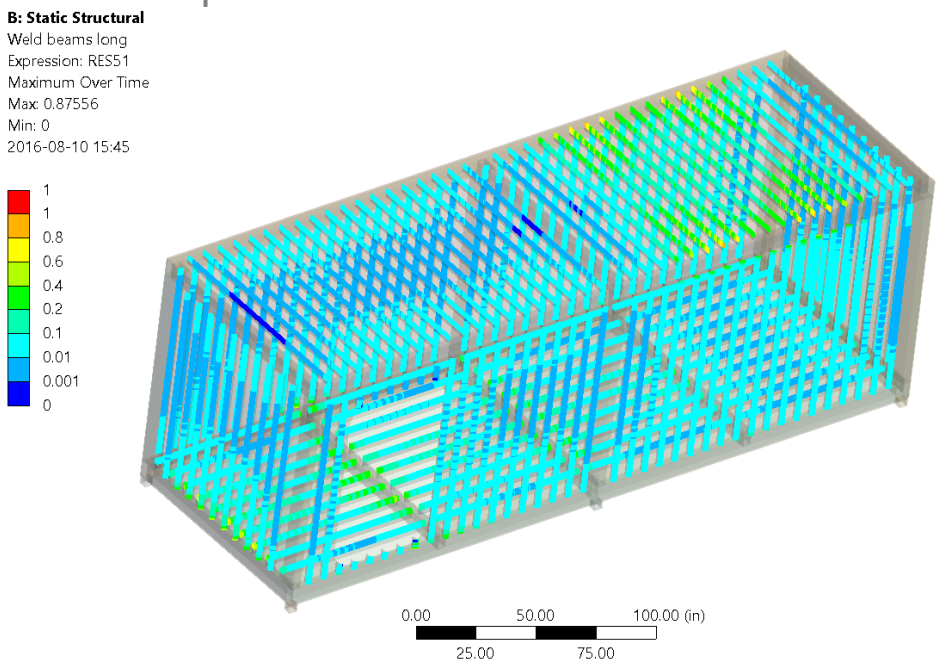
- Container, 210 parts, double sided welds, 920 weld segments
- Three load steps (acceleration loads), solution time 70 sec (small model)

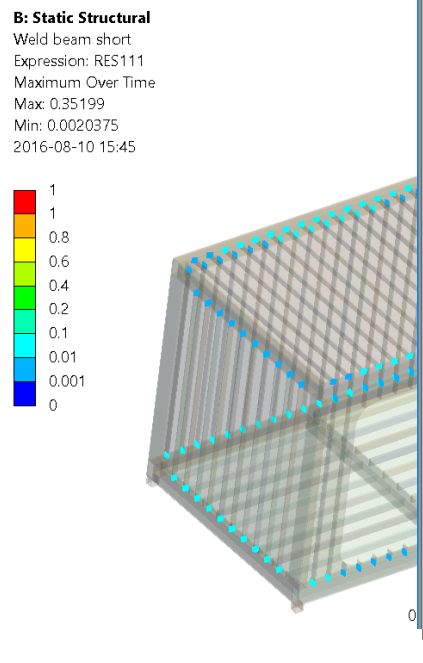



EDR™ MEDESO

# 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




Details of "Weld beams long"

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

EDR™ MEDESO

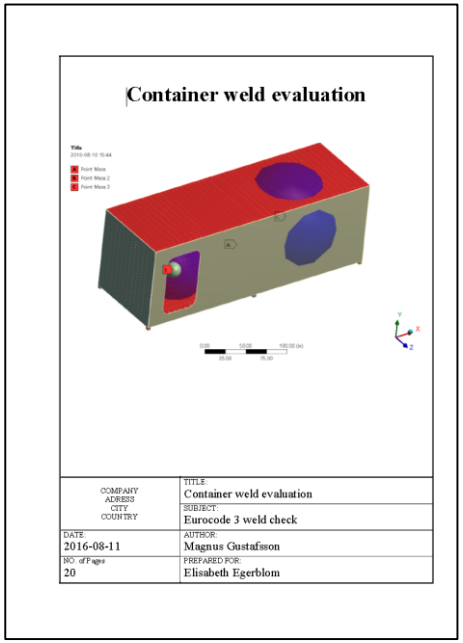
# Manual vs. Automated post processing

- 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

EDR™ MEDESO

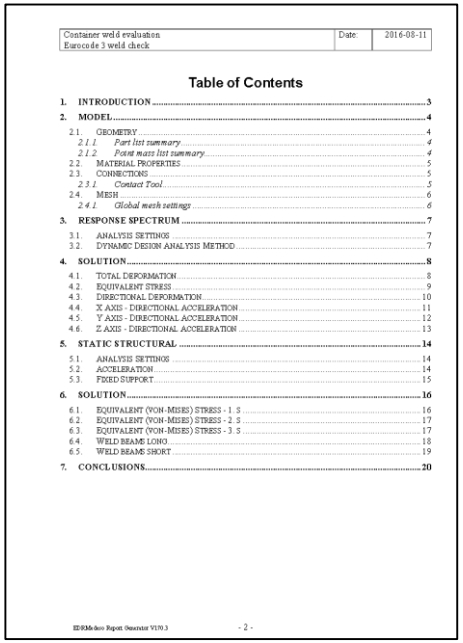
# Report Generator by EDRMedeso

- 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!



