Vibration Self-excitation	Unstable Vibration due to Internal Damping of Shrink Fitted Rotor	Rotating Machinery

Object Machine

Gas turbine-driven multi-stage centrifugal compressor (Fig.1)

Observed Phenomena

When a centrifugal compressor passed its critical speed, low frequency vibrations suddenly occurred, thus further acceleration of speed was made impossible. As the result of three-dimensional analysis in Fig.2, vibrations with a frequency of 64Hz first appeared after a centrifugal compressor passed its critical speed, then frequency changed to 48.8Hz and the amplitude increased. But after reducing the rotating speed, these vibrations disappeared.

Cause Estimation

In the current API standards, no critical speed lay within ±20% range of operating speed. Thus, the rotor has undercut as shown in Fig.1, and the impeller shrink fitted was adopted. Actually, this type of rotor was employed for steam turbines. Judging from the fact that the vibrations occurred immediately after passing the critical speed, that no warming-up operation was employed for the gas turbine driven rotor, and that acceleration time of rotating speed was short, it was assumed that self-excited vibrations occurred due to internal damping due to slip of the shrink fitted parts of the rotor.

Analysis and Data Processing

Calculation was made to see how the critical speed changes depending on the effective rigidity of the shrink fitted parts of the impeller and sleeve, with the results shown in Fig.3. Actual vibration frequencies and calculation ones correspond each other.

Rigidity of shrink fitted part considered: 56.8Hz ↔ 64.0Hz…rigidity of sleeve contributes

Rigidity of shrink fitted part not considered: 46.9Hz ↔ 48.8Hz…sleeve is floating

Moreover, static deflection with and without rigidity of the shrink fitted parts was calculated (Fig.4). From the above, it was judged that the sleeve could not follow the shaft deformation, thus causing slip between them.

Countermeasures and Results

As shown in Fig.5, the shaft was made straight without undercut so as to minimize the difference in static deflections according to the presence or absence of the rigidity of the shrink fitted parts, and the sleeve was made thinner. These countermeasures have prevented the occurrence of unstable vibrations, thus ensuring stable operation.

Lesson

Unstable vibrations due to internal damping, once occurred, will become very large. Thick shaft is preferrable.

References

Morii, Nishimoto, Katayama: Transaction of the Japan Society of Mechanical Engineers, No.938-3, P389

Keywords

Unstable vibration, internal damping

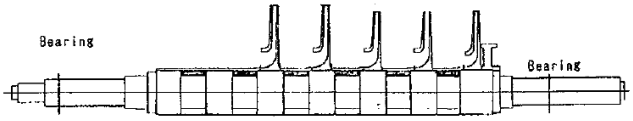

Fig.1 Multi-stage centrifugal compressor

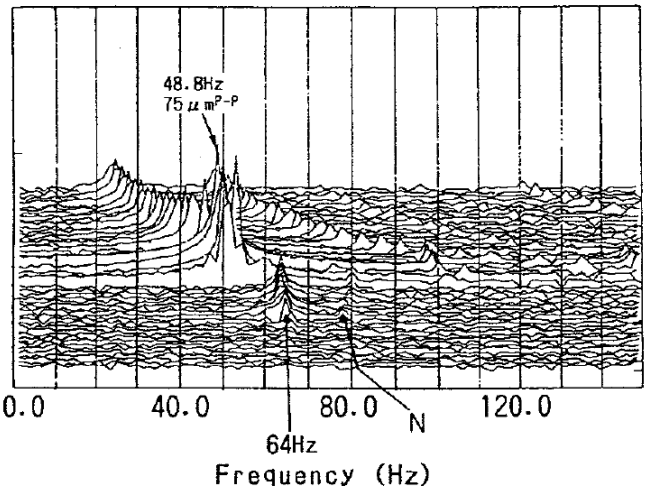

Fig.2 Result of three-dimensional analysis

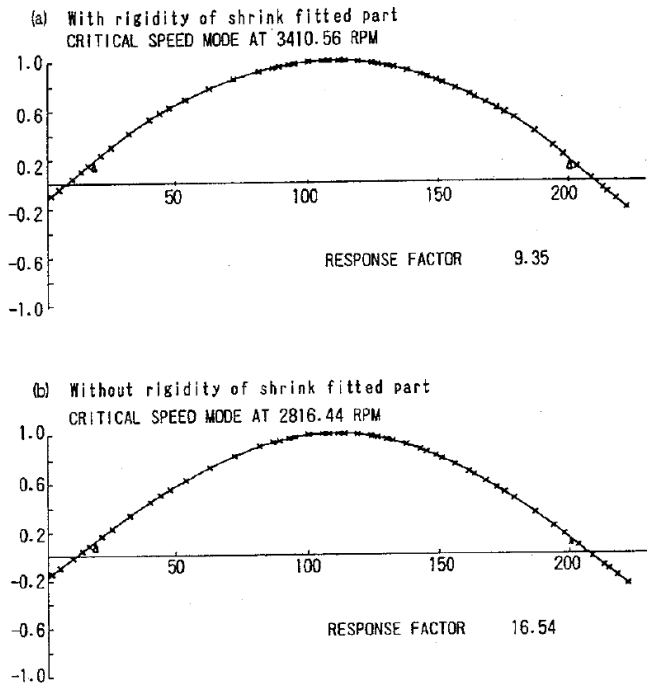

Fig.3 Influence of rigidity of shrink fit on critical speed

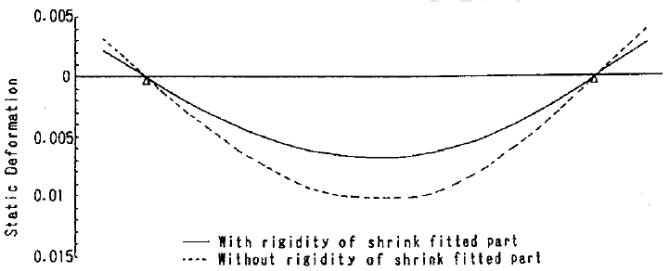

Fig.4 Rigidity of shrink fit and static deflection characteristics

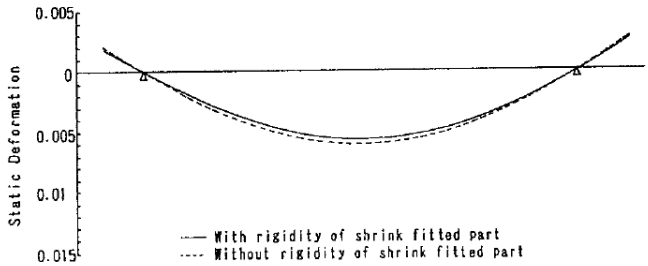

Fig.5 Static deflection characteristics of rotor after taking countermeasures