

A Study on Trigger of Disc Brake Squeal Generation

Masaaki Nishiwaki
Teikyo University

Ryutaro Misumi
Toyota Motor Corp.

ABSTRACT

It is well known that disc brake squeal is often caused by high friction coefficient pad materials. Disc brake squeal is caused by dynamic unstable system under small disturbance of friction force variation. Today, disc brake squeal comes to be simulated by FEA, but it is very difficult to put so many dynamic unstable solutions into stable solutions. Therefore it is very important to make it clear the influence of friction force variation.

This paper describes a study on trigger of disc brake squeal generation. First, the development of experimental set-up for disc brake squeal basic research and experimental results are described. Second, the equation of motion in disc brake squeal is derived and the vibration induced by small disturbance are analyzed. Furthermore, kinetic energy increase per 1 cycle in minute vibration are calculated, which represents the influence of friction and wear between disc and pad with caliper. Based on this analysis, trigger of disc brake squeal generation is considered.

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INTRODUCTION

High brake performance is required for vehicle safety. At the same time, mass reduction of brake system is also required for vehicle economic long run. Under these backgrounds, high friction coefficient pad materials come to be adopted for brake system. But it is well known that brake squeal is often caused by high friction coefficient pad materials. Today, disc brake squeal can be simulated by FE Analysis in actual disc brake system, but it is very difficult to put so many dynamic unstable solutions into stable solutions. Therefore it is very important research theme on disc brake squeal trigger of friction force variation like the references [1] [2] [3]. Disc brake squeal around 2 kHz can be caused by random forced vibration during brake application, which suggests the trigger of disc brake squeal generation [4].

DESIGN OF EXPERIMENTAL SET-UP

Design Concept

Actual disc brake squeal vibration mode is shown in references [4] and [5]. Disc brake squeal can be duplicated by experimental set-up for basic research, which is shown in references [6] [7] [8]. Based on these references, the experiment set-up shown in Figure 1 was designed, which is composed of disc and cantilever type pad-caliper replaced from actual calliper and pads. Pad-caliper consists of small friction material fixed on cantilever which is calculated for its natural frequency shown in reference [9].

Pad Caliper

Figure 1 shows the disc cross section and pad-calipers of referenced papers [6] and this research [9]. Cantilever type pad-caliper is needed for exciter space. Natural frequency of cantilever type pad-caliper is calculated, which depends on the length and cross section area. The natural frequencies of cantilever type pad-caliper were designed to have the same natural frequencies of thin plate type pad-caliper.

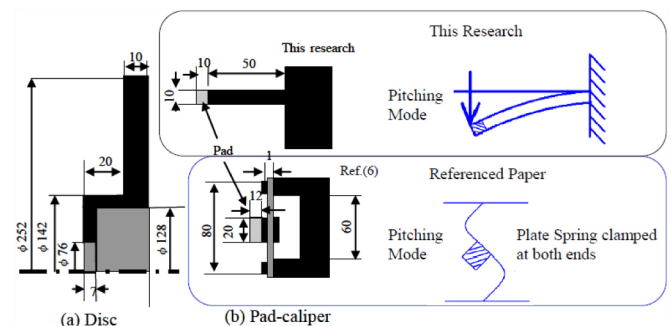


Figure 1. Design of experimental set-up

This cantilever is made of steel with cross section 10 mm square. The natural frequencies of cantilever type pad-caliper is fitted to thin plate type pad-caliper. The length of cantilever is designed by the natural frequency calculation result. The experimental results of cantilever 40 mm and 50 mm are shown in Figure 2. The same kinds of dynamic instability, brake squeal, is caused by the cantilever type pad-caliper.

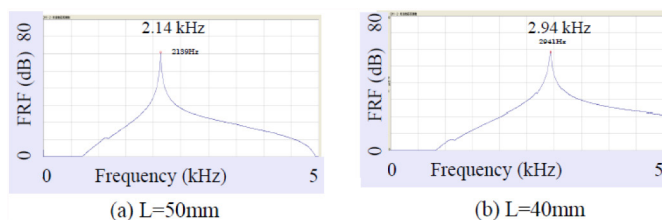


Figure 2. Natural frequency experimental results of each cantilever

Disc

Disc cross section is shown in Figure 1, which is almost same as the reference [6]. Disc material is made of steel not cast iron. The natural frequencies and their vibration modes are studied in reference [10]. The experimental results are shown in Figure 3, which shows the natural frequencies and vibration modes of disc under boundary condition in its center fixed with hub bolts and its circumference free.

