A STUDY ON THE BRUSH NOISE REDUCTION OF A DC MOTOR USING MULTI-BODY DYNAMICS

Tae-Won Park*, Il-Ho Jung**, Jong-Hwi Seo**
*Division of Mechanical Engineering, Ajou University, 5 Wonchun-dong, Yeongtong-gu, Suwon-city, Gyeonggi-do, 443-749, Rep. of Korea
**Graduate School of Mechanical Engineering, Ajou University, 5 Wonchun-dong, Yeongtong-gu, Suwon-city, Gyeonggi-do, 443-749, Rep. of Korea

Summary The DC Motor of a vehicle can cause noise and vibration due to high-speed revolution, which can make a driver feel uncomfortable. There have been various studies that attempted to solve these problems, focusing mostly on the causes of noise and vibration and the means of preventing them. The CAE methodology is more efficient than a real test for the purpose of looking for various design parameters to reduce the noise and vibration of the DC motor. In this study, a design process for reducing brush noise is presented with the use of a computer model which is made by using multi-body dynamics program (DADS). The design parameters to reduce the brush noise and vibration were proposed using a computer model. They were used to reduce the noise and vibration of a DC motor and verified using the test results of a fan DC motor in a vehicle. This method may be applicable to various DC motors.

INTRODUCTION

The DC motor of a fan motor (hereinafter called the DC motor) is widely used as a control motor because of its excellent features: it has a simple structure, it is easy to operate, its revolution is easy to control, and it has an affordable price. However, the DC motor revolves at a high speed, so it can cause noise/vibration during operation of the system. In particular, the DC motor used in the actuators of automobiles and home appliances can give discomfort to users due to noise/vibration. It is necessary to solve this problem.

A survey of previous studies shows that the main cause of noise/vibration in DC motors is the dynamic interaction between the brush and the commutator. Due to the structure of a DC motor, there is the contact between the brush and the commutator, which causes friction. This friction is the main cause of noise/vibration in DC motors, which is generally known as brush noise. Other than this, noise/vibration can also be caused by nonparallel armature and the interaction between the armature shaft and bearing.[1,2] In this study, the multi-body dynamics model of the whole DC motor system was organized to analyze the dynamics features of the DC motor. Based on the result of the dynamics analysis, the characteristics of reaction force between the parts of the DC motor were observed and a study was done on the relevance of reaction force and noise/vibration of the DC motor. An improved design that can reduce brush noise was also presented, and the improved design was finally validated through tests.

MAIN SUBJECT

Dynamics model and Analysis

The target for analysis is a DC brush motor used in the radiator fan of an automobile, which is in the initial stage of development. The parts of the DC motor were modeled with a 3D geometry modeller for dynamics model data, as shown in Fig. 1. The DC motor was modeled with a multi-body dynamics program (DADS) for dynamics analysis, as shown in Table 1. The dynamics model was modeled based on the real data. A case study was carried out about design parameter, as shown Table 2.

