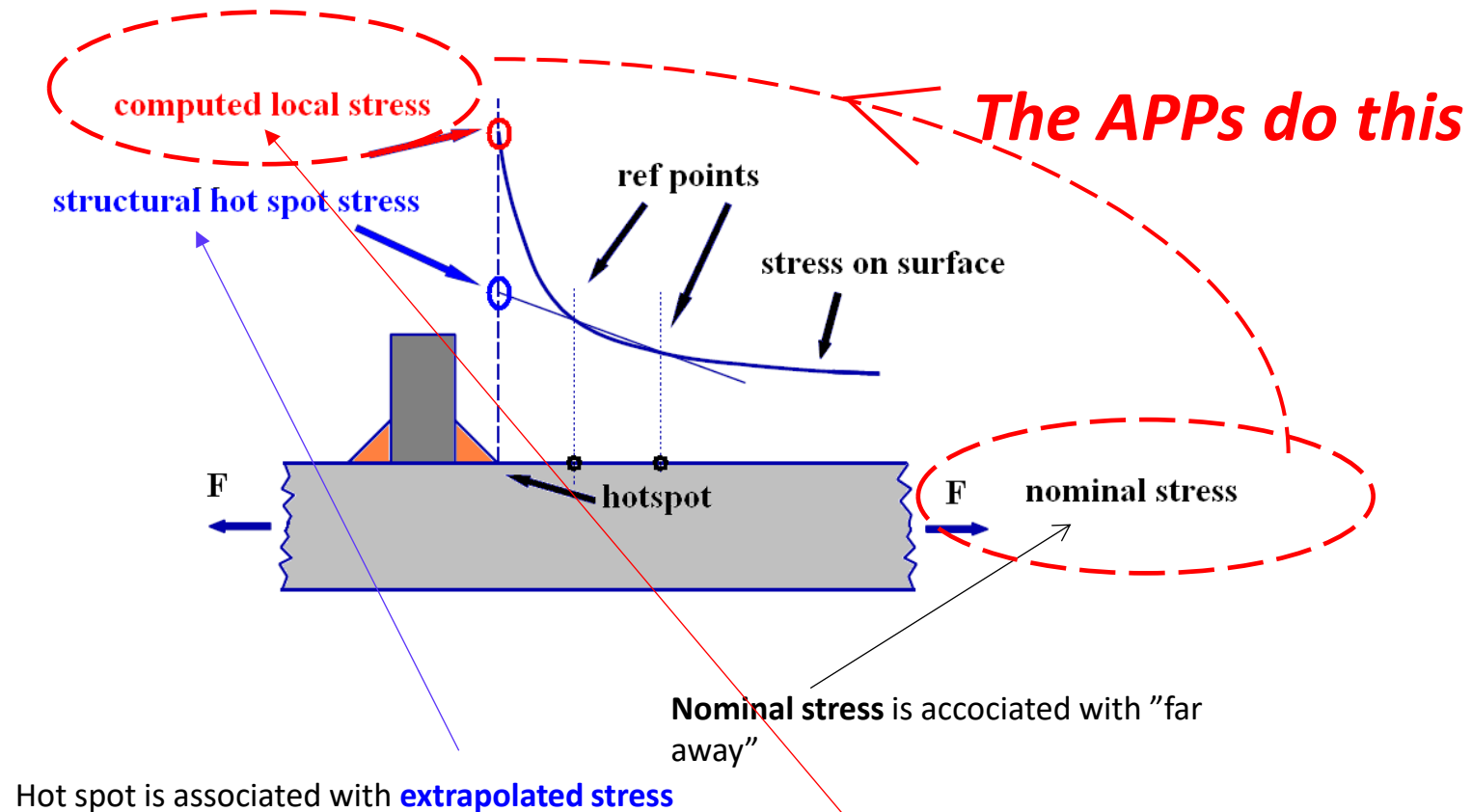


Demo of Weld Analyzer & Weld Optimizer

5 Sept 2024

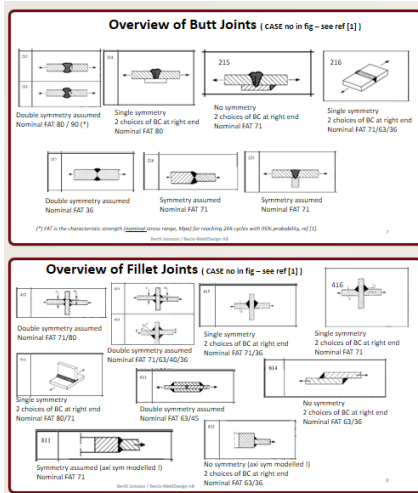
Bertil Jonsson

Different stress measures at the toe



Effective notch stress is associated with the **local stress** using a fictitious radius of for example 1 mm (as welded)

Two APPs for quick analysis of fatigue in welded joints



UI Figure

Weld Joint Analyzer Ver. 1.5

Weld Joint CASE: CASE 416

Read me! This APP computes Effective Notch Stress range for fatigue from nominal tension loads. It is done for different weld joint types according to IIW Recommendations nomenclature. Choose CASE no (above), give appropriate parameter values at left (according to EXPLANATION - see below), then click SOLVE to start the 2D FE-analysis!

Thickness t1 (mm): 20 (No/Yes) Active t1

Penetration i2 (mm): 0 (No/Yes) Active i2

Thickness t2 (mm): 15 (No/Yes) Active t2

Angle Beta (degr): 0 (No/Yes) Active Beta

Length L1 (mm): 50 (No/Yes) Active L1

Height h (mm): 0 (No/Yes) Active h

Length L2 (mm): 300 (No/Yes) Active L2

Off (mm): 0 (No/Yes) Active Off

Length L3 (mm): 0 (No/Yes) Active L3

Active BC

Throat a1 (mm): 7 (No/Yes) Active a1

Throat a2 (mm): 0 (No/Yes) Active a2

Penetration i1 (mm): 8 (No/Yes) Active i1

Boundary Conditions (BC): Stiff (No/Yes) Active BC

Tension (MPa) Load 1, LC: 24

Tension (MPa) Load 2, non-LC: 0

Notch Radius (mm, def=1): 1

FAT - Toe (Mpa, def 225): 225

FAT - Root (Mpa, def 225): 225

Inclination (def m=3): 3

Stand deviation (def s=0.2 in Log N): 0.2

Scale factor deform plot: 200

Click here to get an EXPLANATION of input parameters for the CASE chosen

Show active KNOBS

Press to SOLVE!

Message: Press SOLVE and wait, may take some time

Note: BC active!

