Demo of
Weld Analyzer & Weld Optimizer

5 Sept 2024

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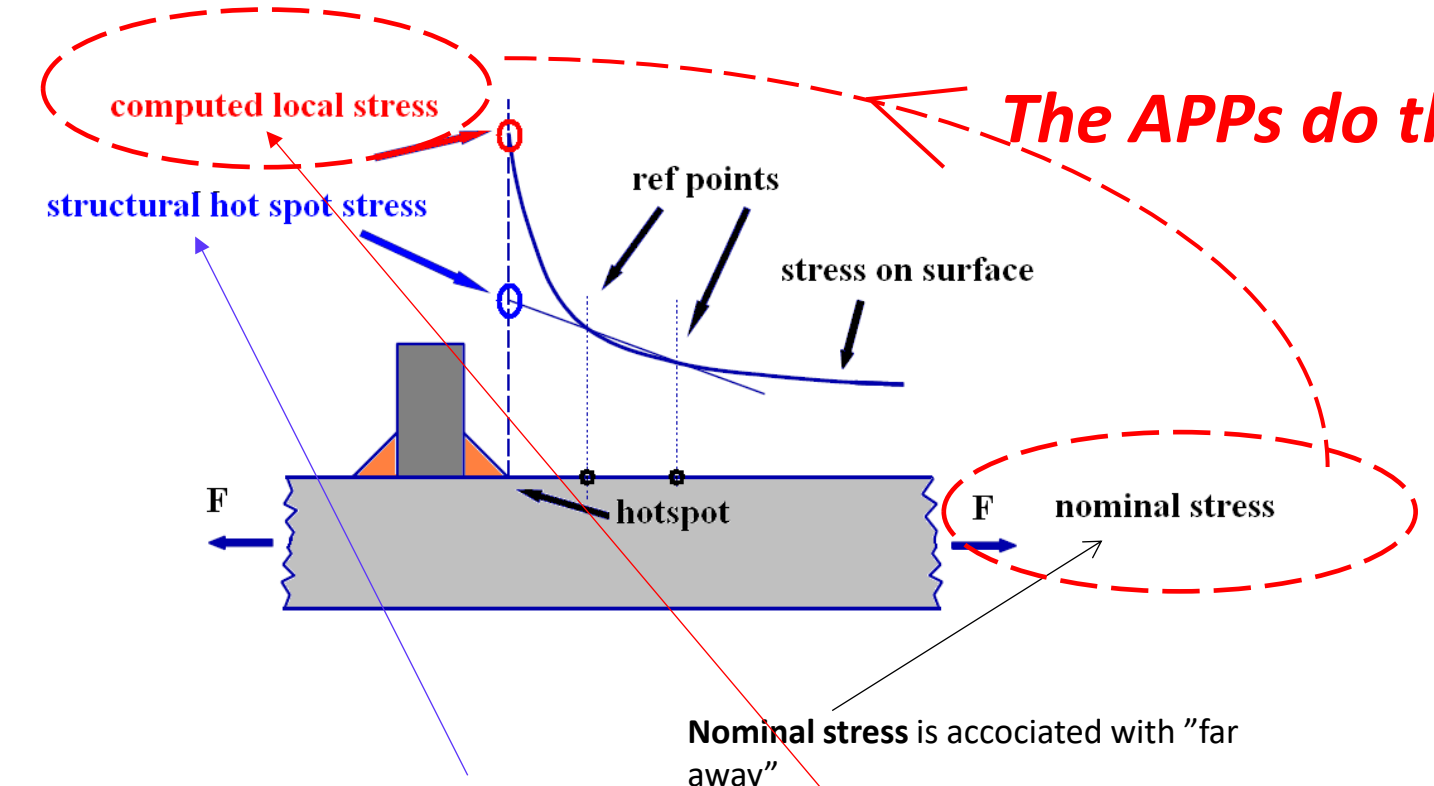
Different stress measures at the toe

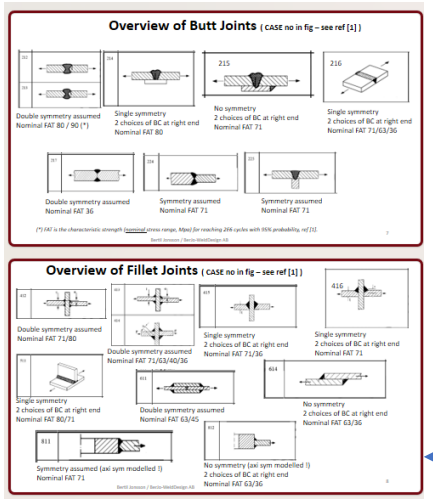


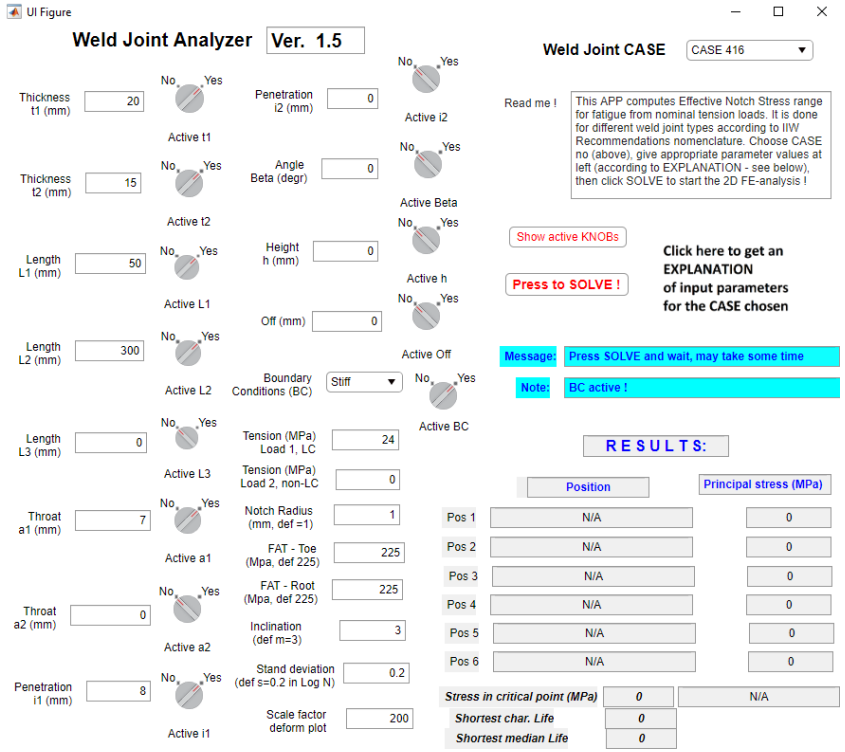
Nominal stress is accociated with ”far away”

