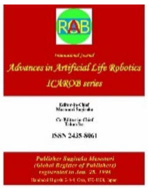
SUGISAKA MASANORI

Journal of Advances in Artificial Life Robotics
Vol. 1(1); June (2020), pp. 50–55
ON LINE ISSN 2435-8061; ISSN-L 2435-8061
https://alife-robotics.org/jallr.html



Research Article

A Study on Prevention of Predictive Failures

Tsutomu Ito[1], Takao Ito[2], Makoto Sakamoto[3]
[1]Department of Business Administration, National Institute of Technology, Ube College, 2-14-1 Tokiwadai, Ube City, Yamaguchi Pref.,755-8555, Japan
[2]Graduate School of Engineering, Hiroshima University, 1-4-1 Kagamiyama, Higashi Hiroshima, 739-7527, Japan
[3]Faculty of Engineering, University of Miyazaki, 1-1 Gakuen Kibanadai-Nishi, Miyazaki, 889-2192, Japan

ARTICLE INFO

Article History

Received 25 November 2019
Accepted 18 July 2020

Keywords

Motor brake
Brake gap
Acceleration
Maintenance

ABSTRACT

Electric motors play an important role as the primary power for conveyor and drop lifts in manufacturing systems especially in automobile manufacturing factories. Many electric motors equipped with brake systems have sensors that determine where they should stop. This brake system needs to be maintained to keep proper brake gap consistent. Measuring the brake gap of electric motors is one of the main jobs of maintenance department, but this is a difficult task because most of the motors are located in unsafe spaces, like the upper end or under the lift pit. This paper proposes a new approach to measure the brake gap of motors to reduce maintenance risks, thus saving costs. The method suggests using vibration acceleration to measure the motor gap in running production system based on mechanical model. The effectiveness of this research is indicative by experience results.

1. Introduction

As the main power source of conveyors and lifts in manufacturing systems, electric motors play an important role in automobile assembling lines as well as other machines. Known as motors with brakes inbuilt, their function is to improve the accuracy of machinery stopping when required. Most of these mechanisms have brake linings, which wear out over long-term use. To maintain the braking function, the necessitates measuring and tuning the brake. The dominant approach of measuring the brake gap is usually reassembling the cover and measure the gap directly by maintenance personnel using thickness gage. From viewpoint of securing the working place, most of the electric motors are housed in the pit (under-ground) or above the machinery. Thus, it makes maintenance process dangerous and inconvenient. To solve this problem, manuscript proposes a new remote approach to measure the brake gap without reassembling the motor based on mechanical model.

This paper is structured as follows. Section 2 reviews the relevant literature on brake measurement. Section 3 explains the structure of motor brake. Section 4 shows calculation and discussions. Section 5 identifies experiment apparatus and condition. Experimental results and discussion are provided in Section 6. Section 7 explains directions for future research.

2. Background

Motor braking tests is a primary determinant of motor performance, which has been the subject of many investigations. For example, Bhau, Patil and Samant presented methodologies used for automotive service brake testing for two wheelers. The main contribution of their study was to compare and contrast three main brake-testing standards, viz., Indian Standards, Federal Motor Vehicle Safety Standards and European Economic Commission Standards [1]. Seyfert, in his study, introduced technical tips about brake maintenance [2]. Sangtarash et al. explained simulation procedures for series braking with optimal braking feel, series braking

Corresponding author's E-mail: t_ito@ube-k.ac.jp, itotakao@hiroshima-u.ac.jp, sakamoto@cc.miyazaki-u.ac.jp

with optimal energy recovery, and parallel braking strategies using CRUISE software [3]. All these studies focused on different aspects of motor braking systems, but studies on industrial motor maintenance have been sparse. In assembly line, many electric motors equipped brake system are required to determine where they should stop. This brake system need to be maintained to keep proper brake gap. Measuring the brake gap of electric motors is one a key job of the maintenance department, but entail significant difficulties because most of the motors are housed in unsafe spaces, such as at the upper end or even under the lift pit. In this study, the authors propose a new approach to measure the brake gap of motors to reduce maintenance risks and save costs. The method is using vibration acceleration to measure the motor gap in running production system based on mechanical model. To our best knowledge, this is the first study that measures the brake gap without machinery stopping.

3. Structure of motor brake

Major motor brake consists of a brake lining, friction plate and actuator. An example of motor brake is shown in Fig.1.

The brake lining is attached to main shaft of motor. Brake lining spins with main shaft of motor freely when brake is free. If brake is activated, friction plate pushes the brake ling by actuator. Typical type of actuator uses coil spring to push the friction plate, and electrical magnet to release brake. Fig.2 and Fig.3 show an image of brake free and brake locking relationship between brake lining and friction plate respectively.

