Case History	Subsynchronous Vibration in High-Pressure Compressor
Self-excited Vibration	

Object Machine

Seventh stage centrifugal high-pressure compressor for propane, rotational speed: 10,140 rpm (169 Hz)

Observed Phenomena

During operation after delivery to the customer, the compressor experienced a subsynchronous vibration, although not a large one, with frequencies around 45 to 49 Hz. This vibration level was not large enough to immediately pose harmful effect on operation. However, the customer requested us to investigate the phenomenon because a rotor vibration alarm might be issued depending on the API standards and the plant operating conditions.

Cause Estimation

The 1st order critical speed was 50 Hz, which was very close to the nonsynchronous vibration component. Also, the 7th stage exit pressure was fluctuating with the same frequency component of the subsynchronous rotor vibration, and coherence between the rotor vibration and pressure fluctuations was about 0.7, showing a relatively high correlation. In addition, according to the site survey result, it was found that though the compressor aerodynamic design was made on the basis that the molecular weight of the working fluid was 39 as per the customer design specification provided at the design stage, the actual molecular weight was 44. As a result, there was no margin from the surge limit in view of the performance curves (QH characteristics), and thus it was considered highly probable that rotating stall occurred.
In other words, the rotating stall of two cells was observed in the single performance test of the blade type, whose frequencies were in fairly good agreement with those of rotor vibration and pressure fluctuations (45 to 49 Hz). From the excitation test performed during operation of the 1st order critical speed of the shaft system, it was also found that Q factor was as large as 50 and the shaft system itself had a small damping.
From the above considerations, it was estimated that the cause of nonsynchronous vibration was rotating stall, and that due to changes in the rotating stall vibration frequency according to plant conditions, an alarm was issued in response to amplified rotor vibrations when approaching the 1st order critical speed of the shaft.

Thus, the following two basic countermeasures were taken:

(1) Suppression of swirl by means of a shunt hole and enhancement of shaft system damping by installing damper bearings

(2) Modification of surge limit by changing the blade flow path

These countermeasures have eliminated the above-mentioned subsynchronous vibration.

Analysis and Data Processing

Fig. 1 shows spectra of the subsynchronous rotor vibration and pressure fluctuations that occurred at site. As is seen from Fig.1, the rotor vibrations had a synchronous component of rotation of 168 Hz as well as a 45 to 49 Hz nonsynchronous component. Also, the 45 to 49 Hz nonsynchronous component accounted for a majority in the pressure fluctuations.

Lesson

In light of variations in the actual machine, robust design is essential with a certain allowance against the design conditions. As for high pressure multi-stage compressors, examination of the rotor system stability, while considering the labyrinth seal excitation force and the impeller excitation force, is absolutely necessary.

References

Nothing in particular

Keyword

Nonsynchronous vibration, unstable vibration, shunt hole, damper bearing

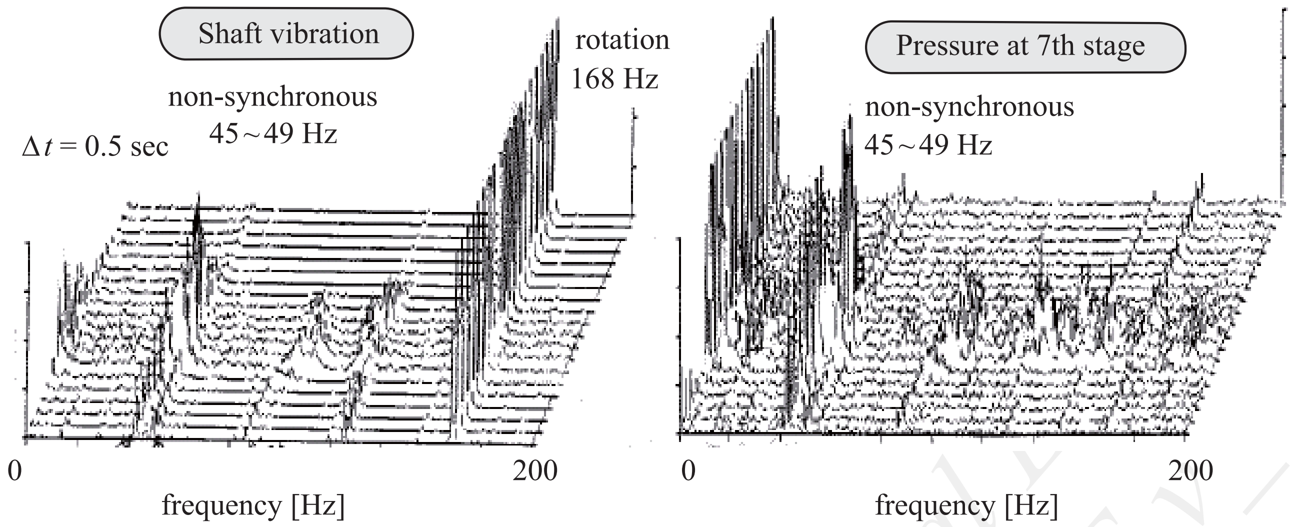

Fig.1: Spectra of rotor vibration and pressure fluctuations