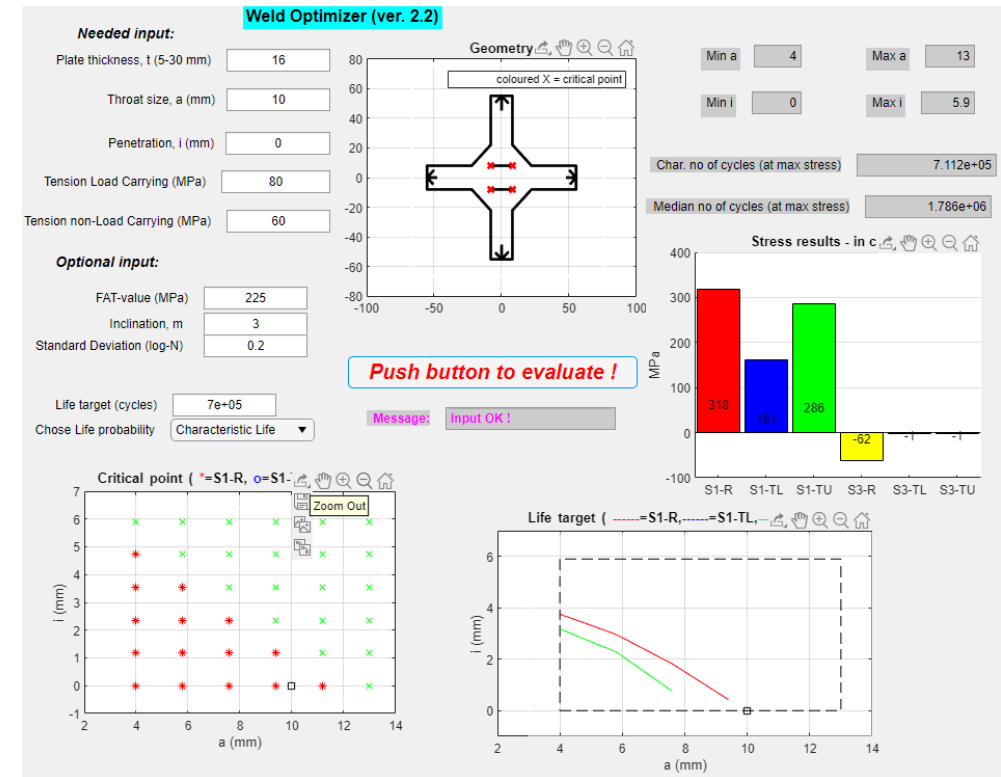
RESULTS:

Position	Principal stress (MPa)
Pos 1	N/A
Pos 2	N/A
Pos 3	N/A
Pos 4	N/A
Pos 5	N/A
Pos 6	N/A

Stress in critical point (MPa): 0

Shortest char. Life: 0

Shortest median Life: 0



Weld Joint Analyzer for
18 different types of joints
(automated FE-models)

Weld Optimizer for
Fillet welds / cruciform joints
(interpolation in a database)

Weld Joint Analyzer

- Ver 1.6 -

This App "translates" nominal stresses into ENS-stresses for 18 different weld joints

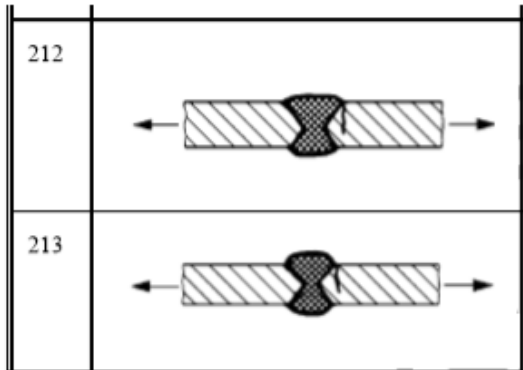
Background

- This APP translates the nominal stresses on some weld joints into the Effective Notch Stresses (ENS, see ref [4 & 5]) using the R1-concept in a FE-model, which is built in the PDE-module of Matlab. The radius (default $R=1$ mm) is an input and so it is possible to use $R=0.3$ mm or $R=0.05$ mm for thinner plates, see ref [6].
- The user can be without any experience of FE and mesh-sizes since the model is automatically built with appropriate size and type of the elements (quadratic triangular plane stress elements). The geometries are taken from IIW Recommendations and, see ref [1], for those cases where the geometry can be viewed as a 2D section of the joint. In summary, there are 8 butt joints and 10 fillet joints described, all parameterized.
- The computed results consist of graphs over stresses in the radii and colour plots of Mises and principal stresses. These plots can be manipulated using the Matlab features, like zooming. Further, the shortest fatigue life is also computed.

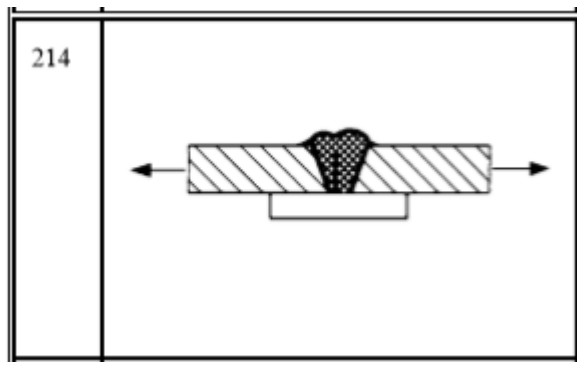
Overview of Joints analyzed

(Case no refers to IIW Recommendations, ref [1])

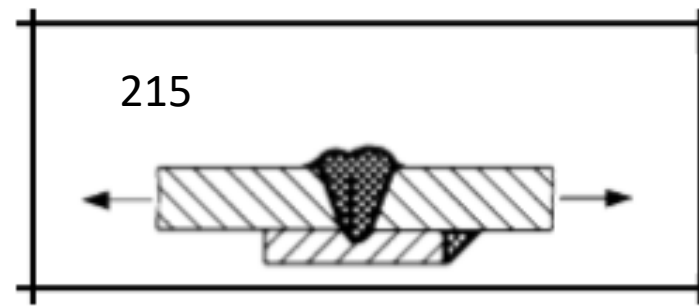
Overview of Butt Joints (CASE no in fig – see ref [1])



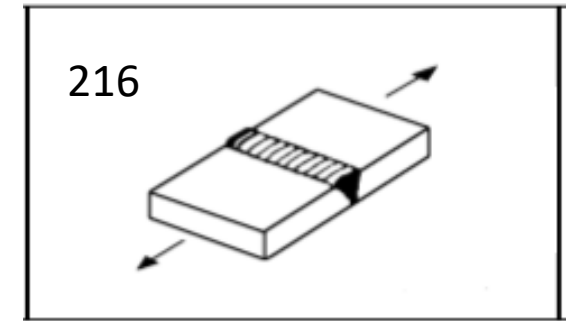
Double symmetry assumed
Nominal FAT 80 / 90 (*)