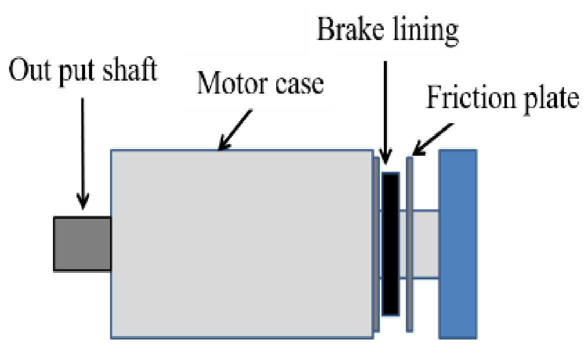


Fig. 1. A Typical image of Motor with Brake.

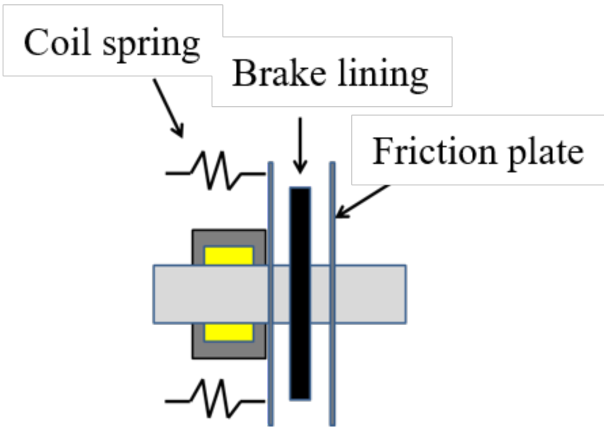


Fig. 2. An Image of Free Position Relationship between Brake Lining and Friction Plate.

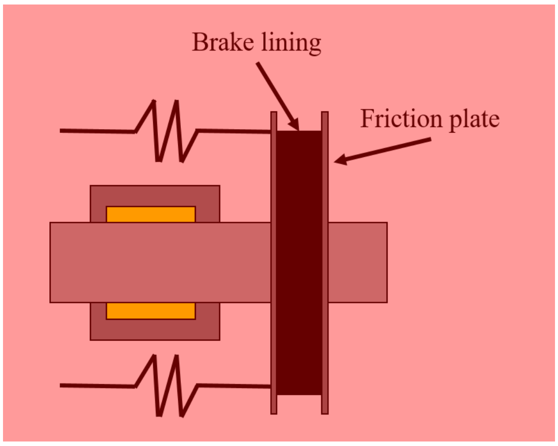


Fig. 3. An Image of Locking Position Relationship between Brake Lining and Friction Plate.

4. Calculation and Discussions

Motor brake is activated by coil spring in actuator to push the friction plate. The structure of our models is shown in Fig.2 and Fig.3, respectively.

On real motors, some coil springs are used, but they can be constructed as one modelled spring with spring rate k[N/m], m[kg] for math of friction plate and brake lining, and Δx[m] for brake gap. The energy this system dispenses is formulated in equation (1).

$$\frac{1}{2}k\Delta x^2 = \frac{1}{2}mv^2 \quad (1)$$

$$\mathrm{v} = \sqrt{\frac{k}{m}}\Delta x \quad (2)$$

This energy system vibrates the motor when the brake is activated. Equation (2) shows the relationship of Δx and v[m/s]. Here v[m/s] indicates the instant velocity when the friction plate hits the brake lining. However, this velocity is difficult to measure. However, based on momentum conservation law, the relationships of acceleration to the brake gap is calculated in the equations below.

$$mv' - mv = F\Delta t \tag{3}$$

$$v' = 0$$

$$\mathrm{F} = \frac{m}{\Delta t}\sqrt{\frac{k}{m}}x \tag{4}$$

$$\ddot{x} = \frac{1}{\Delta t}\sqrt{\frac{k}{m}}x \tag{5}$$

$$\ddot{x} = \beta x \tag{6}$$

Δt signifies a very small amount of time, so it is hard to measure. However, by transforming it as equation (6), the linear relationship between brake gap and acceleration becomes evident. This suggests that measure the vibration acceleration can be used for brake gap.

5. Experiment Apparatus and Condition

Experiment apparatus and conditions are shown below, respectively.

5.1. *Experiment Apparatus*

A set of experimental apparatus is shown in Table 1.