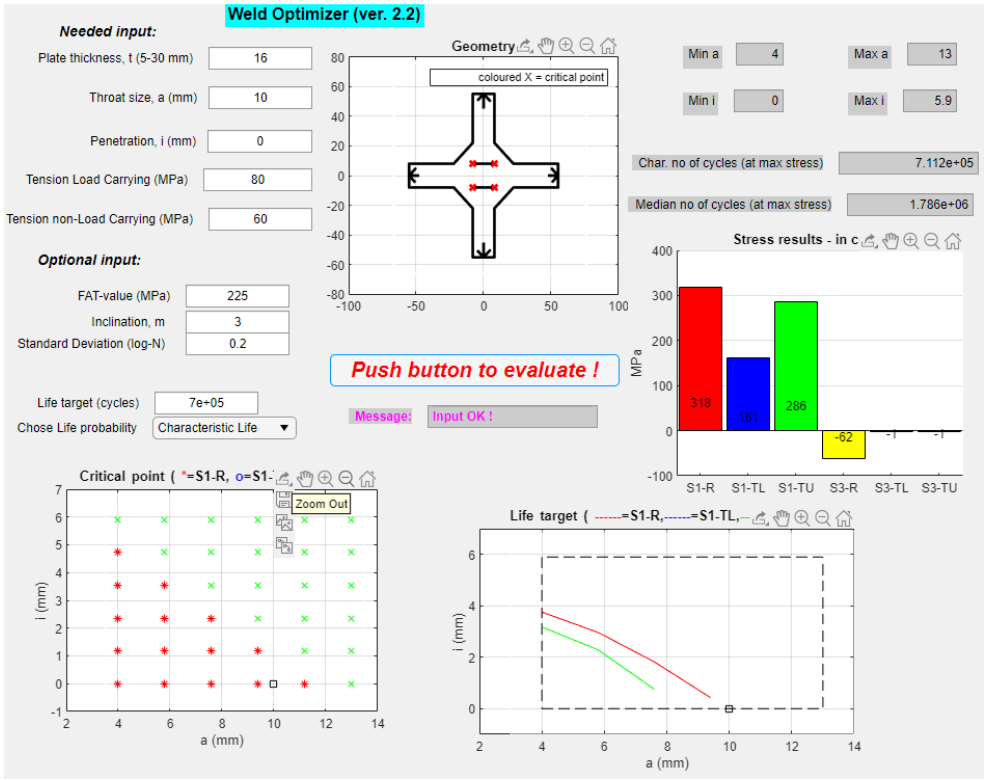
Hot spot is associated with **extrapolated stress**

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







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].

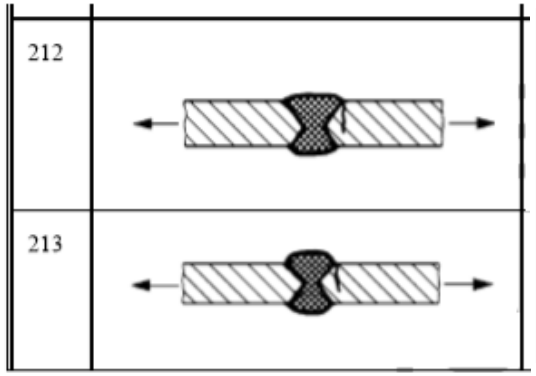
- The user can be without any experience of FE and mesh-sizes since the model is automatically built with appropriate size and type of the elements (quadratic triangular plane stress elements). The geometries are taken from IIW Recommendations and, see ref [1], for those cases where the geometry can 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.

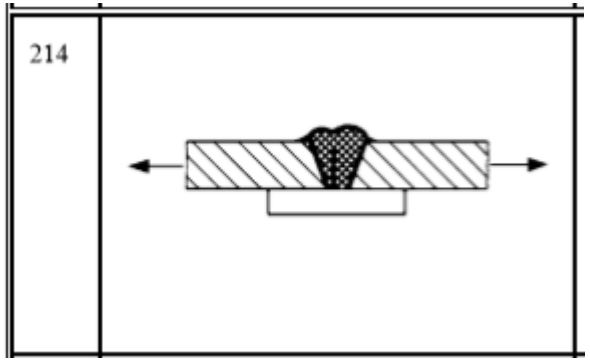
Overview of Joints analyzed

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

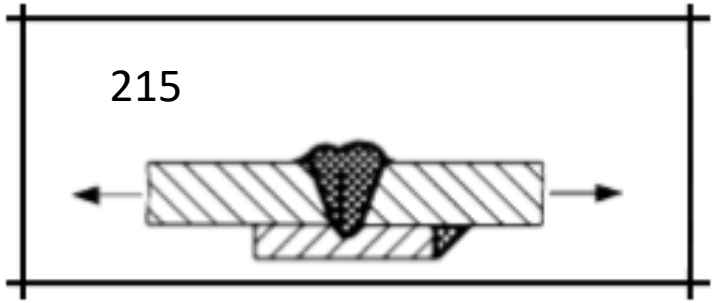
Overview of Butt Joints (CASE no in fig – see ref [1])



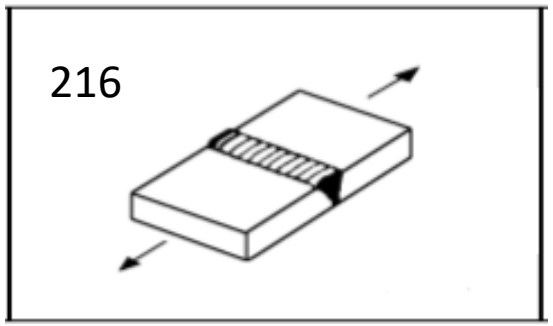
Double symmetry assumed
Nominal FAT 80 / 90 (*)



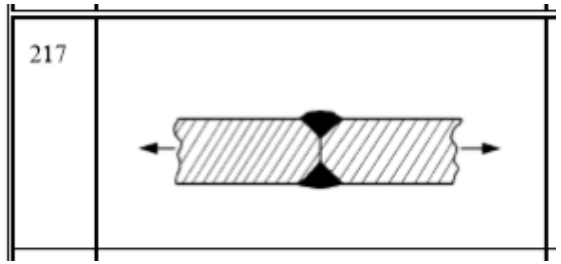
Single symmetry
2 choices of BC at right end
Nominal FAT 80



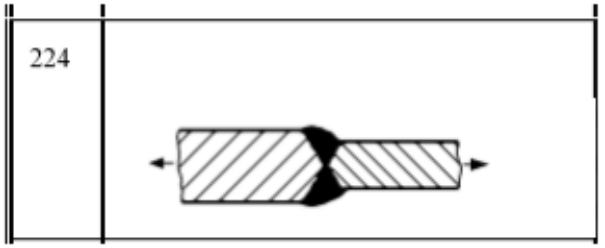
No symmetry
2 choices of BC at right end
Nominal FAT 71



