Fatigue Abstracts

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An investigation into thermomechanical fatigue of metal matrix composites. *Karayaka, M.*
Diss. Abstr. Int. July 1992 **53** (1) 191pp

Experimental and theoretical approaches are used to characterize the thermomechanical deformation behaviour of metal-matrix composites. Experiments on unreinforced and SiC-particulate-reinforced Al 2xxx-T4 have been conducted under several mechanical strain–temperature phasing conditions. Based on stress range, substantial improvements in fatigue life have been observed. However, based on strain range, the effect of reinforcement on fatigue lives differs depending on the mechanical strain–temperature phasing, temperature, and strain rate. Several deformation mechanisms of unreinforced and reinforced Al 2xxx-T4 have been identified, including void formation, crack initiation, intergranular/transgranular crack growth, oxide penetration at the crack tips, crack deflection due to particle interference, and mean stress effects. Theoretical approaches include the development of a general micromechanistic constitutive equation, based on Eshelby's equivalent inclusion theory, and a life prediction methodology for metal-matrix composites. Synergistic effects of particulate reinforcement on high-temperature thermomechanical behaviour are studied. The constitutive model provides insight into the internal stress–strain behaviour, including effective and hydrostatic stresses, of both the matrix and the reinforcement developed during cyclic loading conditions. The deformation behaviour of the constituents is used to develop an experimentally based micromechanistic life prediction model. The damage caused by internal stresses, oxidation, creep and fatigue mechanisms as a function of reinforcement volume fraction is quantified for a wide range of loading conditions.

Crack initiation around holes in a unidirectional MMC under fatigue loading. *Newaz, G. M. and Majumdar, B. S.*
Eng. Fract. Mech. July 1992 **42** (4) 699–711

An investigation was undertaken to understand the fatigue process in unidirectional metal-matrix composites (MMCs) with centre holes. Currently, there is considerable confusion as to the true nature of initiation and growth of cracks from notches in MMCs. A key concern is whether surface cracks are through cracks. Furthermore, an explanation is required for the preferential initiation and growth of four major symmetric cracks at 65–72° from the pole (loading axis). Clarification of these issues is critical for developing rational analysis procedures for damage tolerance. In this investigation, unidirectional eight-ply Ti 15–23/SCS–6 composites with a centre hole were subjected to monotonic and tension–tension fatigue loading at room temperature. Optical and scanning electron microscopy were used to evaluate the initiation and growth of the cracks and to determine their angular orientation around the hole in the specimen. Under fatigue loading, it was found that the major cracks were continuous cracks through the depth of the specimen, and that they were located at 65–72° from the pole. The Hencky–Von Mises failure criterion, an octahedral shear stress criterion, was found to be successful in predicting the preferred initiation sites for the major fatigue cracks. Fatigue crack initiation appeared to be controlled primarily by shear-stress-induced reversed inelastic deformation of the matrix in the hole region. In contrast, under monotonic loading, fracture occurred at 90° from the pole, similar to what is observed in homogeneous metals. Crack initiation in this case appeared to be controlled by fibre fracture. Thus, whereas failure was matrix-dominated in fatigue, it was fibre-dominated under monotonic loading. Photomicrographs, graphs, 13 ref.

Improvement in surface fatigue life of hardened gears by high-intensity shot peening. *Townsend, D. P.*
NASA Technical Memorandum NASA TM-105678 1992 8 pp

Two groups of carburized, hardened, and ground spur gears that were manufactured from the same heat of vacuum-induction-melted vacuum-arc-remelted (VIM–VAR) AISI 9310 steel were endurance tested for surface fatigue. Both groups were manufactured with a standard group 16 rms surface finish. One group was subjected to a shot-peening intensity of 7–9 A, and the second group was subjected to a shot-peening intensity of 15–17 A. All gears were honed after shot peening to a surface finish of 16 rms. The gear pitch diameter was 8.89 cm (3.5 in). Test conditions were a maximum Hz stress of 1.71 GPa (248 ksi), a gear temperature of 350 K and a speed of 10 000 rpm. The lubricant used for the tests was a synthetic paraffinic oil with an additive package. The following results were obtained: The 10% surface fatigue (pitting) life of the high-intensity (15–17 A) shot-peened gears was 2.15 times that of the medium-intensity (7–9 A) shot-peened gears, the same as that calculated from measured residual stress at a depth of 127 μm (5 mil). The measured residual stress for the high-intensity shot-peened gears was 57% higher than that for the medium-intensity shot-peened gears at a depth of 127 μm (5 mil) and 540% higher at a depth of 51 μm (2 mil).

