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HIGH SPEED EXPERIMENTAL STUDY OF FRICTION INDUCED VIBRATION IN DISC BRAKES

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High speed experimental study of friction induced vibration in disc brakes.

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Keywords: dynamic groan, brake noise,

Abstract. Brake dynamic groan noise which is a low frequency phenomena associated with brake stop condition or slow brake release. This phenomenon said to be a friction-speed characteristic and commonly associated with low speed events. Thus a high speed test regarding this phenomenon is done. In conjunction with speed, pressure relation is also tested. Analysis of groan occurrence in relation of the speed and pressure is performed. The pressure relation to this event is expected to widen the study of this phenomenon which currently confined to stick and slip motions.

Introduction

The study of brake related noise is a complicated problem in the industry related. Brake noise is a rising concern as it leads to customer complaints and warranty claims. [1] Thus it`s not a surprise that leading companies in the braking industry spends half of its budget in the effort of studying, understanding and overcoming the noise and vibrations produced within the brake system. [2]. Another factor which gives importance to study the dynamic groan is experimental evidence that is a structure borne noise. [3] Thus vehicle in occupants are more prone to exposed to such a noise compared to other types of noise which behaves in a more localised manner. The groan phenomenon generally is classified as a friction induced vibration which leads to instabilities with frequency range below squel and higher than judder. [4] Thus the frequency range of the groan noise falls in the range of above 500 Hz and below 1000 Hz. There is literature which states groan frequencies lower than the mentioned threshold but those frequencies falls to the lower end of the human hearing threshold thus the 0.5-1kHz is expected to be significant and predominant. The study of brake groan commonly comprises of low speed events such as slow brake release and slow braking at events such as traffic light stops and go. [5] Experimentation and simulations as well covered events of automatic transmission momentarily overcoming brake torque. All most all the studies are grounded on the friction induced vibration mechanisms such as sprag-slip, negative damping and mode coupling.

Experimentation

The experiment is conducted on a brake dynamometer. Initially the brakes are bedded in accordance to SAE J2521 specifications. The variables within this experiment are brake pressure, disc rotational speed and noise. The data will be focused during brake on condition. The brakes pressure is the primary input of the experiment. The brake pressure is conditioned to be a ramp input to generate a targeted sound level of -36 db. The secondary input is the disc rotational speed which is also a response in this experiment. Initial speed is set at 1000 rpm, 1100 rpm and 1200 rpm. The speed reduction during brake on condition is the speed response. The target noise is set as such based on trials which reveal the average of -36 db is the frequent sound level that produced noise within the dynamic groan range. The brake noise recorded in this experiment is referred to 0 db. All these data is recorded simultaneously to identify the characteristic of the generated noise. The data obtained will be analyzed on the occurance of groan in relation to speed and pressure.

Results

The collected data from the experiment are the applied brake pressure in bar, the disc rotational speed, rpm and the sound level, db together with its frequency. The relationships of these variables are shown the plot below. Even though a target sound level is set, achieving the target value accurately is difficult, thus a mean which is close to the target value is acceptable. The actual sound level reached is shown in relation of pressure in fig. 1. From Fig. 1 the sound level that was measured has a range of 12.11, most of the test yielded within this range with a mean of -33.99 dbA. The corresponding brake pressure for this sound level range falls to an average 0.84 bar. This implies that the stated mean sound level is more likely to occur when 0.84 bar brake pressure is applied. The rotational speed presented in fig. 2 is the decelerated quantity due to the effect of on brake condition. The rotational speed of the disc is distributed within a range of 385 with standard deviation 104.7 which is quite a wide distribution. Thus, rotational speed is not an important factor when it comes to noise generation. A designated brake noise can be produced within a wide range of speed with the correct pressure. Fig. 3 shows that the stated mean sound level generated based on the brake pressure and disc rotational speed. In order for the stated mean sound level to occur, various combinations of pressure-speed can be the factor. The dynamic groan phenomenon is present in this experiment fig. 4 shows the frequency range of the generated sound falls within 673 hz up to 836 hz, this is within the dynamic groan range. As the dynamic groan is commonly confined as a low speed occurrence, this results shows the mentioned phenomena can also happen at high speeds. Fig. 5 shows the accelerometer data obtained from accelerometer placed at the brake pads, burst of groan at 100 hz can be seen, this implies that the audible groan which fall in the range of 600Hz to 800Hz is the harmonics of the fundamental vibrations. The propagation of the fundamental vibration in a higher order is the audible groan.