	Maker	Type
Motor	SUMITOMO HEAVY INDUSTRES GEARMOTORS	INDUCTION MOTOR 0.2kw 4P 3φ
Data logger	KEYENCE	NR-600
Amplifire of acceleration pick up	KEYENCE	NR-CA04
	KEYENCE	NR-U65
Data logger software	KEYENCE	Wave Logger pro
Acceleration pick up	SHOWA SOKKI	2304A , Sensitivity 47.6pC/G , 4.86pC/(m/s2) Capacitance 780pF
Shim tape	TRUSCO	TFG-0.05M1

Table. 1 Experimental apparatus.

5.2. *Experiment Condition*

The authors attached the acceleration pick up to motors fitted with magnets. First, an experiment was conducted to confirm the effect of the presence (or absence) of a fan cover on the measurement result of acceleration. From a practical viewpoint, this is expected if it is possible that the fan cover attached is available to be used. Second, an experiment to find out the linearity of vibration acceleration and brake gap was conducted. To demonstrate the several gap, the authors used shim tape to make the clearance between bake lining and friction plate. (A typical picture is shown in Fig.4.)

Vibration acceleration data were collected as plus acceleration and minus acceleration, thus the absolute number and average of 6 times of vibration—as is the norm—was employed. Fig. 5 shows an image for data collection.

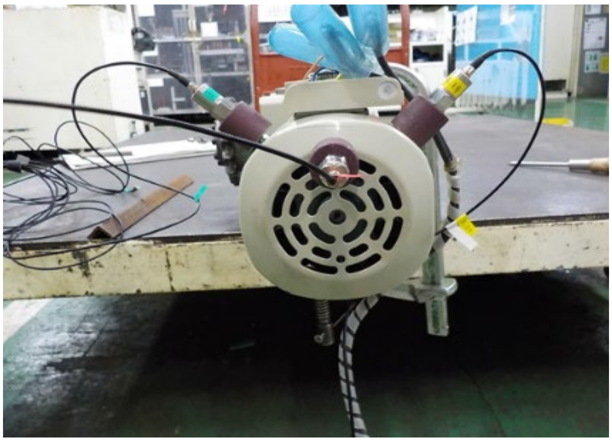


Fig. 4. Experimental Condition.

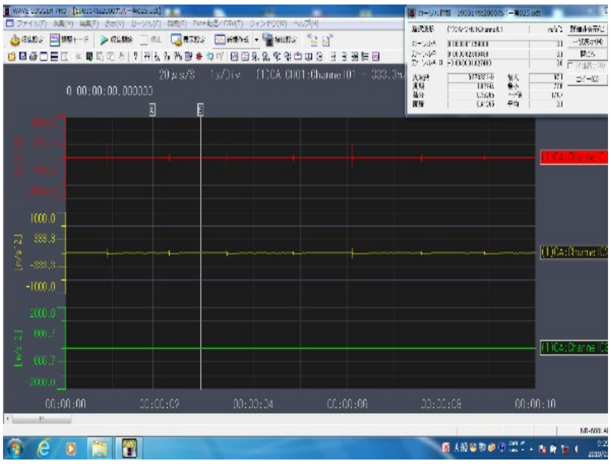


Fig. 5. An Image for Data Collection.

6. Result and Discussion

6.1. *Comparative study with cover*

To clarify the effect of the presence (or absence) of a fan cover on the measurement result of acceleration, two experiments were conducted. The first measured the acceleration with fan cover and the second experiment was conducted without the fan cover. Fig.6 shows the result of these experiments.

Measuring points, A and B are circumferential directions, whereas C is axial direction. It is expected that measuring acceleration without the cover would be higher than that with the cover. Thus, it is better to measure the acceleration without cover. On the other hand, a hard point of the motors case transmit vibration directly to the outside of the motor case. Result of point A shows the possibility of measuring vibration without reassembly the fan cover.

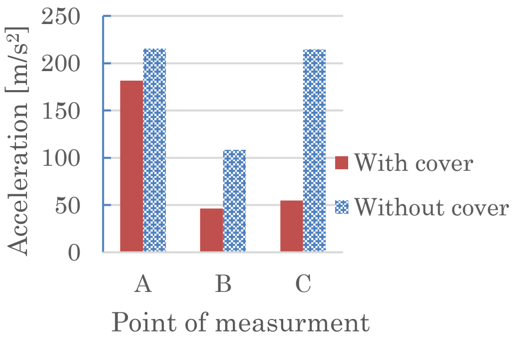


Fig. 6. Difference of Acceleration between Experiments with Cover and without Cover.

6.2. *Relationship of Acceleration and Brake Gap*

To illustrate the linear relationship between measured acceleration and brake gap, an experiment with brake gap between 0.26[mm] to 0.76[mm], difference of 0.05[mm] conducted. Based on the findings shown in Fig.7, a linear relationship between acceleration and quality is observed.

