Mechanical Systems and Signal Processing 25 (2011) 1727–1737

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/jnlabr/ymssp

A numerical investigation into the squeal instability: Effect of damping

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ARTICLE INFO

Article history:
Received 8 June 2010
Accepted 9 December 2010
Available online 22 December 2010

Keywords:
Squeal
Damping
Numerical
Contact instability

ABSTRACT

Between the NVH issues, brake squeal is a harmonic acoustic emission (between 1 and 20 kHz) caused by friction induced vibrations. The onset of squeal is due to an unstable behaviour of the system leading to limit cycle vibrations. A general approach used by several authors to determine the system instabilities is the CEA: Complex Eigenvalues Analysis. This work presents a numerical investigation into the squeal instability on a simplified disc-brake system addressed to analyse the effect of damping on the squeal instability.

The mode lock-in instability is reproduced by a parametrical analysis. The relationship between the distribution of damping on the system components and the propensity of the brake to develop squeal is investigated. The numerical results are validated by the experimental ones, presented in a previous work. The behaviour of the system eigenvalues highlights that, while a homogenous distribution of damping stabilizes the system, a non-uniform repartition of damping can increase the squeal propensity.

1. Introduction

Brake squeal, is a very complex phenomenon investigated for several decades [1,2]. A large variety of approaches to the problem and many explanations about its origin were proposed until now. Nevertheless, there is no complete understanding of the phenomenon yet and a theory uniquely shared on the mechanism of squeal does not exist. Empiric solutions are often adopted by car manufacturers to reduce the squeal emission, like shims or shape adaptation of the brake pad. One recent work [3] deals with the suppression of squeal vibration by introducing structural modifications into the rotor, while new approaches try to account for the uncertainties of the brake system parameters [4].

Various researchers agree in setting the squeal as an example of noise caused by vibrations induced by friction forces [5] that may cause dynamic instability. This phenomenon causes deterioration in the vehicle comfort and it is the source of significant costs for car-companies which are forced to replace brakes still under warranty. Recently [6], an increase of wear at the brake pad sliding surface has been showed as well.

Different types of approaches, analytical, experimental and numerical [1,2], were proposed to explain these self-excited vibrations of braking apparatus that cause the squeal noise. The CEA is the mostly used numerical tool for the prediction of the phenomenon [7,8].

As shown in [8,9] squeal occurs only when a coincidence in frequency of two suitable system modes is obtained (lock-in), i.e. when a disc mode characterized by normal vibrations at the contact surface couples with a system mode having a large

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0888-3270/$ - see front matter
doi:10.1016/j.ymssp.2010.12.005