Validation of the Different

Estimations of N

UNIVERSITY OF CANTABRIA

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1. INTRODUCTION AND OBJECTIVE

Within SINTAP Project, the University of Cantabria has been analysing nineteen materials in order to assure a safety estimation of the parameter N used in some of the SINTAP's equations [1, 2].

Different types of calculations were performed using both total and plastic strains, varying the last point considered of the stress-strain curve and also depending on whether the yield point was fixed or not.

Although some recommendations were made, it was decided to validate them by plotting the corresponding FADs for such expressions.

This Report covers that validation, analyses the degree of conservativeness of each equation and proposes a final recommendation.

2. METHODOLOGY

The parameter noted N is used within SINTAP in the equations defining the Failure Assessment Lines for single levels for values of L_r greater than 1.

$$K_r = K_{r(L_r=1)} L_r^{\frac{N-1}{2N}} \tag{1}$$

In order to validate the expressions recommended in the former reports, it was decided to compare the Failure Assessment Line obtained when using SINTAP option 3 (R6 option 2) with that obtained using these approaches (SINTAP option 1) for the different values of N considered.

If the comparison is done in the whole domain, from $L_r = 0$ to $L_r = L_{r\ max}$, the partial conservativeness of the expressions for the elastic regime (up to $L_r = 1$) would affect the conclusions from $L_r = 1$ on. For instance, if the first part of the equation is too conservative (the line has gone to values of K_r very low), the real shape of the second part of the equation could not be evaluated properly (see Figure 1).

So, as the objective of this study is to analyse just the second part of the FALs ($L_r \geq 1$), the conservativeness of the initial part of the curve should be eliminated. Therefore, it has been supposed that all the Failure Assessment Lines (both SINTAP option 3 and option 1) have a common point at $L_r = 1$ for each material. Figure 2 shows a qualitative picture of the comparative methodology followed in this work.

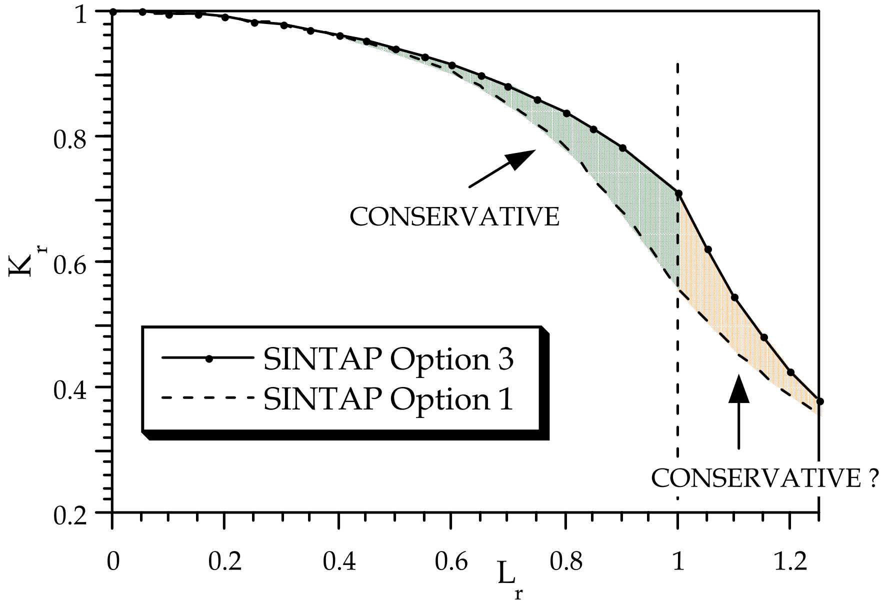

Figure 1.