Calculated coefficients of k [N/mm] for each gap are reported in Table 2.

Gap[mm]	0.26	0.36	0.46	0.56	0.66	0.76	Average
K[N/m]	248.5	364.3	317.5	301.7	276.3	292.2	300.1

Table. 2 Coefficient K[N/m] of each Brake Gap

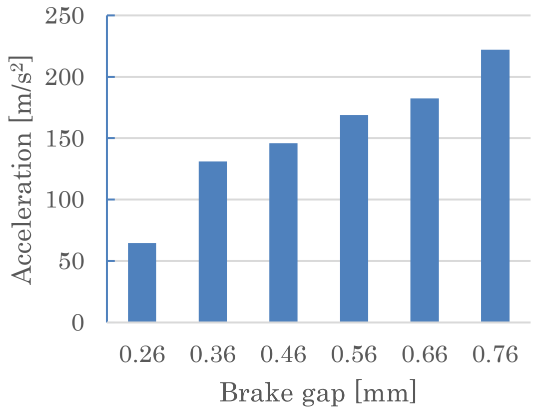


Fig. 7. Relationship between Acceleration and Brake gap.

The relationship between experimental result and calculated with the coefficient k [N/m] is shown in Fig. 8.

Additionally, a t-test was added to the experimental result and shows a statistically significant difference of the acceleration between 0.2[mm] of brake gap.

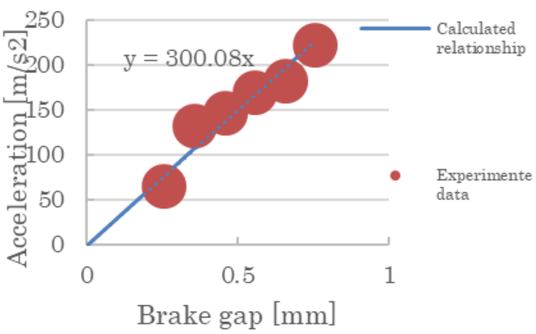


Fig. 8. Relationship between Theoretical Result and Experiment Result.

7. Conclusion

In this study, a new approach to measure the brake gap was proposed. According to the results of the experimental data analysis, the method to measure brake gap with accuracy 0.2mm was observed. The implications are that electrical measurement systems should be operated among IoT system in the future.

References

1. Bhau Kashinath Kumbhar, Satyajit Ramchandra Patil, Suresh Maruti Sawant: A Comparative Study on Automotive Brake Testing Standards, Journal of The Institution of Engineers (India): Series C, Volume 98, Issue 4, pp 527–531, 17 June 2016,
2. Karl Seyfert, Preventive Maintenance Tech Tips: Brake Maintenance, March 2004 Issue,.
3. Farhad Sangtarash, Vahid Esfahanian, Hassan Nehzati, Samaneh Haddadi, Meisam Amiri Bavanpour and Babak Haghpanah, Effect of Different Regenerative Braking Strategies on Braking Performance and Fuel Economy in a Hybrid Electric Bus Employing CRUISE Vehicle Simulation, 23 June 2008, SAEE International,

==

Authors Introduction

Dr. Tsutomu Ito

He is an assistant Professor in Department of Business Administration, National Institute of Technology, Ube College. He has published many papers in refereed journals and proceedings, particularly in the area of industrial management, and computer science. His current research interests include internet of things (IoT), mechanical engineering, artificial intelligence (AI), automata theory, quantitative analysis of Japanese Keiretsu. He was one of the winners of the Best Paper Award in the International Conference on Artificial Life and Robotics (ICAROB) in 2015and 2016. Dr. Ito earned his Doctor degree of Engineering from Hiroshima University, Japan in 2018.

Dr. Takao Ito

He is Professor of Management of Technology (MOT) in Graduate School of Engineering at Hiroshima University. He is serving concurrently as Professor of Harbin Institute of Technology (Weihai) China. He has published numerous papers in refereed journals and proceedings, particularly in the area of management science, and computer science. He has published more than eight academic books including a book on Network Organizations and Information (Japanese Edition). His current research interests include automata theory, artificial intelligence, systems control, quantitative analysis of inter-firm relationships using graph theory, and engineering approach of organizational structures using complex systems theory.

Dr. Makoto Sakamoto

He received the Ph.D. degree in computer science and systems engineering from Yamaguchi University. He is presently an associate professor in the Faculty of Engineering, University of Miyazaki. He is a theoretical computer scientist, and his current main research interests are automata theory, languages and computation. He is also interested in digital geometry, digital image processing, computer vision, computer graphics, virtual reality, augmented reality, entertainment computing, complex systems and so on.

==