Fatigue failure in Pb–Sn–Ag alloy during plastic deformation: a 3D-SIMS imaging study. *Scandurra,A., Licciardello, A., Torrisi, A., Puglisi, O. and La Mantia, A.*
J. Mat. Res. Sept. 1992 **7** (9) 2395–2402

Three-dimensional chemical maps by secondary ion mass spectrometry (3D-SIMS), XPS spectroscopy, and SEM-EDAX microscopy were employed to investigate the effects of accelerated fatigue tests on crack formation in 95.5Pb–2Sn–2.5Ag and 95Pb–5Sn solder joints. These alloys are used in the die-bonding of electronic power device assemblies. The results show that cracks form by Sn depletion from the inner regions of the soldered joint. Simultaneously, there is a recrystallization of the Pb-rich phase in the same regions of the joint. The crack occurs at the critical number of cycles when a Sn-depleted region is formed, yielding weaker inner layers with lower shear strength. A possible explanation of the Sn depletion is also discussed. Cu–Ni plates were soldered for this experiment. Photomicrographs, graphs, spectra, 19 ref.

Stochastic fatigue damage accumulation in high-strength welded steel joints. *Kihl, D. P.*
Diss. Abstr. Int. Aug. 1992 **53** (2) 214 pp

One hundred welded high-strength steel cruciform specimens were tested under stochastic loadings to determine the influence on fatigue life of load intensity, bandwidth and non-normality. Constant-amplitude fatigue tests were also conducted to characterize the fatigue behaviour under constant-amplitude loads. In doing so, comparisons could then be made between the variable-amplitude fatigue test results and fatigue life predictions based on common analysis techniques such as Rayleigh approximation and rainflow analysis. Fatigue life predictions are based on different interpretations of the constant-amplitude *S/N* curve. Both Gaussian and non-Gaussian stochastic loadings were considered, having three different bandwidths ranging from narrowband to broadband. Each condition was further characterized by running tests at several root mean square (rms) stress levels, with a total of four specimens tested at each condition. Non-normality was identified by considering the fourth central moment of the process, kurtosis. A suitable non-linear transformation was used to convert a Gaussian process into a non-Gaussian process having the same mean level, rms and rates of mean level crossing and peak occurrence. Seemingly identical processes, analysed using the Rayleigh approximation method, would result in identical fatigue life estimates. Processes having kurtosis values of 2, 3 (Gaussian), and 5 were investigated. Bandwidth effects were identified by the irregularity factor, the ratio of upward zero crossings to peak occurrences (both of which can easily and accurately be determined in either the time or frequency domains). The narrowband loadings were based on a simulation using a first-order autoregressive method. This method produced a series of Rayleigh-distributed values having a correlation of successive extrema of 0.95. The non-narrowband loadings were based on a Gaussian simulation using smooth power spectral density curves, one having a predominantly unimodel frequency and another having predominantly bimodal frequencies. The results of this analytical and experimental investigation show that non-normality effects can be significant and could lead to unreliable fatigue life predictions if only Rayleigh approximation is used in the fatigue assessment procedure. It was found that the ratio of non-Gaussian to Gaussian fatigue damage increases with increasing values of kurtosis, increases with increasing slope of the *S/N* curve, and also increases with increasing irregularity factor. Narrowband processes, having the highest irregularity factor, unity, exhibit the greatest sensitivity to non-normality. It was also found that even though the beginning of an endurance limit was observed in the constant-amplitude test data, fatigue life predictions for lower stress levels were in closer agreement with experimental results when endurance limit effects were ignored. Fatigue life predictions for stochastic loadings at high rms levels, having stress cycles of up to yield, consistently overpredicted the experimental results by a considerable margin.

Fatigue behaviour of welded joints in offshore steel structures. III. Fracture mechanics. *Scholte, H. G.*
EUR Rep. 13395 1992 270 pp

Three different aspects of the fatigue behaviour of welded joints are investigated. (i) Fatigue behaviour of thick plates with and without attachments: earlier fatigue research up to a plate thickness of 76 mm showed that an increase of the plate thickness has a decreasing effect on the fatigue performance. Since the plate thickness applied in offshore structures tends to increase with the dimensions of those structures, fatigue research is carried out on thick plates. (ii) Fatigue behaviour of butt-welded tubular connections with root defects: in the construction of offshore platforms one-sided welding is often unavoidable and so are root defects. To gain better knowledge of the influence of root defects on fatigue behaviour tests have been carried out on butt-welded tubular joints under axial loading with a constant