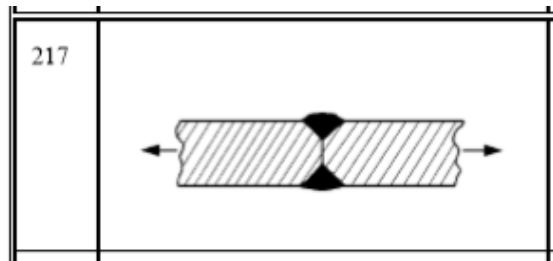
Single symmetry
2 choices of BC at right end
Nominal FAT 80



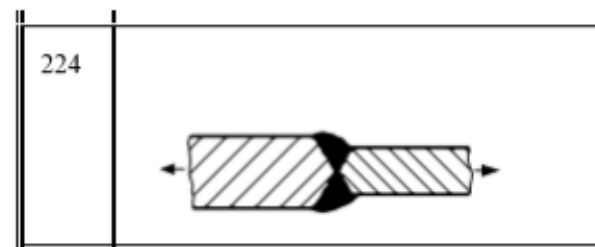
No symmetry
2 choices of BC at right end
Nominal FAT 71



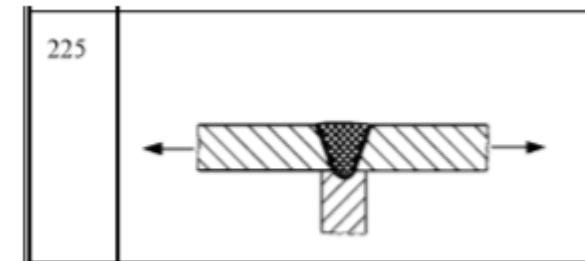
Single symmetry
2 choices of BC at right end
Nominal FAT 71/63/36



Double symmetry assumed
Nominal FAT 36



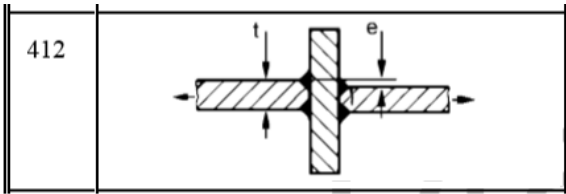
Symmetry assumed
Nominal FAT 71



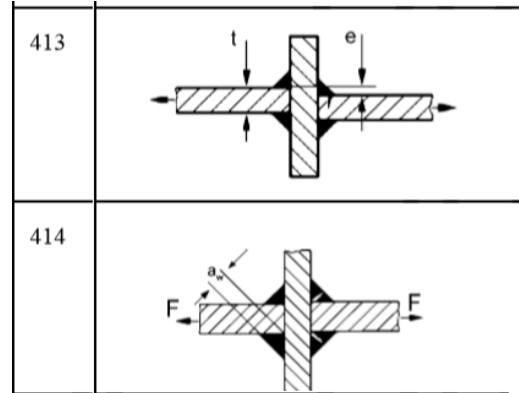
Symmetry assumed
Nominal FAT 71

(*) FAT is the characteristic strength (nominal stress range, Mpa) for reaching 2E6 cycles with 95% probability, ref [1].

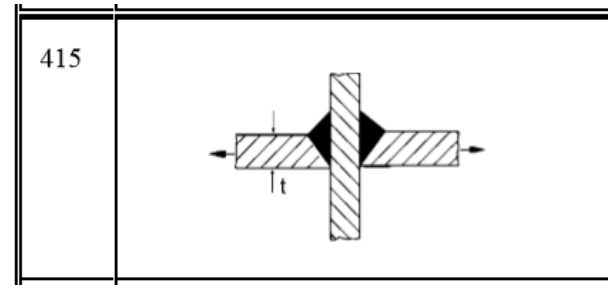
Overview of Fillet Joints (CASE no in fig – see ref [1])



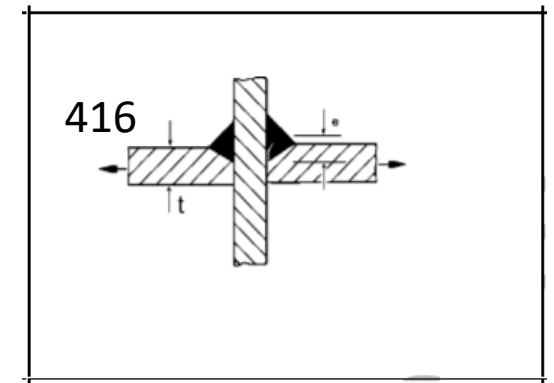
Double symmetry assumed
Nominal FAT 71/80



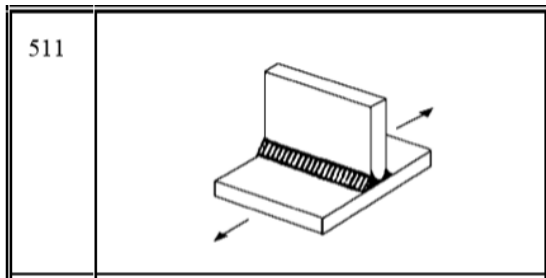
Double symmetry assumed
Nominal FAT 71/63/40/36



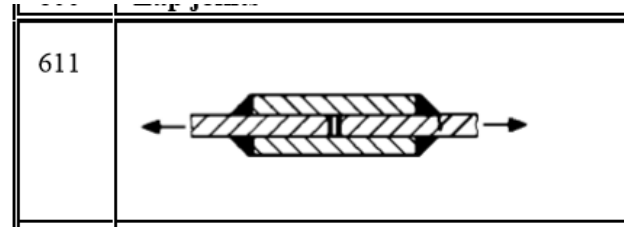
Single symmetry
2 choices of BC at right end
Nominal FAT 71/36



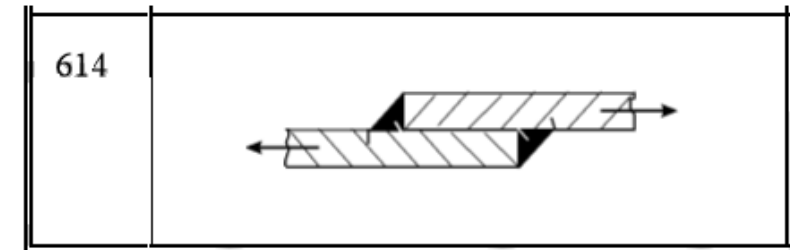
Single symmetry
2 choices of BC at right end
Nominal FAT 71