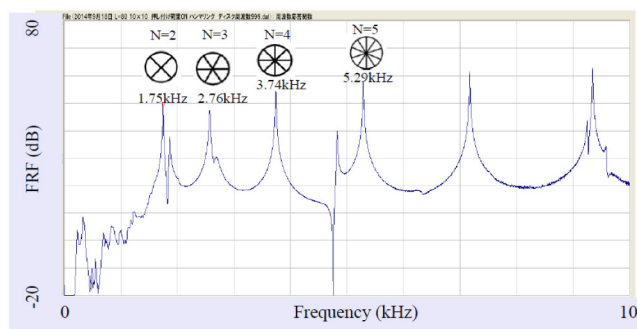


Figure 3. Natural frequency experimental result of disc

Over View of Experimental Set-Up

Experimental set-up over view is shown in Figure 4, which is composed of disc, cantilever type pad-caliper, motor, torque meter, load cell, gap-sensors for measurement of disc vibration mode and exciter for small disturbance of friction force variation.

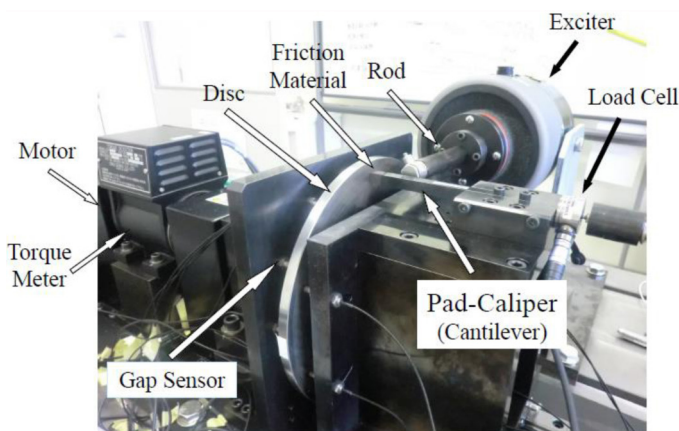


Figure 4. Experimental set-up over view

EXPERIMENTAL RESULTS

Friction tests were done when cantilever load is varied from 0N to 50N every 10N during brake application in disc rotation 1 rpm.

Friction Test 1

Figure 5 shows the experimental result of disc brake squeal 2.71 kHz and motor noise around 1.9 kHz on load 50N. This is given by the pad-caliper of cantilever length 40 mm on load varied from 10N to 50N every 10N, the almost same frequencies of disc brake squeal occurred. Figure 6 shows the experimental result of disc brake squeal 1.94 kHz and motor noise around 1.9 kHz on load 50N. This experimental result is obtained by the pad-caliper of cantilever length 50 mm on load varied from 10N to 50N every 10N. It can be seen that brake squeal frequency depends on the cantilever length. The friction coefficients μ were measured by torque meter and load cell on every load 10N. Friction coefficients μ were 0.40 on load 10N and 0.38 on load 50N.

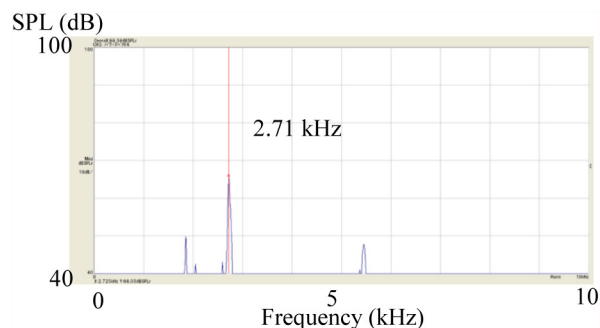


Figure 5. Friction test result for cantilever length 40 mm on load 50N [9]

