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An Experimental Study on Friction-Induced Vibration in Brake System Using Different Friction Materials

Menwer F.M. Alenezi[1] and J. G. Alotaibi[2]
[1]*The Public Authority for Applied Education and Training, Vocational Training Institute, Automotive Mechanic Department, Kuwait*
[2]*Department of Automotive and Marine Technology, Public Authority for Applied Education and Training, Kuwait*

Abstract: The present research investigates the mechanism of excitation of friction-induced vibrations in brake system comprising a disc and two friction materials. The friction materials of brake pads are pressed together and the disk brake rotates between them. Three friction materials from different sources are considered and examined in the disc brake system using a simple brake dynamometer. Influence of several rotational speed and applied brake pressure as an operational condition on the friction-induced vibration is studied. Results from the different comparisons reveal that the maximum magnitudes of vibration approximately at 3.5 kHz for all experimental tests. It is also observed that the maximum value of vibration amplitudes decrease with increasing both the rotational speed and brake applied pressure of the rotor. It is believed that the results of this study will assist in proving that brake pads from different manufacturers have different vibration behaviors at the same conditions.
Keywords: Friction-induced vibration; brake operational conditions; friction materials.

1. Introduction

Vehicle brake systems are extremely complex system, which confront strong variability, and the friction lead to generate vibration. Brake systems can be generated various noise and vibrations disturbances under actual operational conditions. The friction material of the brake pad has been classified as one of the main significant components for vehicle performance. This is because it acts essential functions in several aspects of the brake performance. The main target of brake industries is to develop friction materials being supply a stationary friction coefficient and a small wear rate at several conditions [1–2]. Moreover, selecting the friction materials must be depend on the material of brake rotor for reducing its vibration, noise and wear during braking action [3].

There are different experimental setups for example; pin-on-disk [4], beam-on-beam [5], beam-on disk [6], tribometer [7] and dynamometer [8:10] for investigation friction induced vibrations. These experimentations highlighted a significant correlation between vibration generation and lock-in for two models with components of automotive brake system. Consequently, experimental analyses have described parameters that influence vibration generation. Moreover, these analytical, experiments and numerical approaches have been highly-developed to assist for better realize the brake vibration phenomenon [11]. In previous decades, many research workers have focused on the brake vibration in vehicle for improving automotive rides' comfort.

Generally, there are three common methods to investigate the vibration topics namely; experimental, analytical and computational. The experimental methods altered from a small coupon rub tests to actual vehicle. Recently, the brake dynamometer has become the principal screening platform for describing tendency to investigate vibration problems during braking conditions. The brake dynamometer can be supervised accuracy several operational and environmental factors. In general, there are many types of brake dynamometer are used for intention research [12].

The objective of this research study is to introduce an experimental investigation vibration of disc brake using drag brake dynamometer. Accelerometers are used to measure amplitude and vibration frequency of brake pads. Many tests under different conditions of rotor speed and applied force are conducted and their effects on the vibration generation are observed. The vibration generated from three friction materials of brake pads from different sources is obtained and evaluated.

2. Development of Simple Brake Dynamometer

A simple brake dynamometer is developed to supply the required rotation speed and applied pressure under different braking applications. The driving unit consists of a 7.5 kW AC motor with speed controller in order to change rotating speeds up to 1500 rpm. Disc brake assembly is fixed with the motor through a mild steel coupling and driving shaft, which is held by two ball bearing located between the motor and the brake assembly. The hydraulic braking unit is connected to enforce the required pressure to disc brake system.

All instruments are fixed to measure the operational and environmental parameters during braking event. A S-type load cell is fixed to measure coefficient of friction during the braking procedure through measuring the braking force. Figure 1, shows the simple brake dynamometer that has currently been developed for measuring brake vibration.

