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SIMULATION OF BIAXIAL FATIGUE CRACK GROWTH IN VARIOUS MICROSTRUCTURES MODELLED BY USING VORONOI-POLYGONS

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It is recognized that crack growth in low cycle fatigue is affected by two factors; i.e., material microstructure and stress state. By considering difficulty in conducting experiments for various combinations of these factors, simulation procedures incorporating the two factors with themselves are required in order to describe crack growth behaviour, which determines fatigue life affected by such factors. However, any appropriate procedure is not established.

In this work, a modelling procedure was developed so that it should be applicable to the analysis of crack growth in materials with various microstructures under biaxial fatigue. Microstructures on component surface were modelled with Voronoi-polygons. Figure 1 presents examples of modelled microstructures with different morphologies, in which a grain is expressed as one Voronoi-polygon. In the modelled microstructure, the crack initiation was analysed as the slip plane separation in an individual grain. The number of cycles required for the separation was calculated by using a dislocation pile-up model [1]. The crack growth was analysed as a competition between the growth by crack linkage during crack initiation and propagation stages and the propagation of a dominant crack as a single crack. The fatigue life is defined as the number of cycles at which a dominant crack grows to have a specified length. In the present investigation, simulations are iterated fifty times for a material under a given condition of loading. Consequently, fifty different cracking patterns and fatigue lives are obtained for the material under the loading condition.

Analytical results simulated by using the developed model were compared with experimental observations in fatigue tests which had been carried out using notched specimens of titanium (Ti) alloys [2]. Simulations were conducted by considering (α+β) and β Ti alloys as model materials. Examples of simulated morphologies of cracks in (α+β) Ti alloy are depicted in Figure 2, in which a dominant crack is drawn with a bold line. Figure 3 shows the cracking behaviour observed in experiments using (α+β) Ti alloy. By comparing results in Figs. 2 and 3, it is found that observed cracking morphologies depending on loading mode are well simulated using the present procedure. It was also revealed that scatter-bands of simulated lives almost covers the experimental results. Aforementioned coincidences in simulated and experimental results imply that the proposed procedure using Voronoi-polygons in modelling microstructure is applicable to the analysis of crack growth affected by microstructural variation and stress biaxiality.

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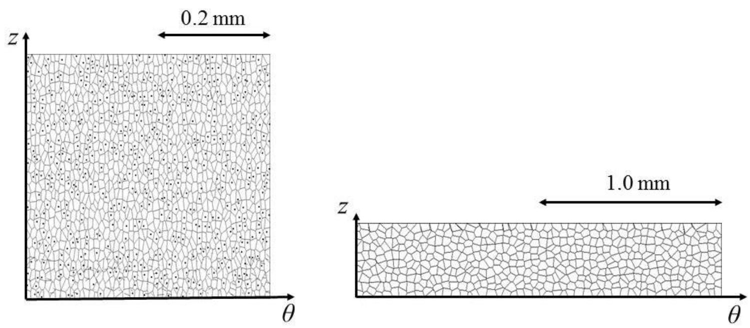
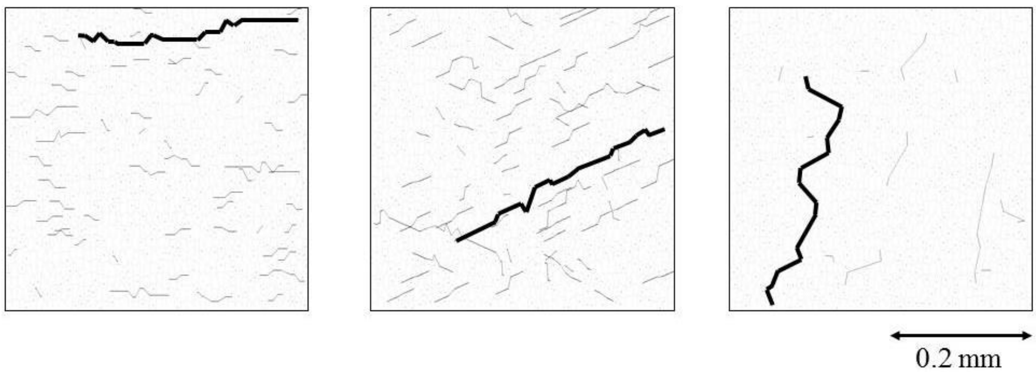


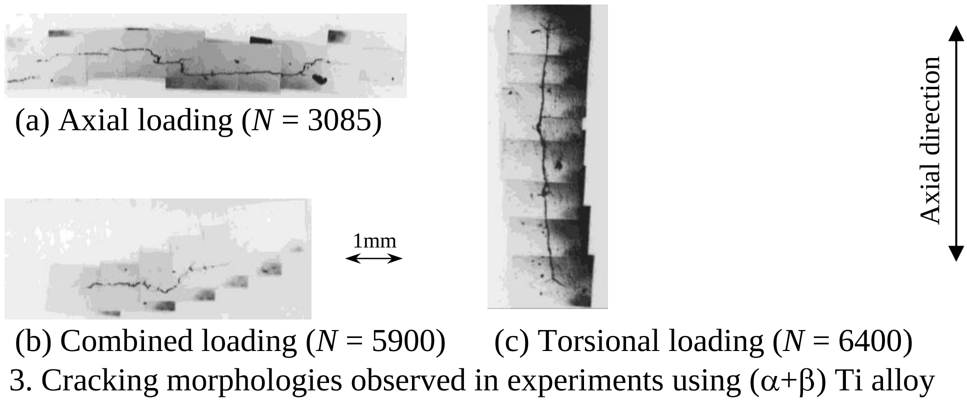
(a) (α+β) Ti-alloy (b) β Ti-alloy

Fig. 1. Examples of modelled microstructures



(a) Axial loading (b) Combined loading (c) Torsional loading

Fig. 2. Simulated cracking morphologies under three loading modes



(b) Combined loading (N = 5900) (c) Torsional loading (N = 6400)

Fig. 3. Cracking morphologies observed in experiments using (α+β) Ti alloy