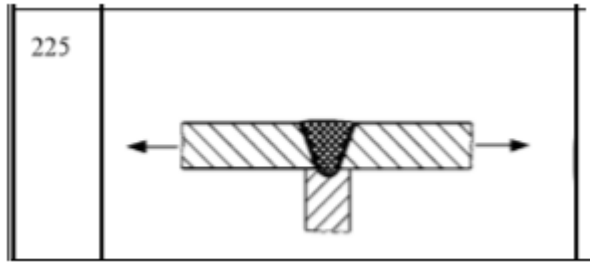
Single symmetry
2 choices of BC at right end
Nominal FAT 71/63/36



Double symmetry assumed
Nominal FAT 36



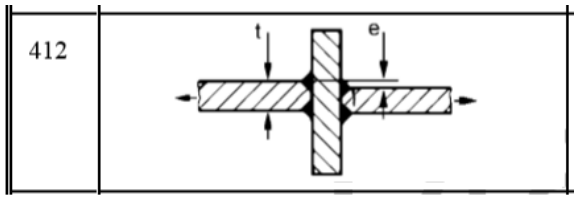
Symmetry assumed
Nominal FAT 71



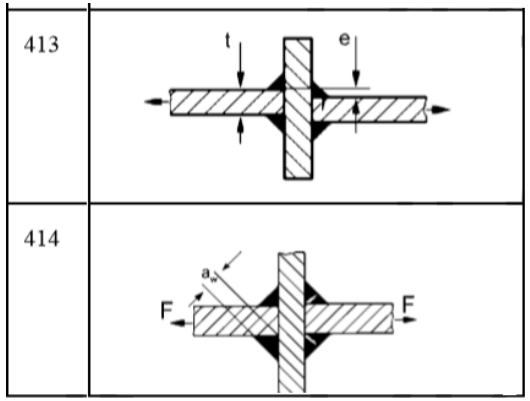
Symmetry assumed
Nominal FAT 71

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

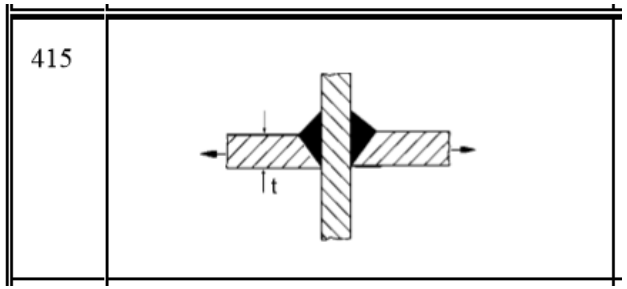
Overview of Fillet Joints (CASE no in fig – see ref [1])



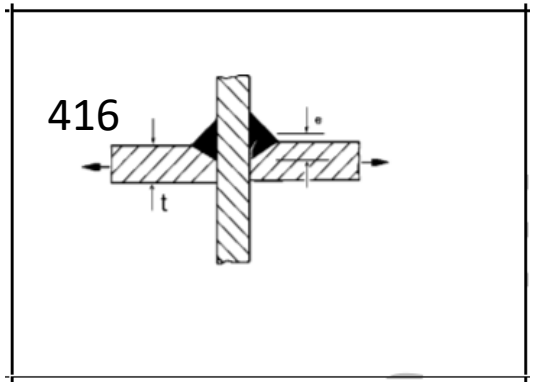
Double symmetry assumed
Nominal FAT 71/80



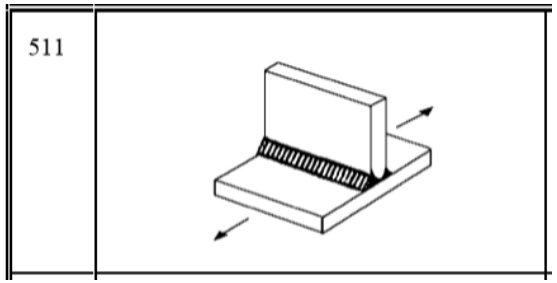
Double symmetry assumed
Nominal FAT 71/63/40/36



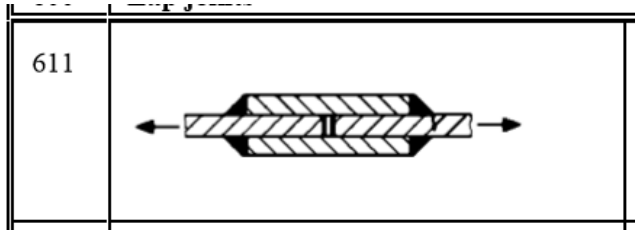
Single symmetry
2 choices of BC at right end
Nominal FAT 71/36



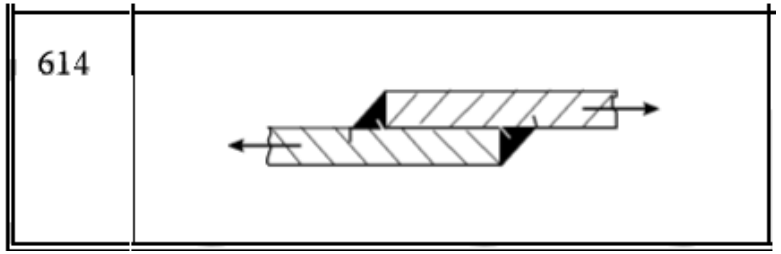
Single symmetry
2 choices of BC at right end
Nominal FAT 71



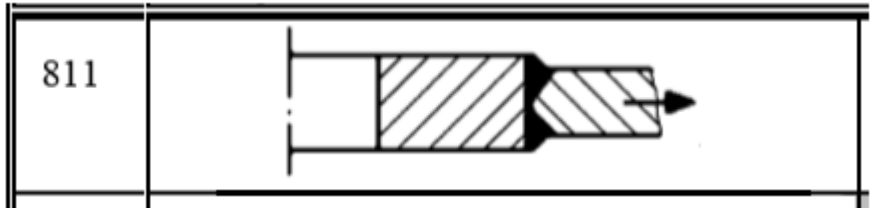
Single symmetry
2 choices of BC at right end
Nominal FAT 80/71



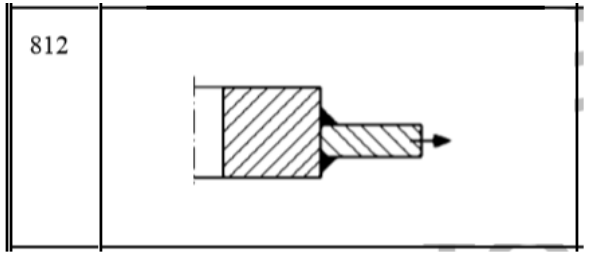
Double symmetry assumed
Nominal FAT 63/45