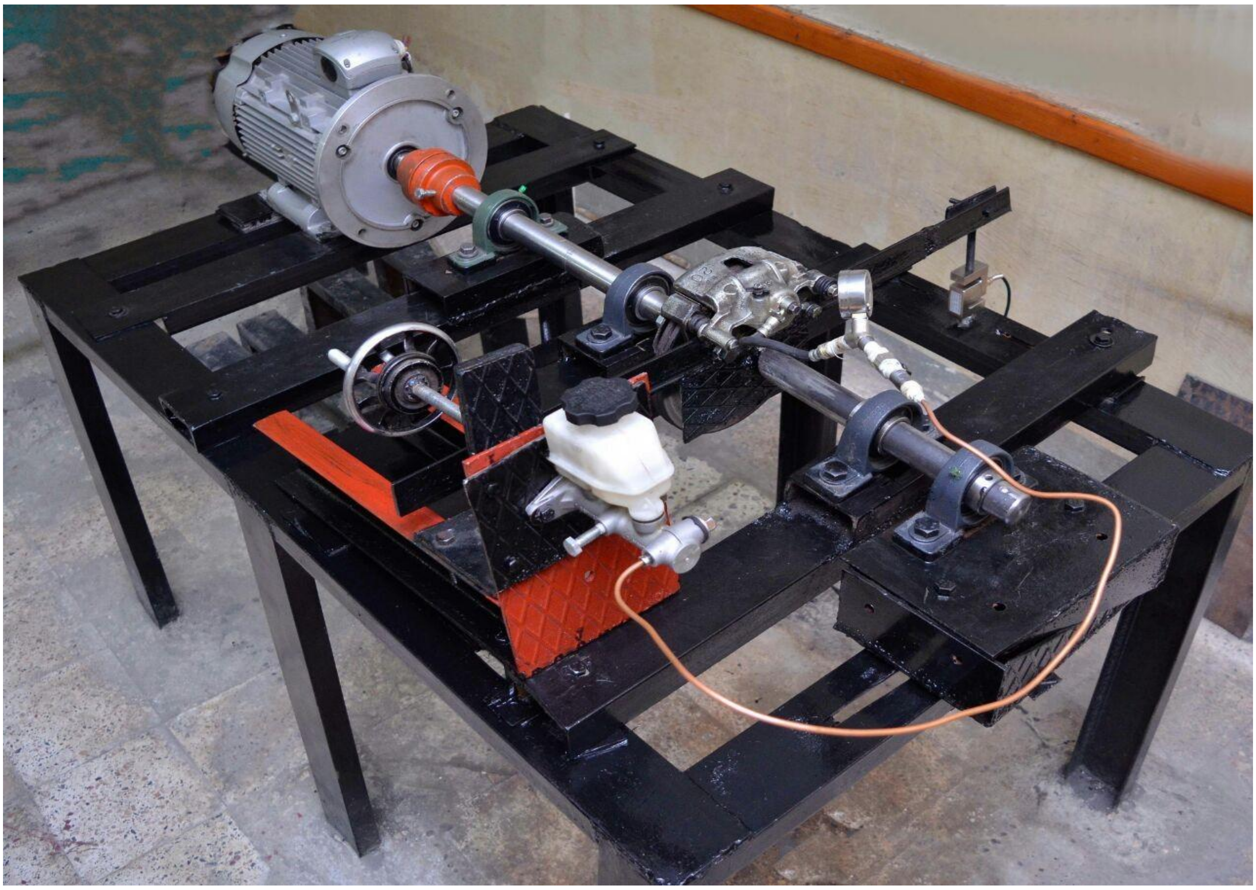

Figure 1: Simple brake dynamometer for measuring brake vibration.

3. Recording Vibration Events

The experimental vibration recording of many tests of three friction materials of braking pads at different pressures and rotational speeds are listed. Each had to be reach to stable condition by running at low speed 400 rpm with a brake pressure of between 2 and 8 bar about half an hour. This process warmed the disc to about 150 °C and also warmed the pads through. After about an hour, the whole of the brake system was hot to the touch. For each brake pad, the testing procedure followed much the same form. After the initial warming, a matrix of running conditions was imposed where the disc speed and the brake pressure were varied. For each speed run, the applied pressure was slowly altered over the suggested range.

The combinations of rotational speed and applied pressure were treated many times and vibration consequences obtained when they occurred. Approximately all tests are carried in the same conditions for 60 seconds of braking time. Vibration frequencies are by accelerometer and analyzed through FFT in time domain and frequency domain, as shown in Figure 2 and Figure 3 respectively.

