



Tribological origin of squeal noise in lubricated elastomer–glass contact



F. Dalzin^{a,b}, A. Le Bot^a, J. Perret-Liaudet^a, D. Mazuyer^{a,*}

^a LTDS-UMR 5513 CNRS, Ecole Centrale de Lyon, 36, Avenue Guy de Collongue, 69134 Ecully Cedex, France

^b Valeo 1 Avenue Pierre et Marie Curie, 63500 Issoire, France

ARTICLE INFO

Article history:

Received 13 January 2015

Received in revised form

7 December 2015

Accepted 11 January 2016

Handling Editor D. Juve

Available online 14 March 2016

ABSTRACT

An experiment of squeal noise on a lubricated elastomer/glass contact is presented. The experimental device, stiff enough to be non-intrusive on the system response up to several kHz, provides the contact force, vibration velocity and contact image with a high sampling rate. It is shown that the self-excited oscillation responsible of squeal involves a single mode and that its apparition is induced by the velocity weakening of friction. Direct observation of the contact by microscopy highlights that the contact is highly heterogeneous and the number of contact spots decreases with the sliding velocity during squeal.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Noise annoyance caused by friction-induced vibration is a major issue encountered in a lot of mechanical systems. To cite a few, typical engineering examples are vehicle brakes [1–7], friction clutches [8], train wheel–rail in curves [9–11], waist seal rubber sliding on glass [12], wiper blade systems [13–16], frictional belts [17] and machine tools [18]. The resulting noises are generally referenced as chatter [19], squeak [20], and squeal [21,22]. All these sounds are produced by a combination of forcing or self-excited nonlinear oscillations of the mechanical system in the presence of a friction force [23–26]. The existence of a coupling between the friction force and the resulting motion induces a loss of stability of the equilibrium state which leads to self-excited oscillations.

Sprag-slip is a typical example of this kind of instability. A coupling between the normal load and the friction force is enforced by a geometrical effect. The normal force and therefore the friction force depend on the solid position. A second example is the mode coupling instability. To describe this phenomenon, a multi-degree of freedom model is required [27,28]. By introducing the normal contact stiffness, a normal vibration at the contact is allowed and again the friction force depends on the solid position. In these two examples, friction is necessarily present but is not constrained to follow a given law. In particular, these instabilities may occur with a friction coefficient independent of the sliding velocity.

This is not the case for the stick-slip vibration phenomenon [29,30]. Stick-slip can simply be explained on the basis of a single-degree-of-freedom system with a frictional sliding mass presenting a kinetic friction weaker than the static friction. This model describes the vibration by a sawtooth displacement–time history where slip and stick phases alternate. An accurate description of the phenomenon generally requires more refined models for friction [31,32]. Some of them include

* Corresponding author.

E-mail addresses: fabien.dalzin@ec-lyon.fr (F. Dalzin), alain.le-bot@ec-lyon.fr (A. Le Bot), joel.perret-liaudet@ec-lyon.fr (J. Perret-Liaudet), denis.mazuyer@ec-lyon.fr (D. Mazuyer).

stiction, hysteresis and acceleration effects [33,34]. One can cite for example the rate-and-state friction law, originally developed to simulate seismic cycles [35–37], and the LuGre model originally developed by the automation community [38]. Stick-slip instability is always induced by the weakening of the friction force with the sliding velocity [39]. This velocity weakening leads to an effective negative damping which results in a Hopf bifurcation [40]. In this scenario, the coupling of friction force with motion occurs by the friction–velocity law.

In this general framework, a scientific challenge is to better understand friction instabilities in terms of the tribological behaviour of interfaces. This paper addresses this particular question.

Tribology is particularly important for wet and/or lubricated contacts [41–46]. The friction force and the sliding velocity are linked by the formation of a fluid interface. The degree of separation of the surfaces determines the lubrication regimes: boundary, mixed, elasto-hydrodynamic and hydrodynamic one. The Stribeck effect [47] governs the transition between the boundary and hydrodynamic regimes.

To investigate the origin of the squeal noise of a lubricated contact, this study presents the results of an experiment conducted on an elastomer sample sliding on a glass surface in the presence of water. The experimental device is designed to be much stiffer than the sample. Therefore, the vibration is confined to the sample alone. By observing the contact by microscopy through the glass, we shall investigate the link that exists between the produced noise and the tribological behaviour of the interface at the microscopic scale.

The paper is organized as follows. Section 2 describes the tribometer, the optical viewing system, and the elastomer sample. Section 3 presents the experimental results. The characteristics of squeal noise are analysed and the modal analysis of the sample is performed. Measurements of the squeal noise level and velocity weakening friction are also presented. Section 4 is a discussion on the role of the evolution of contact area during the squeal. Finally, some conclusions are drawn in Section 5.

2. Description of the experiment

2.1. Experimental set-up

The principle of the experiment is shown in Fig. 1. It consists of observing the contact during the occurrence of squeal. An elastomer sample is pressed against a glass disk with a fixed normal load. The contact is lubricated by water. The disk rotation speed is maintained constant during recording of the noise.

The radius of the disk is 45 mm and the mean distance between the sample and the centre of the disk is 22.5 mm. For all the experiments reported in this paper, the contact is lubricated by 10 ml of distilled water introduced by a pipette near the contact zone. The contact is observed through the glass disk with an optical microscope and a white light source at normal incidence.

The driving velocity ranges from 0.8 to 2100 mm s^{−1} and is accurately imposed by a brushless synchronous motor. The speed is regulated by a high resolution encoder allowing 400 000 tic per revolution which measures the instantaneous speed at 1 kHz. The speed accuracy is better than 1 percent for all speeds.

The static normal force is applied by a micrometer screw in the range 0–100 N. It is controlled with a strain gauge of resolution 0.01 N. The tangential force is measured with a piezoelectric sensor with a high frequency bandwidth.

A laser vibrometer Polytech OFV-505 measures the vibration at one point located on the centre of a sample side. The same signal is processed by two decoders in the controller. The first decoder DD500 delivers the displacement with a resolution of 15 pm. The second decoder VD06 operates by Doppler effect and delivers the vibrational velocity with a resolution of 0.05 μm s^{−1}. The signals corresponding to the normal force, tangential force, vibrational velocity and vibrational displacement are acquired synchronously by an analogue-to-digital data acquisition card at the sampling frequency 20 kHz.

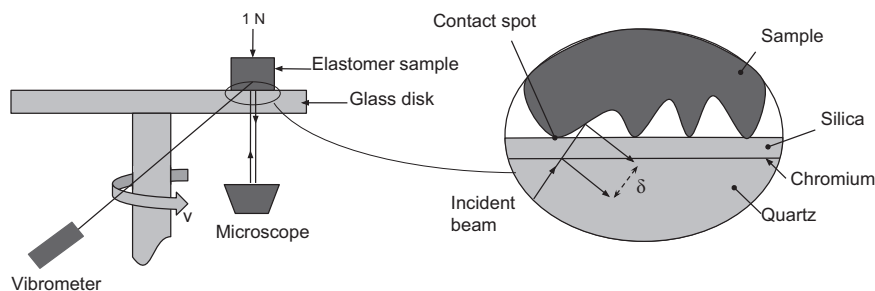


Fig. 1. Principle of the experiment. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

Download English Version:

<https://daneshyari.com/en/article/286927>

Download Persian Version:

<https://daneshyari.com/article/286927>

[Daneshyari.com](https://daneshyari.com)