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THE INFLUENCE OF WALL THICKNESS ON THE FATIGUE LIMIT OF V-NOTCHED BARS MADE OF AS-CAST OR HEAT TREATED DUCTILE IRON

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A fatigue model, previously published in the technical literature [1,2], has been applied to estimate the fatigue limit of ductile irons and heat treated ductile irons in presence of V-shaped notches. When the notch tip radius approaches reduced values, the model is based on the mode I Notch-Stress Intensity Factor (N-SIF). Conversely, when the notch tip radius is large, the classical approach based on the linear elastic stress concentration factor is matched. This model contains the well known Kitagawa-Takahashi [3] as a special case.

1. Introduction

In the recent past, Atzori, Lazzarin and Meneghetti proposed a fatigue model valid for components that include sharp as well as rounded V-shaped notches of any size [2]. This model is the generalization of a previous one proposed by Atzori and Lazzarin [4]. The equation to estimate the fatigue limit of sharp V-shaped notches is the following [2]:

$$\Delta\sigma_{g,th} = \frac{\Delta K_{I,th}^{V}}{\sqrt{\pi}\left(a_{eff}+a_{0}^{V}\right)^{\gamma}} \qquad (1)$$

where $\Delta K_{I,th}^{V}$ is the threshold value of Notch-Stress Intensity Factor, a_{eff} is the effective notch depth and a_0^V is a material and notch geometry-dependent parameter. Appropriate expressions to evaluate all previous material and stress parameters are reported in [2]. It should be noted that when the notch opening angle reduces to zero (i.e. γ=0.5), Eq. 1 exactly match the Linear Elastic Fracture Mechanics (LEFM). The model reported in following Fig. 1 is useful to assess the fatigue limit of any kind of notch (long and short cracks, blunt and crack-like notches with parallel flanks and blunt and sharp notches with an opening angle different from zero), including surface defects, by means of a unified approach; an application of this model is reported in [5,6]. Further an application of such engineering design tool to V-notched bars obtained from as-cast as well as heat treated cast iron Y-blocks of different wall thickness is performed in the present work.

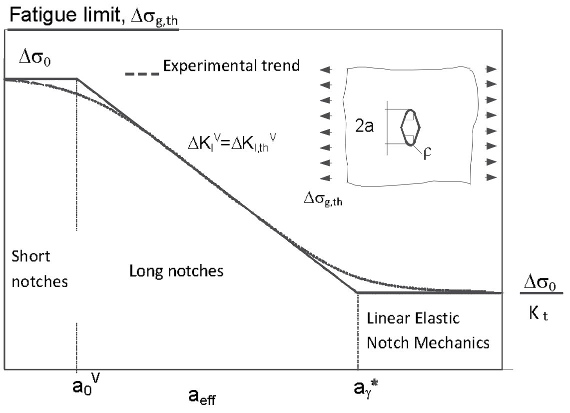

Fig. 1. Fatigue limit estimation of a notched component subject to mode I loading

2. Fatigue characterisation

The proposed fatigue design tool has been applied to estimate the rotating bending fatigue limit of round specimens machined from separately cast test bars made of as-cast or heat treated ductile iron, having relevant wall thickness 25 mm, 50 mm and 75 mm respectively; specimens were characterised by smooth surface (6.5 mm diameter) or by the presence of a V-notch having a 45° notch opening angle (8-1-0.1 and 10-2-0.1: the code indicates gross diameter, notch depth of and notch tip radius respectively). The singularity degree of V-notch characterized by this opening angle is close to the value relevant to a crack 0°: then all the V-notches have been treated as cracks having the same depth of the notches from the stress analysis point of view. A short stair-case procedure was adopted to determine the fatigue limits at 50% probability of survival; run out was assumed at $5\cdot10^6$ cycles. Table 1 reports the stair-case results of plain specimens in terms of stress amplitude $\sigma_{Ag50\%}$ (defined as half the difference between the maximum and the minimum stress) referred to the gross section and, furthermore, the threshold range ΔK_{th} which was calculated by fitting the data relevant to the V-notched specimens. Results referred to relevant wall thickness 25 mm have also been represented as Kitagawa-Takahashi diagram in Figs. 2-5.