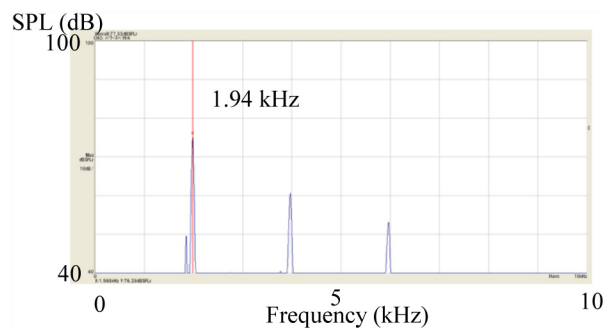


Figure 6. Friction test result for cantilever length 50 mm on load 50N [9]

Friction Test 2

Figure 7 shows the experimental result of disc brake squeal 2.71 kHz and motor noise around 1.9 kHz on load 10N. This experimental result was obtained by the pad-caliper of cantilever length 50 mm under exciter rod contact condition shown in Figure 8. It can be seen that disc brake squeal frequency is varied from 1.94 kHz to 2.71 kHz after exciter rod contact. This disc brake squeal frequency seems to be for cantilever length 40 mm. Figure 8 shows the natural frequency of cantilever in exciter rod contact condition, which is almost same as cantilever length 40 mm.

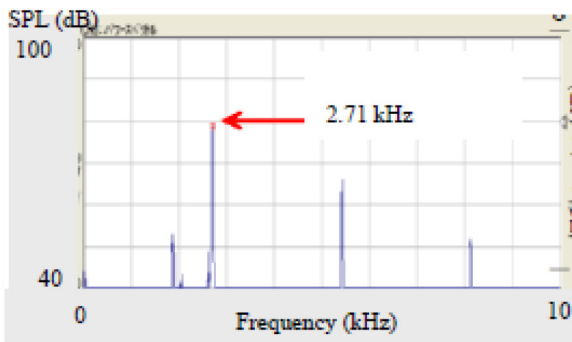


Figure 7. Friction test result for cantilever length 50 mm on load 10N under exciter rod contact condition

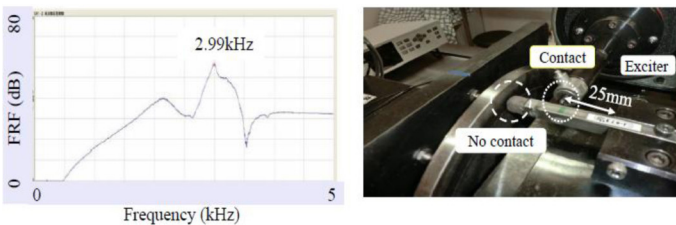


Figure 8. Natural frequency of cantilever length 50 mm on load 10N under exciter rod contact condition

Friction Test 3

Friction Test under Random Force Excitation

It is required to distinguish disc brake squeal and exciter actuation noise. Disc and cantilever vibrate in its brake squeal frequency during disc brake squeal generation. Figure 9 shows the exciter random function actuation noise and no vibrations of cantilever and disc under exciter rod no contact to cantilever. Disc vibration around 8 kHz is assumed to be motor and gear vibration, which is not brake squeal. In this friction test, disc brake squeal didn't occur on load 6N under no exciter actuation, but it occurred at 2.71 kHz on load 7N.

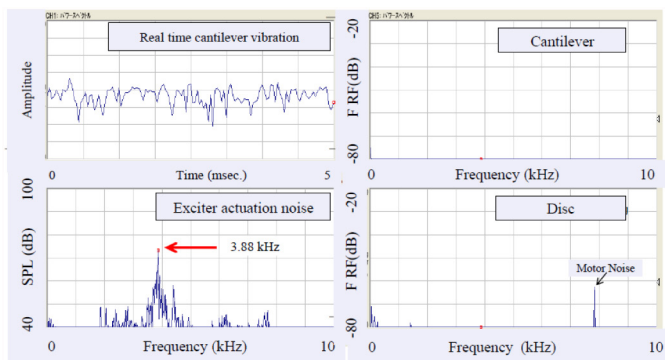


Figure 9. Exciter random function actuation noise

Figure 10 shows the experimental data of exciter random function actuation noise and disc brake squeal 2.71 kHz during brake application on load 6N. Disc brake squeal seems to be caused by exciter random function actuation, because disc and cantilever vibrate in its squeal frequency 2.71 kHz. Figure 11 shows the experimental data of disc brake squeal 2.71 kHz after exciter random function actuation stopped. Disc brake squeal 2.71 kHz seems to be triggered

