THE STUDY ON VIBRATION AND NOISE CHARACTERISTICS OF FAN MOTORS CAUSED BY THE ELECTROMAGBETIC FORCE

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SUMMARY

The fan motors is combined with motor and fan cooling of equipments. The fan motors are using many equipments such as Information equipments, OA equipments, electrical household appliances, in-vehicle equipments, and industrial equipments. Commonly the fan motors are required for high efficiency, high air capacity, and low vibration and noise. In particular, recently market focus to lower noise and vibration. In this study, effect on the noise caused by electromagnetic dynamics and fluid dynamics the small fan motor is clarified. Regarding the vibration and noise in the fan motor, radiated noise generated structure vibration cause by the electromagnetic force of the motor, and fluid noise characteristics caused of the fan by fluid dynamic are clarified. The result is useful for reduction of vibration and noise.

INTRODUCTION

In current motor market, low noise and vibration is increasingly needed in addition to the higher power and efficiency. A motor is requested to accomplish the low noise and vibration and high efficiency simultaneously. A fan motor, which is an electric motor with a fan being installed on it, is highly versatile. Commonly the fan motors are required for high efficiency, high air capacity, and low vibration and noise. In particular, recently market focus to lower noise and vibration. Vibration and noise in the fan motor have been studied separately as problems of fluid dynamics, mechanical structural dynamics, or electromagnetic dynamics. Recent trends in many people's lifestyles brought up reduction of vibration and noise of the fan motors as an important issue. In order to solve these issues, analyses on fluid dynamics, electromagnetic dynamics, and mechanical structural dynamics of the fan motors are needed to be performed not separately but simultaneously. The vibrations and noises caused in three different mechanisms superposition one another. Fluid dynamics of the fan, electromagnetic dynamics of the fan, and mechanical structural characteristics are important factors for vibration and noise in the fan motor.

For the low noise and vibration of a motor, they have researched by electromagnetic force [1] [2], simulation for electromagnetic force induced vibration and noise [3] [4] [5], natural frequency [6] [7], and vibration analysis method [8]. For the noise and vibration of the fan motor, there are many papers. They have researched by reduction of fan noise [9], measurement and visualization of air flow [10] [11], and CFD method [12] [13] [14]. But the papers studied on both phenomena of electromagnetic force and fluid dynamics is not found.

In this study, effect on the noise caused by electromagnetic dynamics and fluid dynamics of the small fan motor is clarified. The harmonic components of different generating mechanism, namely, electromagnetic force of the motor, fluid dynamic force of the fan, and the structural vibration characteristics, were investigated for reduction of vibration and noise。

EXPERIMENTARY METHOD

Table 1 shows specification of fan motor model and fig.1 shows air flow characteristics. First, the vibration characteristics of a non-operating fan motor were obtained by hammer impact test, and experimental modal analysis was conducted. Next, vibration and noise characteristics of the operating fan motor were measured. Fig.1 shows the block diagram of measurement system. Solid lines indicate non-operating condition for modal analysis by hammer impact test, and dashed lines indicate operating condition for frequency analysis of noise and vibration. The block diagram system of the dashed line shown in Fig.1 analyzes the vibration and noise using the measurements shown in Fig.2. The noise was measured by a microphone which was located 1 m from the suction side of a fan motor. A airflow characteristic curve is the measured data when rotating speed 1922 min^{-1} indicated on figure 7 is fixed in fig.1. Noise was measured with the biggest air- flow in the fig. 1.

Table 1 Specifications of fan motor model

Width：W ×Hight:H ×Thickness:T［mm］	120×120×25
Number of poles	4
Number of stator slots	4
Number of blades	9
Operating speed［min^{-1}］	2200