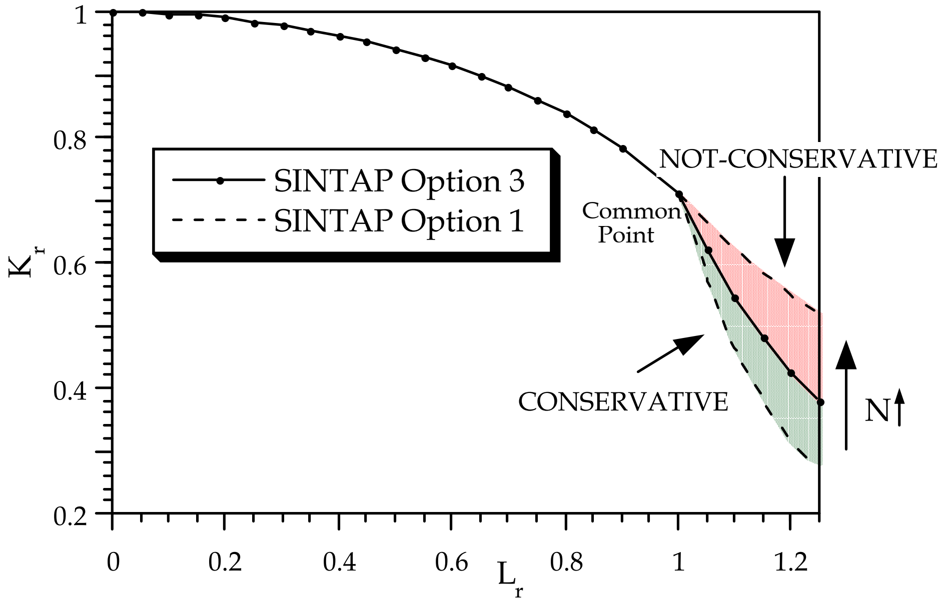

Figure 2.

3. RESULTS

Figures 3 to 21 present the Failure Assessment Lines for nineteen materials. Each figure shows the FAL obtained from SINTAP Option 3 (black line) which follows equation:

$$K_r = \left[\frac{E\varepsilon_{ref}}{L_r \sigma_y} + \frac{L_r^3 \sigma_y}{2E\varepsilon_{ref}} \right]^{-1/2} \quad (2)$$

and those obtained from Equation 1, where N is estimated through:

$$N = m\left(1 - \frac{YS}{UTS}\right) \quad (3)$$

Depending on the gradient, different FALs are obtained. In this Report, the lines presented (green, blue and red) correspond to different values of the slope m, 0.3, 0.4, and 0.5 respectively.

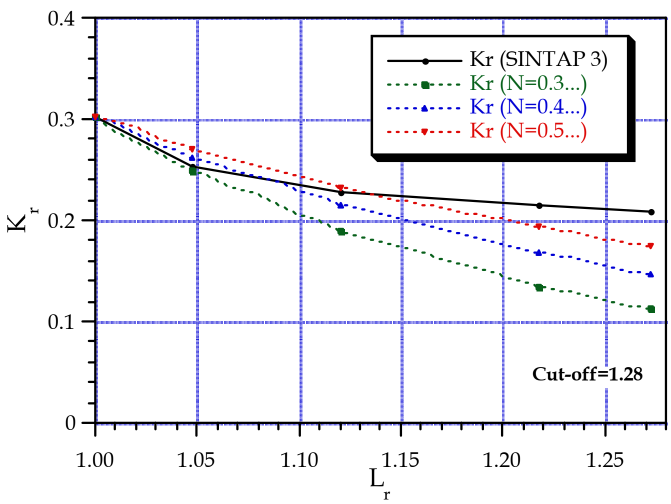

Figure 3. 4Y14 A2 S275 JR Steel.