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



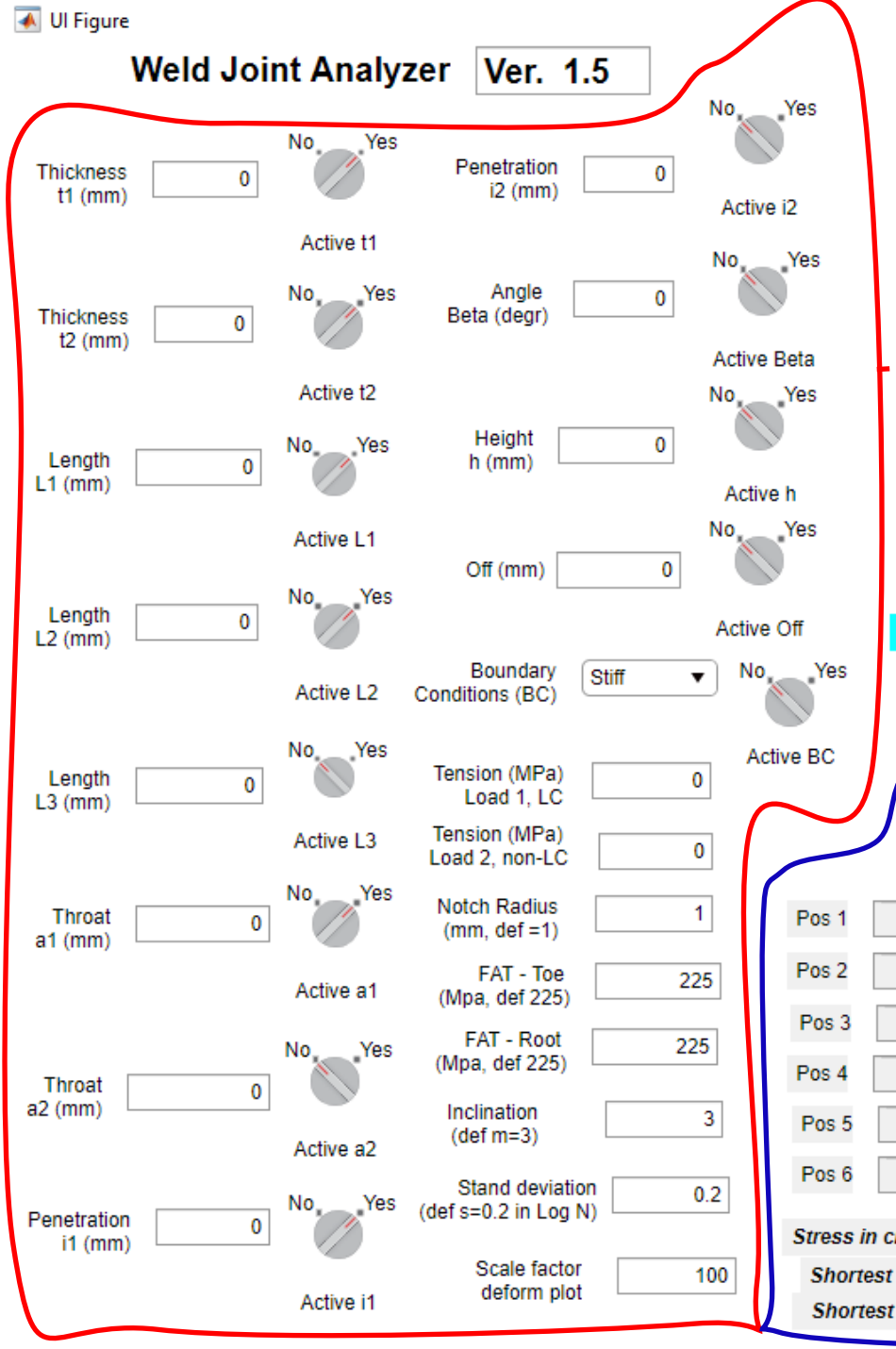
Symmetry assumed (axi sym modelled !)
Nominal FAT 71

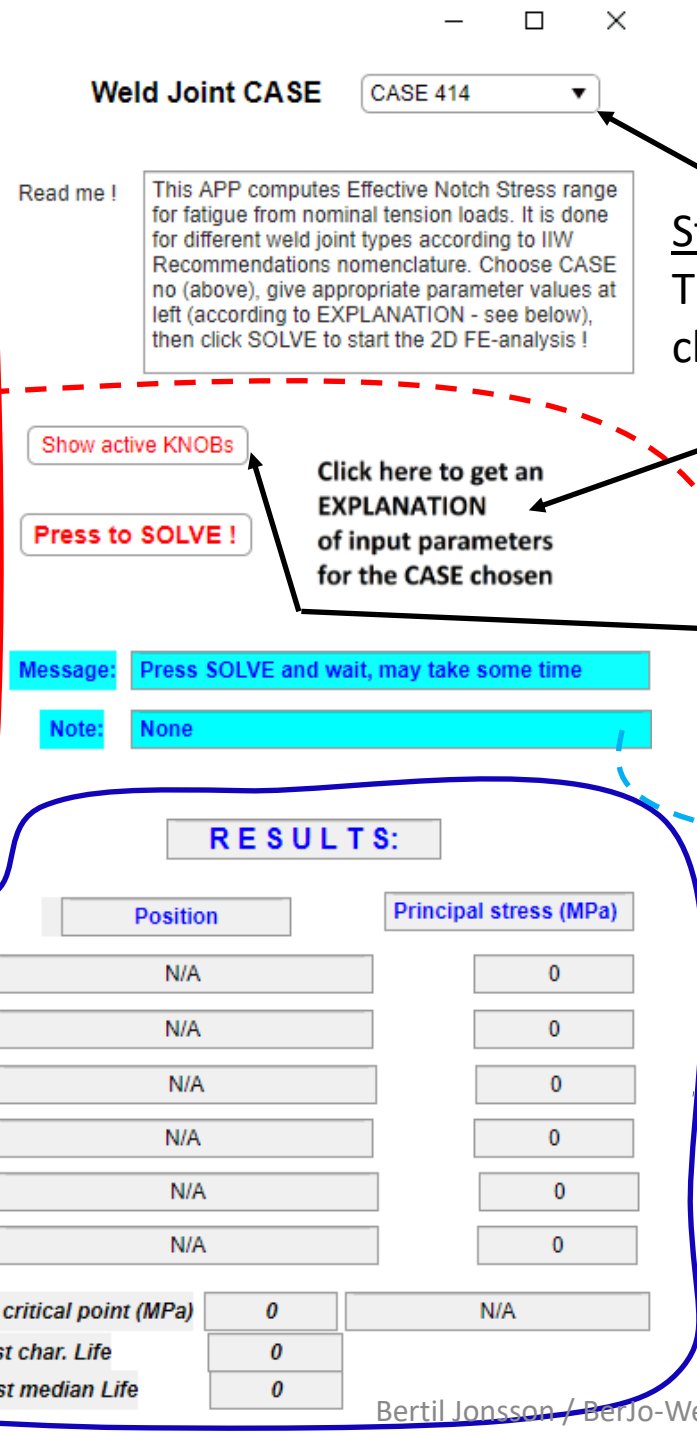


No symmetry (axi sym modelled !)
2 choices of BC at right end
Nominal FAT 63/36

GUI – some general guidance

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.

