

# Vibro-Impact Rotor Dampers For Brake Squeal Attenuation - Towards An Insulator Free Design To Quell Squeal

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## ABSTRACT

This paper explores the use of vibro-impact dampers in attenuating brake squeal. This temperature and pressure independent energy dissipation approach adds damping directly to the rotor discs and thus enables the designer more freedom to design brake pads for doing their primary function – stopping the disc and hence the vehicle in a desired regulated manner without worrying about other effects. The author presents the evolution of the vibro-impact energy dissipation idea into rotor damping concepts and shows experimental data at component level as well as system level - comparison of brake dynamometer test results of a brake system with and without these rotor dampers. Finally the author presents preliminary subjective data on the effect of these dampers on tactile and acoustic responses inside a vehicle subjected to road tests. Also presented are some ideas of implementing the concepts as design integrated with rotor as well as add-on dampers.

## INTRODUCTION

Brake squeal is the noise radiated usually by the brake rotor disc when rotating disc is slowed down or brought to stop through frictional forces when brake pads press against the disc surface. The squeal noise is a friction induced vibration instability and radiates of the discs. The instability occurs as a result of coupling of modes whether of one or more components (rotor, pad, calipers). Depending on the size of the pad and rotor components, the noise frequency could range between 1000 Hz to 16000 Hz.

Brake squeal is a common problem across different brake designs and is usually tackled by damping out the vibrating modes. The damping is supplied to the system with the help of additives to the friction material, backing layer and add-on damping treatments - insulators attached to the back of the backing plate. At the brake-pad insulator subsystem level, the critical damping levels are about 1-10%. Using modal strain energy ratios Nashif and Denys described the difficulty in translating higher levels of insulator damping to system level

damping [1]. They have shown that only a fraction (25%) of the damping of brake pad in caliper gets translated to the brake system once the pads are under pressure. A damping loss factor of 0.078 seen at the brake pad insulator in caliper sub-assembly level was shown to translate to a system level damping loss factor of 0.020 once the pad is pressed against the disc. Effectively low levels of damping (of the rotor), is all that is needed to attenuate brake squeal in the system.

Vibro-Impact dampers (VIDs for short) have been of interest mainly in the academic world [2-6] and some applications have been attempted at, with different success levels in the last few years. Applications include reducing vibrations of cantilevered members of space structures [7], torsional vibrations of IC engines [8] and also in seismic mitigation [9]. VIDs were also tried in reducing automotive steering wheel vibration [10]. In this method of damping of the structural vibrations, energy dissipation is obtained mainly through the impacts of loose vibrating masses with the vibrating structure. The kinetic energy of the oscillating masses gets dissipated into heat and sound energies as they impact the structure as inelastic collisions and ensuing mechanical elastic and plastic deformation of the contacting surfaces.

In the following the results from experiments with simple cantilever beams are presented first to show the working of VIDs. This is followed by the description of experiments with brake-pad, where the temperature independence of the damping gains are proved. Experiments with rotor are then described and the efficacy of VIDs proven first at component level and latter at system level. Finally in-vehicle subjective evaluation of these VIDs is presented.

## DAMPING OF SIMPLE BEAMS

In this section results of an experiment with simple beam subjected to vibrations are presented. A thin beam with a small pocket for holding small masses near one end (free end) is used in the experiment. The loose masses are henceforth referred to as vibro-impact dampers or VIDs for short. The beam is clamped at one end (cantilever) and is subjected to random excitation near

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the clamped end using a magnetic exciter. Response is measured close to the exciter using an accelerometer. The experiment is conducted in two parts – the first with masses attached (using super-glue) to the thin beam on the opposite side of the pocket and second with the masses left loose in the pocket. By attaching the mass to the beam in the first part, it is being shown that the amplitude reduction is not due to the additional mass.

