Exploration of rolling contact fatigue using an ultrasonic testing device.

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Abstract

In fields in which human safety is at stake, such as in aeronautics, or in sensitive installations like nuclear power plants or dams, extremely low failure rates (< 10), or even zero for certain critical components, are required. It is therefore necessary to design parts that are capable of surviving tens of billions of cycles, corresponding to decades of operation. However, the damage mechanisms associated with such a long lifespan are still poorly understood. This is particularly due to a critical lack of experimental data, which is especially laborious and time-consuming to obtain in such contexts using conventional analyses. This lack of experimental data, combined with the extremely high number of cycles to simulate, makes the numerical simulation of such damage difficult or even impossible.
In order to render the study of very high cycle fatigue more accessible, we have designed an ultrasonic fatigue device capable of approaching the rolling contact fatigue (RCF) stress state experienced during rolling on an indented surface, in order to understand the primary cause of failures in aeronautics. It relies on testing specimens made of M50 steel while inducing compressive preload. This leads to a localized multi-axial and non-proportional stress field, induced by an artificial surface defect created via electro-discharge machining (EDM). The experimental device, therefore, enables to simulate the equivalent of several decades of use, or several billion cycles, in just a few dozen hours. This study has thus established numerous links between rolling contact fatigue and ultrasonic fatigue.
Observations reveal that the surface crack initiation occurs along the EDM beyond 108 cycles, with no shift observed from surface defects to sub-surface defects, as commonly seen in VHCF regime. Our analysis suggests that the stress intensity factor range, ΔK, may govern surface initiation in the VHCF regime, particularly when the formation of FGA is not feasible. Consequently, under fixed stress conditions, there exists a critical surface defect size below which short crack initiation becomes improbable. These results mirror the behaviour usually observed for indentations and thereby connect ultrasonic loading with RCF. Besides, initiations of fatigue buttery and FGA appear to be associated with VHCF tests, compression, high levels of multi-axial stresses, and the refinement of microstructure at low temperatures. These findings shed light on a potential link between fatigue buttery and FGAs, attributed to the same underlying cause: cross-slip.

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