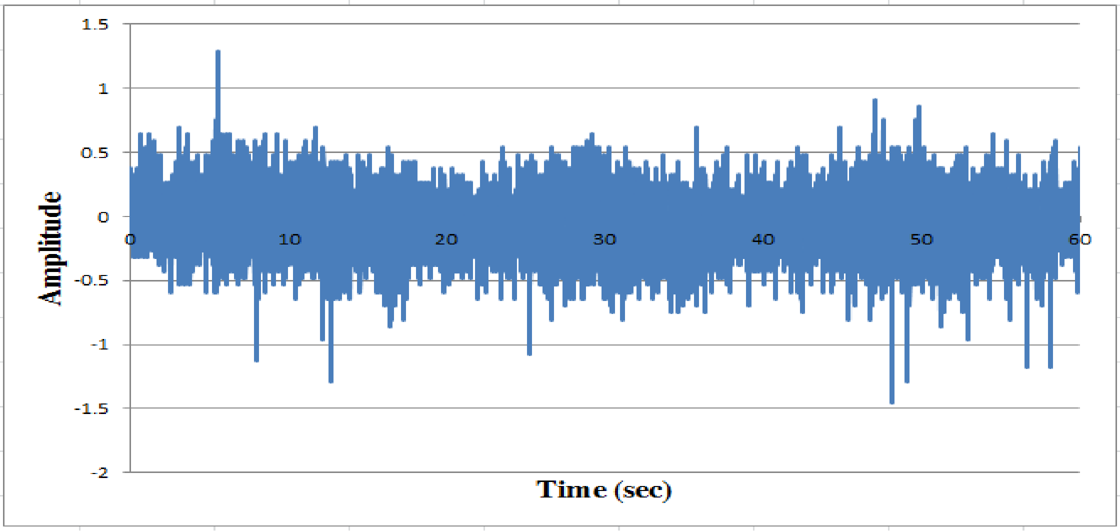

Figure 2 Time domain of vibration measurement

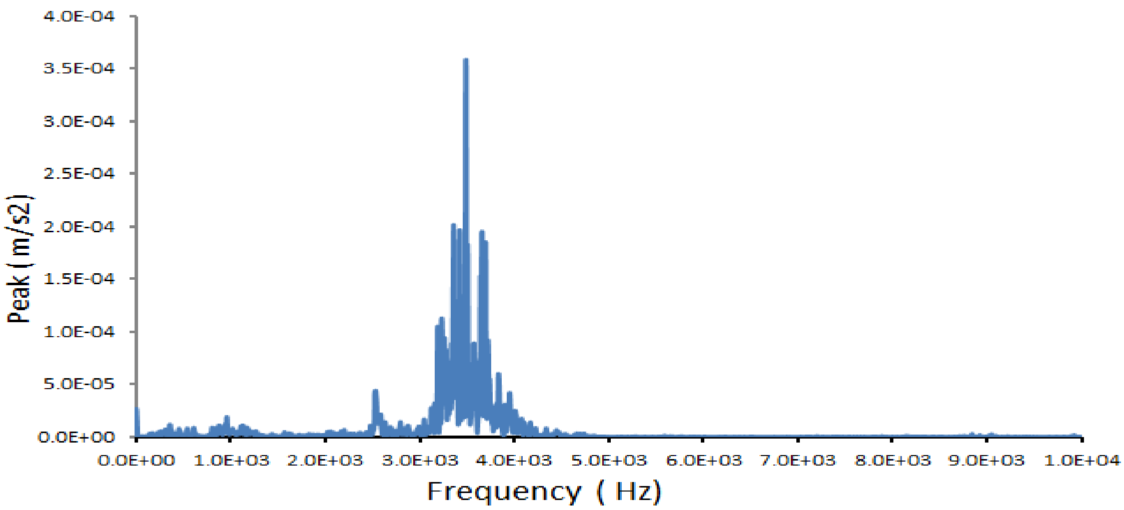

Figure 3 Frequency domain of vibration measurement.

4. Results and Discussions of Vibration Tests

The experimental results of many vibration tests at various operating conditions for each brake pad are listed. The experiments studies are conducted using new brake system. Vibration frequencies are obtained by using accelerometer and FFT for the three pads namely; A, B and C. From experimental tests, it is noticed that the maximum values of the vibration amplitudes do not shift with altering operation conditions and are prevailed approximately at 3.5 kHz, as depicted in Figure 3 for one test and as shown in Tables 1, 2 and 3 for all vibration tests.

Table 1 Vibration tests of Pad A

Vibration tests of Pad A						
Test conditions					Vibration Parameters	
Test	Pressure	Speed	COF	Temperature	Frequency	Max. amplitude
Name	Bar	rpm	-	C°	Hz	$((m/s^2)^2/Hz$
A1	2	400	0.35	102	3455.2	4.80E-04
A2	2	500	0.37	105	3450.5	4.21E-04
A3	2	600	0.34	111	3455.1	3.82E-04
A4	2	700	0.36	118	3458.2	3.22E-04
A5	4	400	0.29	107	3472.5	3.95E-04
A6	4	500	0.34	108	3470.1	3.54E-04

