Case History / Noise	Beat Noise due to Rolling Bearing	Rotating machinery

Object Machine

Motor driven compressor (Fig.1)

Observed Phenomena

During rated operation of a compressor, considerably big "beat noise" was generated that required reduction of "beat noise" level and also vibration. The sound pressure of the noise produced was 90 to 93 dB, and the major component was about 220 Hz, with the observable beat cycle about 1.6 to 2.2 s. (Fig.2, Fig.3 (a)).

Cause Presumed

The following two factors were conceivable for generation of the "beat noise":

(1) Factor arising from induction motor slip (electrical factor)
(2) Factor where rolling bearings were a sound source (mechanical factor)

With regard to (1), the phenomenon exhibited no change even after shutdown the power source to the motor, so that the electrical factor was considered less liable. As for (2) on the other hand, the rolling element passing frequency of the bearings used was calculated (Fig.4) and found to be near 220Hz from among various possible vibrations caused by the rolling bearings. Consequently, it was estimated that the rolling bearings would be the cause for "beat noise" generation, as the frequency was nearly equal to the major component of the "beat noise".

Analysis and Data Processing

The rolling element passing frequency was sensitive to the contact angle between the outer and inner races, as their relationship indicated in Fig.5. The rolling bearings used in this compressor were back to back angular ball bearings, whose contact angle has the following characteristics:

(1) Has a certain degree of variations in the contact angle due to machining accuracy.
(2) Slightly varies due to load variations during operation.

As a result, the rolling element passing frequencies of the two back to back bearings were produced with a slight difference in frequency, which was thought to cause "beat noise".

Countermeasures and Results

The following countermeasures were considered:

(1) To change the back to back construction.
(2) To restrain variations in contact angle by enhancing the accuracy of rolling bearings.
(3) To increase the tightening torques of back to back bearings (to apply sufficient preload to the bearings).

After taking the countermeasures (2) and (3), the "beat noise" level went down to 1/5 (Fig.3 (b)).

Lesson Learned

Use of back to back rolling bearings always has a chance for generating "beat" vibration. It is thus recommended not to employ back to back rolling bearings, if possible.

References

Toyota, T.: *How to Proceed Equipment Diagnosis*, Japan Institute of Plant Maintenance (1991) (in Japanese)