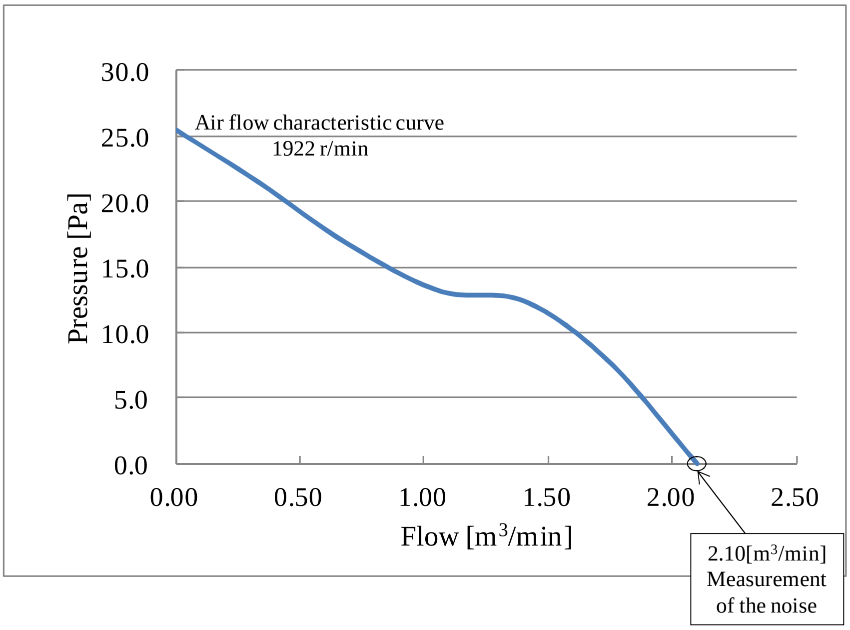

Figure 1: Air flow characteristic curve of the fan motor

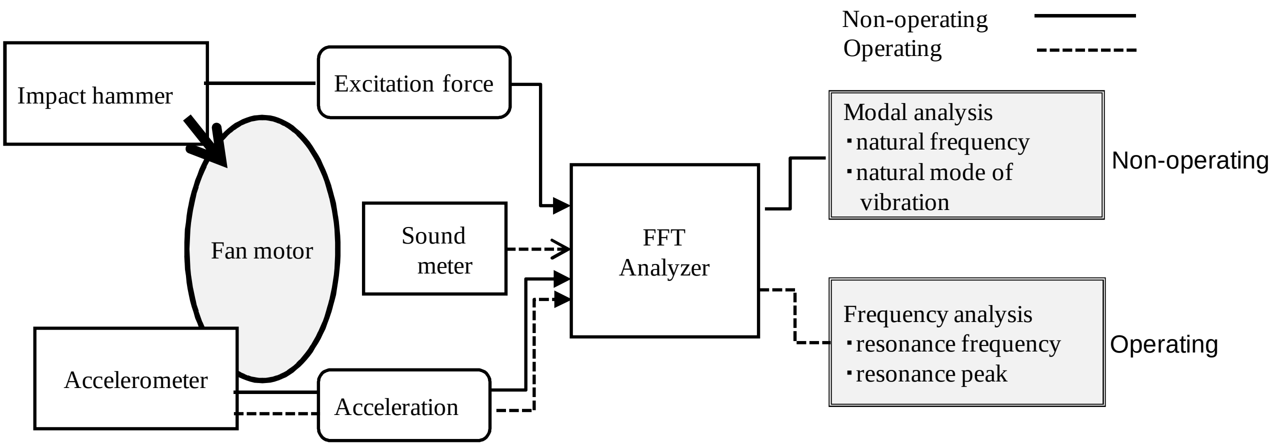

Figure 2: Block diagram of measurement system

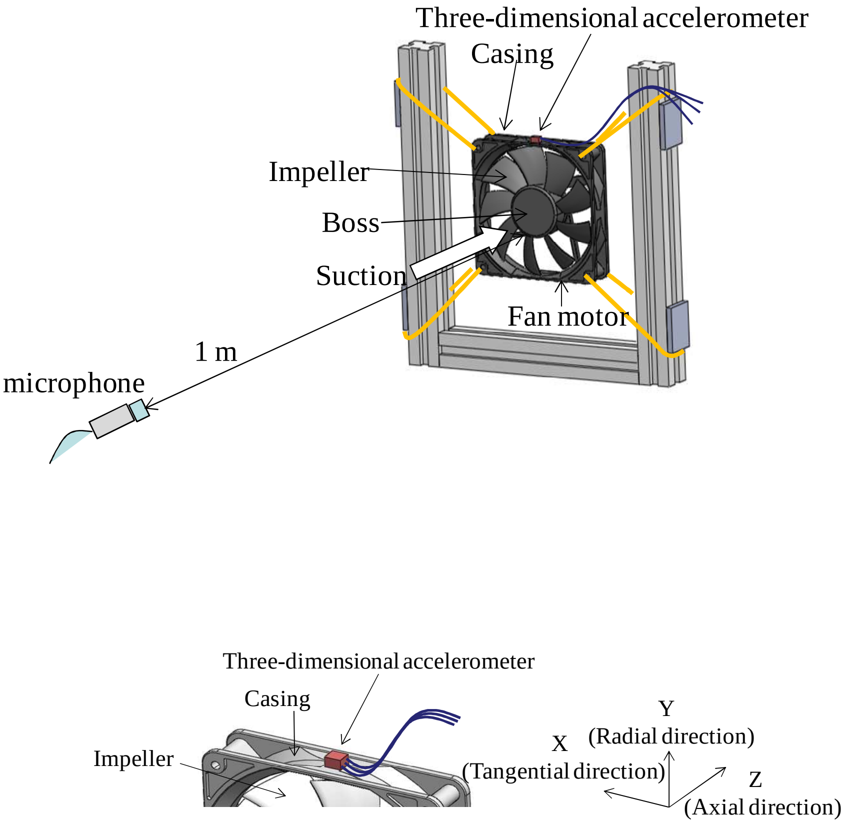

Figure 3: Measurements of measuring three-dimensional acceleration

RESULT OF EXPERIMENT

Vibration characteristics of a non-operating fan motor

An acceleration sensor is set in the radial direction in outside the casing. Blades were struck in the axial direction, and were transfer functions were obtained. Fig. 4 shows transfer function in the axial direction. The highest peak appeared at 530 Hz. Fig.5 shows natural