Note on Engineering Details

No: GL RC-Fru-extern-002, Rev. 2

Title: **Determination of stress magnification factor k_m**

Ref.: /1/ GL Rules and Guidelines Industrial Services IV – 2 „Guideline for the Certification of Offshore Wind Turbines“, Edition 2005

/2/ IIW Document IIW-1823-07 “Recommendations for Fatigue Design of Welded Joints and Components”, A. Hobbacher, Edition 2008

/3/ GL Rules and Guidelines Industrial Services IV – 1 „Guideline for the Certification of Wind Turbines“, Edition 2010

/4/ “Stahlbaukalender” (“Steel Structures Yearbook”), Edition 2006

/5/ “Eurocode 3: Design of steel structures, Part 1-9: Fatigue”

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Within the following note the application of the stress magnification factor k_m will be regulated under observation of the nominal stress approach for welded steel structures (tower and foundation) at on- and offshore wind turbines.

The life time of butt welded structures will be strongly affected by the existing misalignment. Here we have to distinguish between the design misalignment due to plate thickness transition and the misalignment by manufacturing tolerances.

The stress magnification factor for the stress increase at transverse butt welds between plates of different thickness can be calculated approximately by the approach according to /1/ 6.6.6.4.1 (4).

Further on the stress magnification factor may be evaluated in detail corresponding to the following formula:

$$k_{m,calculated} = 1 + \frac{6 * e}{t_{\min}} * \frac{t_{\min}^n}{t_{\min}^n + t_{\max}^n}$$

Formula 1: Calculation of stress magnification factor k_m for butt welds with axial misalignment according to /2/, section 6.3

Parameter definition for formula 1:

t_{min} minimum plate thickness ($t_{min} \leq t_{max}$)

t_{max} maximum plate thickness

e eccentricity

n=1.5 determined by testing corresponding to /2/, section 6.3

The stress magnification factor due to design misalignment shall be applied for the fatigue calculation in general.

A misalignment $k_{m,\ inclusive}$ due to manufacturing tolerances has already been considered within the FAT class.

However if the limits for the already considered misalignment due to manufacturing tolerances are exceeded additional calculations under observation of $k_{m,\ effective}$ shall be taken into account.

Detail category according to /1/ table 6.A.1	**Detail category according to /5/ table 8.3**	**Admissible misalignment "e" of t_{min}**	**$k_{m,\ inclusive}$**	**$k_{m,\ effective}$**
Butt welded joints made in shop in flat position with respect to no. 211 to 212 and 221 to 222	Butt welded joints made in shop in flat position with respect to no. 1, 4, 5 and 7	$\leq$ 5%	1.15	$k_{m,\ calculated}$ / 1.15 $\geq$ 1.0
Butt welded joints with respect to no. 213 to 216 and 223 to 225	Butt welded joint with respect to no. 11	$\leq$ 10%	1.30	$k_{m,\ calculated}$ / 1.30 $\geq$ 1.0

Table 1: Correlation of welding detail and stress magnification factor k_m

The stress magnification factor $k_{m,\ effective}$ due to the imperfection by manufacturing tolerances may be calculated by the following formula.

$$k_{m,effective} = \frac{k_{m,calculated}}{k_{m,inclusive}} \quad \text{(formula 2)}$$

However this factor needs to be applied only if the admissible misalignment "e" has been exceeded.

The stress magnification factor $k_{m,\ design}$ due to design misalignment may also be calculated by formula 1.

$$k_{m,design} = k_{m,calculated} = 1 + \frac{6 * e_{design}}{t_{min}} * \frac{t_{min}^n}{t_{min}^n + t_{max}^n} \quad \text{(formula 3)}$$

If different types of misalignment are to be considered the total misalignment $k_{m,\,total}$ shall be calculated by the following formula.

$$k_{m,total} = 1 + (k_{m,design} - 1) + (k_{m,effektive} - 1) \qquad \text{(formula 4)}$$

The admissible design fatigue resistance $\Delta\sigma_R$ of the detail category has to be multiplied with the stress correction factor f_a.

$$f_a = \frac{1}{k_{m,total}} \qquad \text{(formula 5)}$$

This note replaces Table 6.6.5 of the GL Guideline: IV – 2 „Guideline for the Certification of Offshore Wind Turbines“, Edition 2005.

Further on this note shall be applied for the certification of steel structures according to the GL Guideline: IV – 1 „Guideline for the Certification of Wind Turbines“, Edition 2010.

The issue of misalignment has already been published in /4/. Therein detailed information regarding the consideration of misalignment can be found within “Chapter 2 - Basics and explanations for the fatigue verification according to Eurocode 3” under section 4.3.3.3. This leads to a direct correlation to /5/.

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