Keyword

Beat noise, back to back angular ball bearing, rolling element passing vibration

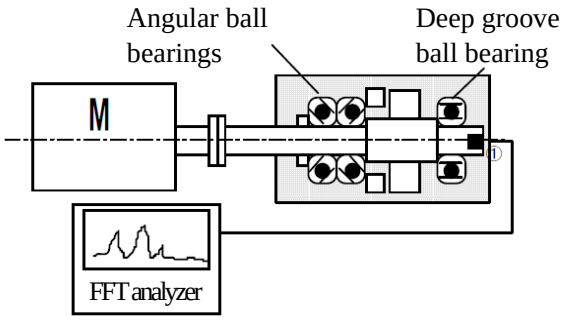

Fig.1 Motor driven compressor

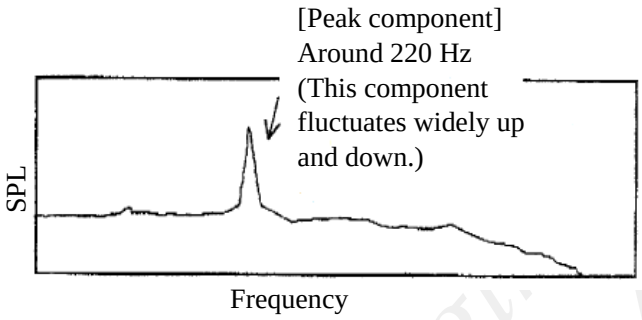

Fig.2 Result of sound pressure measurement

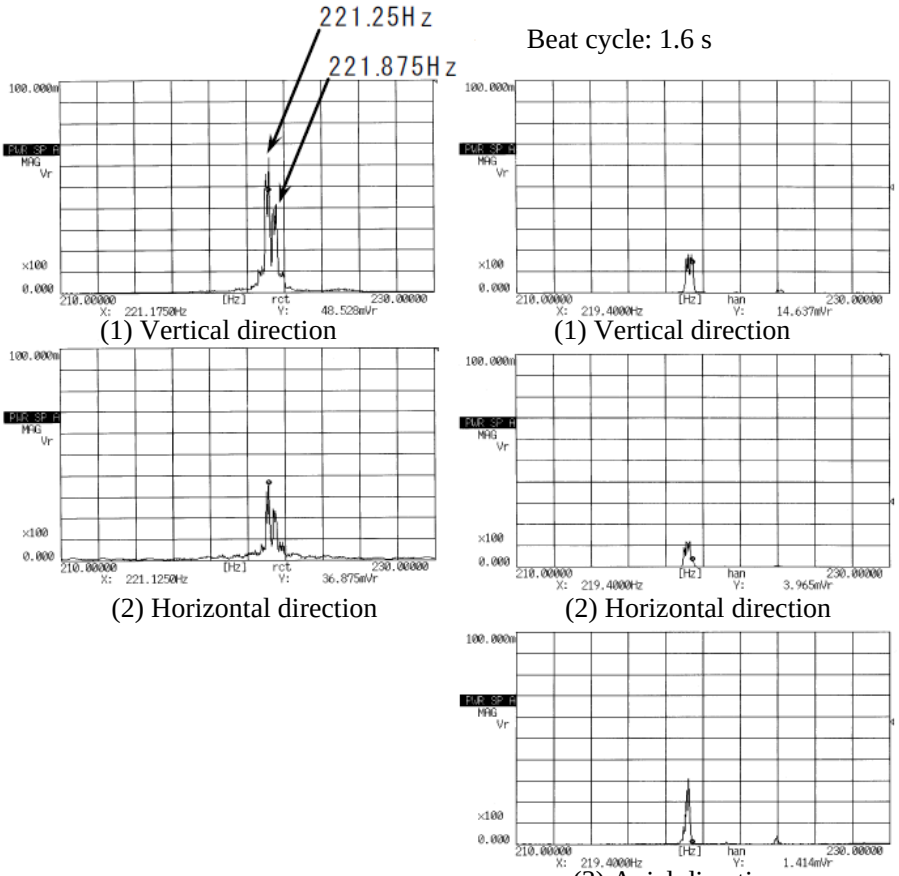

Fig.3 Measured FFT results (Peak Hold of the velocity at bearing casing)

$$f_z = z \times f_c$$

$$f_c = \frac{1}{2} f_0 \left(1 - \frac{d}{D} \cos \alpha \right)$$

f_z : rolling element passing vibration frequency (220.41 Hz)

z: number of rolling elements (11)

f_0 : rotational speed of shaft (48.75 Hz)

d: diameter of rolling element (23.81 mm)

D: pitch circle diameter of bearing (102.49 mm)

α: contact angle (40°) - design value

Fig.4 Calculated values of rolling element passing vibration frequency

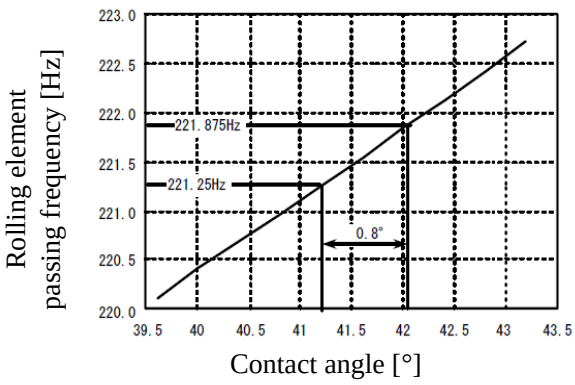

Fig.5 Relationship between contact angle and rolling element passing vibration frequency