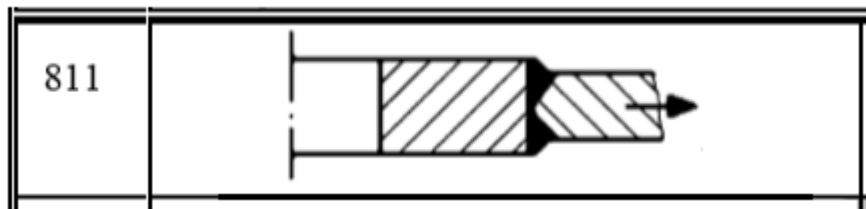
Single symmetry
2 choices of BC at right end
Nominal FAT 80/71



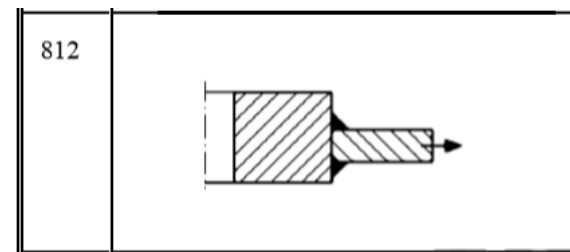
Double symmetry assumed
Nominal FAT 63/45



No symmetry
2 choices of BC at right end
Nominal FAT 63/36



Symmetry assumed (axi sym modelled !)
Nominal FAT 71



No symmetry (axi sym modelled !)
2 choices of BC at right end
Nominal FAT 63/36

GUI – some general guidance

Weld Joint Analyzer Ver. 1.5

Thickness t1 (mm) ☐ No ☒ Yes ☐ Active t1

Thickness t2 (mm) ☐ No ☒ Yes ☐ Active t2

Length L1 (mm) ☐ No ☒ Yes ☐ Active L1

Length L2 (mm) ☐ No ☒ Yes ☐ Active L2

Length L3 (mm) ☐ No ☒ Yes ☐ Active L3

Throat a1 (mm) ☐ No ☒ Yes ☐ Active a1

Throat a2 (mm) ☐ No ☒ Yes ☐ Active a2

Penetration i1 (mm) ☐ No ☒ Yes ☐ Active i1

Penetration i2 (mm) ☐ No ☒ Yes ☐ Active i2

Angle Beta (degr) ☐ No ☒ Yes ☐ Active Beta

Height h (mm) ☐ No ☒ Yes ☐ Active h

Off (mm) ☐ No ☒ Yes ☐ Active Off

Boundary Conditions (BC) ☐ No ☒ Yes ☐ Active BC

Tension (MPa) Load 1, LC

Tension (MPa) Load 2, non-LC

Notch Radius (mm, def =1)

FAT - Toe (Mpa, def 225)

FAT - Root (Mpa, def 225)

Inclination (def m=3)

Stand deviation (def s=0.2 in Log N)

Scale factor deform plot

Weld Joint CASE

CASE 414

Read me !

This APP computes Effective Notch Stress range for fatigue from nominal tension loads. It is done for different weld joint types according to IIW Recommendations nomenclature. Choose CASE no (above), give appropriate parameter values at left (according to EXPLANATION - see below), then click SOLVE to start the 2D FE-analysis !

Show active KNOBS

Press to SOLVE !

Click here to get an EXPLANATION of input parameters for the CASE chosen

Message: Press SOLVE and wait, may take some time

Note: None

RESULTS:

	Position	Principal stress (MPa)
Pos 1	N/A	0
Pos 2	N/A	0
Pos 3	N/A	0
Pos 4	N/A	0
Pos 5	N/A	0
Pos 6	N/A	0
Stress in critical point (MPa)		0
Shortest char. Life		0
Shortest median Life		0

GUI overview

Step 1:

The GUI expects as first action to make the choice of CASE to analyze.

Step 2:

Press here for a graph of input parameters and output positions

Step 3:

Press "KNOBS" to see which input parameters are used (= "yes") for this CASE

Step 4:

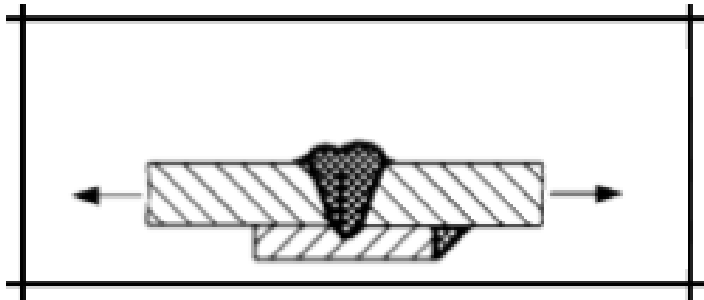
Give input parameters in the white-marked section and check for ev. messages in blue. When done – press **SOLVE !**

Step 5:

Study the output in the grey-marked section and also in the graphs given during the solution.

Demo APP – Weld Analyzer

(studying case 215 – butt weld)



No symmetry
2 choices of BC at right end
Nominal FAT 71

RUN:

Thickness 20 mm in mainplate, $L=200$ mm

Thickness 10 mm in backing bar, $L=50$ mm

Penetration width $i=5$ mm

Butt weld geometry: $\beta=30^\circ$ & $h=0.15t=3$ mm

Apply nominal FAT-level & check if notch stress = 225 Mpa

Summary of demo case 215

UI Figure

Weld Joint Analyzer Ver. 1.5

Weld Joint CASE: CASE 215

Read me ! This APP computes Effective Notch Stress range for fatigue from nominal tension loads. It is done for different weld joint types according to IIW Recommendations nomenclature. Choose CASE no (above), give appropriate parameter values at left (according to EXPLANATION - see below), then click SOLVE to start the 2D FE-analysis !

