FATIGUE RESPONSE OF DOUBLE NOTCHED ALUMINIUM SPECIMENS LOADED UNDER UNIAXIAL STRESS

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Summary: *As part of an evaluation to determinate the influence of the stress gradient on the stress-life response of a given component, a series of double-notched samples was tested uniaxial stress-controlled fatigue tests. Its results were then compared with the results of similar tests made using single notch specimens. Although the inherent geometrical differences between the sample series, the stress concentration factors are in the range of* $2.5 \pm 10\,\%$ *for all series. Nevertheless, the experimental results have shown a very different fatigue response of the double- notched series. To explain the aforementioned behavior, the authors have employed numerical simulation and a non-linear regression function to generate adjusted stress-life curves. The investigation shows, that is not enough to consider the stress concentration factor as main governing parameter, but also the stress gradient and the fatigue notch factor should be taken into account in order to narrow down non-conservative calculations when estimating lifetime.*

Keywords: *double-notched specimens, fatigue, aluminium 2124-T851, stress gradient*

1 Introduction

An extensive fatigue stress controlled testing has been carried out for the alloy 2124-T851 using different geometries: Smooth samples, single notched and bi-notched samples. The selection of these geometries was made based on common features found in aeronautical parts; nevertheless the stress concentration factor generated by them was restricted to the range of $2.5 \pm 10\,\%$. The results have shown a very different fatigue response, although all geometries share similar stress concentration factors.

To study this behavior, the fatigue notch factor has been introduced together with finite element analysis and the Kohout & Věchet stress-life model [1]. The finite element analysis was considered also during the Design of experiment (DOE) stage, to verify the stress concentration generated in each notch and the non-linear Kohout & Věchet model was introduced instead of the classical linear Basquin model. One of the main advantages of the formulation made by Kohout & Věchet is that the model allows working with all non-interrupted experimental points generated during the experimental tests, instead of the finite life region experimental points as requires the Basquin model. Equation 1 shows the formula proposed by Kohout & Věchet.

$$\sigma_(N) = a \left[\frac{(N+B)C}{N+C} \right]^b \tag{1}$$

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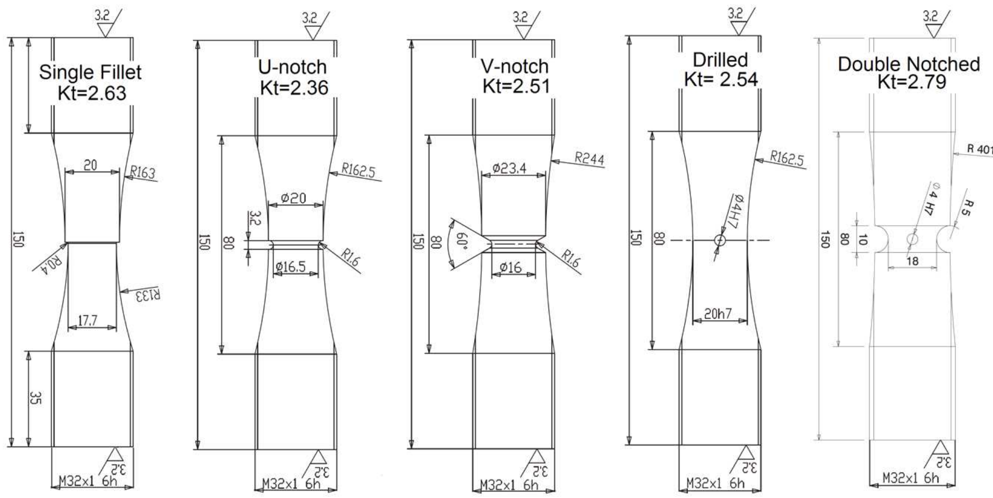

Figure 1: Geometries of the test samples.

The generation and interpretation of the parameters of the model goes beyond the scope of this work, but roughly it can be said that a represents the extrapolated value of function or of the tangent in the point of inflexion for $N = l$, B, C are the life parameters of the function, i.e, the numbers of cycles in which the curve bends for LCF and HCF region and b is the slop of the SN curve.

The fatigue notch factor was then used to estimate the trend of the bi-notched series, based on the single notched samples.

