

Case History	Abnormal Vibration of Electric Motor	Rotating machinery (electric motor)
Forced Vibration		

Object Machine	Three phase induction motor (Fig.1)	
Observed Phenomena	<p>During a load operation of the motor in combination with a turbo blower, abnormal noise with a beat of one to two times per second occurred. In accordance with increasing motor load, the frequency of beat increased, and the vibration also had a tendency to grow (rotor vibration: 95 μm PP, bearing 25 μm PP). The vibration included an abnormal vibration component (58 Hz) near the rotation frequency in addition to the rotation component. This component went up to 6 to 7 times the rotation one at the rated speed and output.</p> <p>During acceleration (at the time of power ON), the component near the rotation frequency went up according to the rotational speed, and at the rated rotational speed, it was closest to the rotation frequency, but no clear relationship with the rotational speed was recognized. On the other hand, during deceleration (at the time of power OFF), the component in question near the rotation frequency instantly disappeared (refer to Fig.2).</p>	
Cause Presumed	<p>Judging from the fact that the abnormal component disappeared upon power source shutdown and that the noise was heard from the motor, the motor was assumed to be the cause. Initially, however, the cause could not be identified, so that the following investigations were conducted.</p> <ol style="list-style-type: none"> (1) Investigation of the natural frequency by means of hammering (2) Investigation on relationship between power supply frequency of the motor ($f_o=60$ Hz), its rotational speed (f_R), abnormal vibration near the rotation frequency (f_V), or frequency of beat (f_B) <p>From among these, it has become clear that the motor slip frequency ($f_o - f_R$) and the abnormal vibration frequency (f_V) have a close relationship. As a consequence, it was estimated that the motor's secondary electromagnetic force was the cause.</p>	
Analysis and Data Processing	<p>The investigation (1) revealed that the slip ring cover had a natural frequency of 62 Hz, but no other problematic natural frequencies were detected.</p> <p>In the investigation (2), the relationship between the motor load and the slip frequency ($f_o - f_R$), or the measured beat frequency (f_B) was examined (Fig.3). As is seen from Fig.3, the frequency of beat (f_B) is nearly equal to the difference between the power supply frequency and the abnormal vibration frequency ($f_o - f_V$), and substantially corresponds to about twice the slip frequency ($2 \times (f_o - f_R)$).</p> <p>It is known that if the secondary circuit of an induction motor has unbalanced impedance, the negative phase rotating magnetic field with a frequency two times the slip frequency ($-2 \times sf_o$) is produced in a rotor fixed coordinate, thus with the positive phase frequency (f_o), generating beat noise (slip-beat sound) ⁽¹⁾. This case is in agreement with this phenomenon.</p>	
Countermeasures and Results	<p>Whirl of a motor rotor also causes the impedance unbalance. As the rotor itself has a high stiffness, the countermeasures were taken mainly to increase the bearing stiffness and to enhance the roundness of stator inside. The details are as follows:</p> <ol style="list-style-type: none"> (1) Bearing gaps were reduced (105 μm \rightarrow 90 μm) and the looseness at each bearing metal was eliminated. (2) The stator inner diameter was machined. (3) Supplementary stiffening was performed by adding a support for the slip ring cover. <p>Consequently, the beat noise has been reduced to an indistinguishable level, while the abnormal vibration component has been cut to about half the rotation component, and thus the problem was solved.</p>	
Lesson Learned	<p>Motor vibration is a problem to be treated in an interdisciplinary area between the electrical engineering and the mechanical engineering, which is hard to understand, but has also been extensively studied.</p>	

References

- (1) Katayama, et al. 1965. *Induction Motors. Power Equipment Course*. Vol.3: Nikkan Kogyou Shimbun. pp. 131, pp. 244 (in Japanese)

Keyword

Forced vibration, slip-beat noise, electromagnetic force, motor, induction motor

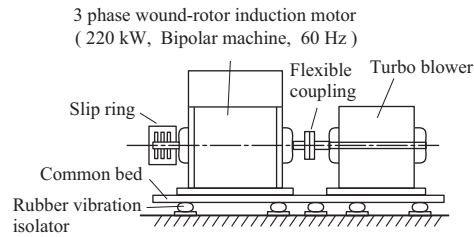
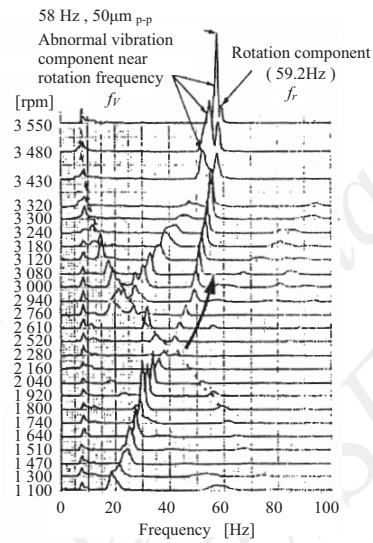
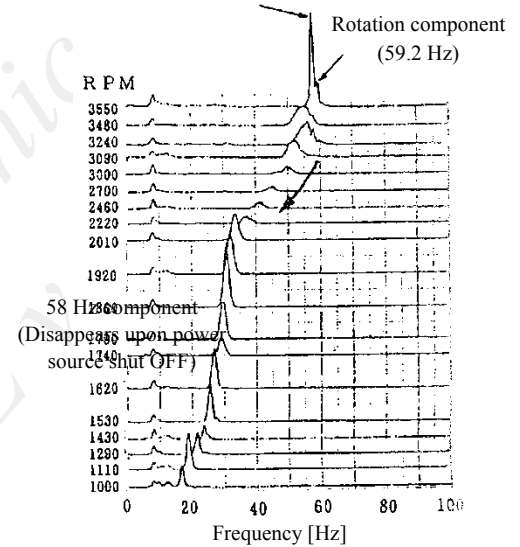


Fig.1 Turbo blower, electric motor

* Generally, $f_v \approx (1 \pm n s) f_0$
 $n=1,2,3\ldots$ is considered



(a) During acceleration



(b) During deceleration

Fig.2 Changes in vibration components near the rotation frequency during acceleration and deceleration

★ Beat due to the frequency twice the slip frequency $2sf$ is caused by unbalance in the rotor winding, bending of the rotor or eccentricity of the rotor.

(Note that

$$s = \frac{N_s - N}{N_s}$$

N_s : rotational speed of the magnetic field

N : rotor speed)

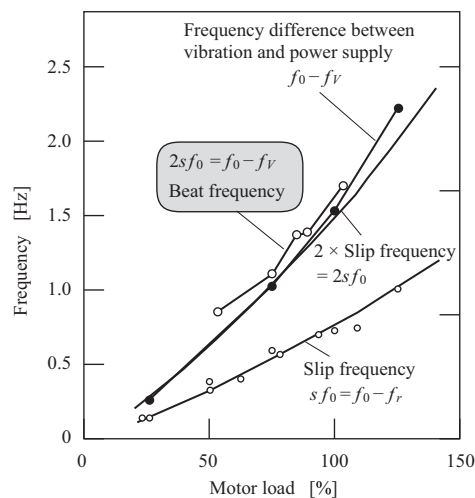


Fig.3 Changes in vibration frequency and beat frequency associated with motor load