Figure 1: Plot of sound level and brake pressure

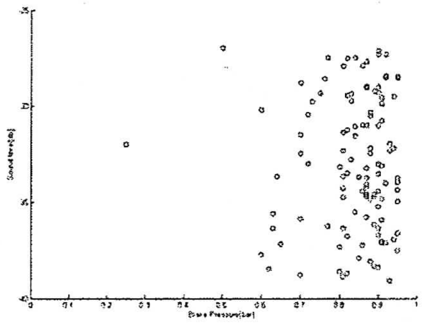


Figure 2 : Plot of sound level and disc rotational speed

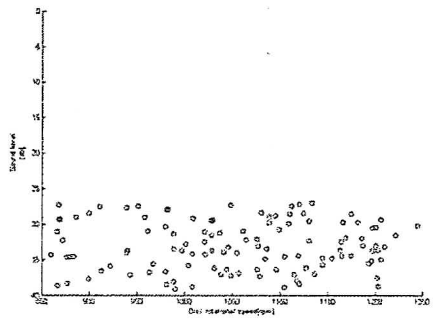


Figure 3: Plot of brake pressure and disc rotational speed

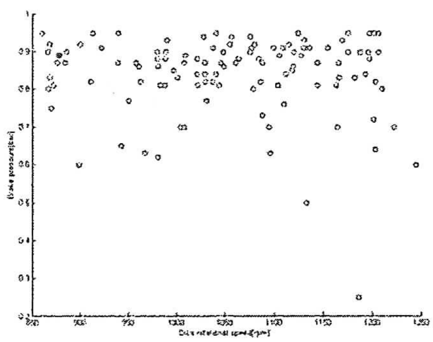


Figure 4: Plot of sound level and frequency

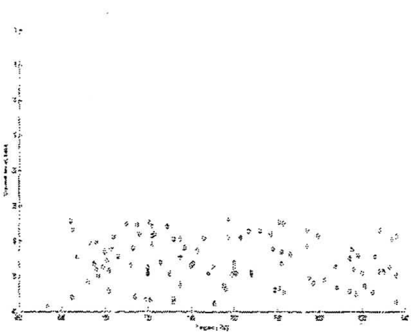
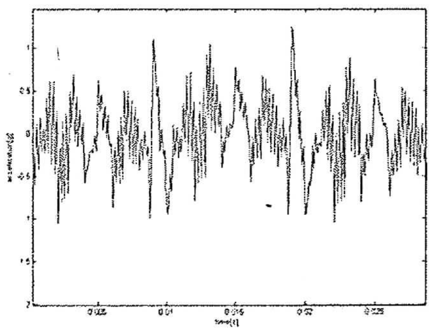


Figure 5: Plot of time-acceleration during braking



Pressure-Speed Characteristics. Brake pad compressibility is a factor in high speed brake judder. [6] Lower pad compressibility is more prone to generate brake noise. A full thickness pad is more compressible then the reduced thickness pad. [7] A full thickness pad behaves dynamically due to the brake input characteristic. The practical brake pressure input is a ramp input. The ramp input creates a pre-loaded condition which reduces compressibility [8]. Other than that, material compression causes barreling, barreling in turn causes the friction force at the edge of the material to increase. Dynamic groan is stated to be a friction-speed characteristic [4]; friction is the product of friction coefficient and normal force thus can be deduced as pressure-speed characteristics due to the influence of pressure on normal force.

Conclusion

1. The definition of dynamic groan is more suited to a pressure-speed characteristic rather than a friction-speed characteristic. This definition is conducive for study and research as pressure which is a parameter rather than friction or compressibility which is a coefficient. A more in depth approach should define the pressure as a function of friction and compressibility.

2. The dynamic groan could happen at high speeds with correlation of pressure.

Reference

1. *Brake Grind Noise Reduction Potential on Vehicle Level - A TPA Study.* **Riemann, D and Haverkamp, M.** 2011. SAE 2011 Annual Brake Colloquium And Engineering Display.

2. *Vibrations and noise in brake systems of vehicles part 2: theorethical investigation techniques.* **V.P.Sergeinko and S.N.Bukharov.** 3, Belarus : Journal of friction and wear , 2009, Vol. 30. ISSN 1068-3666.

3. *Brake Groan Simulation for a MacPhersonStrut Type Suspension.* **Donley.M. and Riesland.D.** SAE 2003 Noise & Vibration Conference and Exhibition : SAE Technical Paper, 2003. doi:10.4271/2003-01-1627.

4. *Aspects of disc brake judder.* **Jacobsson, H.** J. Automobile Engineering, 2003, Vol. 217.

5. *Identification and quantification of stick-slip induced brake groan events.* **Ashley, R.Crowthera and Rajendra, Singh.** s.l. : Journal of Noise Control Engineering, 2008.

6. *A Study of the Mechanism Causing High-Speed Brake Judder.* **Kubota, M., Suenaga, T. and Kazuhiro.** 1998, SAE Technical Paper.

7. *A Dynamometer Investigation of Thermal Judder.* **Little, E., et al., et al.** 1998, SAE Technical Paper.

8. *Another Look of Brake Pads Compressibility.* **HT, Chang, Richard, Kaatz and Charles, Evans.** s.l. : SAE 2010 Brake Colloquium & Exhibition, 2011.