A7	4	600	0.36	110	3471.2	3.05E-04
A8	4	700	0.35	119	3475.5	2.80E-04
A9	6	400	0.37	112	3465.5	2.70E-04
A10	6	500	0.35	120	3456.2	2.41E-04
A11	6	600	0.34	117	3465.6	1.90E-04
A12	6	700	0.38	115	3470.8	1.61E-04
A13	8	400	0.39	112	3458.4	1.80E-04
A14	8	500	0.34	114	3456.6	1.52E-04
A15	8	600	0.33	112	3471.0	1.42E-04
A16	8	700	0.31	118	3465.5	1.23E-04

Table 2 Vibration tests of Pad B

Vibration tests of Pad B						
Test conditions					Vibration Parameters	
Test Name	pressure	speed	COF	Temperature	Frequency	Max. amplitude
	Bar	rpm	-	C°	Hz	mm
B1	2	400	0.31	98	3466.1	5.90E-04
B2	2	500	0.33	101	3461.0	5.51E-04
B3	2	600	0.35	108	3458.3	4.91E-04
B4	2	700	0.34	120	3468.8	4.02E-04
B5	4	400	0.33	122	3482.1	5.50E-04
B6	4	500	0.30	109	3475.3	4.80E-04
B7	4	600	0.31	115	3473.5	4.31E-04
B8	4	700	0.32	112	3477.9	3.81E-04
B9	6	400	0.39	122	3469.8	4.80E-04
B10	6	500	0.33	121	3458.7	4.52E-04
B11	6	600	0.31	120	3465.8	4.10E-04
B12	6	700	0.35	118	3472.1	3.71E-04
B13	8	400	0.36	118	3458.0	3.91E-04
B14	8	500	0.34	119	3466.9	3.55E-04
B15	8	600	0.30	113	3479.0	3.04E-04
B16	8	700	0.33	109	3480.2	2.94E-04

Table 3 Vibration tests of Pad C

Vibration tests of Pad C						
Test conditions					Vibration Parameters	
Test Name	pressure	speed	COF	Temperature	Frequency	Max. amplitude
	Bar	rpm	-	C°	Hz	mm
C1	2	400	0.30	118	3485.3	6.32E-04
C2	2	500	0.34	120	3482.2	5.91E-04
C3	2	600	0.32	115	3477.2	5.65E-04
C4	2	700	0.39	119	3468.8	4.82E-04
C5	4	400	0.35	98	3475.9	6.15E-04
C6	4	500	0.38	110	3478.5	5.60E-04
C7	4	600	0.37	115	3474.6	5.02E-04
C8	4	700	0.33	111	3465.8	4.52E-04
C9	6	400	0.38	117	3466.7	5.61E-04
C10	6	500	0.30	123	3466.8	5.12E-04
C11	6	600	0.31	112	3468.9	4.55E-04
C12	6	700	0.32	103	3472.0	4.16E-04
C13	8	400	0.33	107	3468.8	5.10E-04
C14	8	500	0.38	120	3486.9	4.81E-04
C15	8	600	0.36	109	3481.2	4.55E-04
C16	8	700	0.33	121	3478.3	4.10E-04

4.1 Effect of Applied Pressure on Vibration Amplitude

An important parameter on vibration propensity that has been conducted is the effect of brake line pressure. A series of experiments tests at various pressure levels from 2 to 8 bar are examined to evaluate the outcome of pressure for vibration value of the braking pads at four many rotational speeds 400,500,600 and 700 rpm. Figures 4, 5 and 6 show the average vibration amplitudes with applied pressure.

The result shows that the vibration amplitudes changes with pressure variation. From the experimental results, it can be noticed that with varying the pressure value from 2 to 8 bar the magnitudes of vibration generation decreases. Also, it can be found that at less applied pressure, brake rotor and friction materials are just contact and low friction damping produces between their asperities. Moreover, as the pressure commences to increase, the rotor brake arrives to contact with the friction material of pads and the brake system friction damping starts to increase because of the compressibility of friction materials and the system rigidity is decreased results in decreasing the vibration values.