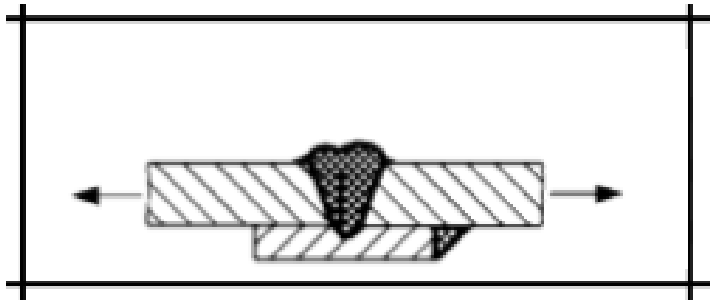
When done – press SOLVE !

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)



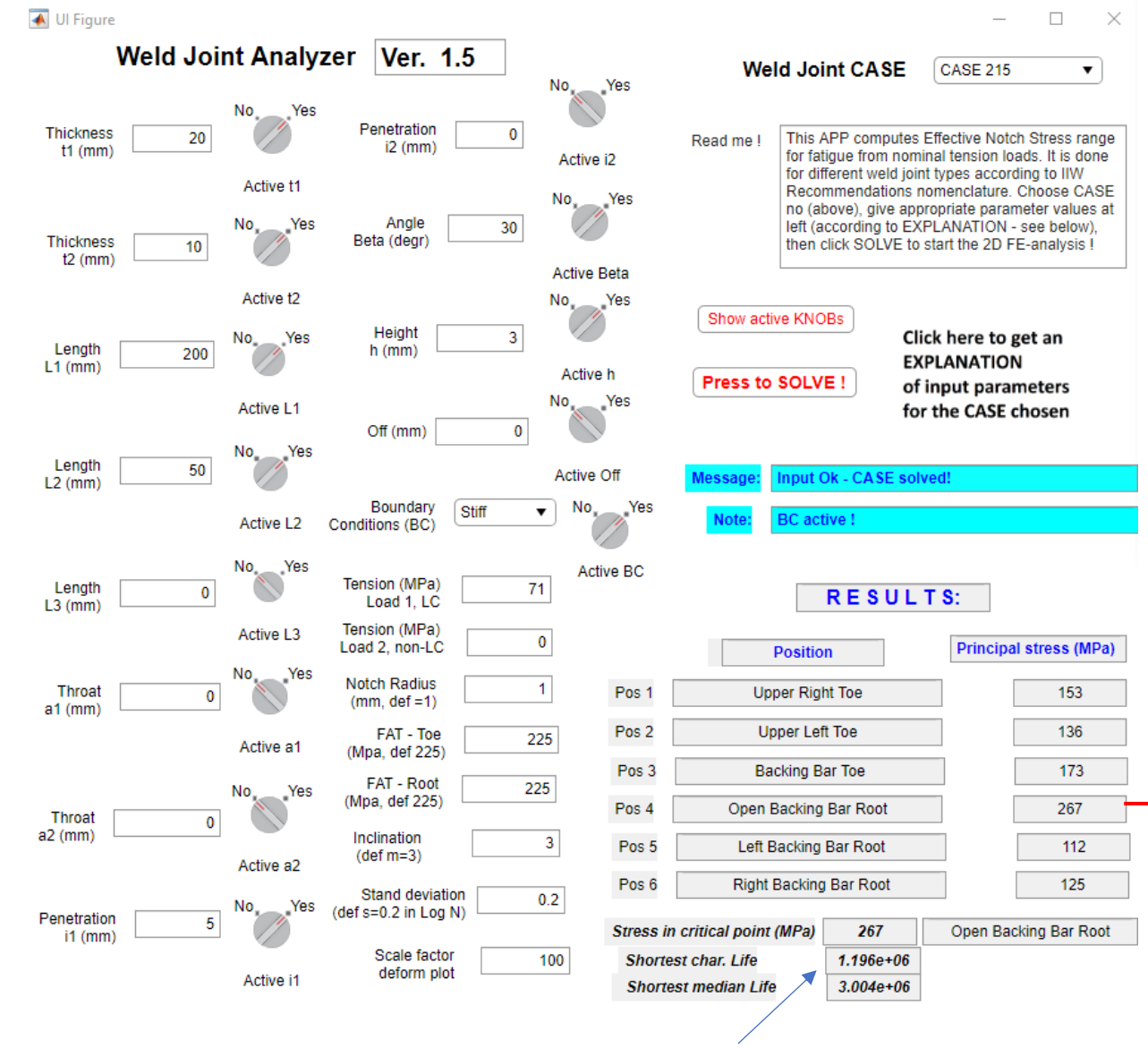
No symmetry
2 choices of BC at right end
Nominal FAT 71

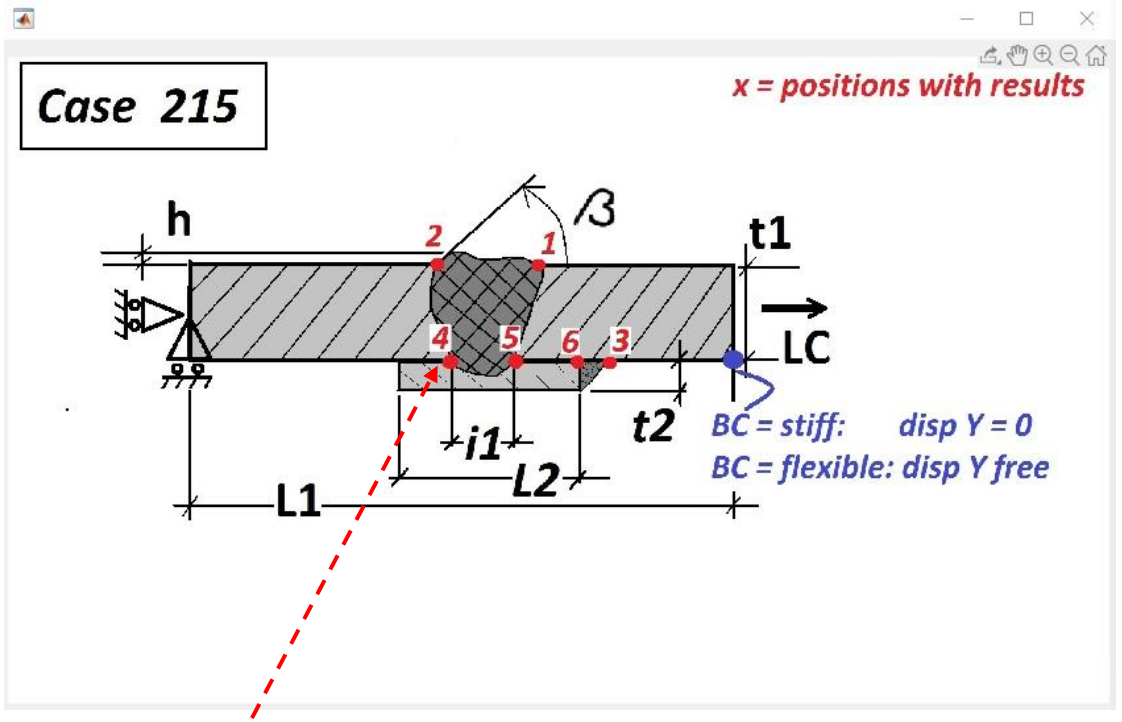
RUN:

