A1. LLOYD'S REGISTER OF SHIPPING PARAMETRIC EQUATIONS FOR STRESS CONCENTRATION FACTORS IN RING-STIFFENED TUBULAR JOINTS (Smedley and Fisher 1991)

\[ \tau = t/T; \quad \beta = d/D; \quad \gamma = D/2T; \quad \alpha = 2L/D; \quad \theta = \text{brace to chord inclination}; \]

SCF ratio = stiffened joint SCF / unstiffened joint SCF; 
CS = chord saddle; BS = brace saddle; IR = ring inner edge; CC = chord crown; 
BC = brace crown; \( d' = \text{brace foot print length} = d/\sin\theta \);
p = average ring separation (for 1 ring = 2 x distance of ring to saddle); 
n = number of rings under the brace foot print; 
\( lw = \text{length of ring web} \); \( tw = \text{thickness of ring web} \); 
\( lf = \text{length of ring flange} \); \( tf = \text{thickness of ring flange} \); 
\( b_e = \text{effective length of chord wall} = \text{min}(1.56 \ T \ \sqrt{\gamma}; \ p) (= 1.56 \ T \ \sqrt{\gamma} \ \text{for one ring}) \)

Chord parameters:

\[ R_{tau} = \frac{n \ lw_i}{T} \]

\[ \kappa_2 = \frac{(12 l_{OC} \ d')^{1/3}}{T} \]

where

\[ l_{OC} = \left[ \frac{d'T^3}{12} + \frac{n}{4} \sum_{i=1}^{n} \left( \frac{lw_i tw_i (tw_i + T)}{12} + \frac{lw_i tw_i}{4} \right)^2 + \frac{lw_i tw_i}{12} + \frac{lw_i tw_i}{12} + \frac{lw_i tw_i}{12} \right] \]

\[ A_c = d'T + \sum_{i=1}^{n} \left( lw_i tw_i + \frac{lw_i tw_i}{4} \right) \]

and
\[
\gamma_{cgc} = \sum_{i=1}^{n} \left( \frac{lw_i tw_i (lw_i + T)}{2} \right) + \frac{yf_i (lw_i + \frac{T}{2} + \frac{bf_i}{2})}{A_c}
\]

\(K_2'\) and \(R_{\text{tau}}'\) are the \(K_2\) and \(R_{\text{tau}}\) parameters calculated for the pair of rings nearest to the crown, i.e., if \(n > 2\), then set \(n = 2\) to find \(K_2'\) and \(R_{\text{tau}}'\).

**Ring Parameters:**

\[K_1 = \frac{A_r}{DT} \quad \text{... (A1.3)}\]

\[I_{\text{mod}} = \left( \frac{I_{OR} / \gamma_{cgr}}{T^2 D / 6} \right) \quad \text{... (A1.4)}\]

where

\[I_{OR} = \frac{b_e T^3}{12} + lw \cdot tw \left( \frac{lw}{2} + yf \right)^2 + b_e T \left( lw + yf + \frac{T}{2} \right)^2 + \frac{lw^3 tw}{12} + \frac{yf y^3}{3} \]

\[- \left( A_r \gamma_{cgr}^2 \right)\]

\[A_r = b_e T + lw \cdot tw + yf \text{ and } \gamma_{cgr} = \frac{b_e T \left( lw + yf + \frac{T}{2} \right) + lw \cdot tw \left( \frac{lw}{2} + yf \right) + \frac{yf y^2}{2}}{A_r} \]

For stresses occurring along the brace/chord intersection, the ring-stiffened joint SCF is given by the product of SCF ratio and unstiffened joint SCF. The SCF ratios for the case of axial loading of brace are given by:

\[\text{SCF ratio}_{CS} = \frac{0.1}{\tau^{0.2} N_{\text{eq}}} \left\{ \frac{5.5}{K_2} + \frac{1}{R_{\text{tau}}} \right\} \quad \text{... (A1.5)}\]

\[\text{SCF ratio}_{CC} = 1.5 \beta^{0.5} \quad \text{... (A1.6)}\]
SCF ratio_{BS} = \frac{0.12}{r} \cdot 0.25 \cdot \frac{10}{K_2} + \frac{1}{R_{\tau_u}} \quad \text{(A1.7)}

SCF ratio_{BC} = r \cdot 0.8 \cdot 0.5 \cdot \sin(4\beta - 3\beta^2 - 0.5) \quad \text{(A1.8)}

SCF_{IR} = \frac{0.3 \cdot r \cdot 0.5 \cdot \sin(\theta)}{N_{re3}} \cdot \left( \frac{6\beta}{l_{mod}} + \frac{\beta}{K_1} \right) \quad \text{(A1.9)}

**N_r** values (equivalent number of rings)
for the case of axial loading of brace:

**Chord saddle:**

\[
N_{re1} = \exp\left(-0.3 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 1
\]
\[
N_{re2} = 2 \cdot \exp\left(-\left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 2
\]
\[
N_{re3} = 1 + 2 \cdot \exp\left(-2.5 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 3
\]
\[
N_{re4} = 2 \cdot \exp\left(-5.0 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) + 2 \cdot \exp\left(-0.5 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 4
\]

**Brace saddle:**

\[
N_{re2} = \exp\left(-0.2 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 1
\]
\[
N_{re2} = 2 \cdot \exp\left(-0.5 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 2
\]
\[
N_{re3} = 1 + 2 \cdot \exp\left(-3.0 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 3
\]
\[
N_{re4} = 2 \cdot \exp\left(-0.5 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) + 2 \cdot \exp\left(-6.0 \cdot \left(\frac{p}{d'}\right)^{0.2}\right) \quad \text{for } n = 4
\]