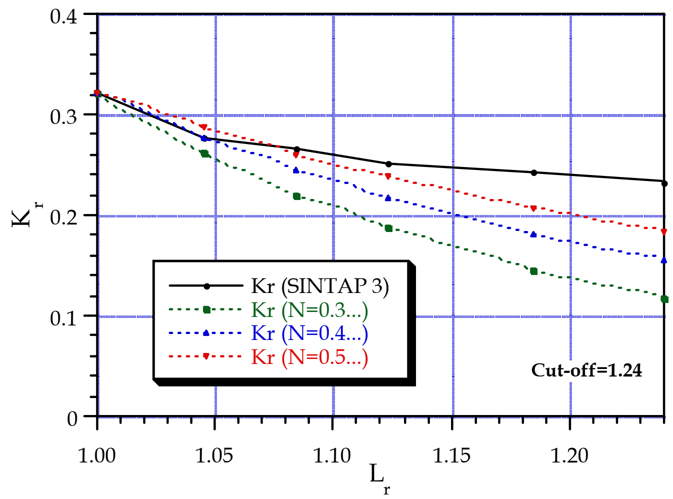

Figure 4. 4Y17 A2 S355 J2 Steel.

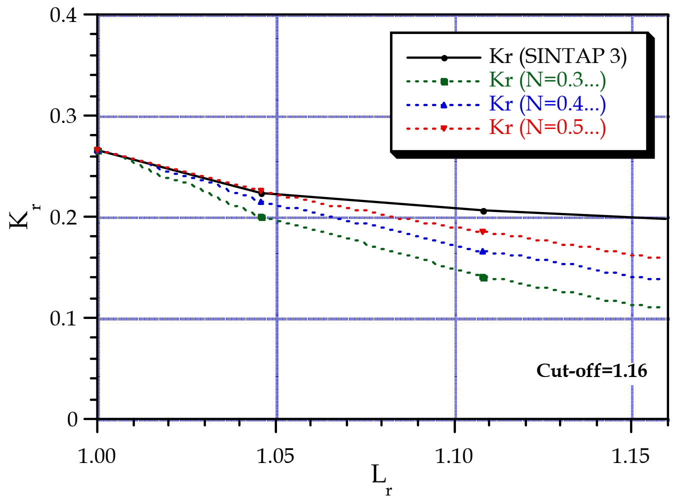

Figure 5. Y6T8D 355 EMZ Steel.

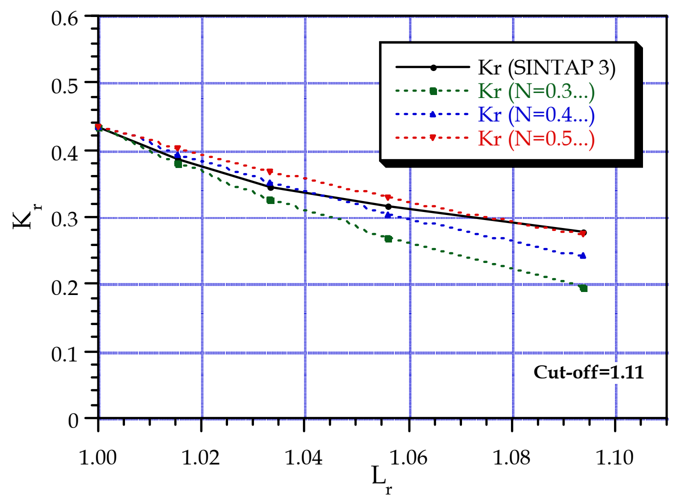

Figure 6. Y6T26H 450 EMZ Steel.

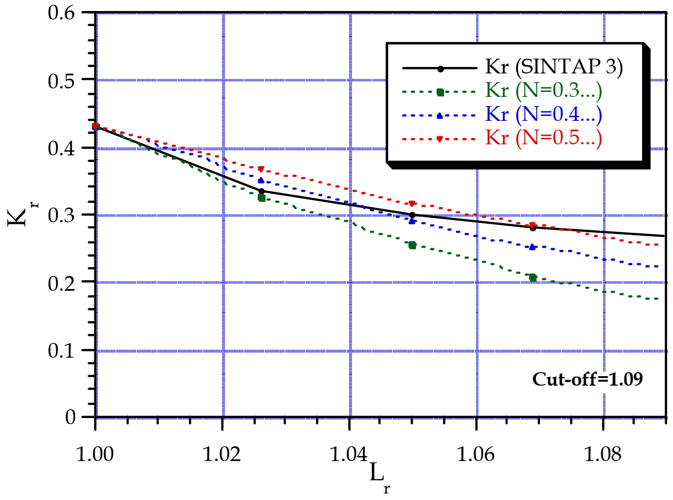

Figure 7. 4Y18 A2 450 EMZ Steel.