Container weld evaluation

| | |
|---|---|
| COMPANY<br>ADRESS<br>CITY<br>COUNTRY | TITLE:<br>Container weld evaluation<br>SUBJECT:<br>Eurocode 3 weld check |
| DATE:<br>2016-08-11 | AUTHOR:<br>Magnus Gustafsson |
| NO. of Pages<br>20 | PREPARED FOR:<br>Elisabeth Egerblom |

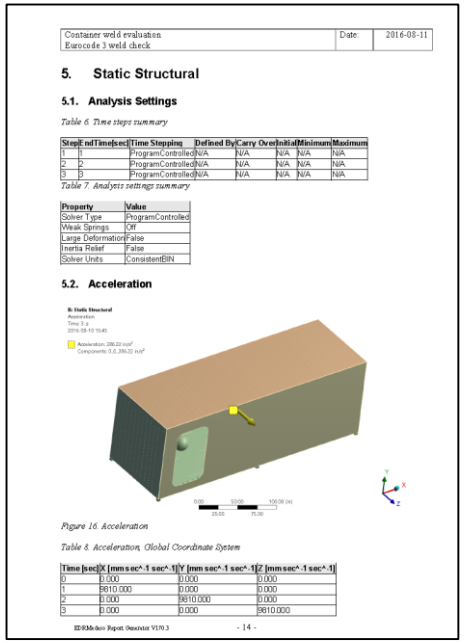


Container weld evaluation | Eurocode 3 weld check | Date: 2016-08-11

Table of Contents


1. INTRODUCTION ..... 3
2. MODEL ..... 4
2.1. GEOMETRY ..... 4
2.1.1. Part list summary ..... 4
2.1.2. Point mass list summary ..... 4
2.2. MATERIAL PROPERTIES ..... 5
2.3. CONNECTIONS ..... 5
2.3.1. Contact Tool ..... 5
2.4. MESH ..... 6
2.4.1. Global mesh settings ..... 6
3. RESPONSE SPECTRUM ..... 7
3.1. ANALYSIS SETTINGS ..... 7
3.2. DYNAMIC DESIGN ANALYSIS METHOD ..... 7
4. SOLUTION ..... 8
4.1. TOTAL DEFORMATION ..... 8
4.2. EQUIVALENT STRESS ..... 9
4.3. DIRECTIONAL DEFORMATION ..... 10
4.4. X AXIS - DIRECTIONAL ACCELERATION ..... 11
4.5. Y AXIS - DIRECTIONAL ACCELERATION ..... 12
4.6. Z AXIS - DIRECTIONAL ACCELERATION ..... 13
5. STATIC STRUCTURAL ..... 14
5.1. ANALYSIS SETTINGS ..... 14
5.2. ACCELERATION ..... 14
5.3. FIXED SUPPORT ..... 15
6. SOLUTION ..... 16
6.1. EQUIVALENT (VON-MISES) STRESS - 1. S ..... 16
6.2. EQUIVALENT (VON-MISES) STRESS - 2. S ..... 17
6.3. EQUIVALENT (VON-MISES) STRESS - 3. S ..... 17
6.4. WELD BEAMS LONG ..... 18
6.5. WELD BEAMS SHORT ..... 19
7. CONCLUSIONS ..... 20





5. Static Structural

5.1. Analysis Settings

*Table 6. Time steps summary*

| Step | EndTime[sec] | Time Stepping | Defined By | Carry Over | Initial | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| 1 | 1 | ProgramControlled | N/A | N/A | N/A | N/A | N/A |
| 2 | 2 | ProgramControlled | N/A | N/A | N/A | N/A | N/A |
| 3 | 3 | ProgramControlled | N/A | N/A | N/A | N/A | N/A |

*Table 7. Analysis settings summary*

| Property | Value |
|---|---|
| Solver Type | ProgramControlled |
| Weak Springs | Off |
| Large Deformation | False |
| Inertia Relief | False |
| Solver Units | ConsistentBIN |

