Estimation of Acoustic Noise and Vibration in an Induction Machine considering Rotor Eccentricity

[1]Do-Jin Kim, [1]Hae-Joong Kim, [1]Jung-Pyo Hong, [2]Chul-Jun Park, [2]Jin-Tai Chung
[1]Department of Automotive Engineering, Hanyang University
[2]Department of Mechanical Engineering, Hanyang University
[1]222 Wangsimni-ro, Seongdong-gu, Seoul, 133-791, Korea
[2]55 Hanyangdaehak-ro, Sangnok-gu, Ansan Kyeonggi-do, 426-791, Korea
hongjp@hanyang.ac.kr

Abstract—The rotor eccentricity is a fault that mainly affects induction motors. In the worst case an eccentricity fault can result in a stator rotor rub thereby causing severe damage to the motor and acoustic noise and vibration. The reasons that lead to unequal air-gap may involve many different factors. It can be caused by: (a) Unbalanced load; (b) Bearing wear; (c) Bent rotor shaft; (d) Mechanical resonance at critical load; (e) Manufacture and assembly tolerance.

In this paper, the acoustic noise using the electromagnetic excitation force is analyzed according to the rotor eccentricity. A 2-D transient analysis is conducted to consider the rotor eccentricity, saturation effect and harmonic components of current. Fourier series has been addressed according to time and space considering harmonic component of electromagnetic excitation force. In the mechanical part, the natural frequency modes of motor components such as bracket, stator and rotor cores are calculated using finite element analysis (FEA) to analyze the natural frequency. The induction motor is fabricated considering the quantity of static eccentricity.

***Index Terms*—Acoustic noise, Electromagnetic forces, Eccentricity, Induction motors, Spectral analysis.**

I. INTRODUCTION

Electric motors are one of the most fundamental motion generation mechanisms in both industrial and household products. Although there are various types of electric motors, induction motors are most popular due to the low cost and ease of operation. Recently, looking for the most suitable motor for a certain application and existent drive system has been focused. In addition, both environmental issues and the demand for low-noise induction motors have increased.

In this regard, various researches on the reduction of noise and vibration of induction motors have been conducted for many years. The vibrations are measured on the surface of the motor frame together with sound pressure levels around the motor and then the measurements are analyzed in connection with modal properties of the motor structure and electromagnetic excitation mechanisms [l-3]. In the analytical studies, it is the estimation of Maxwell stress acting on the stator due to magnetic flux in the air-gap that is the major concern. The Maxwell stress can be estimated by using the classical electromagnetic excitation force and permeance wave theory [4-6], according to which peak frequencies in the power spectrum of the Maxwell stress can be easily located even though magnitudes of the peaks are not well predicted.

In this paper, the acoustic noise of induction motor with rotor eccentricity is calculated using the electromagnetic excitation force and mechanical analysis. The motor consists of 4-pole, 48-stator slots and 60-rotor slots with 3.7 kW, rated power. In order to changing the quantity of static rotor eccentricity, the motor is fabricated using the bolt which on the front and back housing. The fabricated motor is shown in Fig. 1. The acoustic noise of motor is measured in motor-based test at no-load condition due to eliminate the noise generated by dynamo.

II. ANALYSIS METHOD

A. Electromagnetic force

The spectrum analysis for the air gap flux density which consists of time and space harmonics is performed. The radial force calculated from the air gap flux density is analyzed using a Fourier series.

$$F\left(\alpha,t\right)=\sum_{v=6k\pm1}^{\infty}F_{mv}\cos\left(l\omega t\mp vp\alpha+\varphi_{v,l}\right)\tag{1}$$

$$F_{mv}=\frac{3\sqrt{2}}{\pi}\frac{N_1k_{w1v}}{vp}I_1\tag{2}$$

where F_{mv} is MMF, l and v are time and space harmonic order, respectively. $k_{\omega1\upsilon}$ is winding factor, N_1 is the series turns, I_1 is the current, p is pole pair, and $\varphi_{\upsilon,l}$ is phase angle.

In case of pure static eccentricity illustrated in Fig.2, the position of radial minimal air-gap length is fixed in space. In order to consider static eccentricity, the variation of the air gap around the magnetic circuit periphery and with time is

$$g(\alpha,t)=g\left[1-\varepsilon\cos\left(\alpha-\omega_{\varepsilon}t\right)\right]\tag{3}$$

where $g=R-r$, R is the inner stator core radius and r is the outer rotor radius. The equation is $\varepsilon=e/g$. e is the rotor eccentricity and g is an ideal uniform air gap.

B. Natural frequencies

In order to consider mechanical characteristics and resonance, the natural frequency and mode of each component of motor assembly are calculated using FEA with material and geometry. The components of motor such as rotor assembly, stator assembly with housing and motor assembly finally, the designed model can avoid a resonance of motor by mismatching frequency of electromagnetic excitation force to the mechanical natural frequency.