vibration mode of fan motor at 530 Hz. Each blade vibrates in the same phase in the axial direction, and the boss and blades vibrate in opposite phases at 530 Hz.

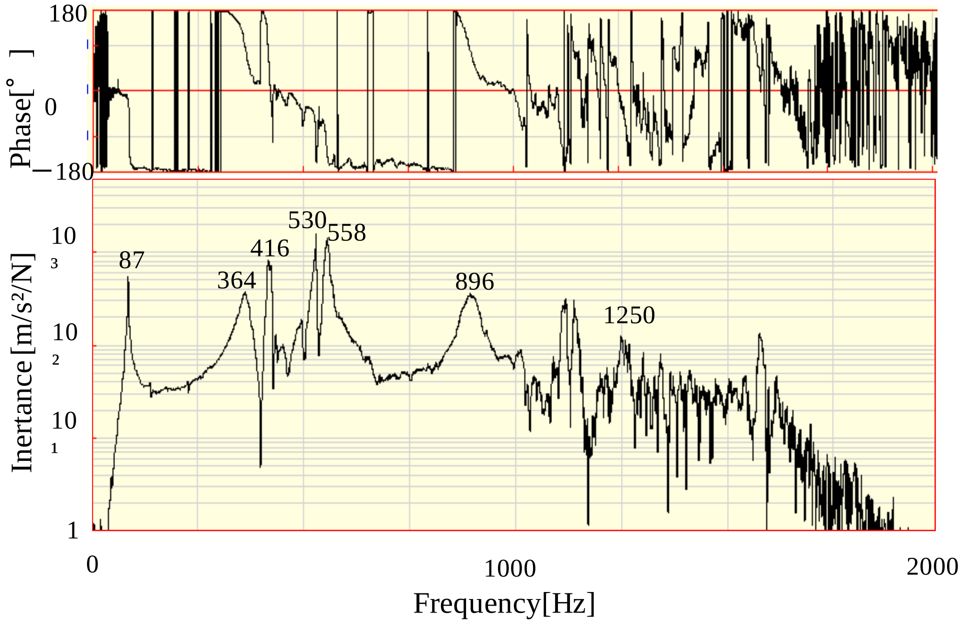

Figure 4: The Transfer function in the axial direction

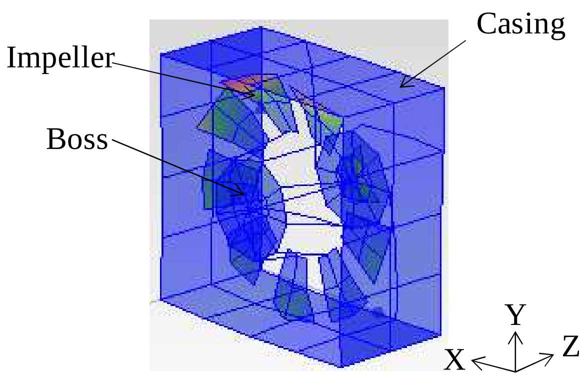

Figure 5: Natural vibration mode of the fan motor at 530 Hz

Vibration and noise characteristics of the operating fan motor

The rotational speed was continuously decreased from 2200 min^{-1} to 1200 min^{-1} while the measurements were taken. Fig.6 shows overall noise level. Significant noise peak was present at 1922 min^{-1}. Fig.7 shows noise level.