2 Application of the Kohout & Věchet model and fatigue notch factor estimation.

After the numerical simulation [2] and having the experimental results (12 samples per geometry, tested under a stress ratio $R = -1$) the next step is to apply the stress-life model to the experimental data:

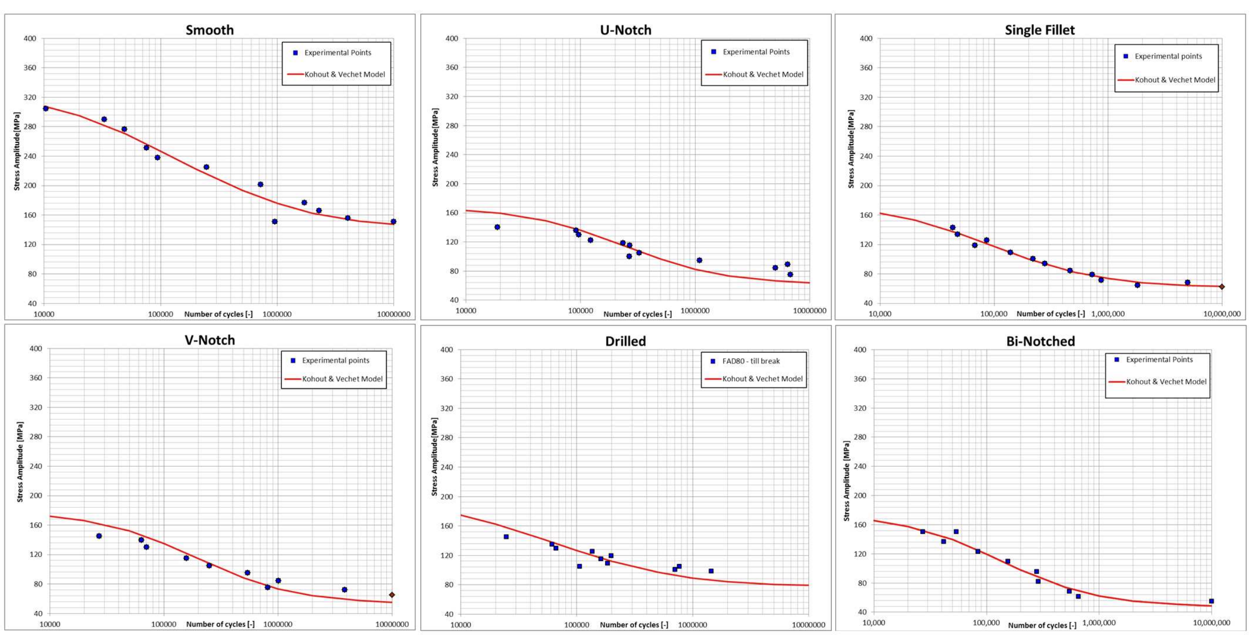

Figure 2: Kohout & Věchet Model applied to the experimental data.

As showed in the figure 2 the fatigue strength at 1x10E cycles gets reduced approximately 3 times for single notched cases and almost 4.5 times for the bi-notched case although all geometries have a similar stress concentration factor.

Having the SN curves for all geometries generated by the Kohout & Věchet model, it is possible to estimate the fatigue notch factor, K_f, which relates the notched fatigue strength and the smooth fatigue strength according to the relation proposed in the equation 2.

$$K_f = \frac{Smooth\_fatigue\_strength}{Notched\_fatigue\_strength} \tag{2}$$

The following table summarizes the evolution of the fatigue notch factors with the number of cycles.

Table 1: Fatigue Notch Factors generated by the K&V Model

Fatique Notch Factors, β, from SN curve according to the Kohout & Věchet model					
N	U-notch	Fillet	V-notch	Drilled	Bi-notched
50000	2.069	2.038	2.022	2.134	2.038
100000	2.092	2.165	2.128	2.223	2.264
200000	2.194	2.330	2.306	2.306	2.690
500000	2.513	2.610	2.753	2.393	3.589
1000000	2.818	2.776	3.153	2.447	4.429

Now based on the fatigue notch factors of the U-notch and the Drilled samples it is possible to use the relations proposed by Němec and Höschl to estimate a superposed fatigue notch factor [4]. Unfortunately the expression proposed by them does not correlate well with our experimental data, and therefore a new relation is proposed. This formulation does not correlate so well with pure elastic stress concentration factors, α, although it is better than the approach proposed by Höschl.

