Accepted Manuscript

An approach to investigating subsurface fatigue in a rolling/sliding contact

Matti Savolainen, Arto Lehtovaara

PII:	S0142-1123(18)30381-5
DOI:	https://doi.org/10.1016/j.ijfatigue.2018.08.014
Reference:	JIJF 4810
To appear in:	*International Journal of Fatigue*
Received Date:	21 May 2018
Revised Date:	8 August 2018
Accepted Date:	11 August 2018

Please cite this article as: Savolainen, M., Lehtovaara, A., An approach to investigating subsurface fatigue in a rolling/sliding contact, *International Journal of Fatigue* (2018), doi: https://doi.org/10.1016/j.ijfatigue.2018.08.014

An approach to investigating subsurface fatigue in a rolling/sliding contact

Matti Savolainen*, Arto Lehtovaara
Group of Tribology and Machine Elements
Laboratory of Materials Science, Tampere University of Technology
PO BOX 527, 33101 Tampere, Finland

Abstract

This paper presents an approach to studying subsurface fatigue failures in a rolling/sliding contact with a twin-disc test device. A series of surface hardened test discs were tested with different load levels. A destructive inspection method was utilised showing subsurface cracks beneath the surface after a large number of load cycles with high loading. In addition, an elastoplastic finite element model considering the effects of increased hardness and residual stresses was created. The calculated results showed critical locations in the discs beneath the surface, which coincided with the experimentally found.

Keywords: Fatigue, twin-disc, subsurface.

1. Introduction

There are two fatigue failure modes, which are well considered in standards for dimensioning gear wheels; tooth root bending fatigue and contact fatigue at the tooth flank [1, 2]. With these failure modes, the initiation of the cracks leading to fatigue failure often start from or close to the surface. Because gear wheels are usually surface hardened, the failure may initiate from a subsurface zone beneath the hardened surface layer. In this region, the material strength is lower than at the surface and the compressive residual stresses induced by the hardening are not effective. However, the material is affected by the balancing tension residual stresses, which may accelerate the growth of the crack. Consequently, a new failure mode called Tooth Interior Fatigue Fracture (TIFF) has recently been proposed to account for the fatigue cracks that are initiated inside a gear tooth [3].

The material strength of a gear wheel has long been defined by conducting push-pull or bending tests for specimen made out of a specific material and with a specific surface treatment [4, 5]. The results of these tests can be used to predict tooth root bending strength when dimensioning a gear wheel. Another commonly used approach is to conduct a full-scale bending test on a single gear tooth. In this way, the effects of the actual geometry and the surface treatment as well as roughness of the tooth are accurately reflected in the results [6, 7, 8].

Traditionally, the durability of the tooth flank has been defined with the aid of an FZG test device [9] by observing the formation of pitting or micropitting marks on the surface of the tooth flank. Several studies have focused on the effect of demanding thermal conditions, comparison of lubricant types and the effect of lubricant viscosity and the surface roughness [10, 11, 12, 13]. In addition, the twin-disc test device has been successfully utilised in research into the effects that the lubricant type, surface roughness and surface treatment have on the formation of micropitting [14]. In their twin-disc tests, Oila et al concluded that the initiation of micropitting is mostly controlled by contact pressure, while its progression is, in turn, mainly driven by the operating speed and slide-to-roll ratio [15]. In addition, Seo et al have reported that higher material ductility and fracture toughness leads to higher resistance to contact fatigue, but a lower resistance to wear [16]. In another study by Seo et al, they evaluated the growth mechanism of fatigue cracks under the condition of lubrication [17]. They concluded that the cracks grew continuously due to the contact pressure, while its growth rate was accelerated by the effect of hydrostatic pressure.

Many finite element-based calculations of a rolling contact have focused on analysing the wheel-rail contact of trains [18, 19, 20]. Ringsberg developed a strategy for prediction of rolling contact fatigue (RCF) crack initiation [21]. He concluded that strain-life approach with elastic-plastic FE analysis makes a powerful combination in predicting the initiation of fatigue cracks. Kráĉalík et al. used 2D finite element models to see whether the crack growth predictions

* Corresponding author: Email: matti.savolainen@tut.fi Tel: +358503015436