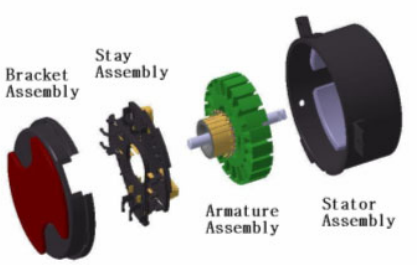


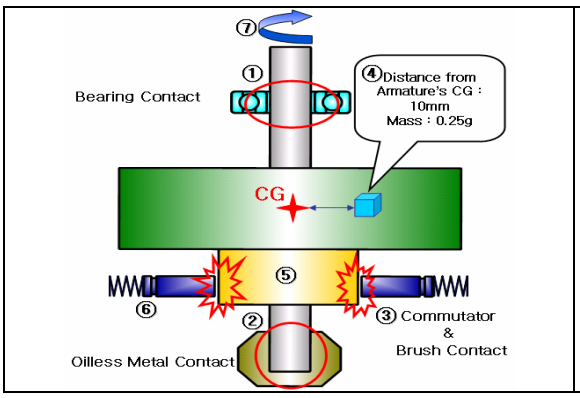
Fig. 1 3D CAD Model of DC motor

Results of dynamics analysis

Among the results of dynamics analysis, bearing reaction forces and reaction forces between brushes and a commutator were observed, as shown Fig. 1 3D CAD Model of DC motor in Table 2. The former was related to the structural vibration of the DC motor and the latter was related to the brush noise. From the results of Table 2, it can be seen that the smaller the design parameters, the lower the noise and vibration level of the DC motor. However, the upper design parameters are very small. Considering the quality cost, lowering the upper design parameters is not a good option for reducing the noise and vibration. Finally it is certain that the roundness of the commutator is the most important design parameter, because the roundness of the commutator was the only variable parameter during the durability test. Referring to Fig. 2, the critical point of the roundness was 0.11 mm. A durability test was carried out to verify the analysis result. After analyzing the result (Table 3) of the durability test, it could be seen that the element that has the biggest influence is the roundness of the commutator. According to the test data, the roundness deteriorated as the DC motor ran and this increased the brush noise. Therefore, the roundness of the commutator needs to be maintained in order to maintain the brush noise under a certain level throughout the durability life span of the DC motor. When compared with the current

DC Motor (#1 ~ 4 in Table 3), in the case of the commutator including lubricating oil (#5, 6 in Table 3), it is obvious that the roundness was maintained below the critical point and the brush noise was reduced after the durability test.

Table 1 Summary of the multi-body dynamics model of the DC motor



- ▶ Clearance and contact using contact element
  - ① Ball bearing
  - ② Metal bearing
  - ③ Between brush (4EA) & commutator
- ▶ Armature unbalance using dummy mass
  - ④ Fixation between armature and dummy
- ▶ ⑤ Roundness of commutator using random number
- ▶ ⑥ Brush Motion using translational joint & Spring
- ▶ ⑦ 2180 RPM revolution using control element

Table 2 Result of dynamics analysis

Design Parameter	Specification	Result	Comment
Commutator Roundness	Max 0.003 mm	Critical Point : 0.1 ~ 0.11 mm	Change during durability test (refer to Table 3) ➔ The most important design parameter to reduce the brush noise
Armature Unbalance	Max 0.25gfcm	The smaller unbalance, the lower vibration	No Change during durability test Unbalance is small enough
Spring Stiffness	10.3 g/mm	The smaller stiffness, the lower vibration	No Change during durability test Stiffness is small enough
Bearing Clearance	Ball : 0.008 ~ 0.013 mm Metal : 0.0045 ~ 0.013 mm	The smaller clearance, the lower vibration	No Change during durability test Clearance is small enough

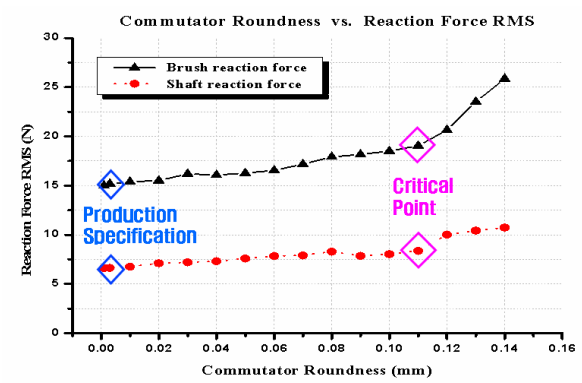


Fig. 2 Graph of Commutator roundness vs. Reaction force

Table 3 Table 1 Relation of roundness and noise before/after durability test

No.	Before		After	
	Roundness [mm]	Noise [dB(A)]	Roundness [mm]	Noise [dB(A)]
#1	Max. 3	61.4	0.146	78.8
#2	Max. 3	58.8	0.140	78.6
#3	Max. 3	60.3	0.137	78.9
#4	Max. 3	59.0	0.148	79.5
#5	Max. 3	60.3	0.078	76.5
#6	Max. 3	56.8	0.042	71.1

CONCLUSIONS

1. Using multi-body dynamics, we can see the dynamics features of the DC motor for a vehicle
2. The smaller each design parameter, the lower the noise and vibration level of the DC motor.
   ➔ Considering the quality cost, the lowering of the upper design parameters has little benefit.
3. After analyzing the result of the dynamics analysis and the durability test, it is obvious that the roundness of the commutator is the most important design parameter to reduce the brush noise of the DC motor.
   ➔ The roundness of the commutator needs to be maintained in order to maintain the brush noise under a certain level throughout the durability life span of the DC motor.
   ➔ Commutator including lubricating oil can reduce brush noise after durability test.

References

[1] H. Kang: The Study of DC Motor Noise and Vibration, SAE 951350, p. 2461, 1995.
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[3] J. S. Kim: A Study on the Active Balancing System for High-Speed Rotating Machinery, Ph.D. Dissertation, Ajou University, 2003.