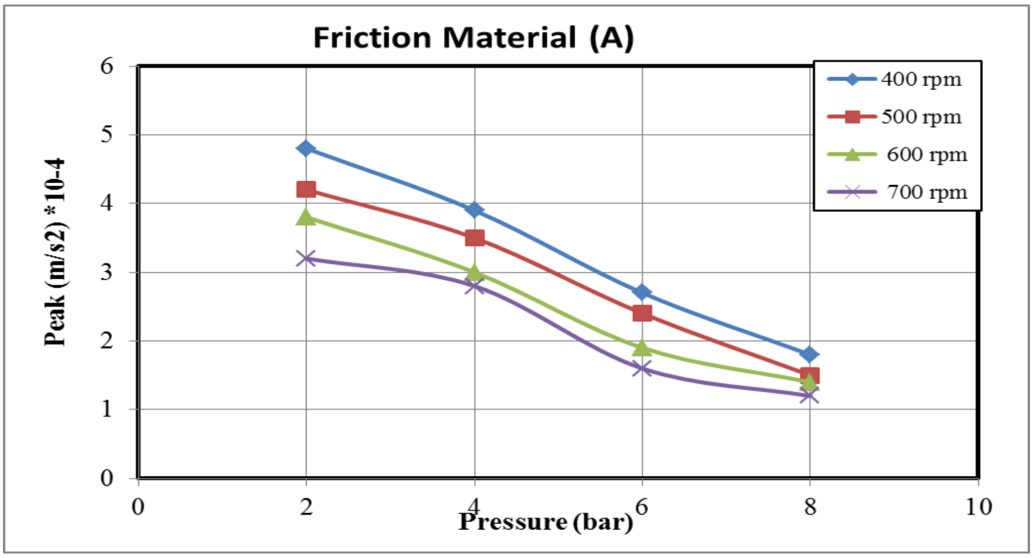

Figure 4 Influence of applied pressure on vibration at different speed for pad A.

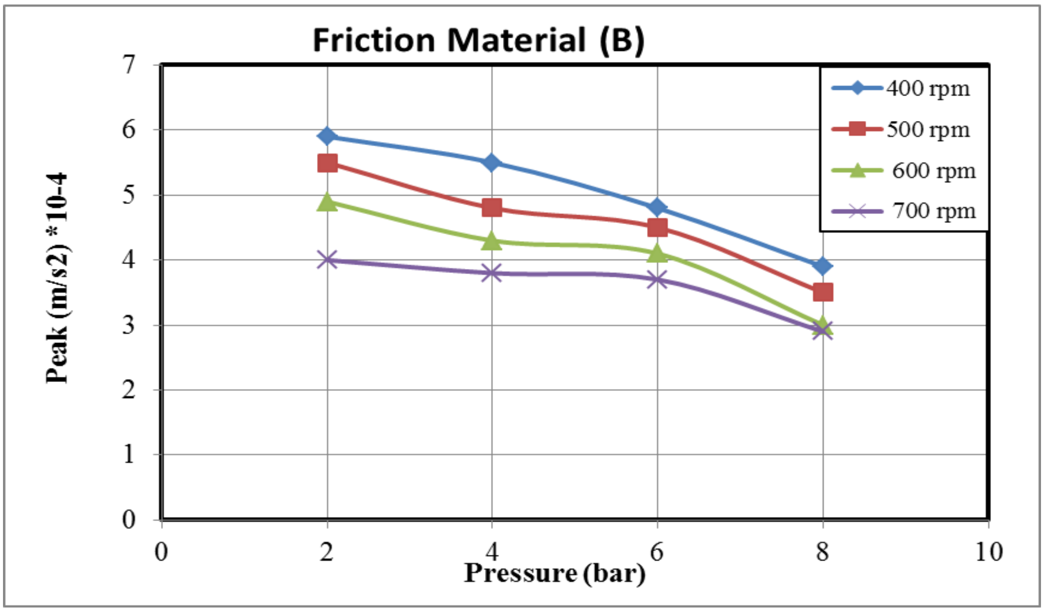

Figure 5 Influence of applied pressure on vibration at different speed for pad B.