Thickness t1 (mm): 20
Active t1: No
Thickness t2 (mm): 10
Active t2: No
Length L1 (mm): 200
Active L1: No
Length L2 (mm): 50
Active L2: No
Length L3 (mm): 0
Active L3: No
Throat a1 (mm): 0
Active a1: No
Throat a2 (mm): 0
Active a2: No
Penetration i1 (mm): 5
Active i1: No

Penetration i2 (mm): 0
Active i2: No
Angle Beta (degr): 30
Active Beta: No
Height h (mm): 3
Active h: No
Off (mm): 0
Active Off: No
Boundary Conditions (BC): Stiff
Active BC: No

Tension (MPa) Load 1, LC: 71
Tension (MPa) Load 2, non-LC: 0
Notch Radius (mm, def =1): 1
FAT - Toe (Mpa, def 225): 225
FAT - Root (Mpa, def 225): 225
Inclination (def m=3): 3
Stand deviation (def s=0.2 in Log N): 0.2
Scale factor deform plot: 100

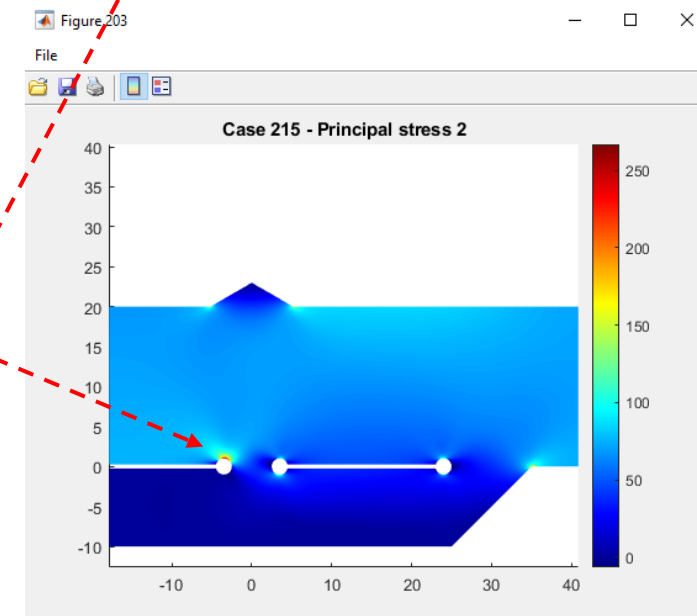
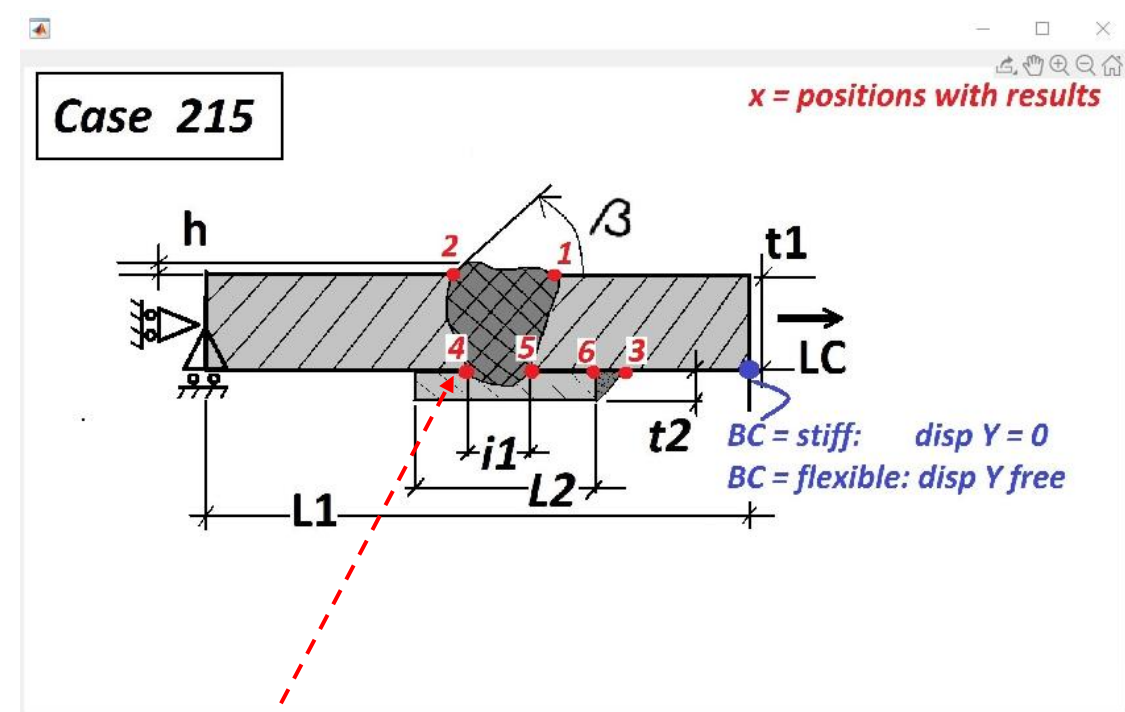
Click here to get an EXPLANATION of input parameters for the CASE chosen

Message: Input Ok - CASE solved!
Note: BC active !

RESULTS:

Position	Principal stress (MPa)
Pos 1 Upper Right Toe	153
Pos 2 Upper Left Toe	136
Pos 3 Backing Bar Toe	173
Pos 4 Open Backing Bar Root	267
Pos 5 Left Backing Bar Root	112
Pos 6 Right Backing Bar Root	125

Stress in critical point (MPa): 267
Shortest char. Life: 1.196e+06
Shortest median Life: 3.004e+06



Although nominal FAT 71 is applied, the life 2E6 cycles is not reached !

Conclusions Weld Analyzer

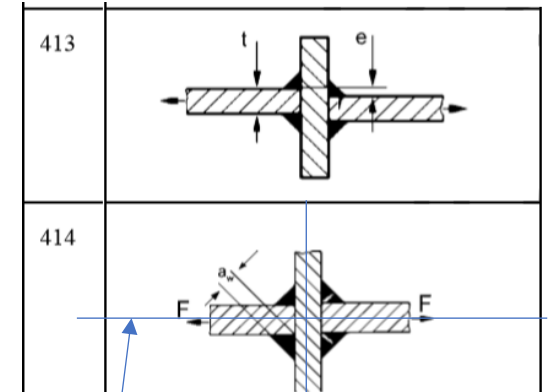
- The nominal method is often not accurate and can deviate from target life of 2E6 cycles for the FAT-level. The nominal result is often conservative, but not always – non-conservative findings happens!
- The APP "Weld Analyzer" is an easy to use tool to quickly and accurately analyze commonly used weld joint types, since the ENS-method* is being used.

