M04-001

Thermal dissipation investigation in very high cycle fatigue

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VHCF tests are often performed by a high frequency fatigue test system, such as ultrasonic fatigue test machine with 20 kHz. In the article, simple VHCF tests are performed to investigate the fatigue behavior for steel. The test results in Wöhler diagram show a large scatter in VHCF regime. Thermal dissipation in VHCF is observed which is caused by the local inelastic deformation. Multi scales model are applied to estimate the inelastic deformation and the thermal dissipation in VHCF with the help of the conductivity law. The fatigue dissipation test results are used to verify the models.

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M04-002

Experimental and analytical study of the effect of variable amplitude loadings in VHCF regime

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Components and structures (e.g. helicopter rotors, wind turbine components or wheelset axels) are commonly exposed a very high number of cycles with variable amplitudes. For the study of the influence of variable amplitude loadings in the very high cycle fatigue regime different load-time-histories up to 109 cycles are used, which have different amounts of small amplitudes beneath the fatigue strength of the investigated material. The experiments are performed with an ultrasonic fatigue testing system with frequencies up to 20 kHz. In order to avoid an excessive heat development of the specimen, pulsed loadings with adequate pause lengths are applied. Therefore, only block loadings can be realized. The used load-time-histories have been counted by the rainflow method and then divided into different number of classes providing that within every class a minimum number of cycles restricted by the experimental performance is given. The classes have been reconstructed to a load-time-history by varying the sequence of the classes. The influence of the different reconstructions as well as of the amount of the amplitudes beneath the fatigue strength is quantified by the fatigue lifetime. Moreover the crack initiation lifetime is registered. The subsurface crack initiation is detected using an adapted potential drop method. These experimental data are used to proof conventional analytical approaches of structural durability (e.g. Miner's rule or damage parameter approaches) in the VHCF regime.

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M04-003

Is there a threshold for PSB formation in iron

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A thin flat specimen (1 mm thickness) tested on a piezoelectric fatigue machine in 20 kHz frequency on high cycle fatigue domain and beyond. The result shows that body centered cubic Armco iron (with 80 ppm of carbon content) could fail after 10^9 cycles at a loading below the yield stress. Observations under scanning electron microscope on the specimen surface and the fracture surface indicated gigacycle fatigue failure originated in the specimen surface and related to the formation of persistent slip band (PSB). The microstructure evolution was observed by optical microscope. It was found that PSB not only appear at beginning of ultrasonic fatigue test but also increase numbers of PSB by continue the number of cyclic loading. The temperature recording on the specimen surface was achieved by an infrared focal plane array camera. Energy dissipation was studied base on the localized heat resource.

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M04-004

Subsurface non defect fatigue crack origin and local plasticity exhaustion

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During very high cycle fatigue (VHCF), "fish eye" is a fatigue crack origin commonly observed. Recently, fatigue crack origins in the base metals or subsurface non-defect fatigue crack origins (SNDFCO) have been studied. This paper provides some discussion on the phenomena and mechanisms from the recent investigations using six metal materials with different microstructures. It will mainly focus the damage mechanisms in the VHCF regime. The results show that the strains or damage in these materials in the VHCF regime were highly localized, especially in the multi-phase materials, where the local maximum strain can be eight times higher than the average strain value in the specimen. This high strain localization can cause a local plasticity exhaustion that leads to a stress concentration and consequently fatigue crack initiation, and finally the formation of SNDFCO. For pure single phase austenitic material, strain localization can also occur due to dislocation accumulation at or near grain boundaries, which can become fatigue crack initiation origin in the VHCF regime. The results in this paper indicate that fatigue damage and crack initiation mechanisms in the VHCF regime can be different in different metals due to the mechanisms for local plasticity exhaustion.

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M04-005

Fatigue strength prediction for high-strength steels with fish-eye mode failure

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A model is developed to predict the fatigue strength of high-strength steels with fish-eye mode failure, which takes into account the effect of inclusion size at the fracture origin. It is shown that the fatigue strength σ_a, fatigue life N and inclusion size a_0 at the fracture origin are well correlated with $\sigma_a = Cnla_0m$, where C, l and m are parameters. Then, the model is used to predict the fatigue strength with the estimated maximum inclusion size under a certain probability, which shows a good agreement with the present experimental results and the ones in literature. The paper also indicates that it may be a way to investigate the reliability of fatigue strength through the probability for determining the maximum inclusion size of materials.

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M04-006

Application of Dang Van criterion to rolling contact fatigue in wind turbine roller bearings

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A 2-D plane strain finite element simulation of rolling contact in wind turbine roller bearings is used to study very high cycle fatigue (VHCF). Focus is on fatigue in the inner ring, where the effect of residual stresses and hardness variation along the depth are accounted for. The Dang Van multiaxial fatigue criterion is applied, simulating the contact on the bearing raceway by substituting the roller with the Hertzian static pressure distribution. Contact without friction is assumed here and the material used for the simulation is taken to be an AISI 52100 bearing steel. Both an initially stress free bearing and different residual stress distributions are considered. An assumed residual stress distribution, equilibrated by an elastic step calculation, is subsequently subjected to the stresses caused by the contact with the roller. The effect of variable hardness along the depth is also studied, relating its values to the fatigue limit parameters for the