Improved Bending Correction Factor for Fatigue Assessment of Welded Joints

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ABSTRACT

It has long been recognized that the fatigue performance of welded joints subjected to bending stress is significantly better than those tested actually under a pure membrane stress. Since published design curves are based almost exclusively on test data obtained under membrane stress, they are conservative with respect to joints in bending. In preparation for the revision of BS 7608:1993, a correction procedure to allow for this was developed using fracture mechanics methods following BS 7910:2015. Subsequent consideration of published fatigue test data, however, indicated that the correction procedure over-estimated the benefit. Consequently, a new correction, based directly on the available fatigue test data, was produced and included in BS 7608:2015. A conclusion to draw from the above is that the current fracture mechanics solutions for bending underestimate the stress intensity factor and are therefore non-conservative. This has wide implications for both industry and BS 7910. An alternative conclusion is that the experimental data are the problem since the specimens tested axially were not identical to those tested in bending. In view of the importance of this issue in relation to both fatigue design using BS 7608 and fatigue crack growth assessment using BS 7910, a parametric study based on fracture mechanics with both the 2D and 3D $M_k$ solutions was conducted to review $k_{tb}$-revision derived in the revision work for BS 7608:1993. A new equation for the bending correction factor $k_{tb}$ was introduced into BS7608:2014+A1:2015 (BSI, 2015). In order to carry out further investigation on the effect of thickness and bending on the fatigue performance, especially in the case where the plate thickness $t$ is less than the reference thickness $t_0$ of 25mm in BS 7608:2015, a fatigue test programme using identical specimens for both axial and bending loading, was carried out by TWI Ltd (TWI). This study outlines the testing results, analysis performed and presents new proposed bending correction factor based on the results. In addition, the validation of the current correction factor $k_{tb}$ in BS 7608:2015 by the new testing data are presented.

THICKNESS AND BENDING CORRECTION FACTOR $k_0$ IN BS7608:2015

The thickness and bending correction factor $k_0$ was derived for various plate thicknesses using available existing fatigue test data. The correction factor is calculated using Equations 1 and 2. The application of the correction factor on stress ranges obtained from the relevant S-N curve, such that:

$$ S = k_{tb} S_B $$

where,

For $t > 25mm$:

$$ k_{tb} = \left( \frac{t_B}{t_{eff}} \right)^b \left[ 1 + 0.18 \Omega^{1.4} \right] $$

(2)

For $4mm \leq t \leq 25mm$:

$$ k_{tb} = \left( \frac{t_B}{t_{eff}} \right)^b \left[ 1 + \Omega\left( \frac{t_B}{t} \right)^b - 1 \right] \times \left[ 1 + 0.18 \Omega^{1.4} \right] $$

(3)

and

$\Omega$ is the degree of bending.

$b$ is defined for various joint geometries in BS 7608 (BSI, 2015).

$t_B$ is the thickness relevant to the basic S-N curve for the detail.