**Ring inner edge:**

\[
N_{re3} = \exp\left(-0.1 \cdot \left(\frac{p}{d'}\right)^{2}\right) \quad \text{for } n = 1
\]
\[
N_{re3} = 2 \cdot \exp\left(-0.25 \cdot \left(\frac{p}{d'}\right)^{2}\right) \quad \text{for } n = 2
\]
\[
N_{re3} = 1 + 2 \cdot \exp\left(-3.0 \cdot \left(\frac{p}{d'}\right)^{2}\right) \quad \text{for } n = 3
\]
\[
N_{re4} = 2 \cdot \exp\left(-0.25 \cdot \left(\frac{p}{d'}\right)^{2}\right) + 2 \cdot \exp\left(-30.0 \cdot \left(\frac{p}{d'}\right)^{2}\right) \quad \text{for } n = 4
\]
Range of applicability:

The above equations are generally valid for joint parameters within the following limits:

\[ 0.40 < r < 1.00; \quad 0.26 < \beta < 0.80; \quad 12.0 < \gamma < 33.50; \quad 5.00 < \alpha < 13.30; \]
\[ 30^\circ < \theta < 90^\circ; \quad 1 \leq n \leq 4; \quad 0.49 < R_{\text{max}} < 5.30; \quad 1.40 < K_2 < 10.91; \]
\[ 0.18 < K_f < 1.04; \quad 0.17 < l_{\text{mod}} < 28.50. \]

A2. PARAMETRIC EQUATIONS DEVELOPED BY SERC-MADRAS FOR STRESS CONCENTRATION FACTORS IN RING-STIFFENED STEEL TUBULAR JOINTS (Ramachandra Murthy et al 1990)

Tubular T joints subjected to axial loading of brace:

\[
\text{SCF}_{\text{chord}} = 0.729 \beta^{0.54} \gamma^{0.633} \tau^{1.077} x^{-0.178} \psi^{-0.117} \quad \ldots (A2.1)
\]
\[
\text{SCF}_{\text{brace}} = 0.79 \beta^{0.104} \gamma^{0.28} \tau^{0.451} x^{-0.27} \psi^{-0.131} \quad \ldots (A2.2)
\]

where \( x = \) stiffener width/chord diameter = \( b/D \) and
\( \psi = \) stiffener thickness/chord wall thickness = \( T/T \)

A3. PARAMETRIC EQUATIONS RECOMMENDED BY UNDERWATER ENGINEERING GROUP, GREAT BRITAIN FOR STRESS CONCENTRATION FACTORS IN UNSTIFFENED T JOINT SUBJECTED TO AXIAL LOADING OF BRACE (Underwater Engineering Group 1985)

Chord saddle SCF:

\[
\text{SCF}_{\text{chord}} = \gamma \tau \beta \left( 6.78 - 6.42 \beta^{1/2} \right) x \sin^{1.7 + 0.7 \beta^1} \theta \left( Q_{\beta}^* Q_{\gamma}^* \right)^{1/2} \quad \ldots (A3.1)
\]

Chord crown SCF:

\[
\text{SCF}_{\text{chord}} = \left( X_{c'}^* + X_{c''}^* \right) \sqrt{Q_{\gamma}^*}, \quad \ldots (A3.2)
\]

where \( X_{c'}^* = \left[ 0.7 + 1.37 \gamma^{1/2} \tau \left( 1 - \beta \right) \right] \left( 2 \sin^{1/2} \theta - \sin^3 \theta \right) \)
\[
X_{c'} = \frac{\tau \left( 2 \gamma - \tau \right) \left( \alpha / 2 - \beta / \sin \theta \right) \sin \theta}{2 \gamma - 3}
\]
\[
X_{c''}^* = 1.05 + \frac{30 \tau^{1.5} \left( 12 - \beta \right) \left( \cos^4 \theta + 0.15 \right)}{\gamma}
\]
\[ Q_p' = 1 \text{ for } \beta \leq 0.6 \]

\[ Q_p' = 0.3 / \beta (1 - 0.833\beta) \text{ for } \beta > 0.6 \]

\[ Q_r' = 1 \text{ for } \gamma < 20.0 \]

\[ Q_r' = 480 (40 - 0.833\gamma) / \gamma \text{ for } 20 \leq \gamma \leq 40 \]

The SCFs are limited to a minimum of 1.5. Lower values are allowed if justified by experimental or numerical evidence.

For brace SCF, \( SCF_b = 1 + 0.63 \ SCF_c \), where \( SCF_b \) and \( SCF_c \) denote the brace and chord SCFs respectively.

The above SCF equations recommended by the Underwater Engineering Group are valid for the following range of values:

\[ 2.5 \leq \alpha \leq 40 \]
\[ 0.13 \leq \beta \leq 1.0 \]
\[ 12.0 \leq \gamma \leq 40.0 \]
\[ 0.25 \leq \tau \leq 1.00. \]


\[ SCF_{chord} = 3.06 \tau \sqrt[\gamma]{} \quad (A4.1) \]

\[ SCF_{brace} = 1.0 + 0.375 (1 + \sqrt[\gamma]{\pi/\beta}) \times SCF_{chord} \geq 1.8 \quad (A4.2) \]