REDUCTION OF DISC BRAKE SQUEAL NOISE THROUGH BRAKE PAD MODIFICATION

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Abstract

One of the common noise issues in automotive industry is disc brake squeal. Many researchers conduct deep studies to reducing and eliminating disc brake squeal in the past decades. This paper proposes fourmodifications on the Malaysian national car brake pads to suppress squeal noise. The original and modified brake pads were subjected to dynamometer tests in accordance with SAE J2521 test procedure.It was noticed that the pad geometry modification reduced the brake noise intensity by 6% with the first modification, 12% with the second modification, 19% with the third modification, and 22% with the fourth modification. Additional modification was done by adding shims at the back of the brake pads and it showed the greatest squeal noise reduction. It was found also through the experiment that the disc brake squeal is significantly affected by brake pads structural geometry.

Keywords

brake squeal; brake pads; dynamometer tests; structural modification; experiment

1.0 INTRODUCTION

A braking system is a system consist of caliper, piston, brake disc, and brake pads. It has the function to decelerate a moving car by applying forces from the piston to the brake pads and channeling to the brake disc. When two frictional surfaces; disc brake and brake pads are contact with each other, a vibration will be induced as well as the noises as described by Polettoet al. [1]. The noises coming from the dynamic instability between the contact between the pad lining and the brake disc creating an annoying noise which is brake squeal.

According to Kim and Zhou [2], brake squeal is an annoying noise induced from the contact between two surface that have frictions and brake squeal can be divided into two types which is low squeal frequency range from 1 kHz to 3 kHz and high squeal frequency which the frequency is from 3kHz to 15 kHz. The approach that was used in this project is structural modifications.Brake squeal can be generated by severalconditions such as temperature, humidity, pressure on the pads, and speed as described by Hetzler and Willner [3].Based on the previous work, not only the parameters are important, the design of the braking system including calipers, brake pads, shims, role of friction coefficient, role of stiffness, role of elastic constants are also being considered to reduce the squeal noise.

From the past researches, hypotheses were made where the mechanisms of brake squeal can be grouped into five main categories or their combinations. The categories involved are stick-slip, negative damping, geometric or kinematics constrain, modal coupling or mode lock-in and “hammering” excitation as described by Tan and Chen [4].

One of the contributing factors to the brake squeal is the stick-slip vibration. The phenomena were observed and studied by researchers to understand and explain the squeal noise. The stick-slip vibration is a phenomenon occur when there is changes in friction coefficients between the static and dynamic state. Such mechanism excited by applying brake under low speed is one of the challenges in the automotive industry as discussed by Wei et al. [5].

2.0 EXPERIMENTAL SETUP

The experimental test was carried out by using a prepared brake squeal test rig in the automotive laboratory of the UniversitiTeknologi Malaysia (UTM). The original brake pads of the Malaysian national car were utilized in this study experiment by adopting the test procedures implied by the SAE J2521 drag test procedures. Before the brake squeal test is performed, the brake pads must undergo bedding-in process to increase the braking performance. Then multiple tests were conducted using the original brake pads by varying the brake squeal main parameters which are the hydraulic applied pressure and the disc rotor rotational speed.

2.1 Proposed Brake Pad Modifications

The proposed structural modifications on the brake pads are as follows;

(a) Machining a 3 mm straight slot with 8 mm depth at the center of each pad to form the modified brake pads 1 (MBP1) as shown in Figure 1.

(b) Machining a 3 mm straight slot with 8 mm depth at the center of pad with 55° chamfer at each pad edge for each pad to form the modified brake pads 2 (MBP2) as shown in Figure 2.

(c) Machining a 50° trigonal slot with 3 mm width and 8 mm depth at the center of the pad to form modified brake pads 3 (MBP3) as shown in Figure 3.

(d) Machining a 50° trigonal slot with 3mm width and 8mm depth at the center of the pad with 55° chamfer at each pad edge for each pad to form the modified brake pads 4 (MBP4) as shown in Figure 4.

Figure 1: MBP1

Figure 2: MBP2

Figure 3: MBP3

Figure 4: MBP4

Additional modification also are done on the brake pads by adding shims at the back of the brake pads.