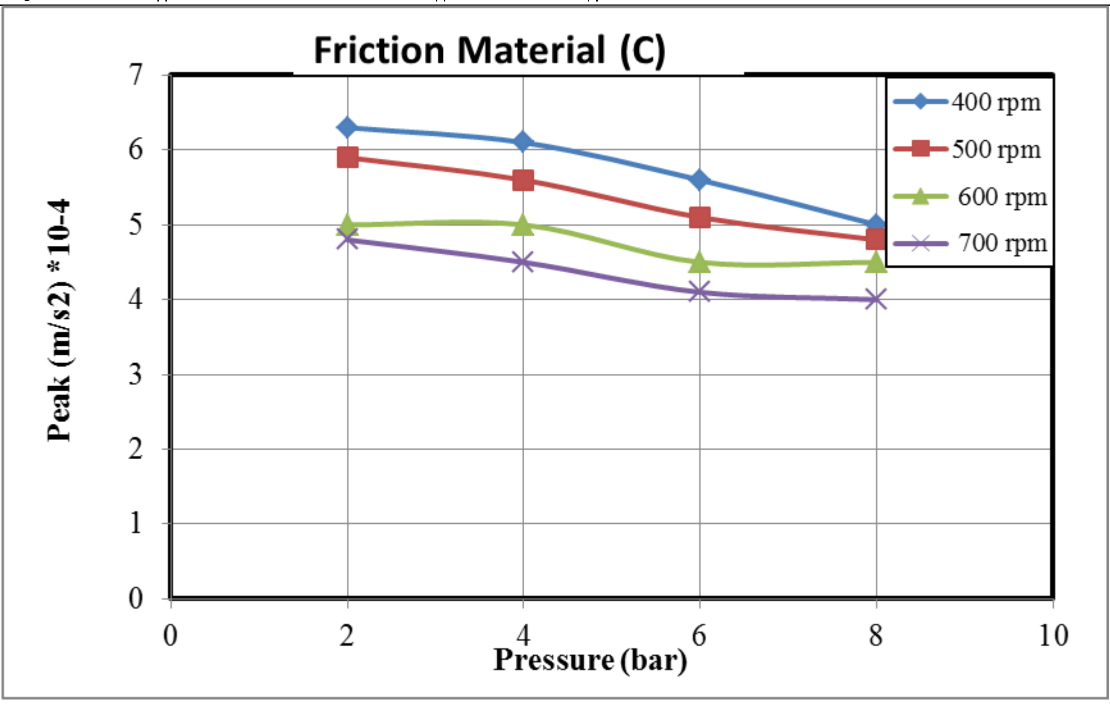

Figure 6 Influence of applied pressure on vibration at different speed for pad C.

4.2 Effect of Rotational Speed on Vibration Amplitude

To look into the influence of the rotational speed, several vibration measuring for four values of rotational speed 400,500,600 and 700 rpm, temperature range 90-125 C° and varying applied pressure starts from 2 to 8 bar are carried.

From the experimental results shown in Figures 7, 18 and 9, it can be discovered that the increase of the rotating speed reducing the vibration amplitude for several applied pressure. It is may be the behavior is the cause why vehicle vibration frequently takes place at low velocity. It is observed that the obtained results match with the previous findings introduced in research paper by Baillet et al. [13] and results as described by Giannini et al. [14].

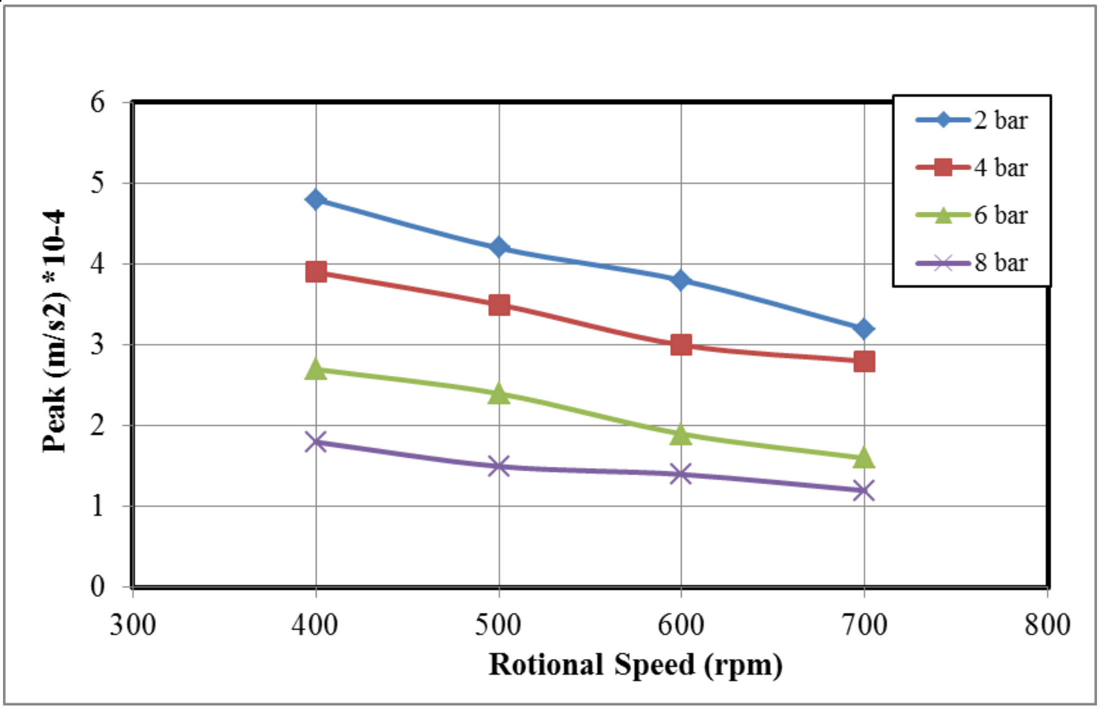

Figure 7 Influence of rational speed on vibration at different pressure for pad A.

