

# EXPERIMENTAL INVESTIGATION OF BRAKE JUDDER NOISE

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# EXPERIMENTAL INVESTIGATION OF BRAKE JUDDER NOISE

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To my beloved family.

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## ABSTRACT

Brake judder is a braking induced, forced vibration that typically occurs in vehicles. The judder frequency is directly proportional to the revolution speed of the wheel and therefore also to the velocity of the vehicle. The driver experiences judder as vibrations in the steering wheel, brake pedal and structure floor. Brake judder can be split into two distinct groups – “hot” and “cold” judder, both of which can be classified as a mechanically induced vibration. Until recently research efforts regarding brake judder have been overshadowed by other brake related issues such as brake noise for example squeal and groan. This research studies the cold judder by using brake judder test rig (half vehicle). After applying three different pressures (5 bar, 10 bar, 16 bar) for each speed (420 rpm, 330 rpm, 250 rpm and 165 rpm), the results show that at 10 bar and 16 bar give a high vibration amplitude that leads to uncomfortable feeling. The result of non-contact displacement sensors show that the disc thickness variation (DTV), disc surface waviness and side run-out (SRO) combination is the cause of brake judder. After inserting a 3mm thick round rubber between the pad and the caliper the magnitude of vibration at the axial steering direction for velocity of 250 rpm and 420 rpm, and brake pressure of 16 bar changed from fairly uncomfortable region to little uncomfortable region and the magnitude of vibration of brake pedal changed from uncomfortable region to fairly uncomfortable region.

## ABSTRAK

Sentakan brek merupakan sejenis getaran brek yang teruja dan dipaksa yang biasanya berlaku kepada kenderaan. Frekuensi sentakan adalah berkadar terus dengan kelajuan putaran roda dan juga halaju kenderaan berkenaan. Pemandu merasai sentakan tersebut dalam bentuk getaran pada roda stereng, pedal brek dan struktur rantai. Sentakan brek boleh dibahagikan kepada dua kumpulan ketara – sentakan “panas” dan “sejuk”, di mana kedua-duanya boleh diklasifikasikan sebagai sentakan teruja secara mekanikal. Sehingga kini usaha-usaha penyelidikan mengenai sentakan brek telah dibayangi oleh isu-isu lain yang berkaitan dengan brek seperti bunyi brek contohnya decitan dan kerikan. Kajian ini mennjurus kepada sentakan sejuk menggunakan rig ujian gegaran brek (separuh kenderaan). Setelah mengenakan tiga tekanan yang berbeza (5 bar, 10 bar, 16 bar) untuk setiap kelajuan revolusi (420 rpm, 330 rpm, 250 rpm dan 165 rpm), didapati bahawa pada tekanan 10 bar dan 16 bar amplitud getaran yang tinggi terhasil dan ini memberi kesan kepada keselesaan. Hasil daripada sensor penyesaran tak-sentuh menunjukkan kombinasi ketebalan cakera, ketidakserataan permukaan cakera dan kehausan sisi mengakibatkan gegaran brek. Setelah memasukkan getah bulat setebal 3 mm di antara pad dan angkup, magnitud getaran pada paksi arahan stereng dengan halaju 250 rpm dan 420 rpm, dan tekanan brek 16 bar berubah daripada bahagian agak tidak selesa kepada bahagian tidak selesa sedikit dan magnitud getaran pedal brek berubah daripada bahagian tidak selesa kepada bahagian yang agak tidak selesa.

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background**

Judder is a term used by automotive engineers to describe brake induced vibration in the automotive industry [1, 2]. Judder is usually perceived by the driver as minor to severe vibrations transferred through the chassis during braking [3–4]. It is often evidenced in a shaking steering wheel, dashboard, windshield, shaking seat and under a severe condition, in overall vehicle vibration. Though the judder phenomenon has existed for a long time, recent years have seen an increase in judder complaints by customers. This may be due to increases in highway speeds, changes in the brake materials and an increased demand for driving comfort. Thus, many studies have been reported and have revealed several important causes of judder including imbalance of rotating components, total run-out, thickness variation, concentricity, assembly tolerances and thermal distortion. The judder phenomenon can be classified into two distinct subgroups; they are Hot (Thermal) or Cold Judder.

Hot judder is usually produced as a result of longer more moderate braking from high speed where the vehicle does not come to a complete stop [5]. The vibration being transmitted to the driver. These vibrations are the result of uneven

thermal distributions believed to be the result of phenomena called Hot Spots. Hot Spots are classified as concentrated thermal regions that alternate between both sides of a disc that distort it in such a way that produces a sinusoidal waviness around its edges. Once the brake pads (friction material) comes in contact with the sinusoidal surface during braking severe vibrations are induced as a result and can produce hazardous conditions for the person driving the vehicle [6].

Cold judder on the other hand is the result of uneven disc wear patterns or DTV. These variations in the disc surface are usually the result of extensive vehicle road usage. DTV is usually attributed to the following causes; waviness of rotor surface, misalignment of axis (Run-out), elastic deflection, thermal distortion, wear and friction material transfers [7.8]. Whilst many institutions and companies are currently involved in research in this area there is very little published data on the DTV phenomenon as compared to other such effects like squeal. This is probably due to judder having inherent complexities and the relative shortage of analytical models that can predict its behavior satisfactorily.

Brake judder still poses a serious design problem for the brake refinement engineer. It may take the form of cold or hot judder but in both cases it presents itself as a vibration directly related to wheel speed. Both types may be felt by the driver through the brake pedal, steering wheel or vehicle floor pan, with higher ‘drone’ frequencies becoming audible within the cabin [9].

## **1.2 Problem Statement**

The low frequency phenomena, such as brake judder and groan, have received much less attention. But there is a growing interest from the automotive industry concerning brake judder. Even though few companies would admit that

they have the problem, it is not unusual to meet people who have experienced the problem in their own passenger cars. Much of the knowledge concerning brake judder remains within the companies. Hence, very few people have the full picture.

Brake judder has recently received a significant brake research effort and has seen to be more problematic than the other type of noises. Brake judder can cause minor to severe vibrations transferred to vehicle chassis including steering wheel and brake pedal. This may affect comfort feeling of the driver and passengers.

### **1.3 Objective of Study**

There are two main objectives need to be achieved in this project:

1. To identify a main cause of brake judder noise that contributes to steering wheel and brake pedal vibration.
2. To propose brake judder reduction solution to reduce steering wheel and brake pedal vibration.

### **1.4 Scope of Study**

1. Brake judder test is conducting using brake test rig that available in the laboratory.



2. Measurements of vibration response are made at brake pad, caliper, suspension unit and steering wheel based on different speeds and hydraulic pressures.
3. Frequency of interests is up to 500 Hz (typical range of brake judder).
4. Propose a solution using rubber as a damper to prevent brake judder

## **1.5 Thesis Organization**

This thesis consists of five chapters summarized as follows:

Chapter Two comprises a literature survey on the subject of brake noise in general and brake squeal in particular. Chapter Two provides review of brake judder and the methods that used to reduce or avoid brake judder.

Chapter Three concentrates on the methodology of the experiment and show the overall procedure of it with all test rig devices, and show the reduction method of this research.

Chapter Four presents the results of the brake judder experiment and gathering the data in relation to serve the objective of this research and discuss these results.

Chapter Five summarizes the results and provides conclusions of the present work. Recommendations for further work are also presented in this chapter.

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