3.0 RESULTS AND DISCUSSION

The brake squeal testing on the first brake pads modification resulted in a reduction in the brake squeal by 6 % with a maximum sound pressure squeal intensity of 93 dBA. The testing on the second brake pads modification resulted in a squeal reduction of 12 % with an SPL maximum value of 87 dBA. The testing on the third brake pads modification resulted in a squeal reduction of 19 % with an SPL maximum value of 80 dBA. The testing on the fourth brake pads modification resulted in a squeal reduction of 22 % with an SPL maximum value of 77 dBA.

3.1 Original Brake Pads

The maximum squeal noise was induced in Test 13 at 99 dBA where the rotational speed and the hydraulic pressure is41 rpm and 3 kg/cm^2 as shown in Table 1.The detected squeal frequencies during the squeal event were in the range between 4208 Hz and 9101 Hz respectively. In Figure 5, it was noticed that the squeal noise was repeated during each squeal event with slight uniformity.

Table 1: Squeal data for the original brake pads

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	3	36	93	4208, 8427
Test 2	3	41	95	4208, 8447
Test 3	4	25	86	4316, 8662
Test 4	4	31	81	4336, 8740
Test 5	4	36	90	4395, 8798
Test 6	4	41	92	4307, 8652
Test 7	5	31	87	4521, 9082
Test 8	5	36	95	4521, 9063
Test 9	5	41	93	4326, 8564
Test 10	6	25	92	4541, 9101
Test 11	6	31	95	4482, 8984
Test 12	6	36	97	4511, 9023
Test 13	6	41	99	4521, 9053
Test 14	7	25	97	4560, 9101
Test 15	7	31	92	4541, 9101

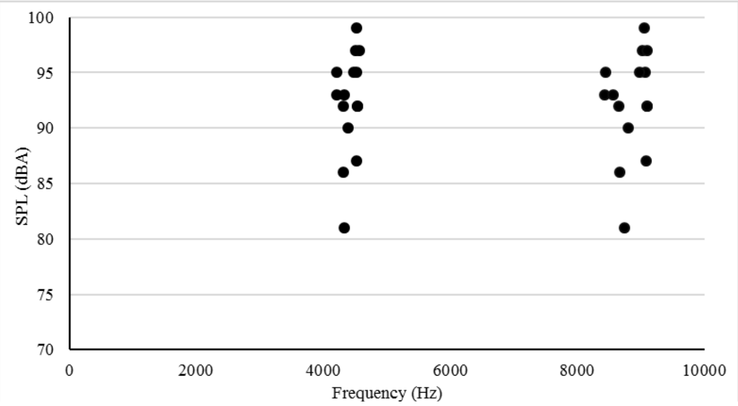

Figure 5: SPL for the original brake pads with different frequencies

3.2 Modified Brake Pads 1 (Mbp1)

The maximum squeal noise generated by MBP1 was detected with two test which is Test 2 and Test 5 with SPL of 93 dBA as shown in Table 2.The squeal event happened with the same hydraulic pressure of 1 kg/cm2 but with different rotational speed. All the squeal event happened in MBP1 were in frequency range of 4169 to 9296 Hz. Figure 6 shows that the squeal frequencies during the squeal event are uniform.

Table 2: Squeal data for MBP1

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	1	26	92	4619, 9258
Test 2	1	31	93	4638, 9296
Test 3	1	35	92	4628, 9267
Test 4	1	41	92	4648, 9287
Test 5	1	45	93	4648, 9277
Test 6	1	50	92	4628, 9277