Table 1. Fatigue tests results

Material	w. t.[mm] (HBW)	$\sigma_{Ag50\%}$ [MPa]	ΔK_{th} [MPa·√m]
DI ferritic	25 (156)	278.6	12.66
	50 (145)	277.5	14.34
	75 (161)	265.0	16.54
DI pearlitic	25 (250)	350.0	17.71
	50 (239)	315.0	20.14
	75 (244)	326.7	19.76
IDI® [7]	25 (255)	390.0	15.96
	50 (249)	321.4	18.75
	75 (242)	314.0	19.53
ADI 1050	25 (346)	441.3	20.25
	50 (349)	362.2	24.69
	75 (354)	355.7	23.13

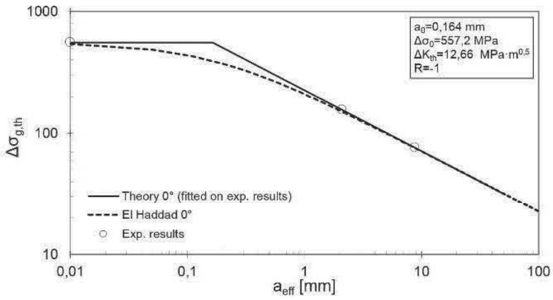

Fig. 2. Kitagawa diagram of DI ferritic (w.t. 25mm)

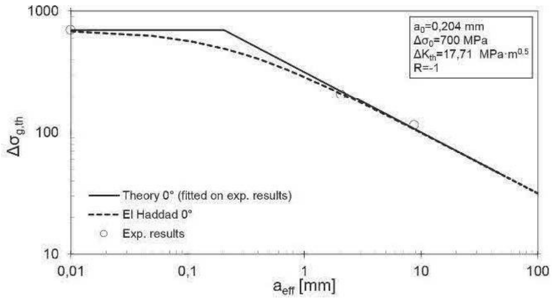

Fig. 3. Kitagawa diagram of DI pearlitic (w.t. 25 mm)

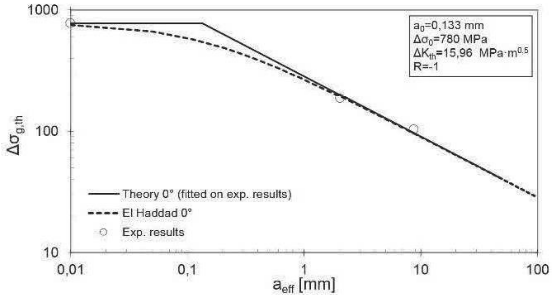

Fig. 4. Kitagawa diagram of IDI® (w.t. 25 mm)

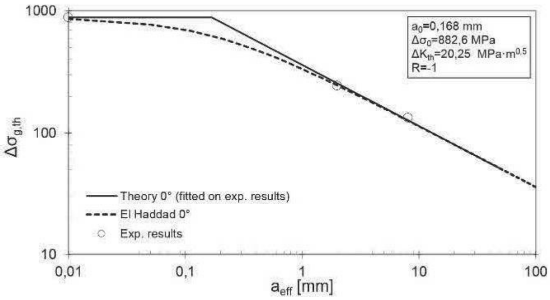

Fig. 5. Kitagawa diagram of ADI 1050 (w.t. 25 mm)

3. Conclusion

The paper illustrated the application of a fatigue testing procedure in presence of notch effects. The material fatigue behavior has been characterized experimentally by means of smooth specimens, in order to derive the plain fatigue limit, and by means of sharply notched specimens, in order to found the threshold value of the stress intensity factor. All theoretical estimations indicate a sharp behavior of the notched specimens, i.e. the 0.1 mm notch tip radius is ineffective on the fatigue strength, which can be assimilated to that of notch having a zero notch tip radius. A complete set of data to be used in fatigue design was provided. Many efforts in terms of investigation at microscale are now continuing to better understand the microstructure response vs wall thickness under severely notched conditions, since the threshold value ΔK_{th} remains consistent.

Acknowledgments

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