The relation of harmonic components and frequency caused by blade-passing force and electromagnetic force is shown below.

The frequency f_z of the fluid noise caused by blade-passing force has the following relation.

$$f_z = mnz \qquad (m = 1,2,\cdots) \tag{1}$$

Here, n is a rotational frequency and z is number of blades.

There is the following relation to the frequency f_e of electromagnetic force.

$$f_e = k \times (2n/p) \qquad (k = 1,2,\cdots) \tag{2}$$

Here, k is a harmonic components, n is a rotational frequency and p is number of poles. 4th component of blade number appeared.

Fluid noise which depends on the number of blades was present. And harmonic components on the noise caused by electromagnetic force were also confirmed. Frequency of 512 Hz corresponds to 530 Hz, and is equal with 32nd component of electromagnetic force, but component of blade-passing noise doesn't exist. The rounded squares indicate the points where an integral multiple of the fundamental frequency of blade-passing force equals that of the electromagnetic force.

Fig.8 shows frequency analysis result at 1922 min^{-1} when the significant peak is occurred. The part surrounded by the square shows that the frequency blade number of impeller and the frequency from electromagnetic force are equal. Frequency of 576 Hz and 1152 Hz are both blade-passing frequencies that depend on the number of blades as well as harmonic frequencies of the electromagnetic force. Therefore, noise peaks were present at 576 Hz and 1152 Hz. Since harmonic frequencies of blade-passing noise and those of electromagnetic force coincided with one another, these prominent peaks were occurred by the mutual interaction between the fluid dynamic force and electromagnetic force as external force. Frequency of 512 Hz is the natural frequency of structure and electromagnetic force will be in a resonant condition, and it shows a significant peak. Fig.9 shows noise level of the 32nd electromagnetic force versus rotational speed. The significant resonance occurred at 1922 min^{-1}.

Fig.10 shows amplitude in the axial direction. The rotational speed was continuously from 2200 min^{-1} to 1200 min^{-1} while the measurements were taken. 4th component of blade number appeared. About electromagnetic force, vibration occurs in an 8th integral multiple harmonics degree. 4th component of blade-passing force and 72nd component of electromagnetic component by the rounded square has excited the fan motor simultaneously. Fig.11 shows frequency analysis result at 1922 min^{-1} when the significant peak is occurred. Fig.12 shows vibration amplitude of the 32nd electromagnetic force in the axial direction versus rotational speed. The significant resonance occurred at 1922 min^{-1} in the same manner at the noise (Fig.9).

As mentioned above, significant vibration and noise has occurred by electromagnetic dynamics, and occurred in the axial direction.