(*) ENS = *Effective Notch Stress Method*

Weld Optimizer

- Ver 2.2 -

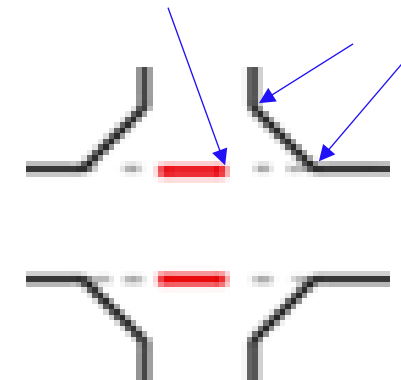
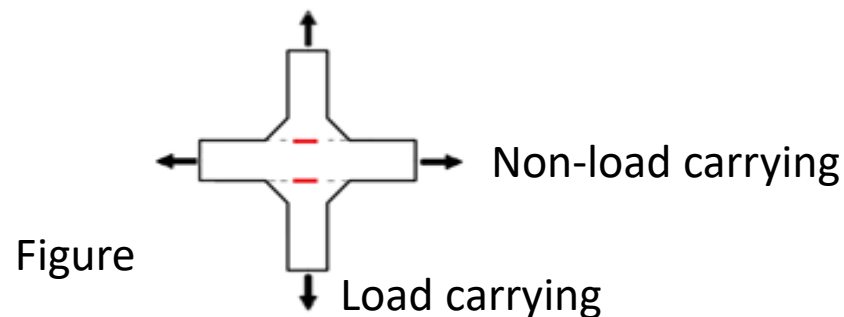
This App "translates" nominal stresses into
ENS-stresses for fillet welds



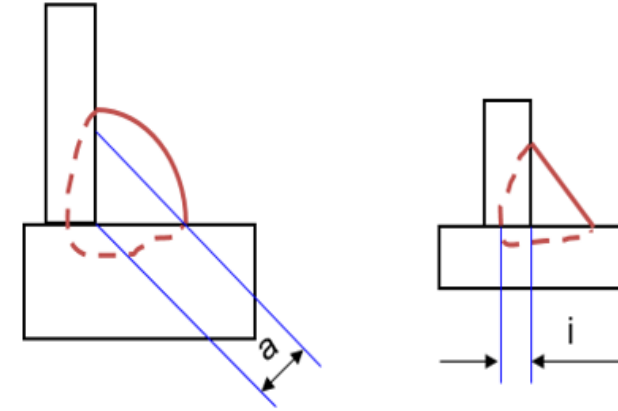
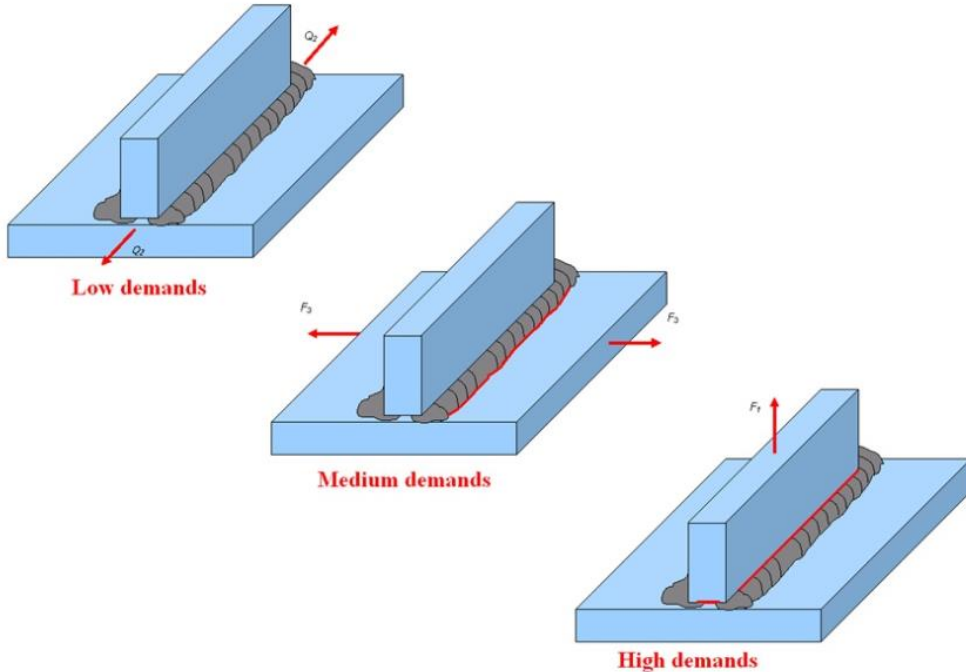
Double symmetry assumed
Nominal FAT 71/63/40/36

Weld case, analysis methods.

- This Matlab App computes the R1-concept stress, see ref [1] and [5], respons for any combination of load-carrying and non-load carrying nominal tension in **cruciform joints, see figure below**. It is here assumed that loads are proportional and working simultaneously. One could express this like: nominal tension stresses are translated into local R1-stresses.
- The geometry of the weld can be varied for **thickness (5-30 mm)**, for throat size (variation depends on thickness) and penetration (variation depends on thickness).
- For $t \leq 10$ mm, $R=0.3$ mm was used in the FE-analysis, see more in ref [6], but then the computed stresses are scaled according to different FAT-values ($FAT225/FAT340=root$ & $FAT225/FAT300=toe$) so that all results in the App are **referring to R1**. The FAT-values for $R=0.3$ mm is an upgrade made March 2020 from ref. 1: IIW Recommendations / Hobbacher (from FAT 320 for both toe & root to FAT 300 Mpa for toe & FAT340 for root). Note that for $R=1$, FAT is same on toe and root, but for $R=0.30$ there is a difference between toe & root.
- The results are presented as principal stress ranges in **three possible critical points: weld root, weld toe up and weld toe low**. Besides the computed stresses, an overview of possible critical points are plotted + curves for same fatigue life (=same stress).
- The computed stresses are determined from **interpolation between a lot of 2D-FE-models** (6 throats*6 penetrations*12 load-comb for each thickness).



Definitions and background



Definition of throat size (a) and penetration (i)

Design for purpose:

One example where different loads lead to different requirements and further different welding processes in the workshop.