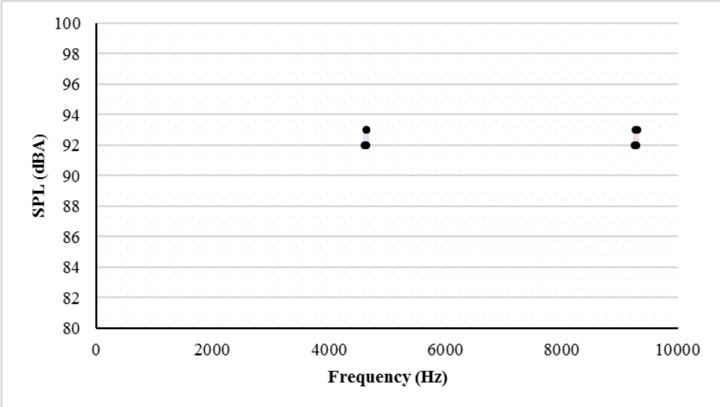

Figure 6: SPL for MBP1 with different frequencies

3.3 Modified Brake Pads 2 (Mbp2)

The maximum squeal noise generated during this squeal event is 87 dBA with rotational speed and hydraulic pressure are 36 rpm and 8 kg/cm2 as shown in Table 3. All the squeal event happened in MBP2 were in frequency range of 5361 to 9091 Hz.In Figure 7, it is noticed that the squeal was repeated during the squeal event but without uniformity.

Table 3: Squeal data for MBP2

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	1	31	84	5498, 9013
Test 2	2	31	84	5732, 8535
Test 3	2	36	83	5742, 8515
Test 4	5	26	86	5507, 7236
Test 5	5	36	84	5390, 7353
Test 6	5	41	85	5380, 7304
Test 7	5	45	74	5458, 9091
Test 8	5	50	78	5800, 8378
Test 9	8	36	87	5771, 7119
Test 10	9	31	76	6054, 7890
Test 11	9	36	80	5761, 7109
Test 12	9	41	84	5361, 7314
Test 13	10	45	73	5644, 8710
Test 14	10	50	71	6025, 7929

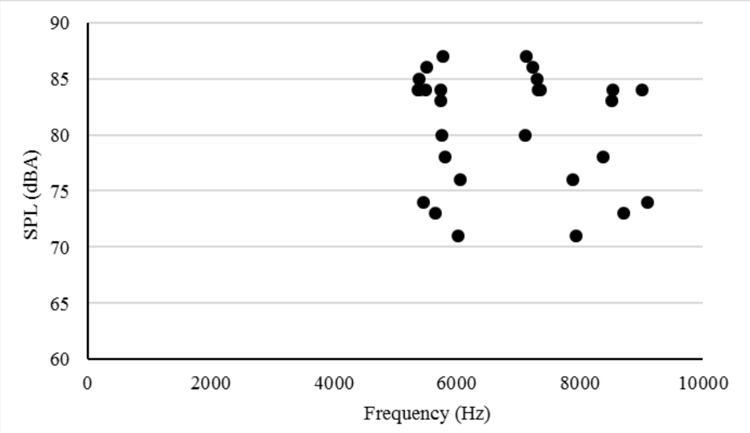

Figure 7: SPL for MBP2 with different frequencies

3.4 Modified Brake Pads 3 (Mbp3)

Test 1 and Test 2 for MBP3 was categorized as the maximum squeal noise and shared the same SPL values of 80 dBA with different rotational speed and hydraulic pressure as shown in Table 4.The squeal noise was repeated during each squeal event but without uniformity as shown in Figure 4.The detected squeal frequencies during the squeal event are ranged in values between 4121 Hz and 9140 Hz respectively.

Table 4: Squeal data for MBP3

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	1	21	80	4570, 9140
Test 2	1	41	80	5449, 9101
Test 3	1	45	78	4326, 8642
Test 4	1	50	77	4326, 8642
Test 5	3	36	77	5800, 8339
Test 6	4	36	76	5898, 8134
Test 7	5	26	77	4127, 8105
Test 8	5	31	74	4121, 8101
Test 9	5	36	75	6035, 7910

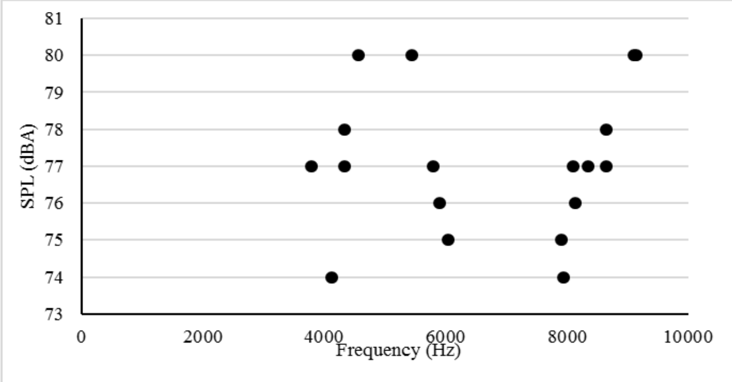

Figure 8: SPL for MBP3 with different frequencies

3.5 Modified Brake Pads 4 (Mbp4)

Test 1 is considered as the maximum squeal noise for this modification with 77 dBA as shown in Table 5.The frequencies of induced squeal noise are in the range of 4189 to 8437 Hz. The squeal frequencies are approximately uniform through the squeal event for MBP4 as shown in Figure 9.

