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Very high cycle fatigue behavior under constant and variable amplitude loading

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Abstract

Components and structures are often exposed a very high number of cycles. The investigations in the field of very high cycle fatigue (VHCF) are mainly focused on experiments without mean stresses and with constant amplitude loading. Therefore, within the scope of this paper, investigations with constant and variable amplitudes with different mean stresses will be presented. For studying variable amplitude loadings in the VHCF regime systematic two-step block loading experiments have been performed, in which the maximum load amplitudes of the high block and the number of cycles of the low block with amplitudes below the fatigue strength have been varied. Moreover, the standardized load-time-histories Felix/28 and WISPER have been used. The influence of different reconstructions as well as the amount of the amplitudes beneath the fatigue strength of the investigated high strength steel on the initiation site, the *S-N* curve and the lifetime prediction has been investigated. Due to the variable amplitude loadings arrest marks are produced within the fish-eye surrounding the inclusion. The sizes and the area, where arrest marks are observable, as well as the spacings between the arrest marks are influenced by the different load sequences. By counting and measuring the arrest marks an average crack growth rate for the crack propagation within the fish eye can be calculated. Moreover, the short crack growth curve is used for calculating lifetimes using fracture mechanical approaches.

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Keywords: VHCF, variable amplitude loading, mean stresses, fatigue

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1. Introduction

In many applications components and structures, like helicopter rotors, ship propellers, wind turbines or wheelset axles, but also medical products, are commonly exposed to more than 10^8 cycles. However, due to such a high number of cycles the fatigue strength defined by Wöhler is not always given. Moreover, in the very high cycle fatigue (VHCF) regime cracks predominately initiate in the interior of a component with a typical fish-eye formation. The initiation in the interior is influenced by e.g. the size, the position, the shape and the hardness of the inclusion. These investigations are predominately performed with constant amplitude loadings except for few studies, e.g. Mayer et al. (2007, 2009), Fitzka and Mayer (2015), Ogawa et al. (2014) or Meischel et al. (2015). But, during assembly, transport and especially operation machines or means of travel are exposed variable amplitude loadings with different mean stresses. Therefore, the influence of different stress ratios and standardized load spectra in terms of Felix/28 and WISPER on *S-N* curves in the VHCF regime has been investigated.

2. Experimental setup

For the experimental investigations the ultrasonic testing system (Fig. 1a) developed by the BOKU Vienna (Mayer (2006) or Stanzl-Tschegg (2014)) is used. The testing system was extended with a load frame for the investigations of mean stress effects. Both the ultrasonic testing system and the load frame are computer-controlled. Therefore, the comprehensive software Ultrasonic Fatigue Testing Software for Variable Amplitude Loading (UFaTeS^{VAL}) has been developed (Müller, Sander (2013)). With UFaTeS^{VAL} it is possible to perform automatically VHCF experiments with constant and variable amplitude loadings in terms of block loads as well as different mean stresses. In order to avoid heating due to internal damping, the specimen is cooled by a fan and a pulsed loading is applied. For an optimal pulse-pause-sequence the temperature is measured at the surface of the specimen using an IR sensor and the pulse and pause length are adapted during the experiments. Because the heating of the specimen is significantly influenced by the stress amplitude, the adaptation of the pulse-pause-sequence is even important for variable amplitude loadings in order to reduce testing time. For the realization of experiments with $R > -1$ the lower end of the specimen is mounted with a counter bearing, which must be situated at a vibration node. The crack length at the surface is measured with an optical microscope, which is mounted on a 360°-ring.

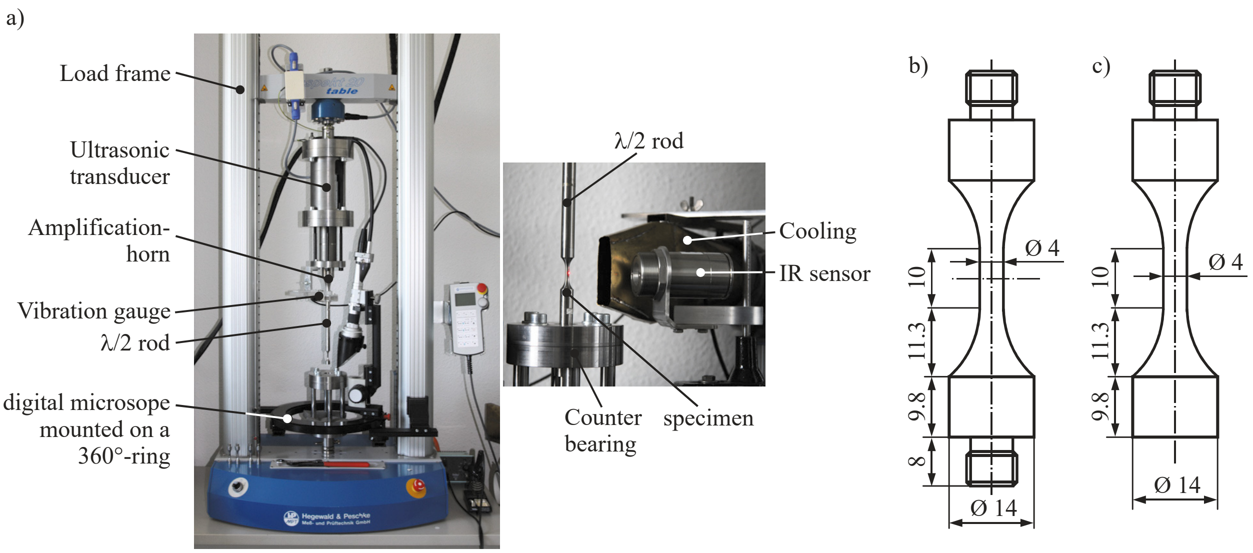

Fig. 1. a) Experimental setup with the used specimen b) for $R > -1$ and c) $R = -1$