GUI – some general guidance

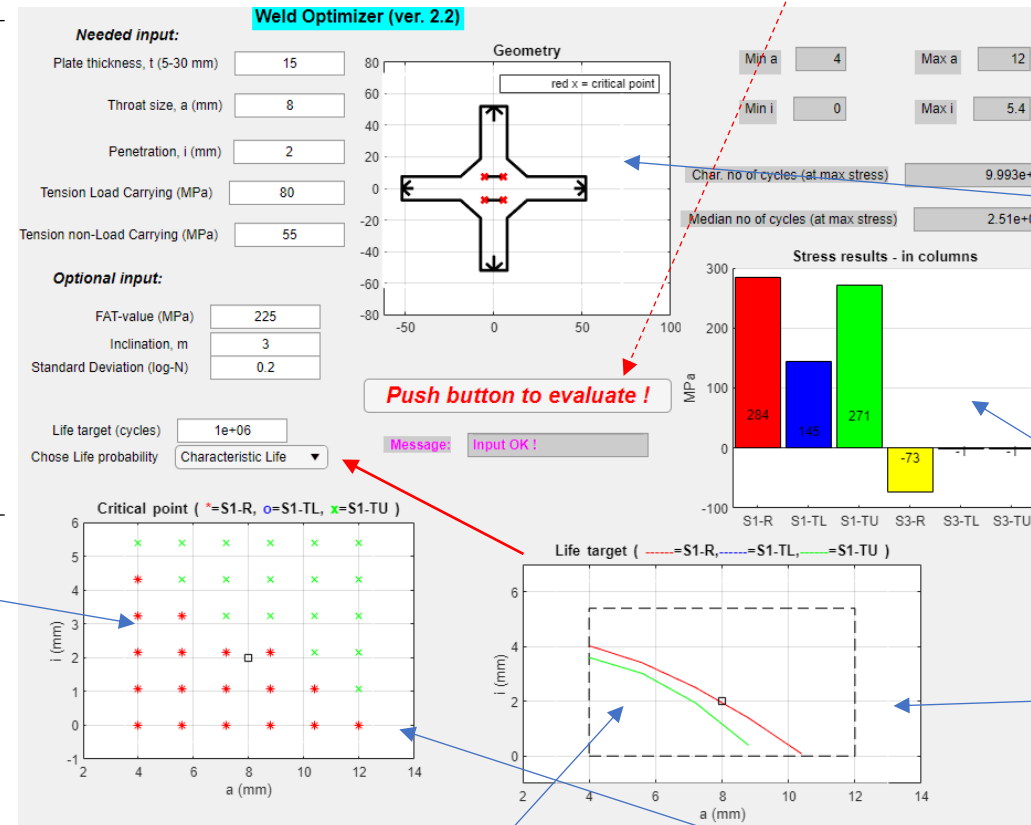
Overview of the Matlab APP, in- & out-put

Computed
life in cycles

The analysis is made when the **push button** is pressed !

Cells (white) at left
= input parameters

Symbols (*, o, x) in diagram
indicate which point in the
weld is critical (root, upper
toe or lower toe) for this
comb of t, a, i and loading.



Cells (grey) at right =
output parameters

Geometry of current
weld+loads, critical
points (x) indicated.

Stresses computed for current
case (function of t, a, i and
tensions).
Colours match in all figures.

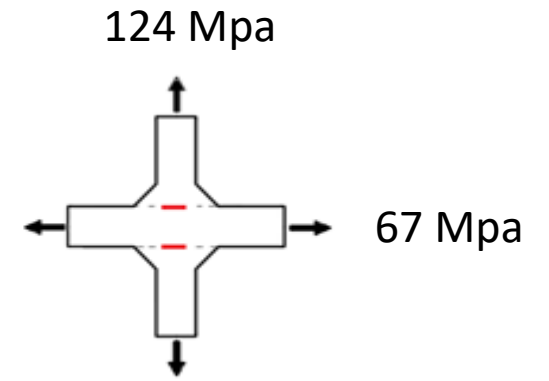
Red line (---) indicate where Root- σ = life target
Green line (---) indicate where Toe-Up- σ = life target
Blue line (---) indicate where Toe-Low- σ = life target

Demo APP – Optimizer

(Study how to find the optimal weld throat)

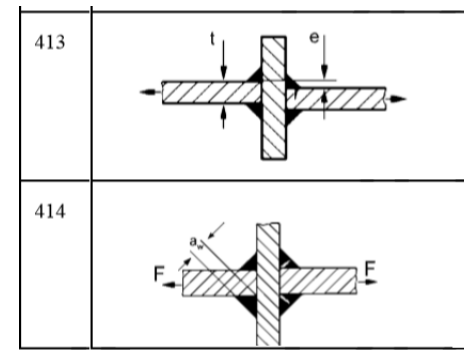
Optimal throat size

- Optimal: have the same fatigue stress in weld toe & weld root
- Run case
 - Thickness $t=20$ mm
 - Throat size $a=10$ mm, no penetration ($i=0$ mm)
 - Nominal tension:
 - Load carrying stress = 124 Mpa
 - Non-load-carrying stress = 67 Mpa
 - Characteristic life target = 350.000 cycles
- Does the suggested weld geometry (a & i) fulfill optimal design ***and*** life target ?