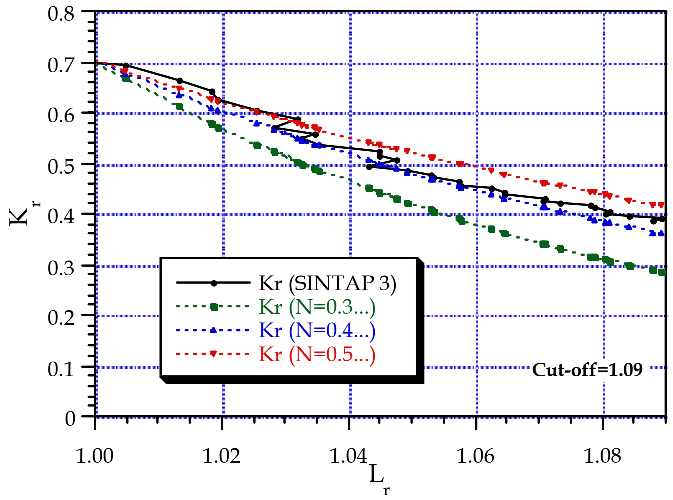

Figure 8. Microalloyed Steel E500.

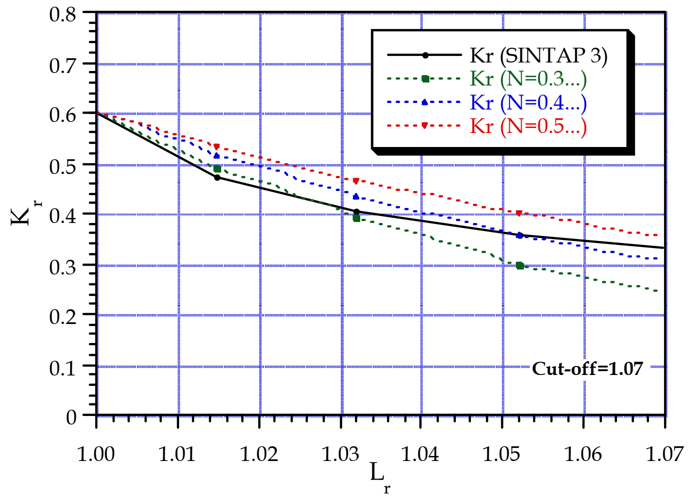

Figure 9. Y6A22D2C StE690 Steel.

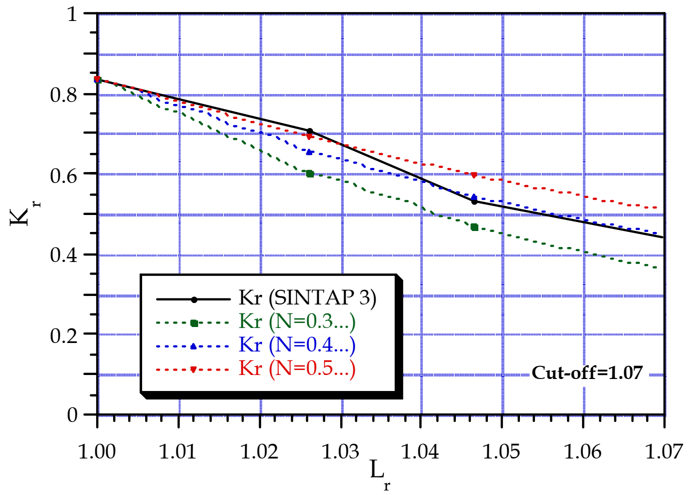

Figure 10. Y6A4A4D StE690 Steel.

