Materials and Design 32 (2011) 4986–4993

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Short Communication

# Fretting–fatigue behavior of steel wires in low cycle fatigue

Dagang Wang [a,c], Dekun Zhang [b,*], Shirong Ge [a]

[a] School of Mechanical and Electrical Engineering, China University of Mining and Technology, Xuzhou 221116, China
[b] School of Materials Science and Engineering, China University of Mining and Technology, Daxue Road, Xuzhou 221116, China
[c] Chair of Technical Mechanics, Department of Mechanical Engineering, University of Wuppertal, Wuppertal 42119, Germany

ARTICLE INFO

*Article history:*
Received 25 April 2011
Accepted 20 June 2011
Available online 25 June 2011

ABSTRACT

The effect of strain amplitude on fretting–fatigue behavior of steel wires in low cycle fatigue was investigated using a fretting–fatigue test rig which was capable of applying a constant normal contact load. The fretting regime was identified based on the shape of the hysteresis loop of tangential force versus displacement amplitude. The variations of the normalized tangential force with increasing cycle numbers and fretting–fatigue lives at different strain amplitudes were explored. The morphologies of fretting contact scars after fretting–fatigue tests were observed by scanning electron microscopy and optical microscopy to examine the failure mechanisms of steel wires. The acoustic emission technique was used to characterize the fretting–fatigue damage in the fretting–fatigue test. The results show that the fretting regimes are all located in mixed fretting regimes at different strain amplitudes. The increase in strain amplitude increases the normalized tangential force and decreases the fretting fatigue life. The abrasive wear, adhesive wear and fatigue wear are main wear mechanisms for all fretting–fatigue tests at different strain amplitudes. The accumulative total acoustic emission events during fretting–fatigue until fracture of the tensile steel wire decrease with increasing strain amplitude. An increase of the strain amplitude results in the accelerated crack nucleation and propagation and thereby the decreased life.


## 1. Introduction

Hoisting rope is an important component of the winding equipment in coalmine, because its intensity and fatigue life have great effect on the reliability level of winder operations [1,2]. Structurally, hoisting rope is twisted tightly between strands and strands, wires and wires. When the hoist is running, the rope is subjected to axial cyclic stretching load and cyclic bending load on the drum and guide wheel, which results in the relative sliding among the strands and wires and thereby the fretting wear between steel wires. The interaction of fretting wear and cyclic stress causes the crack initiation, propagation and final fracture, i.e. fretting–fatigue, which increases fatigue failure of steel wire rope [3–6]. Therefore, reducing the fretting–fatigue damage of steel wires has been considered as an effective method to prolong the service life of hoisting rope.

Périera et al. [7] conducted the study of fretting–fatigue behavior of bridge engineering cables in a solution of sodium chloride. He concluded that there was no significant influence of the NaCl solution in terms of lifespan, but the presence of corrosion products was observed at the micro-scars and fracture surfaces in comparison with the results of fretting–fatigue tests carried out in air. Urvoy et al. [8] and Dieng et al. [9] investigated the effect of lubrication and zinc coating on the fretting–fatigue behavior of high strength steel wires. They found that the endurance limits of smooth, galvanized and lubricated wires in the fretting–fatigue process were 100 MPa, 170 MPa and 250 MPa, respectively. Siegert et al. [10] showed that the reduction of fatigue limit for the cable was caused by the friction force between steel wires in fretting–fatigue. Giglio and Manes [11] reported several analytical formulations to estimate the state of stress in the internal and external wires of a rope. Siegert [12] determined the normal contact force in a multilayer strand and the relative displacement amplitude between wires. Then a fretting–fatigue device was developed; it aimed at reproducing the contact fatigue conditions in spiral strands undergoing free bending deformation. Hobbs and Raoof [13] explored different mechanisms of inter-wire fretting–fatigue inside steel cables under different modes of external cyclic loading. Then he determined interwire/interlayer contact forces and associated relative displacements in practical large-diameter spiral strands using some straightforward formulations. Páczelt and Beleznai [14] proposed p-extension concept in the finite element method for simple straight two-layered wire rope strand, and calculated the contact stress and deformation using Hertz-theory in the case of line and point contacts. Jiang et al. [15] analyzed the one-layered strand under tension and torsion and derived the contact forces between steel wires. From the literature study mentioned above, it is found that the previous efforts have been focused on investigating fretting–fatigue behaviors of steel wires

* Corresponding author. Tel.: +86 516 83591918; fax: +86 516 83591916.
*E-mail address:* dkzhang@cumt.edu.cn (D. Zhang).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.06.037