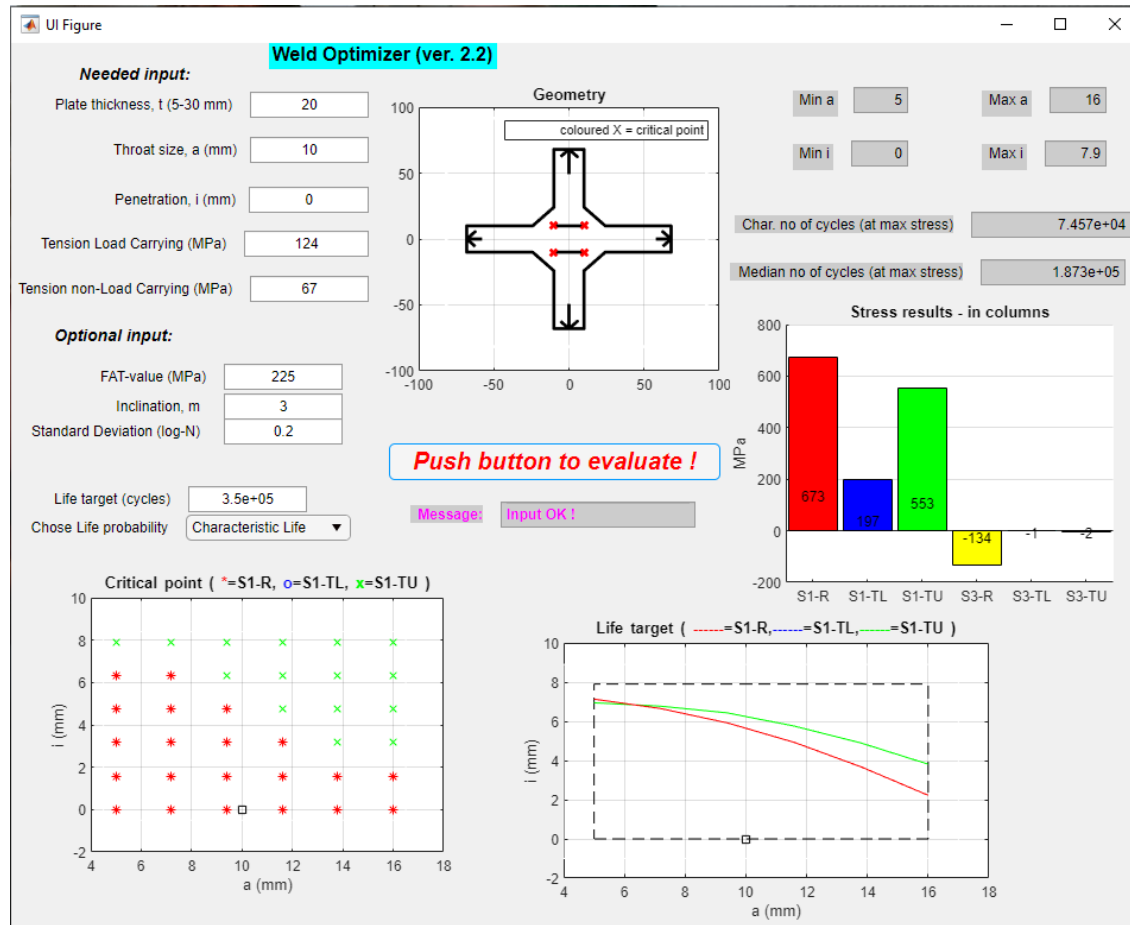
Nominell ansats

Double symmetry assumed
Nominal FAT 71/63/40/36

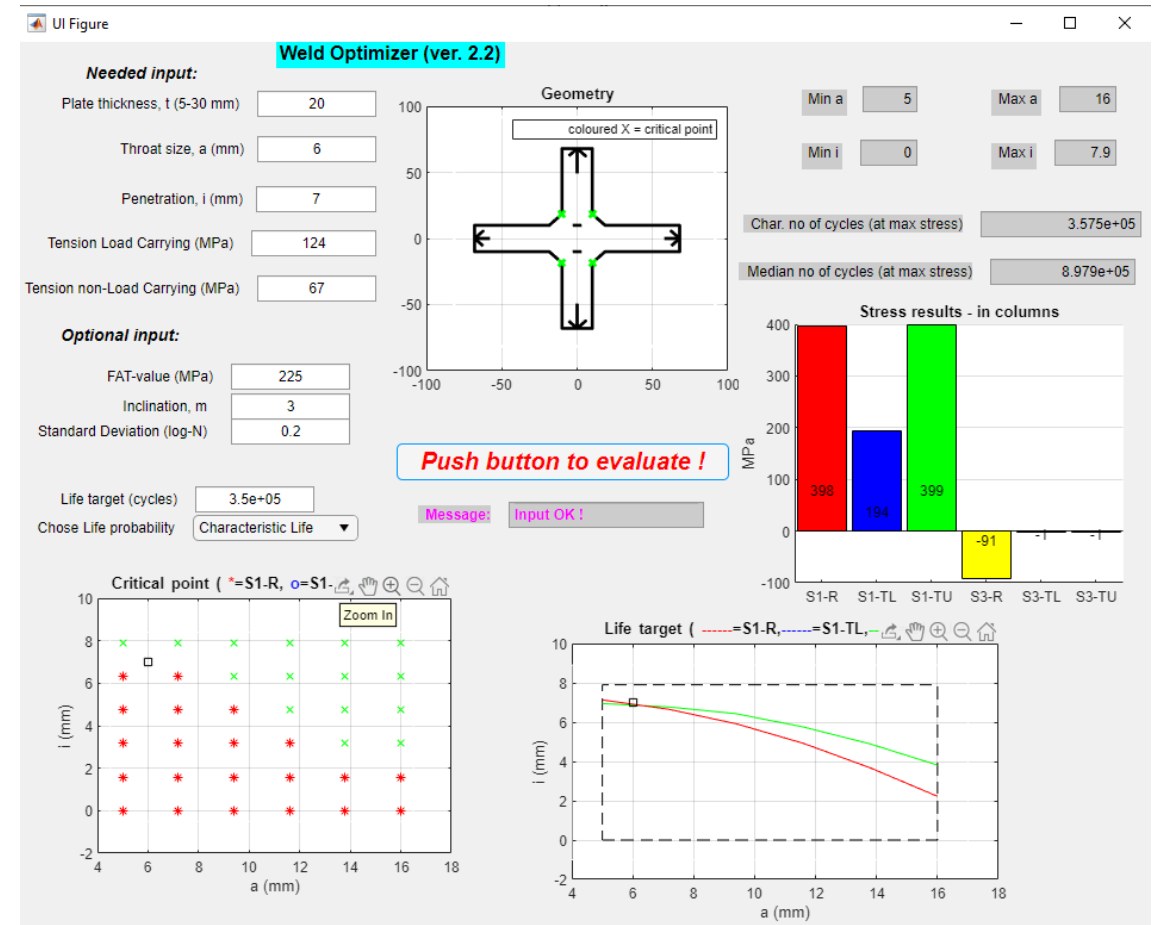


- Slarvern kanske bara kollar tåsidan (FAT 71):
 - Påkänning 124 Mpa, FAT 71 ger $N = 2E6 * (71/124)^3 \approx 375.000$ cykler **> mål Ok!**
- Koll på rotsidan (FAT 36):
 - Påkänning roten = $124 * (t/2a) = 124$ Mpa ger $N \approx 50.000$ cykler **<< målet, ej Ok!**
 - Prova inbränning 5 mm $\rightarrow$ påkänning roten = 92 Mpa $\rightarrow$ **$N \approx 120.000 < \text{målet...}$**
- Slutsats:
 - Man måste ha full inbränning (full fogberedning) $\rightarrow$ **tåsidan kritisk men Ok, se ovan**

Results from the App "Weld Optimizer"



Initial results, $a=10$, $i=0$
 Weld root most critical, toe is not
 Life target is not met (75.000 cycles vs 350.000 cycles)



Final findings, $a=6$, $i=7$
 Weld toe and root are equal stressed (optimal weld)
 Life target is met

Conclusions for the APP "Weld Optimizer"

- The APP can give quick and accurate guidance for fillet welds design.
- Useful for cases like:
 - Quickly find weld parameters meeting life target
 - Reduce weight (reduce thickness) while keeping life target
 - Reduce weld size and thereby welding time and consumables
 - Finding an optimal weld geometry
 - etc

Summary of the 2 APPs

- Two (2) Apps have been developed for quick weld joint analysis (ENS-method)
- They are using Matlab, but are free-standing for a user (Matlab not needed)
- Running time for an analysis is appr. 1 seconds to 1 minute
- A free copy can be tried for a period of 1 month
- Requirements for PC: Windows 10, appr. 1 Gb memory.

Link to homepage: <https://berjo-welddesign.se/index.html>