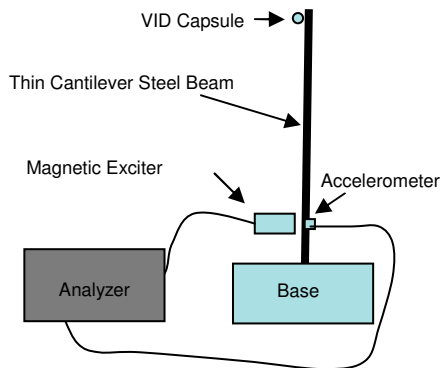


**Figure 1: Experimental setup for measuring damping due to impacts on a cantilever beam**

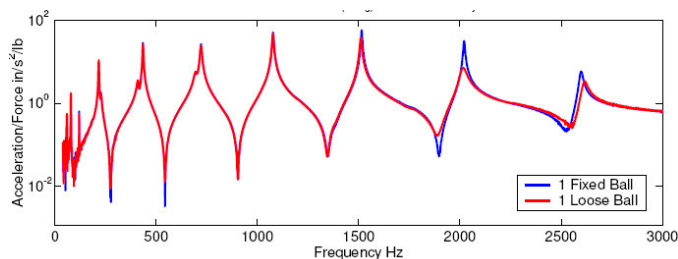


**Figure 2: Experimental point inertance of a cantilever with and without impact dampers – indicates significant increase in damping levels especially at higher frequencies**

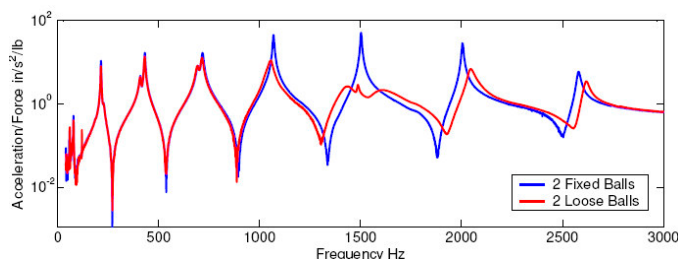


**Figure 3: Experimental point inertance of a cantilever with multiple impacting masses**

Comparison of figures 2 and 3 indicate VIDs can be designed to maximize damping at different frequencies of interest. The design parameters could include the mass, clearances, number of contact surfaces, etc.

## DAMPING OF A BRAKE PAD

In this section a brake pad under “free-free” boundary conditions is subjected to random excitation. The brake

pads under consideration were made using “integral molding” (IM) process – allowing holes in the backing plate of the brake pad which is partially filled with friction material. The depth of the IM holes of the brake pad can be slightly increased to allow for holding loose masses – 4.5 mm steel balls were used as loose masses. Another option is to drill blind holes at strategic locations in the backing plate to hold these loose masses. The latter option was used in this test.



**Figure 4: Brake-Pad with Vibro-Impact Dampers in strategically located holes in the backing plate.**

A regular silicone adhesive based insulator placed on top of the backing plate also served as a cover for these holes and held the loose masses in place.

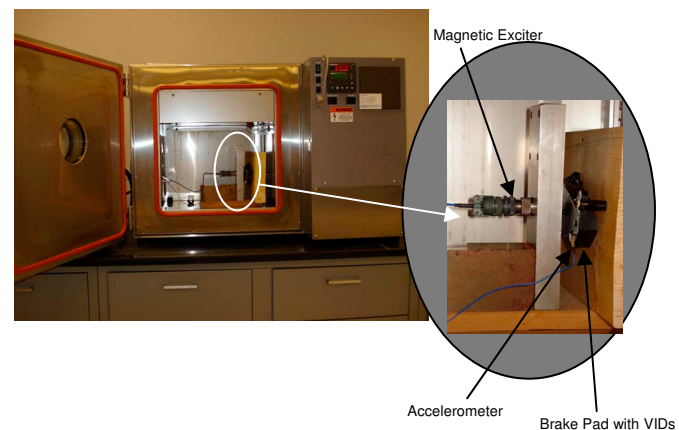


**Figure 5: Experimental set up to measure damping of the brake-pad and insulator assembly with and w/o VIDs as a function of temperature**

Figure 5 illustrates a temperature oven in which the brake-pad insulator assembly is mounted vertically – to mimic the brake pad position in the calipers. As in the earlier examples, the brake pad is excited using a magnetic exciter and the acceleration measured off the backing plate. This is repeated at different temperatures between 0 and 300 °F in 25 °F increments. At the end of temperature sweep, the FRFs are processed to compute the damping at each of the modal peaks. The experiment was first conducted with a bare pad, then with brake pad with an insulator and finally with VIDs interposed in the holes of backing plate and held in place by the insulator on top.