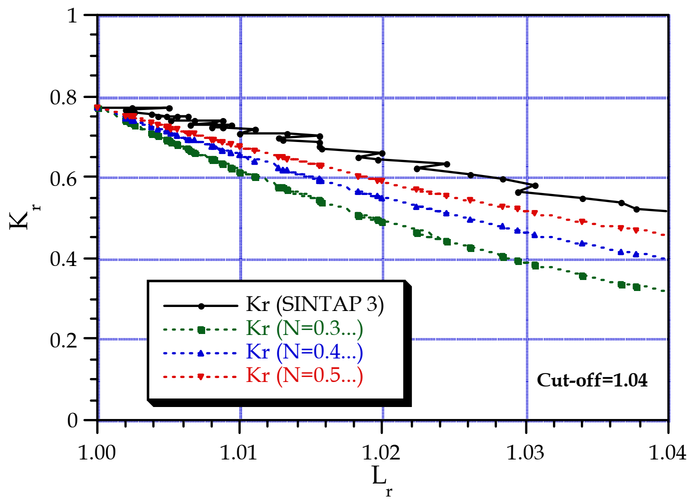

Figure 11. Microalloyed Steel E690 (1).

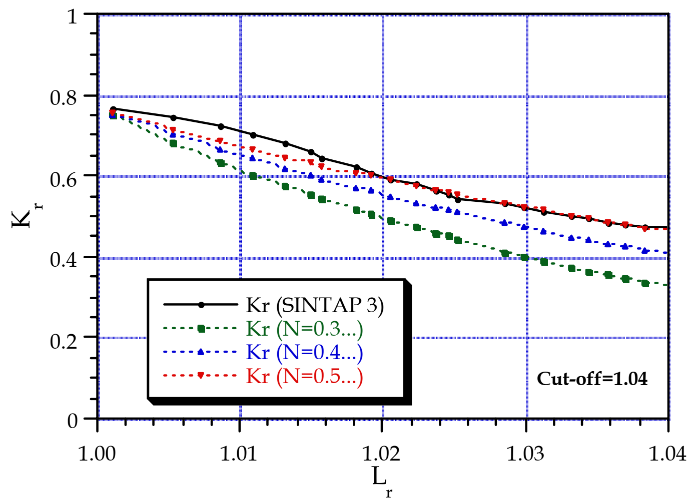

Figure 12. Microalloyed Steel E690 (2).

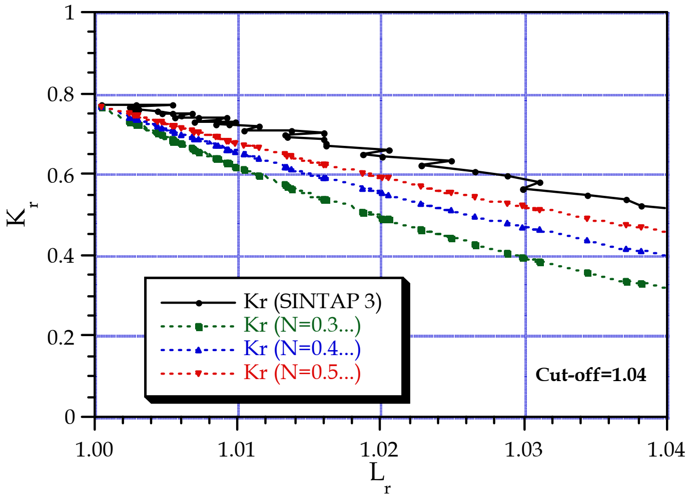

Figure 13. Microalloyed Steel E690 (3).

