Noise	Sound Generation Mechanism of Outer Rotor Type Motor	Rotating Machinery
Noise		

Object Machine

Blower motor for automobile air conditioner (Fig.1). Rotor specifying outer diameter φ80, rated output 130 W, the operational speed for-at the upper limit of 4,000rpm. Outer rotor type motor wherein the outer surface rotates, as the rotor covers the stator. The rotor excessively vibrated on the certain speed range in the rotational speed and the noise sound is generated and then spread outside.

Observed Phenomena

Generally, when rotating, motors generate magnetic sounds with an electromagnetic force acting upon the motor structures (1). In case of an inner rotor type motor, a noise peak is observed on the stator resonance frequency, while in case of a blower motor that is an outer rotor type motor, two noise peaks are observed on either side of the rotor resonance frequency (Fig.2). Magnetic sounds occurred at a rotating speed 2,783rpm, while the rotor mechanical resonance frequency 2,226Hz was 48th the number of revolutions, and two noise peaks 2,133Hz and 2,319Hz, as the sound resonances, corresponded to 46th and 50th respectively. But the noise generation mechanism was not yet clear.

Cause Estimation

At the resonance frequency of 2,226Hz, the rotor vibrates as standing waves of a secondary mode on circular ring, and the standing waves are composed by adding a forward wave and backward wave having the same propagation speed (Fig.3). As the rotor rotates, the standing waves also rotate (if the rotor rotating direction is defined as the forward), and the propagation speed of the forward wave increases by an amount of the rotor rotating speed, while that of the backward wave decreases by the same amount. The noises, generated by the forward wave and backward wave having a different propagation speed, were thought that it has been observed as resulting two different noise peaks.

Analysis and Data Processing

By visualizing the rotor surface vibrations at two noise peak frequencies, a hypothesis verification was undertaken to confirm that the vibration mode of each frequency is the forward wave and the backward wave respectively. However, the rotor as the target is a rotating body, and surface vibration measurement requires multiple and simultaneous measurement, thus a system adopting a non-steady state sound source exploration method was configured (Fig.4). In this system, the vibration level at each point on the rotor surface was calculated from sound data obtained by a microphone array fixed on the periphery. Visualization of the rotor surface vibrations at two noise peak frequencies observed the forward wave with a propagation direction that matches the rotor rotating direction at the noise peak frequency of 2,319Hz that is relatively high, while at the noise peak frequency of 2,133Hz that is relatively low, the receding wave with a propagation direction opposite to the rotor rotating direction was observed (Fig.5). Thus, the correctness of the hypothesis was verified.

Countermeasures and Results

It has been verified that both of the noise peaks were noises incurred by a secondary circular ring mode of the rotor. Thus, noise reduction was achieved by a structural modification by which mass addition and stiffening at the belly and node positions of a secondary circular ring mode.

Lesson

In the mode analysis that is growing popular in recent years, only the steady state results of standing waves are indicated, while no description is made as to the propagation and reflection of forward wave that occur during the process, or the amplification and offsetting due to interference of backward wave. Knowledge that is basic but is liable to be often overlooked may be helpful in the design involving noise and vibration.

References

(1) Sun, Tao, et al: Effect of pole and slot combination on noise and vibration in permanent magnet synchronous motor, Magnetics, IEEE Transactions on 47.5, pp.1038-1041(2011)

Keywords

Motor, outer rotor, sound source exploration, standing wave, forward wave, backward wave

Fig.1 Appearance of blower motor

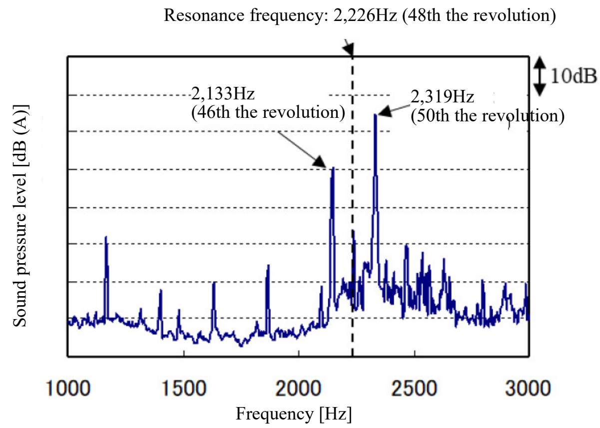


Fig.2 Frequency characteristics of sounds near the blower motor
(number of revolutions 2,738rpm)