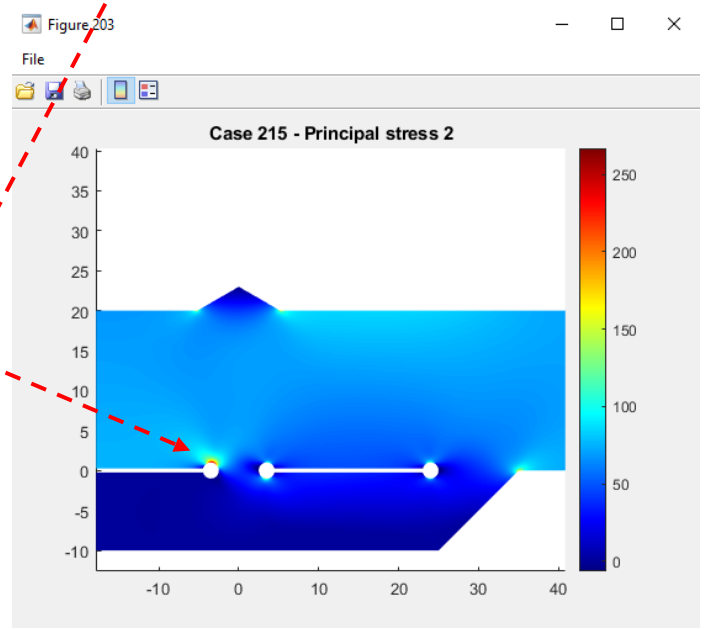
Thickness 20 mm in mainplate, L=200 mm
Thickness 10 mm in backing bar, L=50 mm
Penetration width i=5 mm
Butt weld geometry: $\beta=30^{O}$ & h=0.15t=3 mm

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

Summary of demo case 215







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!

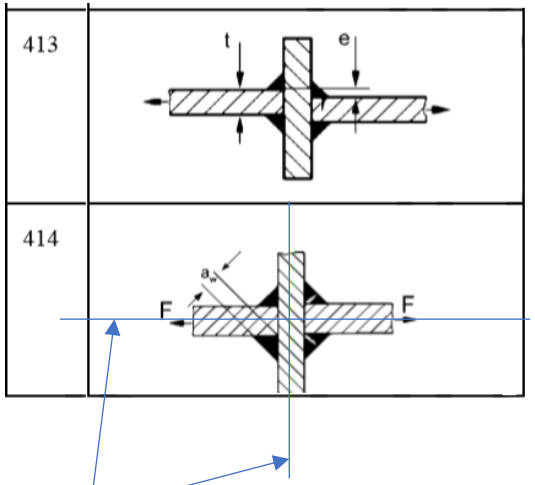
- The APP ”Weld Analyzer” is an easy to use tool to quickly and accurately analyze commonly used weld joint types, since the ENS-method* is being used.

(*) ENS = Effective Notch Stress Method

Weld Optimizer

- Ver 2.2 -

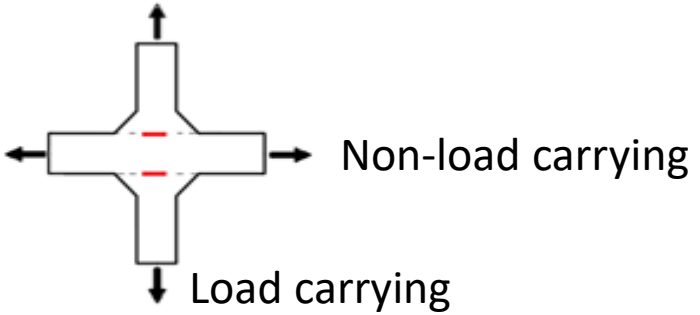
This App ”translates” nominal stresses into ENS-stresses for fillet welds



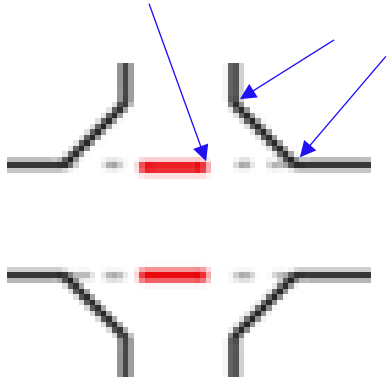
Double symmetry assumed
Nominal FAT 71/63/40/36

Weld case, analysis methods.

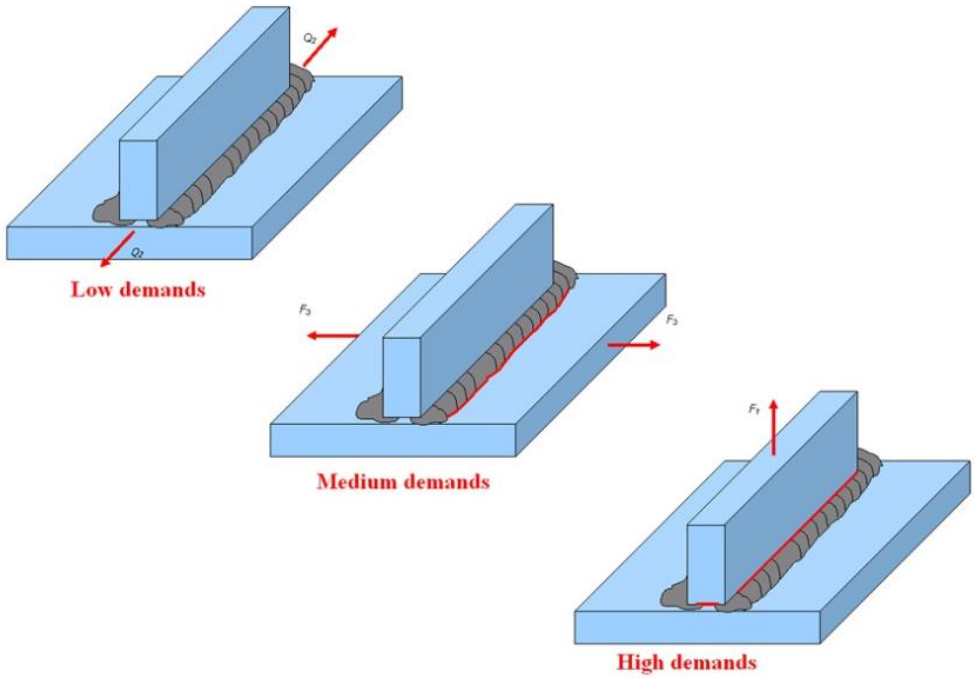
- This Matlab App computes the R1-concept stress, see ref [1] and [5], respons for any combination of load-carrying and non-load carrying nominal tension in cruciform joints, see figure below. It is here assumed that loads are proportional and working simultaneously. One could express this like: nominal 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 ≤ 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.

