Accepted Manuscript

Experimental analysis and modelling of c-crack propagation in silicon nitride ball bearing element under rolling contact fatigue

Mian Hammad Nazir, Zulfiqar Ahmad Khan, Adil Saeed

PII: S0301-679X(18)30223-8

DOI: 10.1016/j.triboint.2018.04.030

Reference: JTRI 5209

To appear in: *Tribology International*

Received Date: 6 March 2018

Revised Date: 23 April 2018

Accepted Date: 25 April 2018

Please cite this article as: Nazir MH, Khan ZA, Saeed A, Experimental analysis and modelling of c-crack propagation in silicon nitride ball bearing element under rolling contact fatigue, *Tribology International* (2018), doi: 10.1016/j.triboint.2018.04.030.

Experimental Analysis and Modelling of C-crack Propagation in Silicon Nitride Ball Bearing Element under Rolling Contact Fatigue

Mian Hammad Nazir[1], Zulfiqar Ahmad Khan[1], Adil Saeed[1]

[1]NanoCorr, Energy and Modelling Research Group (NCEM),
Bournemouth University Talbot Campus, Poole, Dorset, BH12 5BB, UK

Abstract

A comprehensive model for predicting fatigue failure probability of surface c-shaped cracks in silicon nitride ball bearing elements under rolling contact fatigue (RCF) has been presented in this paper. Firstly, three-dimensional finite element analysis (FEA) is used to determine the stress intensity factors (SIFs) along the front of crack by using fracture mechanics approach. Then the propagation uncertainty of c-crack is evaluated by using surrogate models built upon highly accurate finite element modelling for equivalent stress intensity factors. Finally, the Monte Carlo Simulations combined with surrogate models are used to predict the failure probability of rolling ball bearing element. Simulation results reveal that it is possible to reduce the failure probability of ball bearing element up to 95% by reducing the maximum crack size and enhancing the fracture toughness of the ball material. The modelling results have been verified by experimental studies showing that the current predictions of c-crack fatigue failures were consistent with the experimental results. Fatigues crack initiation and propagation is a significant failure mechanism within ceramic ball bearing elements. It presents design and durability challenges for both manufacturers and users. A three-fold approach, to simulate fatigue propagation of c-shaped crack in rolling contact ceramic bearing element presented in this paper, is novel and will solve major durability issues within ceramic ball bearing elements subject to rolling contact fatigue.

Keywords: Silicon nitride; Ball bearing; Rolling contact fatigue; Finite element method; c-crack propagation; Monte-Carlo Simulation

Contents

1. Introduction 2
2. Experiment 3
2.1. Materials 3
2.2. Sample Preparation 3
2.3. Test Equipment 4
2.4. Test Procedure 5
2.5. Experimental Observations 6
2.5.1. Effect of Crack Position on RCF 6
2.5.2. Effect of Crack Geometry on RCF 7
3. Modelling 9
3.1. Rolling Contact Fatigue (RCF) Model 10
3.1.1. Loading analysis 10
3.1.2. c-crack geometry 12
3.1.3. Mixed Mode Stress Intensity Factor (SIFs) at c-crack tip due to RCF 13
3.1.4. FEA of c-crack subjected to RCF 15
3.2. Uncertain Failure Probability Model 16
3.2.1. Surrogate modelling 16
3.2.2. Monte Carlo Simulation (MCS) using Surrogate modelling 17