8 WOP3B Lecture 8: Static and dynamic loading of welds and rivits[1] (04/06/2020)

8.1 Static loading on welds

Recall the FBD of a weld:

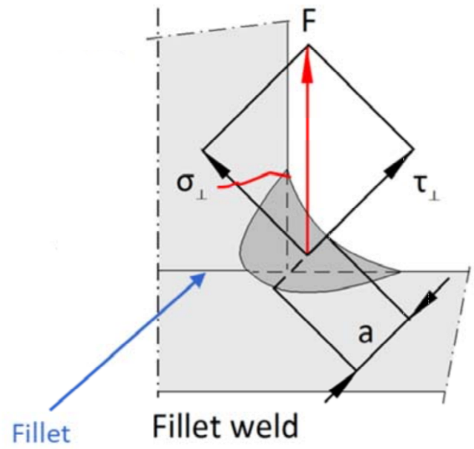

Figure 1: The FBD of a typical fillet weld

The resulting force F in a weld is made up of the 2 components $\sigma_\perp$ and $\tau_\perp$. Applying some mechanics of materials we find:

$$\sigma_\perp = \tau_\perp = \frac{F/\sqrt{2}}{aL} \tag{1}$$

$$\tau_\parallel = 0 \tag{2}$$

The equivalent stress is then given as:

$$\sigma_{eq} = \frac{F\sqrt{2}}{aL} \tag{3}$$

We usually do not consider stress concentrations for static loads on ductile materials. We saw before in the lecture on rotary bending fatigue this is a much more important factor under dynamic loads.

8.2 Dynamic loads on welds

As mentioned stress concentrations are very important to consider when analyzing dynamic loads. When looking at figure 1 we can see a small fillet between the welded parts. This fillet is a stress riser which decreases the endurance limit. Furthermore for static loads we only consider the weld depth a. The overall geometry of a weld is much more important to consider for dynamically loaded welds. Figure below shows some key difference is shapes of a weld.

[1] Although the lecture mainly talks about welds it also applies the same to rivits

Figure 2: Flat convex and concave welds where a is the depth considered for static loading. The concave weld has a smoother transition in geometry and thus a lower local stress concentration.

Considering stress concentrations is especially important for butt-welds. The strength of butt welds does normally need to be considered as the strength of the weld will always be equal to or greater then the material that is being welded. When analyzing dynamic loads however the change in thickness will cause a local concentration in stress. Furthermore the local change in microstructure will make the material brittle and easier to fracture.

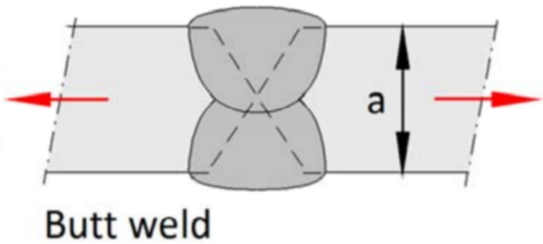

Figure 3: A typical butt-weld

8.3 Detail categories of welds

welds will via euronorm often be denoted with a detail category. The detail category is a standardized value for the endurance limit of a weld. The endurance limit of a weld will be given at $2(10)^6$ cycles. Because of this welds are almost always SLD rather then ILD. In figure 4 the general SN-curve for weld strength by category number is shown.

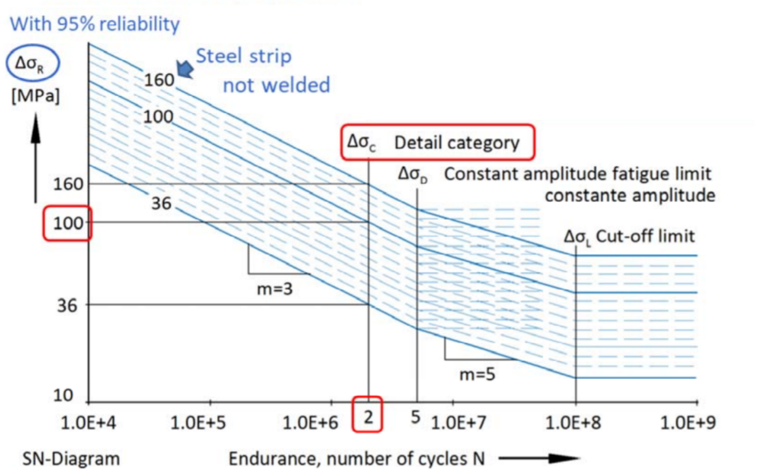

Figure 4: The general SN-curve for the endurance limit. Category number of 160 denotes an unwelded strip of steel.

$$N_r = \left(\frac{\Delta\sigma_C}{\Delta\sigma_R}\right)^m N_C \begin{cases} m = 3, \sigma_R \geq \sigma_D \\ m = 5, \sigma_D > \sigma_R \geq \Delta\sigma_C \end{cases} \tag{4}$$

$$\Delta\sigma_D = \left(\frac{2}{5}\right)^{\frac{1}{3}} \Delta\sigma_C \tag{5}$$

$$\Delta\sigma_C = \left(\frac{5}{100}\right)^{\frac{1}{5}} \Delta\sigma_D \tag{6}$$

$$\tag{7}$$

N_R denotes the amount of cycles untill failure. σ_C denotes the endurance limit based on the given weld category. $N_C = 2(10^6)$ and σ_R is the applied load.

8.4 High grade steel and welding

Typically construction steel is used for welding. The high strength of an high grade ($> 0.3\%$C) is usually reached through heat treatment. Welding steel will locally heat the steel changing the microstructure. This causes the strength of the joint to go back to that of a low carbon steel. Because of this applying higher grade steel is an ineffective and expensive solution.

8.5 Methods of improving weld fatigue strength

- Omit welded joints
- Move welded joints to lower stress areas
- Select weld details with high detail category numbers
- Smooth geometric discontinuities
- Remedial surface grinding
- Post weld heat treatment
- Ultrasonic Impact Treatment (UIT), Hammer peening