Engineering Failure Analysis 56 (2015) 348–359

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

A study of the wear mechanisms of disk and shoe brake pads

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ARTICLE INFO

Article history:
Received 2 September 2014
Received in revised form 23 December 2014
Accepted 4 January 2015
Available online 29 January 2015

Keywords:
Wear mechanisms
Third body layer
Friction film
Disk pad
Shoe pad

ABSTRACT

In the present work, a study and description of the wear mechanisms implied in disk and shoe pads (bodies) was presented. These were subjected to real service, roughly 8 months, in a city as Poza Rica in Mexico that is extremely warm (high temperatures between 40 °C and 50 °C), which lead to cause a more rapid wear process. The surface characteristics and the differences in the wear modes of the brake pads were shown. These observations allowed concluding that high sliding and abrasion wear deformed the disk pad surfaces leading to form third body layers, friction layers and friction films that determined the friction behavior of the automotive brakes. In relation to the shoe pads, although sliding wear occurred, the wear mechanism more evident was the formation of fatigue cracks due to the impact actions with the drum (counter-body). The images of the unworn and worn surfaces were obtained by using scanning electron microscopy (SEM). In addition, energy-dispersive X-ray spectroscopy (EDS) was employed to obtain the chemical analysis of unworn and worn pads. Finally, Atomic Force Microscopy (AFM) was utilized to have a perspective of the degradation of the worn pads.

1. Introduction

The wear mechanisms present in braking systems have studied by several researchers over the years. These are quite unpredictable because of the contact variations that exist in these specific and complex systems. Erikson et al. [1], for instance, conducted an investigation of the connection between brake pad surface topography and the occurrence of squeals. A characterization of the break pad surfaces was performed after interrupting the testing under both silent and squealing conditions. The brake pads used in the tests were two pairs of metal-fiber reinforced organic pads. One of the pairs was standard production formulation for the Volvo 850 and the other pair slightly reformulated for increased high-speed performance. The results showed the presence of contact plateaus "flat areas rising a few micrometers over the rough surrounding" after the sliding action of the pads against the cast iron disks. In addition, Eriksson et al. [2] carried out a research work on the nature of tribological contact in automotive breaks in disk pads. In this study, the term "contact plateaus" constantly was indicated as the higher asperities firstly making contact with the high irregularities of the disk (counter-body), in a brake system. It also presented an analysis on the wear mechanisms in automotive breaks produced by the

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http://dx.doi.org/10.1016/j.engfailanal.2015.01.004
1350-6307/

contact surface variations causing rapid deterioration processes, affected by braking force changes, vibrations and wave motions in the brake pad and cast iron disk, and slow degradation processes where the thermally induced deformation, shape adaptation and contamination and cleaning played an important role.

Osterle et al. [3] conducted a study of the chemical and microstructural changes occurring during braking simulation. In this work, a series of reciprocating tests on the surface of a conventional disk brake pad material, were performed. Characterization techniques such as scanning electron microscope and energy-dispersive X-ray spectroscopy (SEM/EDS), selected area diffraction (SAD) and transmission electron microscopy (TEM) were used to know the chemical changes, before and after testing. The wear debris produced by three-body abrasive wear was analyzed. The major wear mechanism was delamination of filler particles from the organic binder, supported by local degradation of the phenolic resin during asperity heating. Quartz crystals preserved thereby adopting the function of primary contact areas. In other research, Osterle et al. [4] presented a work related to the surface changes induced by repeated brake applications and provided some explanations about how the surface was modified to produce the tribofilms that affect the friction and wear properties of automotive disk brakes. The focus in this work was to analyze the third body layer formed from the wear debris produced by the contact between the disk pad (body) and the steel disk (counter-body). Techniques such as transmission electron microscopy (TEM), the focused ion beam (FIB), energy dispersive X-ray spectroscopy (EDX), light optical microscopy (LM) and Raman spectroscopy (RS) employed to reveal details of the third body and loose wear particles. On the other hand, Severin and Dorsch [5] performed experimental tests to show the effect of the metal particles in the friction lining and the importance of thermoelastic instability (TEI) for the functionality of large-scale drum and disk brakes. The results showed that the concentration of iron particles that diffused into the lining during the friction process was relevant to determine the value of the coefficient of friction (COF) in the industrial brakes. The wear mechanism probably was a result from the interaction between the local friction surface temperature, the local friction intensity, the heat depending on the thermal contact resistance and in large brake systems, of the deformation of the friction partner.

In this study, the wear mechanisms of disk and shoe pads identified using SEM images. EDS analysis was employed to compare the chemical analysis of unworn and worn surfaces and the AFM technique used to obtain the 3D roughness profiles of the unworn and worn pads, respectively.

2. Experimental details

2.1. Experimental procedure

The tribological characterization was carried out on the disk (9 cm long and 4 cm wide) and brake shoe (12 cm long and 4 cm wide) pads (bodies). Firstly, small samples were extracted from unworn and worn pads (1 cm^2) of different zones to perform a chemical analysis to compare the results. Micrographs of the damaged surfaces and identification of the different constituents of the disk and shoe pads were obtained using a scanning electron microscope (SEM) Quanta 3D FEG (FEI) equipped with an Energy-dispersive X-ray spectrometer (EDS). In addition, roughness profiles of both brake pads, before and after real service, were obtained by using an AFM (Microscope diMultimode V, Vecco, Controller diNano-scope V). In respect to the shoe pads, a blowtorch was used to heat the pad carefully and removed it, completely, as seen in Fig. 1.

Fig. 2a and b shows the samples of the unworn and worn disk pads after real service, for roughly 8 months. The disk pad (body) presented higher wear damage in one side by the high contact stresses with the steel disk (counter-body). On the other hand, Fig. 2c and d, exhibits the surfaces of unworn and worn shoe pads (body). The damage in this particular case was caused by the contact with the drum (counter-body).

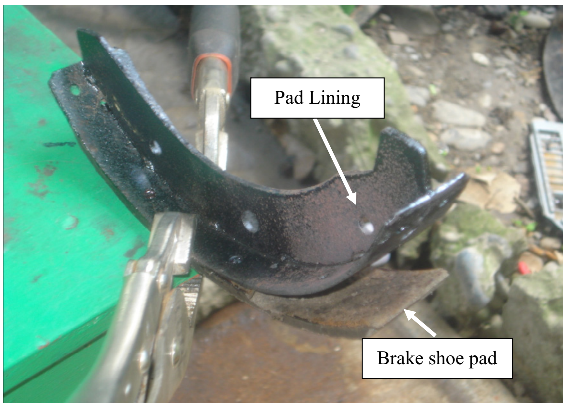

Fig. 1. Extraction of the shoe pad.