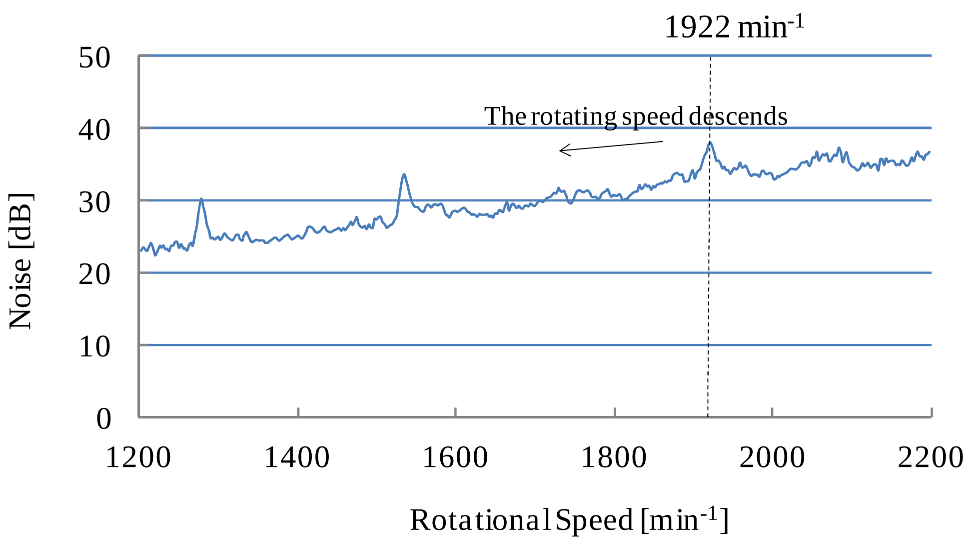

Figure 6: Overall noise level versus rotational speed

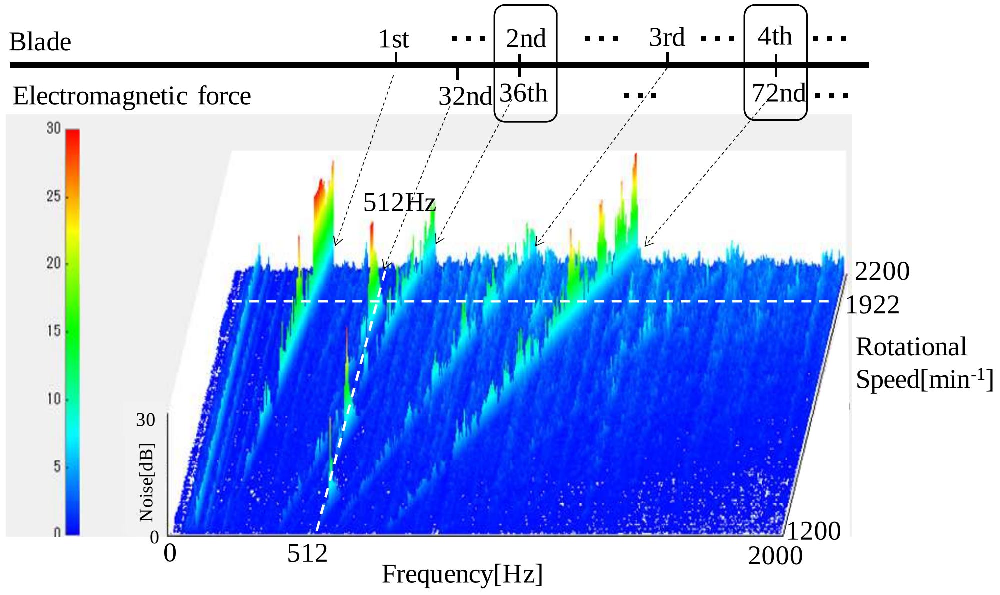

Figure 7: Natural vibration mode of the fan motor at 530 Hz

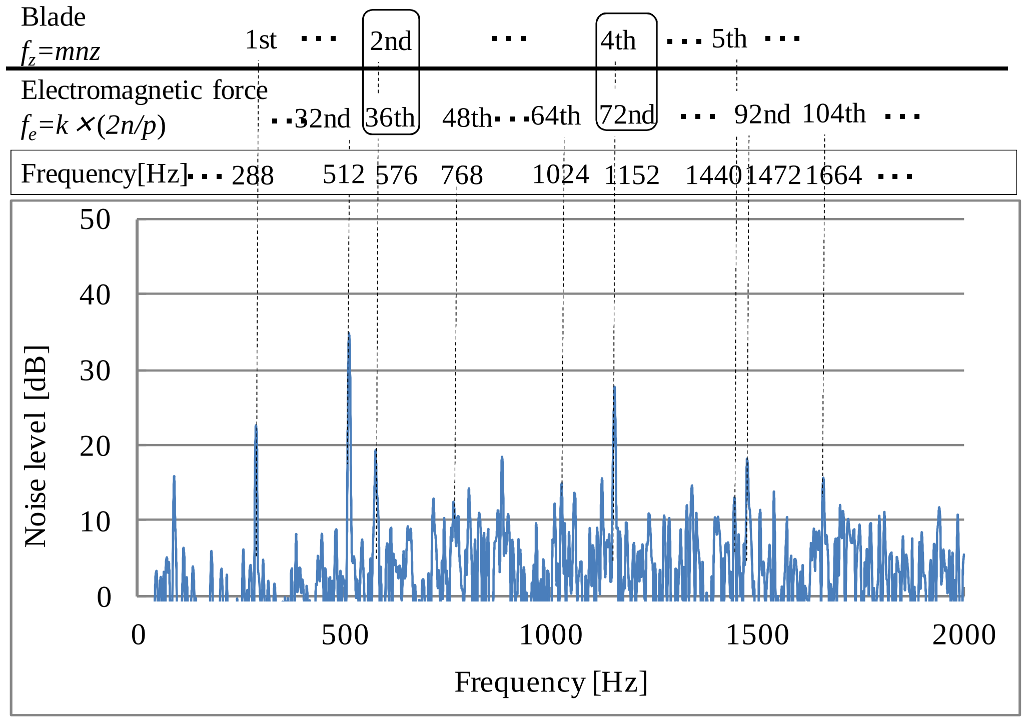

Figure 8: Noise level measured at 1922 min^{-1}

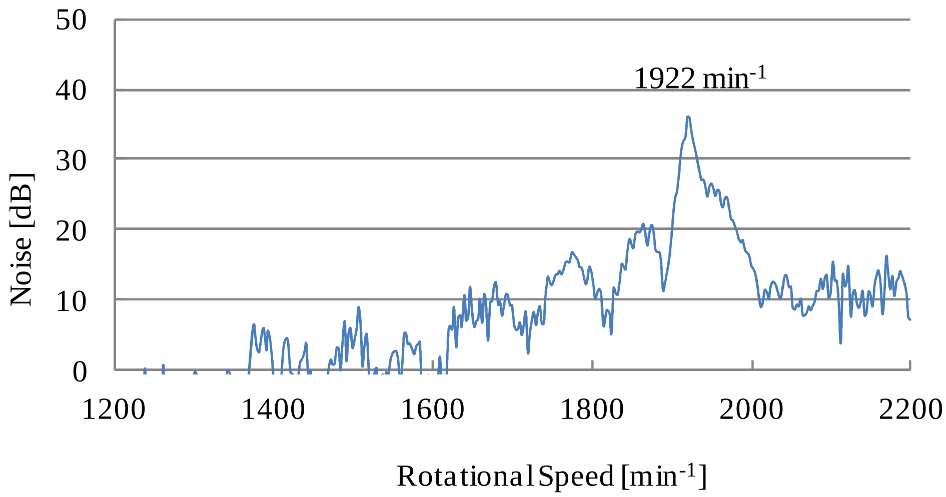

Figure 9: Noise level of the 32nd electromagnetic force

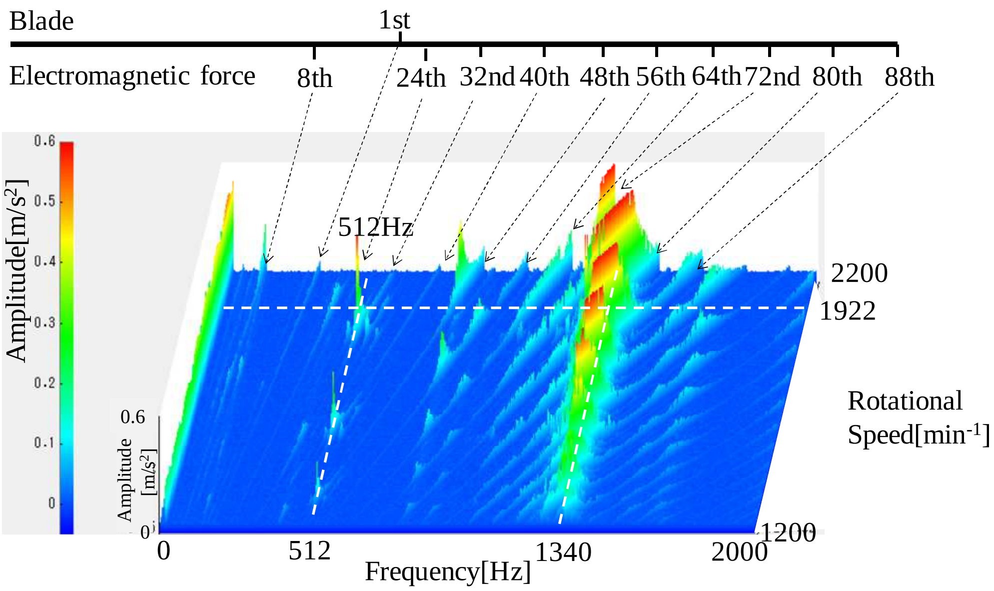

Figure 10: Vibration amplitude in the axial direction

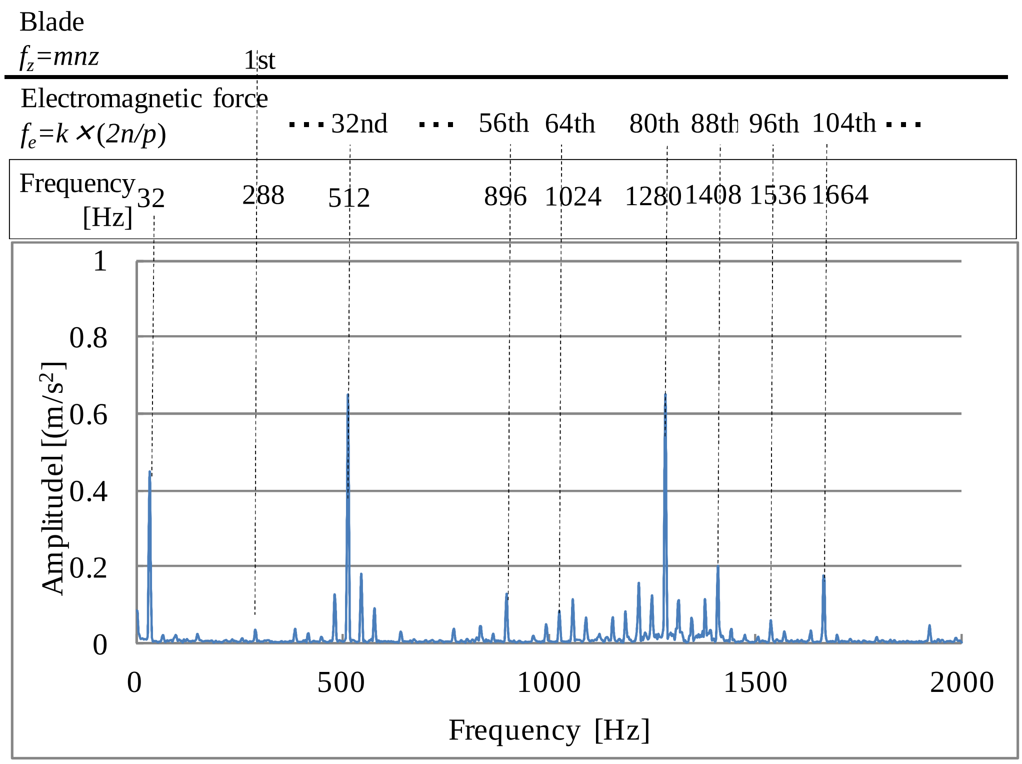

Figure 11: Vibration amplitude in the axial direction at 1922 min^{-1}

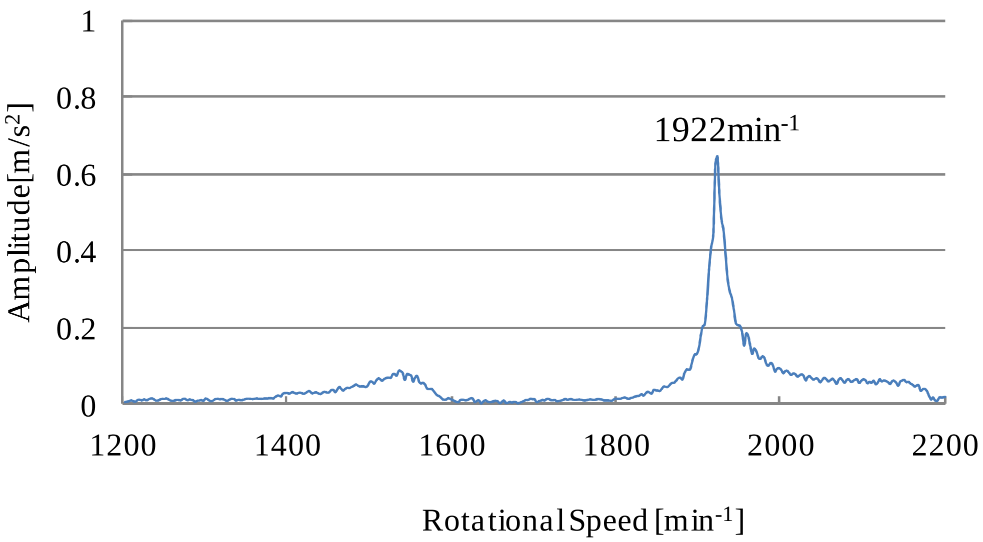

Figure 12: Vibration amplitude of the 32nd electromagnetic force in the axial direction

