FATIGUE CRACK GROWTH IN LARGE WEB DEFLECTION

J. Djubek and J. Kriváček *

The crack growth stress of web is supposed to be bending and membrane. The non-linear problem of the deformations of slender initially curved rectangular web is presented. The fatigue crack growth equation $da/dN = B(\Delta S)^m$ is considered, where ΔS is the range of strain energy density factor. The numerical results are presented for web loaded in shear. In non-linear algebraic equations the high number of deflection function or stress function coefficients w_{mn} and ϕ_{mn} is used.

CRACK GROWTH IN LARGE WEB DEFLECTION

For continuum element the strain energy density function is used. We suppose that the load history may be the kind (or included in) of structural and geometrical imperfections. For satisfactorilly large number of cycles the differential Kármán-Marguerre´s equations are used. Let us have the simply connected domain $\Omega = (0,a) \times (0,b)$. The crack is supposed to be on the boundary of the domain. Inside of the domain the crack is not considered. The effect of shear stresses is considered and the first attention is focused to the maximum tensile stresses on the boundary. The crack starts at the point of maximum tensile stresses. For the web loaded in shear which example is solved in the paper the unrestrained edges are discussed. The homogeneous boundary conditions were used and the biharmonic function ϕ_0 is chosen in the form $\phi_0 = -\lambda \sigma_E xy$, where λ is the load parameter and

$$\sigma_E = \frac{Et^2}{12(1-\nu^2)b^2} .$$

* Institute of Construction and Architecture of SAS, 842 20 Bratislava, Dúbravská cesta, Czechoslovakia

Solution to the system of non-linear algebraic equation

The Galerkin method was succesfully used in a solution to the formulated problem. The stress function is assumed as follows

$$\phi = \sum_{r=2} \sum_{s=2} \phi_{rs} \left[\cos \frac{r\pi x}{a} - \cos\left(1 - (-1)^r\right) \frac{\pi x}{2a}\right] \left[\cos \frac{s\pi y}{b} - \cos\left(1 - (-1)^s\right) \frac{\pi y}{2b}\right] \quad (1)$$

Numerical solution of algebraic equations is given for the rectangular web (a/b = 2) loaded in shear. 20 coefficients w_{mn} and 25 coefficients ϕ_{mn} were considered. The initial web deflection $|w_0|/t$ is presented in Fig. 1.

The stresses on digigraph DGF 1712 in Computer Centre of SAS were plotted and the coefficient

$$\varrho = \frac{\tau_{xy}\sqrt{3}}{\sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}} \quad (2)$$

was calculated. The normal and shear stresses σ_x, σ_y, τ_{xy} in (2) express either the membrane stresses (the coefficient ϱ_m in Fig. 1) or the membrane and bending stresses (ϱ_{m+b} in Fig.). τ/τ_{cr} is the shear stress devided by critical shear stress of rectangular web and $\tau_{cr} = 6{,}54\,\sigma_E$. Web panel width is considered b, web panel length a, t is thickness of web sheet and R is considered design strength.

Fatigue crack load. It is supposed that the stable crack growth is not connected with the web deflection changes. The crack growth relation is plotted in the form $da/dN = B\,(\Delta S)^m$, where ΔS is the range of strain energy density factor, a is the crack length and N the number of cycles. For the simple solution we assume that the fatigue crack of the length $2a_i$ (in the web thickness direction on the web boundary) grows in the direction to web centre. The number of cycles is considered in the form

$$N_f = \sum_{i=1}^{j} \frac{a_i - a_{i-1}}{B\,(\Delta S)^m}, \quad (3)$$

where $B = 6181 \times 10^{-11}$, $m = 1{,}414$, the number of elements $j = 26$ and $\Delta S = 50$ to $8000\ J/m^2$. The material properties are given by $\sigma_{fl} = 517$ MPa, $(dW/dV)_c = 48{,}46\ MJ/m^3$, $K_{1c} = 103{,}52$ MPa $\sqrt{m}$, $S_c = 13{,}485$ kN/m, $c = 2t$ and $\Delta t = 1$ mm. Some results are analysed in Fig. 2.

REFERENCES

(1) Djubek,J., Kriváček, J., Acta Technica ČSAV,Vol.33, 1988, (in print).

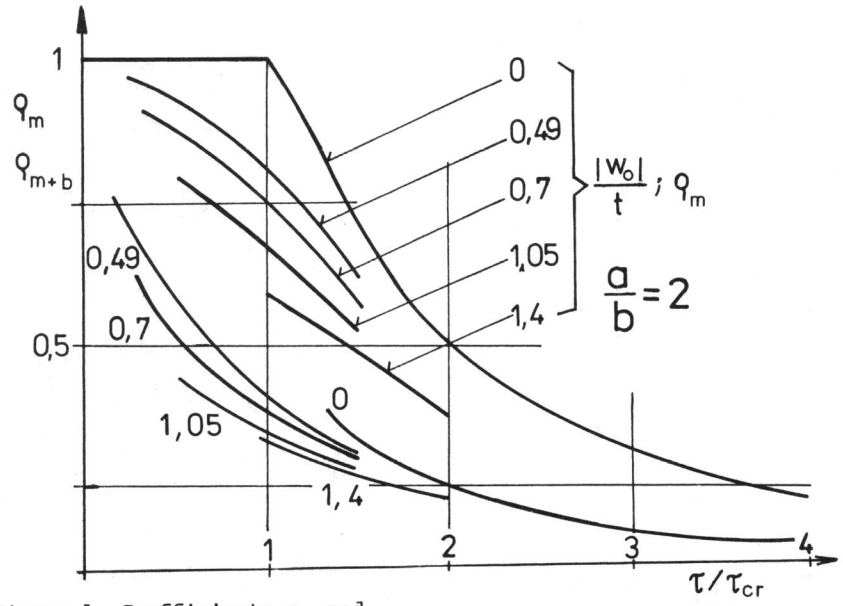

Figure 1 Coefficients φ_m and φ_{m+b}

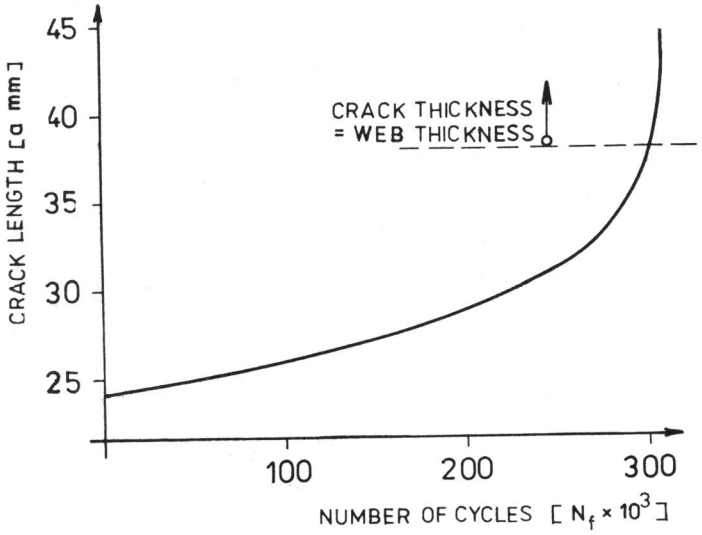

Figure 2 Fatigue life curve for edge cracked web