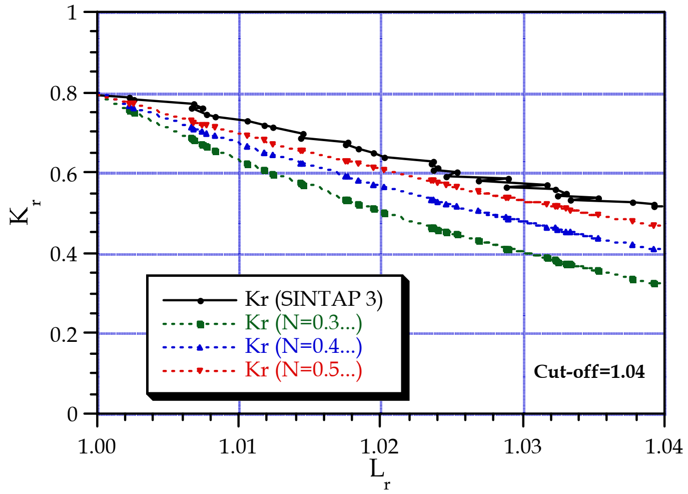

Figure 14. Microalloyed Steel E690 (4).

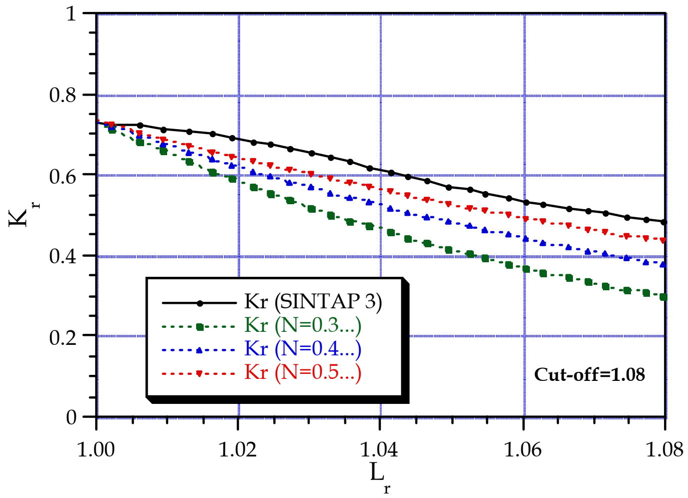

Figure 15. Normalised Steel 4135A (1).

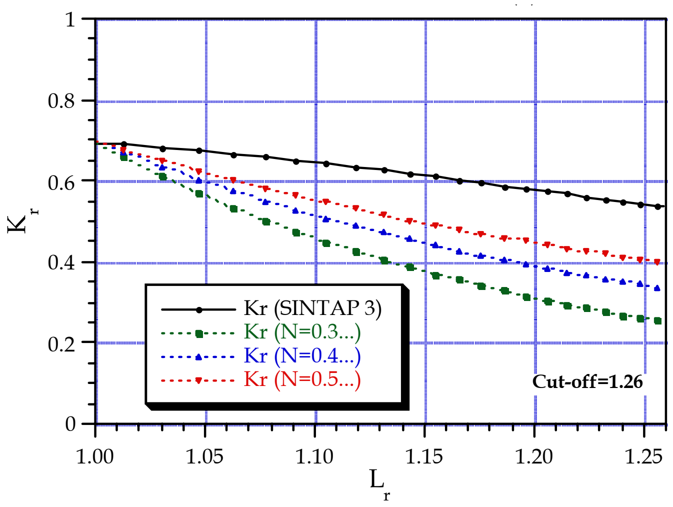

Figure 16. Normalised Steel 4135A (2).