Table 5: Squeal data for MBP4

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	1	26	77	4189, 8408
Test 2	1	31	74	4199, 8408
Test 3	1	36	72	4189, 8369
Test 4	1	41	74	4218, 8437
Test 5	1	45	72	4208, 8417
Test 6	1	50	74	4189, 8388

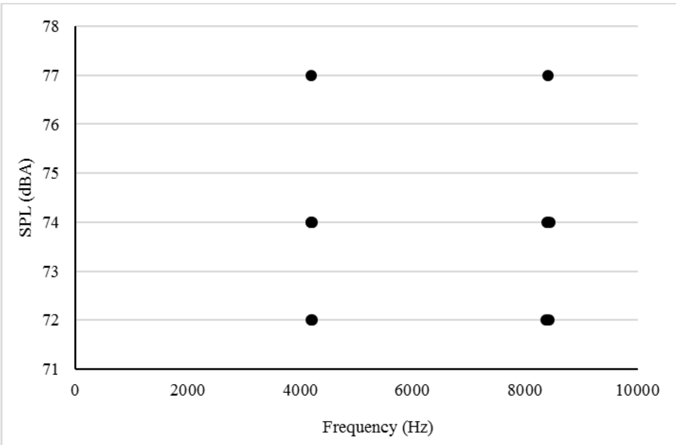

Figure 9: SPL for MBP4 with different frequencies

3.6 Modified Brake Pads With Shims

Additional modification was added to the brake pads by adding shims at the back of the brake pads. The results show that the modified brake pads with shims has greatest reduction of squeal noise as one of the functions for shims is to reduce vibration and noise in the brake rotor. Table 6 show that the maximum SPL detected for MBP1 with shims was 72 dBA. Table 7 show that the maximum SPL detected for MBP2 with shims was 74 dBA. Table 8 show that the maximum SPL detected for MBP3 with shims was 72 dBA. Table 9 show that the maximum SPL detected for MBP1 with shims was 70 dBA.

Table 6: Squeal data for MBP1 with shims

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	1	41	70	5634, 7177
Test 2	1	45	72	5058, 7539
Test 3	1	50	70	5292, 7548

Table 7: Squeal data for MBP2 with shims

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	1	41	70	820, 9648
Test 2	1	45	74	800, 9628
Test 3	1	50	74	654, 9667
Test 4	5	26	74	5996, 7041
Test 5	5	36	72	214, 7392
Test 6	5	41	73	5605, 7187
Test 7	5	45	73	5019, 7490
Test 8	5	50	72	4882, 7597
Test 9	5	75	73	4140, 7880
Test 10	10	36	73	5595, 7177
Test 11	10	41	73	5224, 7402
Test 12	10	45	73	4726, 7646
Test 13	10	50	71	4658, 7675

Table 8: Squeal data for MBP3 with shims

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	5	41	72	1855, 9082
Test 2	5	45	72	1542, 9101

Table 9: Squeal data for MBP4 with shims

	Pressure (kg/cm2)	Speed (rpm)	SPL (dBA)	Squeal Frequency (Hz)
Test 1	10	45	70	3339, 6689
Test 2	10	50	70	3340, 6692

4.0 CONCLUSION

It is noticed that the pad geometry modification reduced the brake noise intensity by 6% with the first modification, 12% with the second modification, 19% with the third modification, and 22% with the fourth modification.Additional modification was added to the brake pads by adding shims at the back of the brake pads. The results show that the modified brake pads with shims give greatest reduction of squeal noise as one of the functions for shims is to reduce vibration and noise in the brake rotor It is recommended that the data from the experimental work need to be validate by simulation and more importantly by vehicle road test because in this experimental work, the effect of environmental is neglected.

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