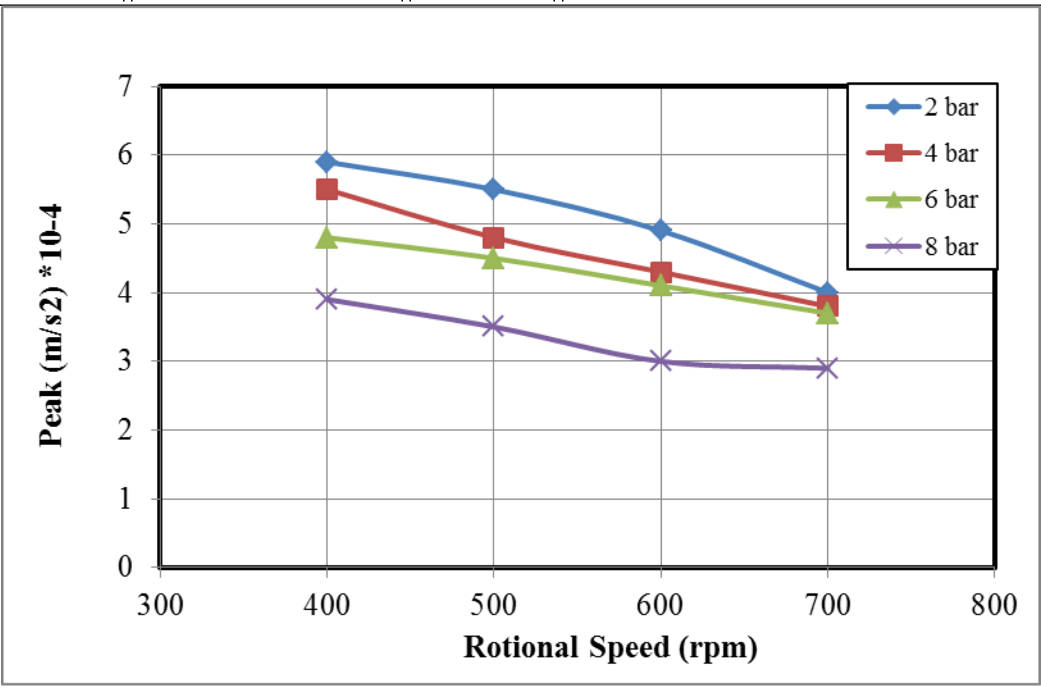

Figure 8 Influence of rational speed on vibration at different pressure for pad B.