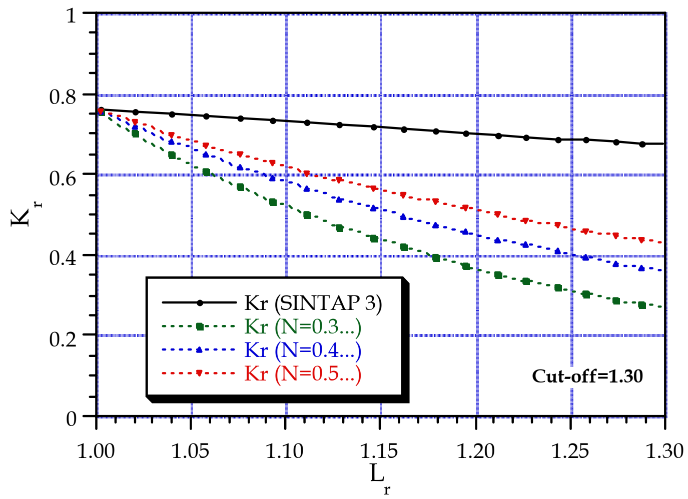

Figure 17. Quenched Steel 4135B.

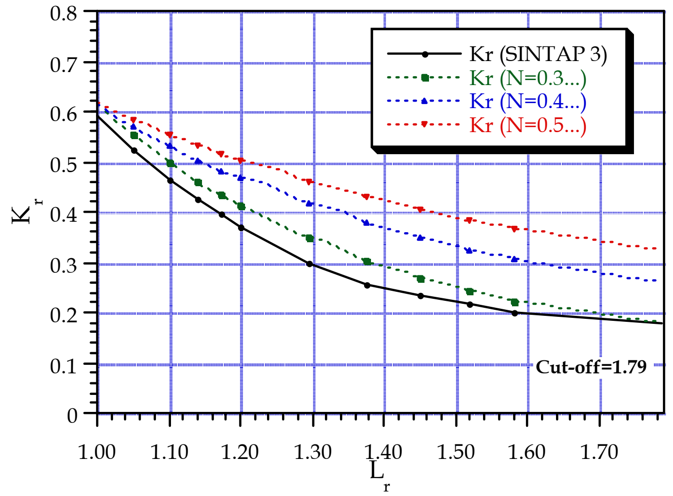

Figure 18. Austenitic Steel.

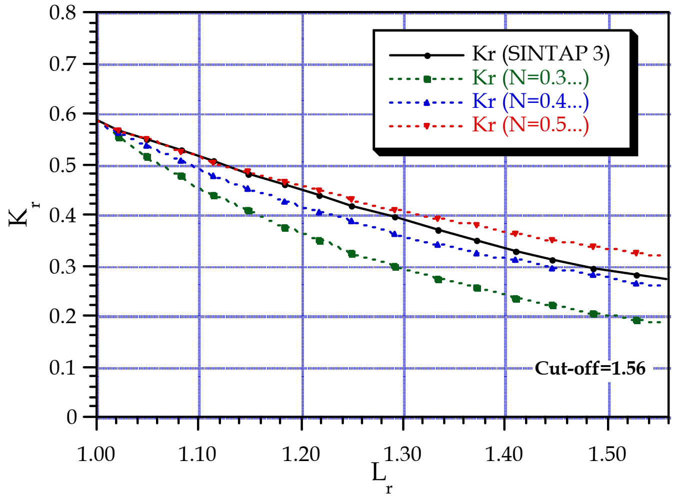

Figure 19. Aged Stainless Steel.

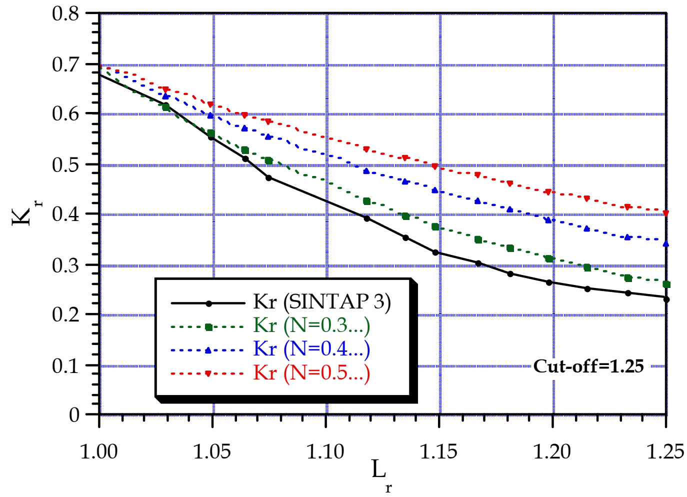

Figure 20. Stainless Weld Steel.