C. *Simulation result of noise*

The distribution of radiated noise is identified using acoustic analysis. The noise in a high frequency region is to analyze the distribution of the radiation. The noise is simulated using a LMS Virtual. Lab. The components of force which is calculated on the air gap put in the tooth of stator according to rotor position. The measurement points of noise in simulation are similar to the actual case data at no-load condition. The result of noise simulation is shown as Fig. 4.

III. EXPERIMENT

A motor test is conducted under no-load conditions to eliminate the noise generated by the dynamometer. The experimental set-up is shown in Fig. 5. The microphone is installed on side and in front of motor. To verify the proposed process, the measured noise and analysis result of FEA are compared.

IV. CONCLUSION

The influence of rotor eccentricity on the magnetic forces which act on the stator surface, on the harmonic spectrum of these forces and on the noise level of the machine is shown. A comparison from simulation results obtained with the FEAwas made for the no eccentricity case and for the case with changing the eccentricity level for a 3.7 kW induction motor.

V. REFERENCE

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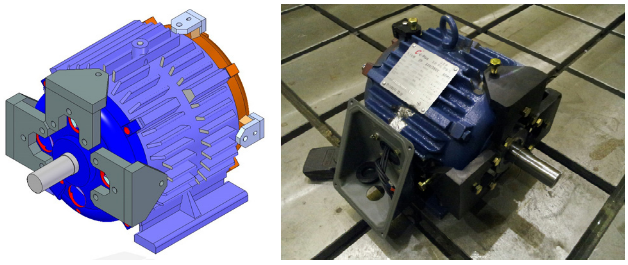
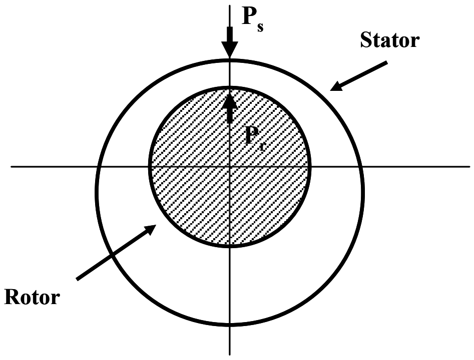
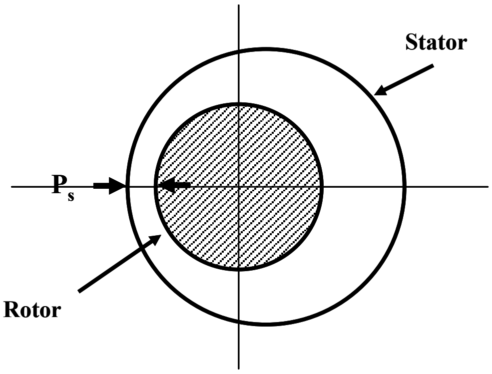


Fig. 1. 3.7 kW induction motor

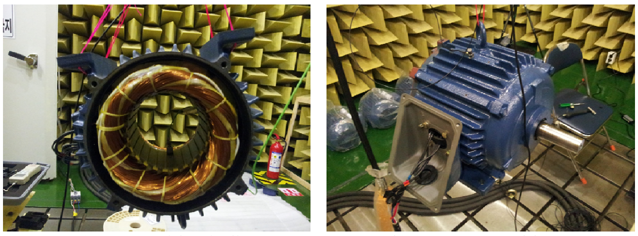


(a) The upper and lower side eccentricity



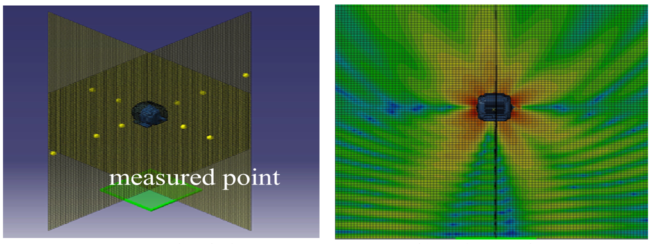
(b) The left and the right side

Fig. 2. Cross section view of a motor with a static eccentricity



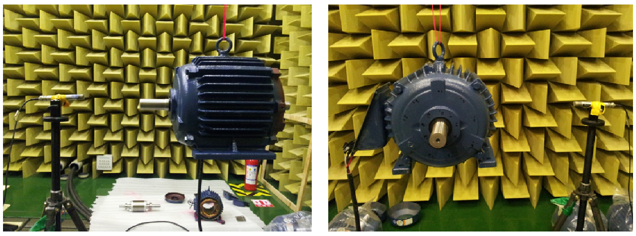
(a) Stator with winding (b) Motor assembly

Fig. 3. Test of natural frequency mode



(a) FEA simulation (b) Noise result

Fig. 4. FEA simulation to calculate noise of motor



(a) Microphone in front of motor (b) Microphone by motor

Fig. 5. 3.7 kW induction motor undergoing noise test