MULTILEVEL FATIGUE FROM LIFE PREDICTION METHODS

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A life prediction method has been used to compute the life of a given alloy in conditions of multilevel fatigue. The effect of the order of the loads has been verified for two levels and repeated blocks of them. In case of two levels, a double linear scheme was obtained with the demarcation point depending upon the completion of the nucleation stage. In case of successive blocks at two levels the results depend on the selected life fraction values: for large LF the two-level limit is approached; for small LF and many blocks in succession, the order becomes indifferent and the favourable combination leading to total life greater than one can no longer be observed.

INTRODUCTION

It is as yet impossible to insert the complex evidence about the microstructural aspects of fracture into the current life prediction models (LPM) for alloys. Taking into account both the possible agreement with microstructural observations and the efficiency for life predicting, a continuous damage model developed at ONERA has been selected in a version with successive micronucleation and micropropagation stages (1).

Results have been obtained concerning the applicability of this LPM to various alloys under different stress conditions. In particular, it has been shown that a satisfactory agreement with experimental data can be obtained for some superalloys (2). The results obtained from the LPM can be plotted on creep-fatigue maps, specific diagrams that show demarcation lines among ranges of creep, fatigue, and their interaction, together with information on damage and total life (3). This is a useful way for representing the material behaviour and for establishing connections with experimental observations at the microstructural level.

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In the present communication the research is extended to prediction of fatigue data in case of multilevel loads applied at high temperature.

TWO-LEVEL LOADS

As well known, the two-level high-low (HL) and the low-high (LH) sequences represent critical conditions for the reliability of any LPM. Thus, a first attempt has been devoted to check the two-levels behaviour, before investigating more complex cases. The computations have been carried out for IN 100 at 800°C, using the parameters given by the authors of the LPM (1), load conditions corresponding to fatigue without creep contribution (10 Hz), and sinusoidal wave of $D\sigma$ stress amplitude with zero mean value.

On the basis of the known Wöhler curve, load conditions (here indicated as X) have been chosen giving - if singly applied - significant lives Nr, as shown in tab. 1.

TABLE 1 - Load Conditions

$D\sigma$ (MPa)	249.6	253.5	261.0	270.0	283.1	308.0	334.0	368.5	420.0	465.0	511.8	566.0	608.0
Nr	10^6	$5\cdot10^5$	$2\cdot10^5$	10^5	$5\cdot10^4$	$2\cdot10^4$	10^4	$5\cdot10^3$	$2\cdot10^3$	10^3	$5\cdot10^2$	$2\cdot10^2$	10^2
X	A	B	C	D	E	F	G	H	I	L	M	N	O

Computations have been performed for all combinations of the load conditions of tab. 1, imposing selected values of life fraction (LF) at the first level and applying the second level until rupture. The results corresponding to G-X and X-G sequences are reported in fig. 1. The obtained two-level results follow the double-linear scheme, taking into account the order effect. It may be seen that the demarcation point occurs along a vertical (horizontal) line when the first (second) level is fixed, in direct relation to the nucleation life (Nn) at each level.

REPEATED LOAD BLOCKS AT TWO LEVELS

Complex sequences of loads can easily be dealt with by the LPM. As a first extension of the two-level case, repeated applications of two load blocks, defined by selected LF for each level, have been considered. The sequence is continued until rupture occurs, as indicated for a few cases in fig. 2. A systematic investigation - giving a complete outlook on the behaviour of the material in such conditions - may be a significant step in view of predicting the behaviour under the load sequences occurring in practical applications.

The levels have been systematically modified for deducing the effect of the stress amplitude and of the order. Computations have been carried out for a sequence of LF values with 4% increases, starting from 2%. Selected results for combinations of A, G, O load conditions are reported in fig. 3, together with the A-A, G-G, O-O cases, shown for a better understanding of the general situation.

It may be noted that a different behaviour is observed to correspond to the cumulation of small or large LF. As the LF values grow, the number of blocks decreases and the two-level case represents the lowest (highest) limit condition for blocks in the LH (HL) sequence. On the contrary, when the LF values are small the number of blocks grows and the level order effect vanishes; both LH and HL sequences provide the same results, reported as dotted lines in fig. 3. These lines always occur below the 45° line and can be superimposed by exchanging the x-y axes of the symmetric diagrams.