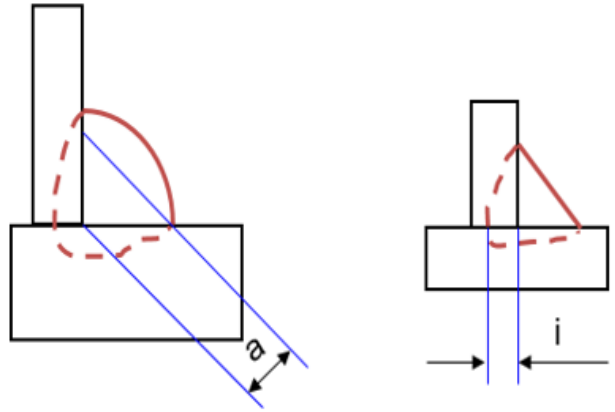


Figure



Definitions and background





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

Design for purpose:

One example where differents 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

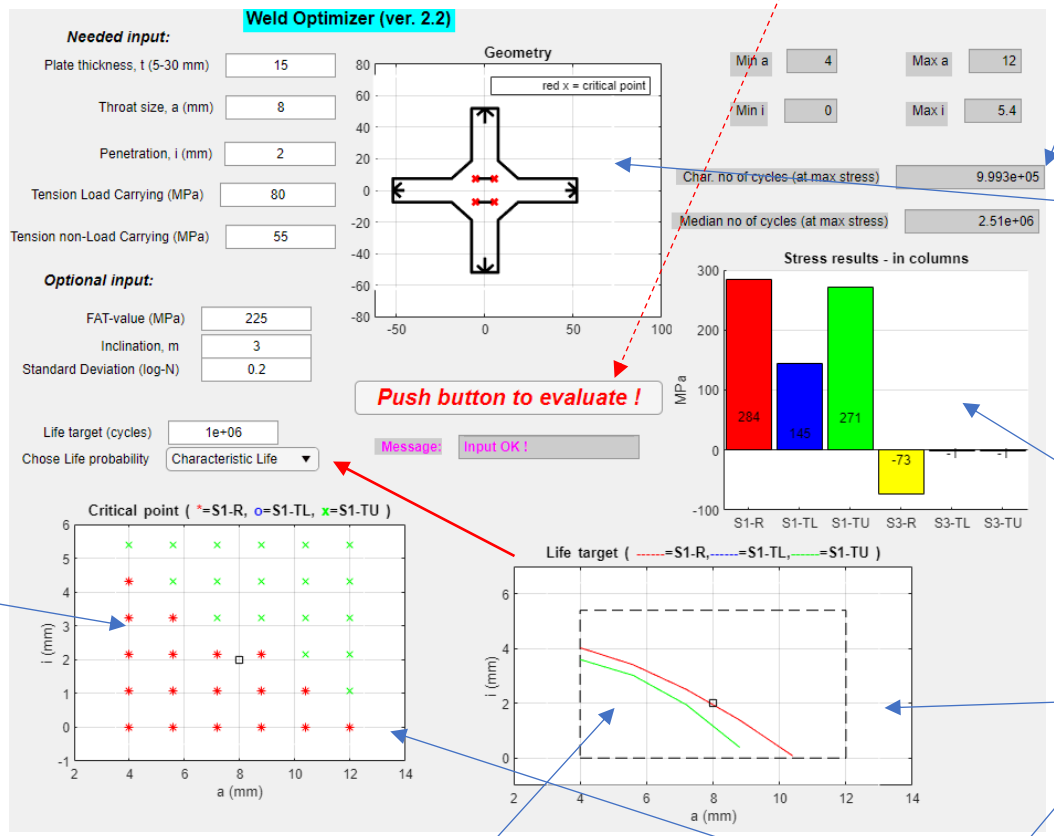
The analysis is made when the push button is pressed !

Computed life in cycles

Cells (grey) at right = output parameters

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

Cells (white) at left = input parameters



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

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.

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

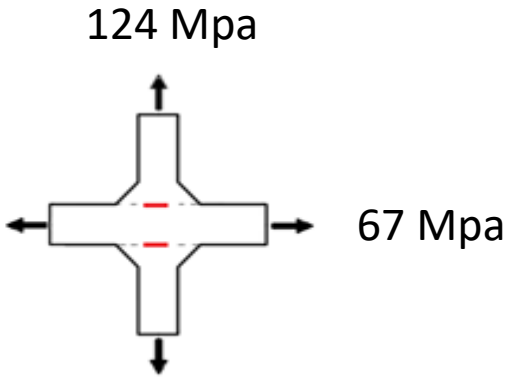
Demo APP – Optimizer

(Study how to find the optimal weld throat)

Optimal throat size

- Optimal: have the same fatigue stress in weld toe & weld root

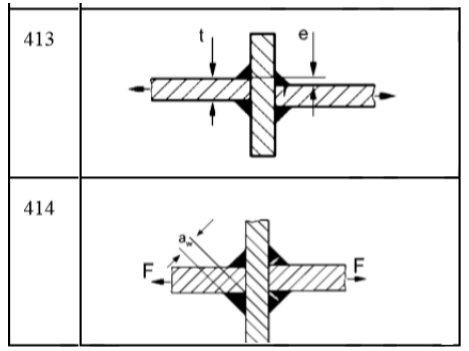
- **Run case**
  - Thickness t20 mm
  - Throat size a=10 mm, no penetration (i=0 mm)
  - Nominal tension:
  - Load carrying stress = 124 Mpa
  - Non-load-carrying stress = 67 Mpa
  - Characteristic life target = 350.000 cycles



- Does the suggested weld geometry (a & i) fulfill optimal design ***and*** life target ?