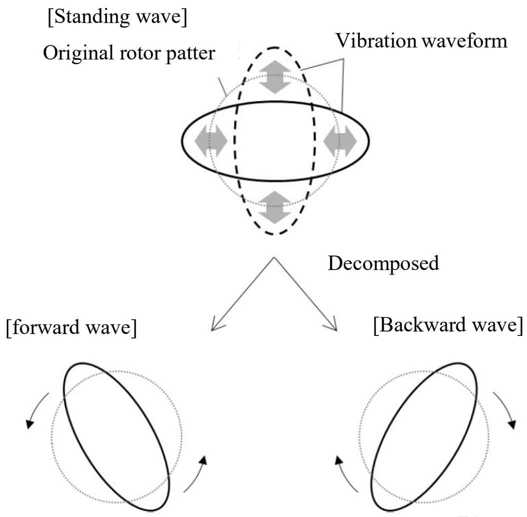


Fig.3 Traveling wave and receding wave constituting the secondary steady state waves of circular ring

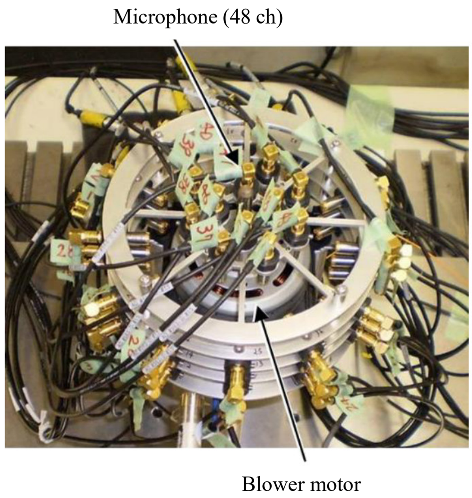
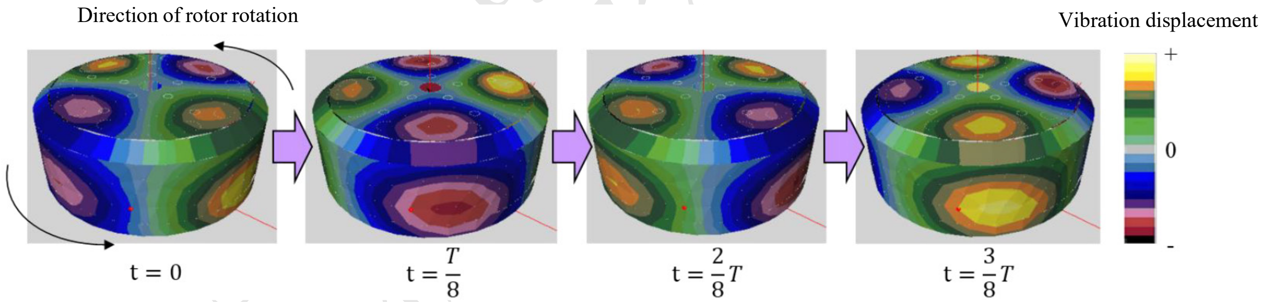
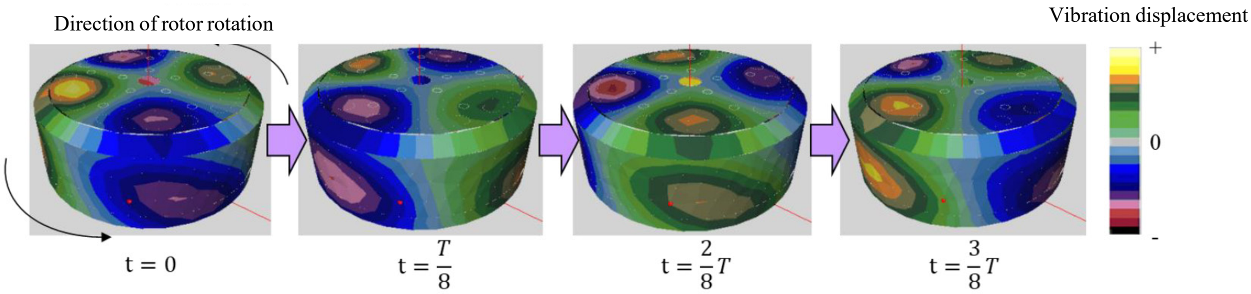


Fig.4 Non-steady state sound source exploration system



(a) 2,319Hz (the resonance belly moves in the same direction of the rotor rotation=forward wave)



(b) 2,133Hz (the resonance belly moves in the direction opposite to the rotor rotation=backward wave)
Fig.5 Time history changes in the rotor surface vibrations at two noise peaks
(T: period [s] for the resonance belly to make one revolution)