CONCLUSION

Fatigue life of IN 100 under multilevel load conditions has been studied by a LPM. The obtained results appear to be promising. They refer to simple fatigue without creep contribution and to successive application of two load levels. Further applications are under way, such as extensions to lower frequencies, where the creep contribution cannot be neglected, and to three-level loads. Preliminary results have already been obtained.

REFERENCES

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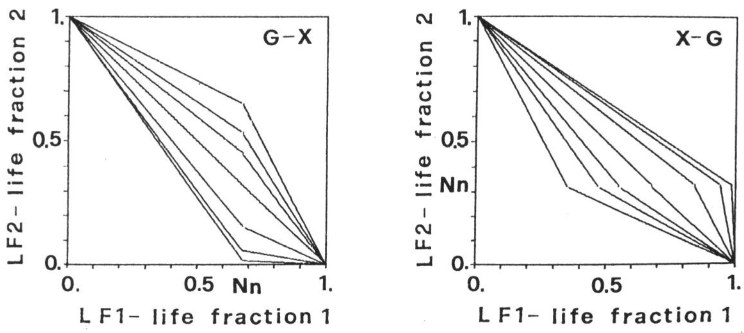

Figure 1. Two-level results for G-X and X-G levels.

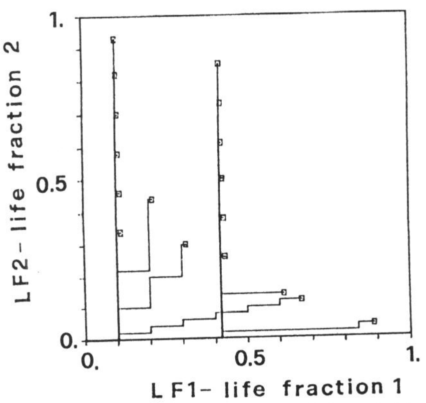

Figure 2. Examples of paths for repeated load blocks (A-O levels).

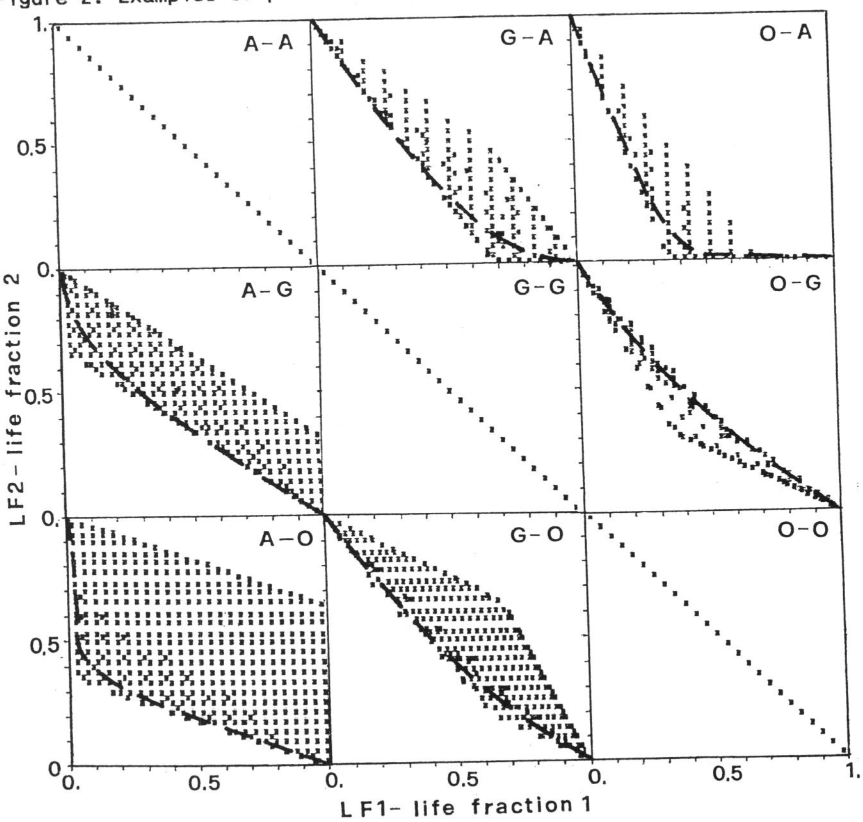

Figure 3. Results for repeated load blocks.