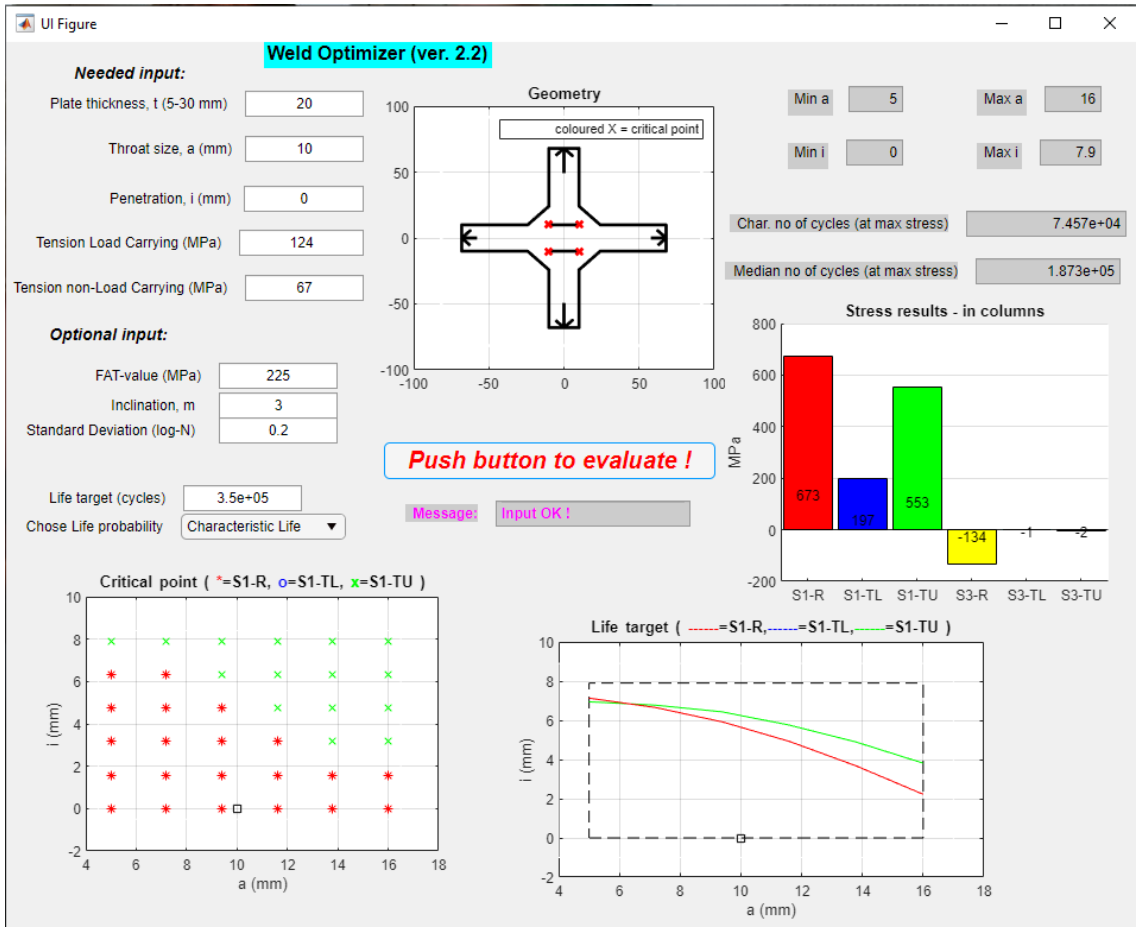
Nominell ansats

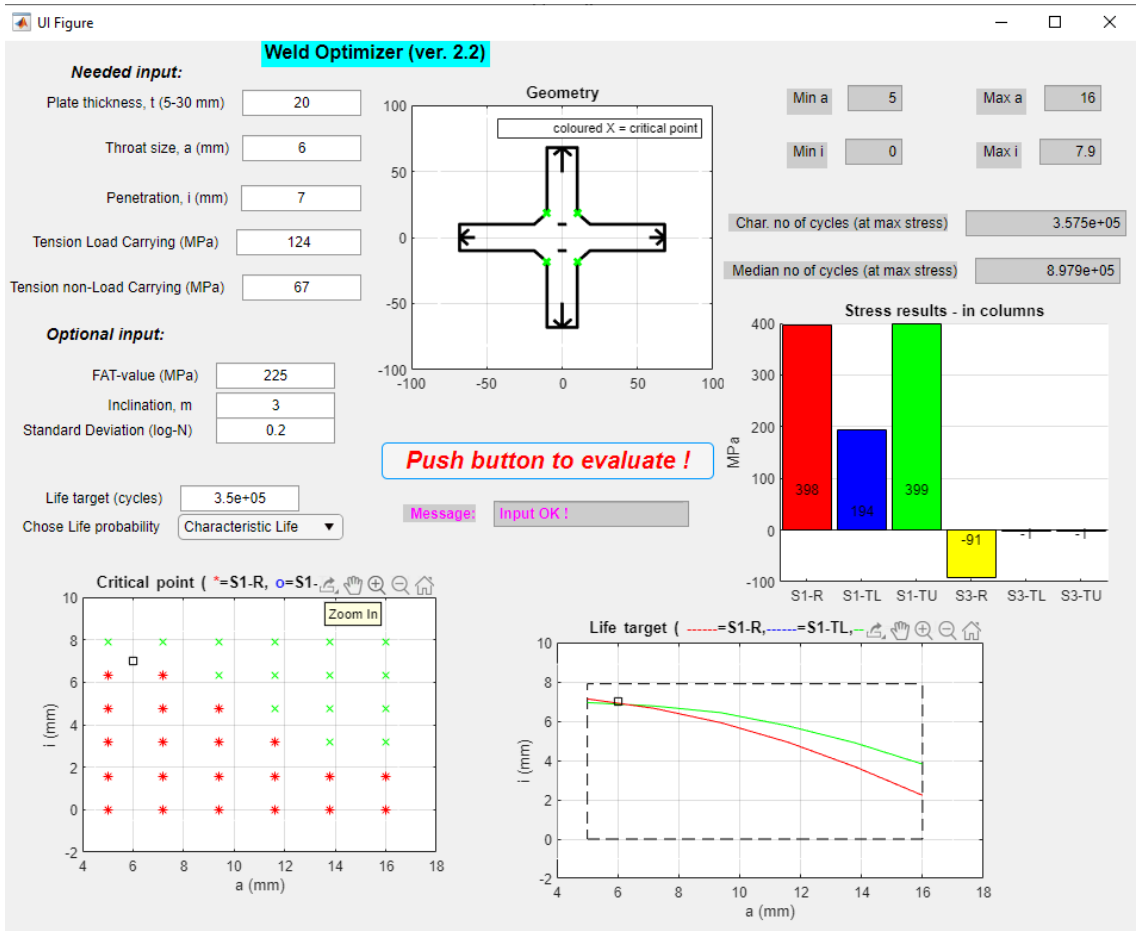
Double symmetry assumed
Nominal FAT 71/63/40/36



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

Results from the App ”Weld Optimizer”





Initial results, a10, i0
Weld root most critical, toe is not
Life target is not met (75.000 cycles vs 350.000 cycles)

Final findings, a6, i7
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