Table 2: Fatigue notch factors based on the Kohout & Věchet model of the experimental results, calculated according the proposed formula, and calculated according Němec and Höschl.

N	Bi-notch	Proposed FMLA	Relative Diff.	Němec	Relative Diff.	Höschl	Relative Diff.
10000	1.890	2.191	15.91%	1.191	37.00%	3.073	62.59%
20000	1.922	2.228	15.90%	1.228	36.13%	3.126	62.64%
50000	2.038	2.281	11.94%	1.281	37.13%	3.203	57.16%
100000	2.264	2.428	7.22%	1.428	36.95%	3.315	46.42%
200000	2.690	2.753	2.36%	1.753	34.82%	3.500	30.11%
500000	3.589	3.621	0.88%	2.621	26.98%	3.906	8.83%
1000000	4.429	4.449	0.44%	3.449	22.13%	4.265	3.70%

The proposed formula allows to estimate the fatigue notch factor of the bi-notched sample not only for the endurance limit, but also for the whole high cycle fatigue region as shows the table 2.

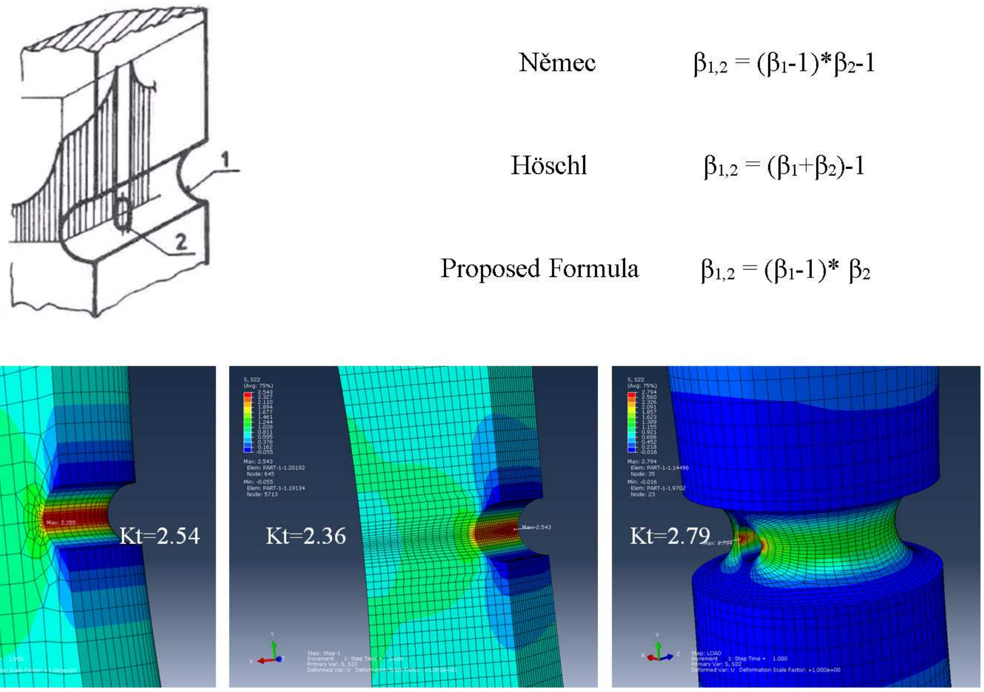

Figure 3: An approach based on stress concentration factors only is not enough to replicate the behavior of double-notched samples.

3 Conclusions

The Kohout & Věchet model for stress-life allows to estimate the fatigue behavior of notched samples in a similar fashion as the Basquin model does.

The Kohout & Věchet model takes advantage of the application of a non-linear regression to all experimental data points, which allows to apply it beyond the finite life region.

The superposition of stress concentrators leads to high fatigue notch factors, that cannot be predicted satisfactorily using the traditional approaches formulated by Němec of Höschl.

A modified formula of the classical formulations allows to simulate the fatigue behavior of double-notched samples with a very close correlation.

Different geometries should be tested in order to validate or discard a general application of the proposed formula.

4 Acknowledgment

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