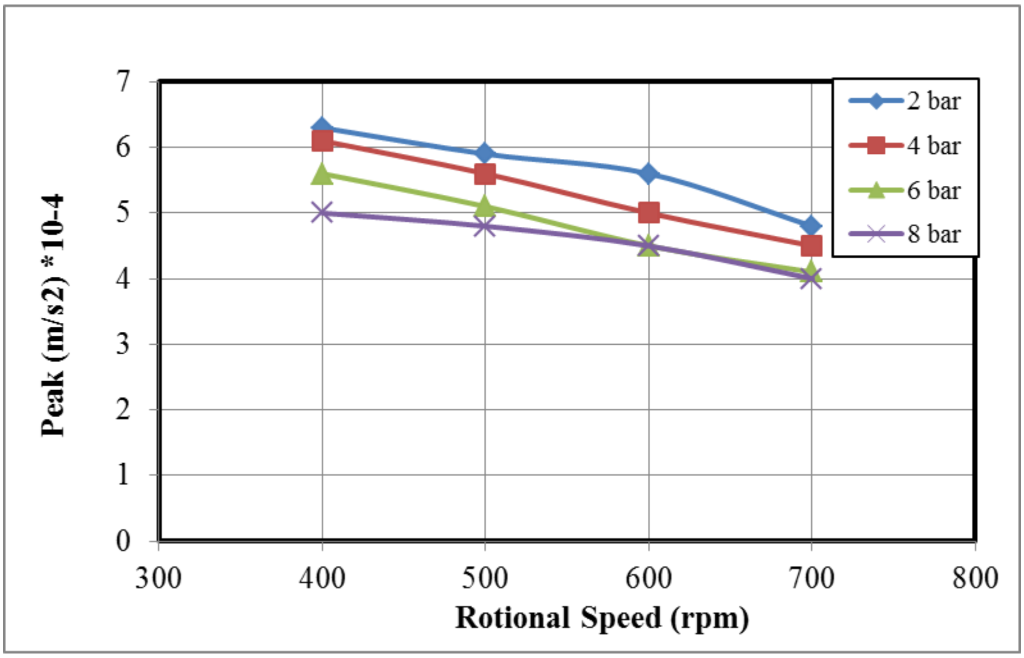

Figure 9 Influence of rational speed on vibration at different pressure for pad C.

5. Conclusion

The brake dynamometer is developed and built for measuring of brake vibration induced by friction between components. Several operating conditions are employed to the disc brake mechanism. It is reported that the maximum value of the brake pad vibration value exhales from all experimental tests are dominant at frequency of 3.5 kHz. Moreover, it is observed that the vibration amplitude is depending on the brake pressure and the rational speed. Furthermore, it is concluded that, the increase of the applied force decreases the vibration magnitude for all samples at all speeds. Also, it can be viewed that the increase of the speed decreases the amplitude of vibration for all samples. Finally, it can be reported that brake pads from different manufacturers have different vibration behaviors at the same conditions.

References

[1]. Kim SJ, Jang H. Friction and wear of friction materials containing two different phenolic resins reinforced with aramid pulp. Tribol Int 2000;33:477–84.

[2]. Cho MH, Kim SJ, Kim D, Jang H. Effects of ingredients on tribological characteristics of a brake lining: an experimental case study. Wear 2005;258:1682–7.

[3]. T. Butlin, J. Woodhouse, A systematic experimental study of squeal initiation, Journal of Sound and Vibration 330 (21) (2011) 5077–5095.

[4]. T. Butlin, J. Woodhouse, Friction-induced vibration: model development and comparison with large-scale experimental tests, Journal of Sound and Vibration 332 (21) (2013) 5302–5321.

[5]. A. Meziane, L. Baillet, B. Laulagnet, Experimental and numerical investigation of friction-induced vibration of a beam-on-beam in contact with friction, Applied Acoustics 71 (9) (2010) 843–853.

[6]. F. Massi, O. Giannini, L. Baillet, Brake squeal as dynamic instability: an experimental investigation, The Journal of the Acoustical Society of America 120 (3) (2006) 1388–1398.

[7]. Amr M. M. Rabia, Nouby M. Ghazaly, M. M. M. Salem, Ali M. Abd-El-Tawwab “Experimental Studies of Automotive Disc Brake Noise and Vibration: A Review” International Journal of Modern Engineering Research (IJMER), Vol.3, Issue.1, pp-199-203, 2013.

[8]. J. Bao, Z. Zhu, M. Tong, Y. Yin, Y. Peng, Influence of braking pressure on tribological performance of non-asbestos brake shoe for mine hoister during emergency braking, Indus. Lubricat. Tribol. 64 (4) (2012) 230–236.

[9]. H. Koylu, A. Cinar, Experimental design of control strategy based on brake pressure changes on wet and slippery surfaces of rough road for variable damper setting during braking with activated anti-lock brake system, J. Automob. Eng. 226 (10) (2012) 1303–1324.

[10]. Mahmoud, K. R. M., Mostafa M. Makrahy, k. A. Abd El-Gwwad, Nouby M. Ghazaly and Ali M. Abd-El-Tawwab “Effect of Wedge Inclination Angle on Self-Amplification Action of A New Adaptive Wedge Disc Brake” Int. J. Vehicle Performance, Vol. 2, No. 2, 2016.

[11]. Gongyu Pan and Lei Chen “Impact Analysis of Brake Pad Backplate Structure and Friction Lining Material on Disc-Brake Noise” Advances in Materials Science and Engineering, Volume 2018.

[12]. Kang, J., & Choi, S., "Brake dynamometer model predicting brake torque variation due to disc thickness variation", Proc. IMechE Vol. 221 Part D: J. Automobile Engineering, IMechE, 2007.

[13]. Baillet L., S. D’Errico, and B. Laulagnet, Understanding of the squealing noise using the temporal finite element method, Journal of Sound and Vibration, Vol. 292, 2006, 443–460.

[14]. O. Giannini, A. Akay, and F. Massi, Experimental analysis of brake squeal noise on a laboratory brake set-up, Journal of Sound and Vibration, Vol. 292, 2006, 1–20.