by exciter random function actuation, because disc and cantilever continued to vibrate in its squeal frequency 2.71 kHz after exciter random actuation stopped.

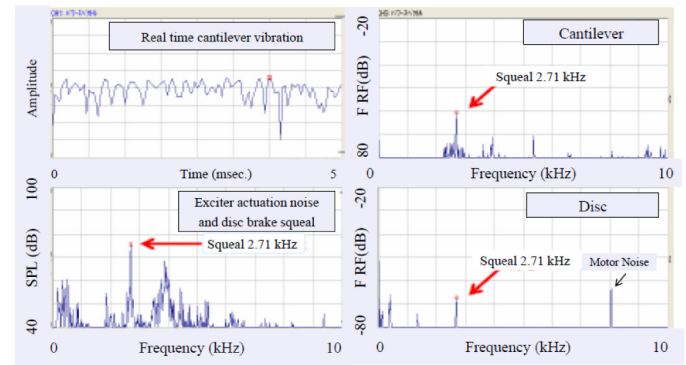


Figure 10. Brake squeal 2.71 kHz under exciter random function actuation

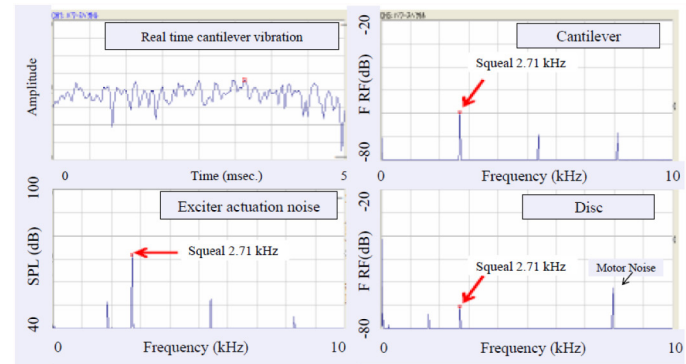


Figure 11. Brake squeal 2.71 kHz after exciter random actuation stopped

Friction Test under Sin Wave Force Actuation

Frequency of Sin Function 2.71 kHz

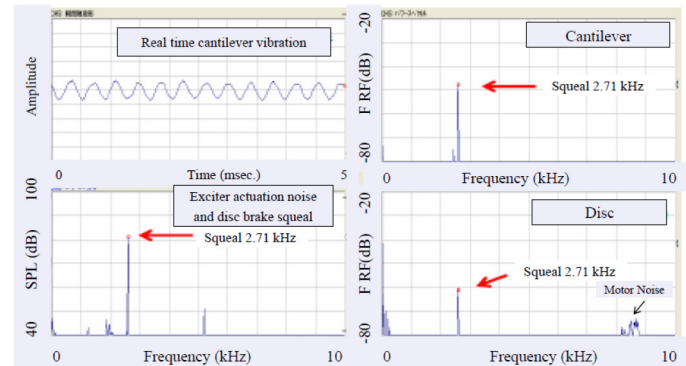


Figure 12. Brake squeal 2.71 kHz under exciter sin function actuation

Figure 12 shows the experimental data of exciter sin function actuation noise and disc brake squeal 2.71 kHz during brake application on load 6 N. This brake squeal 2.71 kHz continued after exciter sin function actuation stopped, which is shown in Figure 13. Figure 13 is the experimental data of time chart of water fall plotted graph. It can be seen that brake squeal 2.71 kHz continued after exciter sin function actuation stopped. Disc brake squeal seems to be caused by exciter sin function actuation, because disc and cantilever