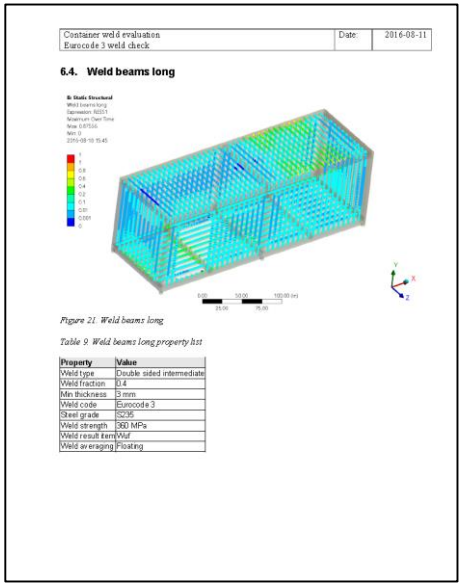
5.2. Acceleration

*Figure 16. Acceleration*

*Table 8. Acceleration, Global Coordinate System*

| Time [sec] | X [mm sec^-1 sec^-1] | Y [mm sec^-1 sec^-1] | Z [mm sec^-1 sec^-1] |
|---|---|---|---|
| 0 | 0.000 | 0.000 | 0.000 |
| 1 | 9810.000 | 0.000 | 0.000 |
| 2 | 0.000 | 9810.000 | 0.000 |
| 3 | 0.000 | 0.000 | 9810.000 |







6.4. Weld beams long

*Figure 21. Weld beams long*

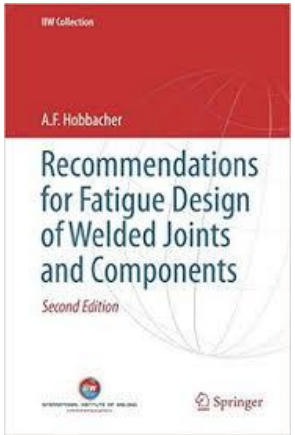
*Table 9. Weld beams long property list*

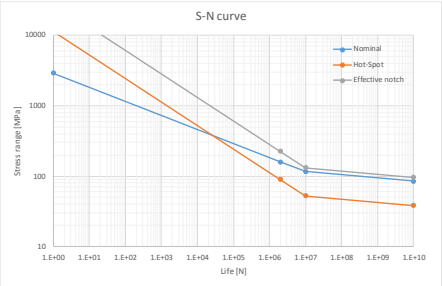
| Property | Value |
|---|---|
| Weld type | Double sided intermediate |
| Weld fraction | 0.4 |
| Min thickness | 3 mm |
| Weld code | eurocode 3 |
| Steel grade | S235 |
| Weld strength | 360 MPa |
| Weld result item | Wef |
| Weld averaging | Floating |

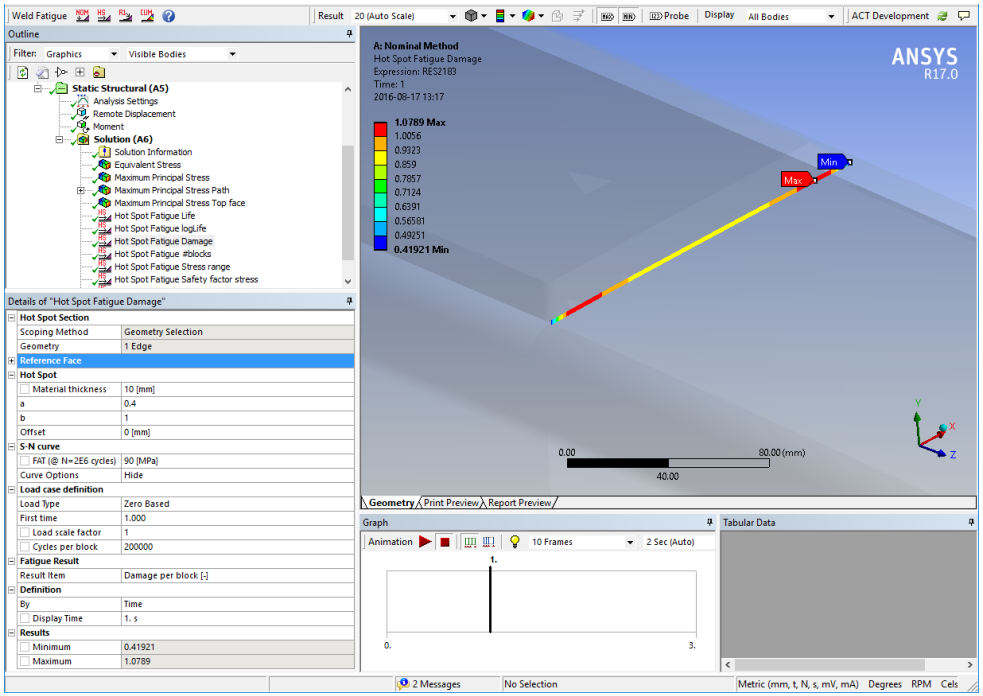
EDR™ MEDESO

# 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



# Conclusions

- 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.

EDR™ MEDESO

EDR™ MEDESO

# THANK YOU!

**Magnus Gustafsson**

**magnus.gustafsson@edrmedeso.com**