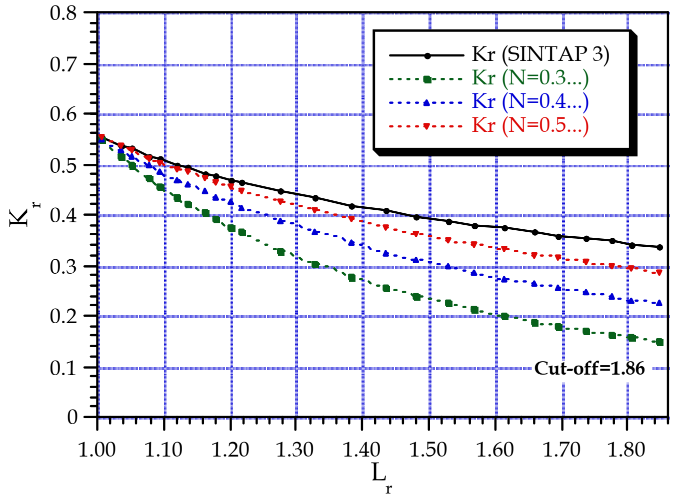

Figure 21. Aluminium.

4. ANALYSIS

As the objective of this work is to propose a safety estimation of N which reproduce safety FALs for low assessment levels, the conservativeness of the different suggestions (gradients of 0.3, 0.4 and 0.5) has been studied.

In Table 1 a summary is presented where it can be seen how many times each option has been partially or totally not-conservative if compared with SINTAP option 3.

Table 1. *Results for nineteen materials*

gradient (m)	times partially not-conservative (PNC)	%	times totally not-conservative (TNC)	%	PNC + TNC	%
0.3	1	5	2	11	3	16
0.4	5	26	2	11	7	37
0.5	5	26	5	26	10	52

It can be seen that the results obtained for a gradient of 0.5 are not satisfactory as a probability of 50% to be not-conservative (partially or totally) is obtained.

With respect to the results for 0.3 and 0.4, there is no difference according to how many times they are TNC, however, there is a significant increase about the times they are PNC.

If the materials where a gradient of 0.3 can be not-conservative are not considered, a new analysis can be done. This is presented in Table 2.

Table 2. *Results for sixteen materials*

gradient (m)	times PNC	%	times TNC	%	PNC + TNC	%
0.4	4	25	0	0	4	25
0.5	4	25	3	19	7	44

It can be seen that going from a gradient of 0.3 to 0.4 represents an increase of 25% in partially not-conservative events, but not new TNC situations appear. Again a big difference is observed when the gradient considered is 0.5, for which TNC events appear.

5. CONCLUSION

Three different gradients have been validated to estimate the safety conditions of the N approach.

It has been shown that the results for a value of 0.5 are not acceptable as it implies an important possibility of total not-conservative results when compared to SINTAP option 3 FAL. Contrarily, the results for 0.3 and 0.4 are quite reasonable.

The value of 0.3 should be considered in terms of assuring an almost totally conservative equation to derive SINTAP option 1 when compared to higher options of SINTAP.

6. REFERENCES

[1] J. Ruiz Ocejo and F. Gutiérrez-Solana, "On the Strain Hardening Exponent Definition and its Influence within SINTAP", Report, SINTAP/UC/07, April 1998.

[2] J. Ruiz Ocejo and F. Gutiérrez-Solana, Report, SINTAP/UC/08, June 1998.

Note: SINTAP option 1 and option 3 follow the notation in SINTAP rev. 0.4.