Noise characteristics after switching off the power supply to the motor

The rotational speed was continuously decreased from 2200 min^{-1} to 1200 min^{-1} while measurement was taken. Dashed line (free run) indicates that measurements were taken immediately after switching off the power supply to the motor. Compared to when voltage was c0ntinuouly decreased (voltage change), no significant peak were present in the free run operation. After switching off the power supply to the motor, the most excitation force is fluid dynamic force.

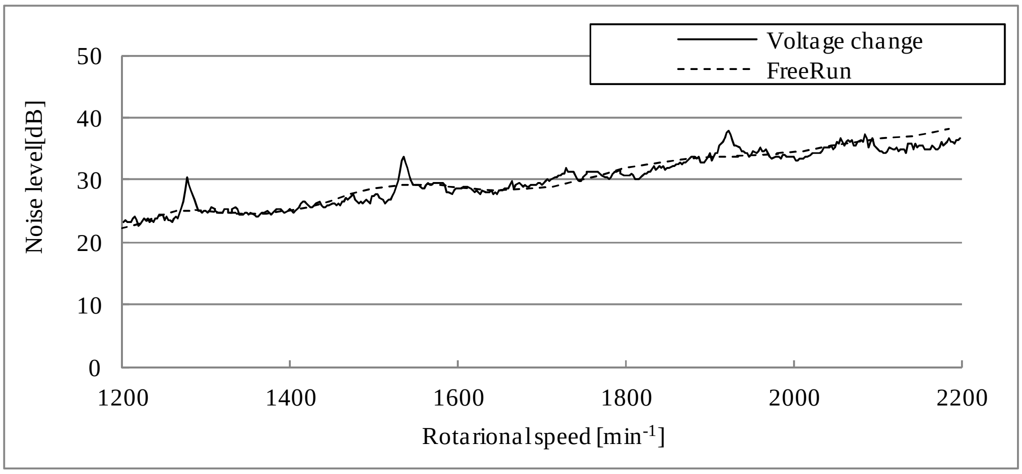

Figure 13: Overall noise level

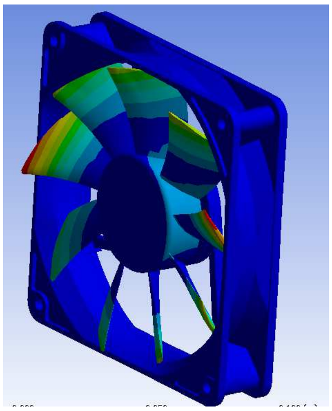

Figure 14: Natural frequency mode at 538 Hz by simulation

CALCULATION

Structural vibration analysis of the fan motor was carried out, and main vibration modes were investigated. Fig.14 shows the mode in which each blade vibrate in the same phase in the axial direction. This vibration mode is equivalent to Fig.4. The difference of the structural vibration analysis result and experimental result of natural frequency is less the 2 %, and is agreement in general.

CONCLUSION

The vibration and noise characteristic caused by the harmonics component of electromagnetic dynamics of the motor, fluid dynamics of the fan and structural was investigated for the phenomenon which occurs for the small fan motor at the time of operation. And, it was shown clearly that there are the following features.

(1) The noise of the fan was caused by the blade-passing force and the electromagnetic force were prominent. Significant peaks were present at frequencies at which both the blade-passing force and the electromagnetic force have their harmonic components. In particular, noise becomes maximum at a frequency that the harmonic frequency of the fan motor in the axial direction to match.

(2) The significant vibration and noise were occurred by the electromagnetic dynamics, and largest peak was occurred in the axial direction.

This study will be developed for other type of fans from now on, too.

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