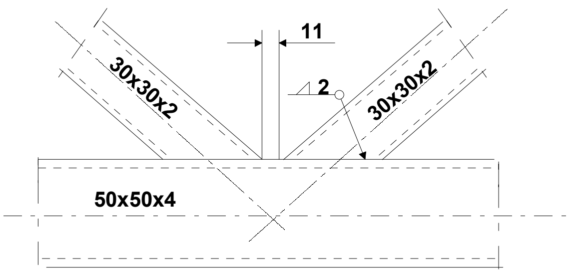
DESIGN EXAMPLE 4 - FATIGUE STRENGTH OF A WELDED HOLLOW SECTION JOINT

This example considers the fatigue strength of the chord of a welded hollow section joint. Fatigue may be a problem in stainless steel structures, which are subjected to repeated fluctuations of stresses. Fatigue of welded hollow section joints may be a problem e.g. in oil platforms, masts, chimneys, bridges, cranes and transport equipment.

EN 1993-1-9:2005 is applicable to stainless steels for estimating the fatigue strength of steel structures also. Therefore the section and clause references in this example are to EN 1993-1-9:2005. Section 8

The example shows the following design tasks for fatigue assessment:
- determination of the fatigue strength curve
- determination of secondary bending moments in the joint
- determination of the partial safety factor for fatigue strength and
- fatigue assessment for variable amplitude loading.

The chords of the joint are RHS 50x50x4 and braces RHS 30x30x2. The material is grade 1.4301 stainless steel with 0,2% proof stress of 220 N/mm^2.



Actions

Determined fatigue stress spectra for the chord during the required design life is:

Nominal stress range	Number of cycles
$\Delta\sigma_1 = 100$ N/mm^2	$n_1 = 10 \times 10^3$
$\Delta\sigma_2 = 70$ N/mm^2	$n_2 = 100 \times 10^3$
$\Delta\sigma_3 = 40$ N/mm^2	$n_3 = 1000 \times 10^3$

References below are to EN 1993-1-9:2005

Structural analysis

The detail category of the joint depends on the dimensions of chord and braces. In this example $b_0 = 50$ mm, $b_i = 30$ mm, $t_0 = 4$ mm and $t_i = 2$ mm.

Because $t_0 / t_i = 2$, the detail category is 71. — Table 8.7

Because $0,5(b_0 - b_i) = 10$ mm, $g = 11$ mm, $1,1(b_0 - b_i) = 22$ mm and $2t_0 = 8$ mm, the joint also satisfies the conditions $0,5(b_0 - b_i) \leq g \leq 1,1(b_0 - b_i)$ and $g \geq 2t_0$. — Table 8.7

Effect of secondary bending moments in the joint

The effects of secondary bending moments are taken into account by multiplying the stress ranges due to axial member forces by coefficient $k_{1,0} = 1,5$ — Clause 4 (2), Table 4.1

Partial safety factors

When it is assumed that the structure is damage tolerant and the consequence of failure is low, the safety factor for fatigue strength is $\gamma_{\mathrm{Mf}} = 1,0$. — Clause 3 (7), Table 3.1

Partial safety factor for loading is $\gamma_{\mathrm{Ff}} = 1,0$.

Fatigue assessment

Reference stress range corresponding 2×10^6 stress fluctuations for detail category 71 is:

$\Delta\sigma_{\mathrm{c}} = 71$ N/mm^2

The fatigue strength curve for lattice girders has a constant slope $m = 5$ — Figure 7.1

The number of stress fluctuations corresponding nominal stress range $\Delta\sigma_i$ is

$$N_i = 2 \times 10^6 \left[\frac{\Delta\sigma_{\mathrm{c}}}{\gamma_{\mathrm{Mf}} \gamma_{\mathrm{Ff}} \left(k_{1,0} \Delta\sigma_i\right)} \right]^m \text{ and}$$

$\Delta\sigma_1 = 100$ N/mm^2 $\quad N_1 = 47,5 \times 10^3$

$\Delta\sigma_2 = 70$ N/mm^2 $\quad N_2 = 283 \times 10^3$

$\Delta\sigma_3 = 40$ N/mm^2 $\quad N_3 = 4640 \times 10^3$

Palmgren-Miner rule of cumulative damage

Partial damage because of n_i cycles of stress range $\Delta\sigma_i$ is

$D_{d,i} = n_{Ei} / N_{Ei}$. Therefore for — A.5 (1)

$\Delta\sigma_1 = 100$ N/mm^2 $\quad D_{d,1} = 0{,}21$

$\Delta\sigma_2 = 70$ N/mm^2 $\quad D_{d,2} = 0{,}35$

$\Delta\sigma_3 = 40$ N/mm^2 $\quad D_{d,3} = 0{,}22$

The cumulative damage during the design life $D_d = \sum_i^n \frac{n_{Ei}}{N_{Ri}} = \sum D_{d,i} = 0{,}78$ — A.5 (1)

Because the cumulative damage is less than unity, the calculated design life of the chord is more than the required design life. — Clause 8(4)

The procedure described above shall also be repeated for the brace.

BLANK PAGE