Case History / Self-Excited Vibration	Vibration due to Oil Whip of Steam Turbine	Rotating machinery (turbine & generator)

Object Machine

Power generation steam turbine 8,100 rpm 6,000 kW (Fig.1)

Observed Phenomena

During rated operation (rotating speed of 8,100 rpm, and 6,000 kW), excessive vibration occurred at 40% loads or less.

Cause Presumed

According to the report that excessive vibration occurred at reduced load under constant rotating speed, it was assessed that self-excited vibration occurred. Also based on a hearing result that circular cylindrical bearings are used, an assessment was made that this is likely to be caused by oil whip.
The basis for assessing oil whip as the cause is that changing the bearing lubricant temperature causes the load to vary at which the excessive vibration starts to occur, and also that the load at which the excessive vibration occurs by decreasing the load under a certain temperature and the load at which the excessive vibration ceases by increasing the load are different (due to hysteresis found in occurring parameters). On a later date, the phenomenon was verified by referring to wave records.
After further investigation of the mechanism of the machine, it was found that the turbine experiences partial extraction for low load. As a result of the partial extraction, the bearing load decreased, causing the journals to float up and enter the oil whip occurring region (instability region), thus possibly leading to the emergence of oil whip.

Analysis and Data Processing

Immediately after occurrence of the vibration, we rushed to the site, and the instrument available was only the machine-side vibration monitoring instrument (with the output only of vibration level). In order to verify oil whip on the basis of the above estimation, an operational proposal was made to investigate the changes in vibration by forcibly altering the lubrication oil temperature and also decreasing/increasing the load. As a result, the vibration data as indicated in Fig.2 were obtained. From Fig.2, it is observed that the load is approx. 1,700 kW for the lubricant temperature of 57°C and approx. 1,000 kW for 65.5°C, that is, the excessive vibration occurring load changes depending on the lubricant temperature, and also that the vibration occurring load and the vibration decreasing load change at 57°C, that is, hysteresis exists.
On a later date, oil whip was reconfirmed from the vibration waveforms (Fig.3).

★ Circular cylindrical bearings should not be used for high speed steam turbines.

Countermeasures and Results

As emergency countermeasures, the lubrication oil temperature causing no excessive vibration was determined and low load operation was maintained by keeping this lubricant temperature. In the meantime, bearing bushes having smaller bearing width were fabricated, and the bearing pressure was increased so as to prevent the occurrence of oil whip for the entire load range. After replacing the bearing bushes, the turbine experiences no excessive vibration for the entire load range. * The bush width was also shortened.

Lesson

Solving problems requires the full understanding of how vibration and machines are related. It is important to know the mechanism and structure of the machine, and also to hear well from the machine designers and operating staff (in other words, a person requesting the solution of vibration problems should disclose all the information to a person in charge of solving them). This is an example that there are cases to be solved without relying on sophisticated instruments, and that a quick response to the accident leads to success. The most important thing is to convince the customers fast enough.

References	Nothing in particular.
Keyword	Oil whip, steam turbine, low load, partial extraction, circular cylindrical bearing, instability region, hysteresis

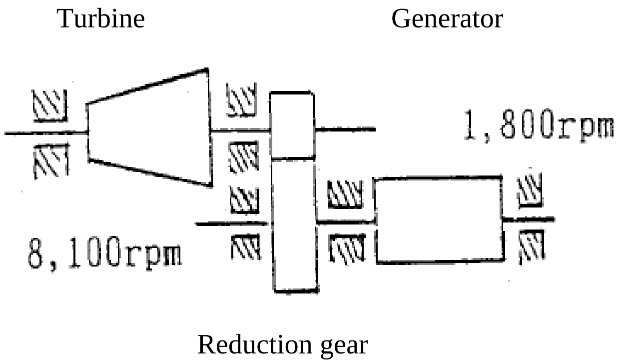

Fig.1: Steam turbine generator set
★ Bearing load requires consideration of reaction force from the gears due to load changes.

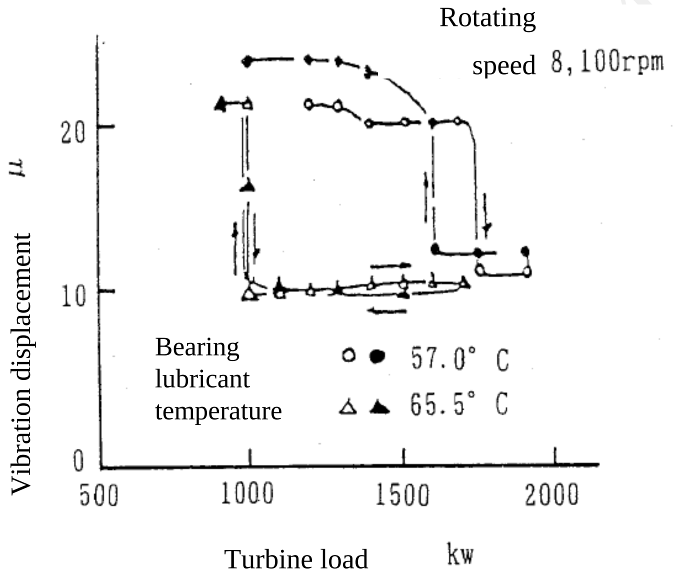

Fig.2: Relationship between turbine load and vibration

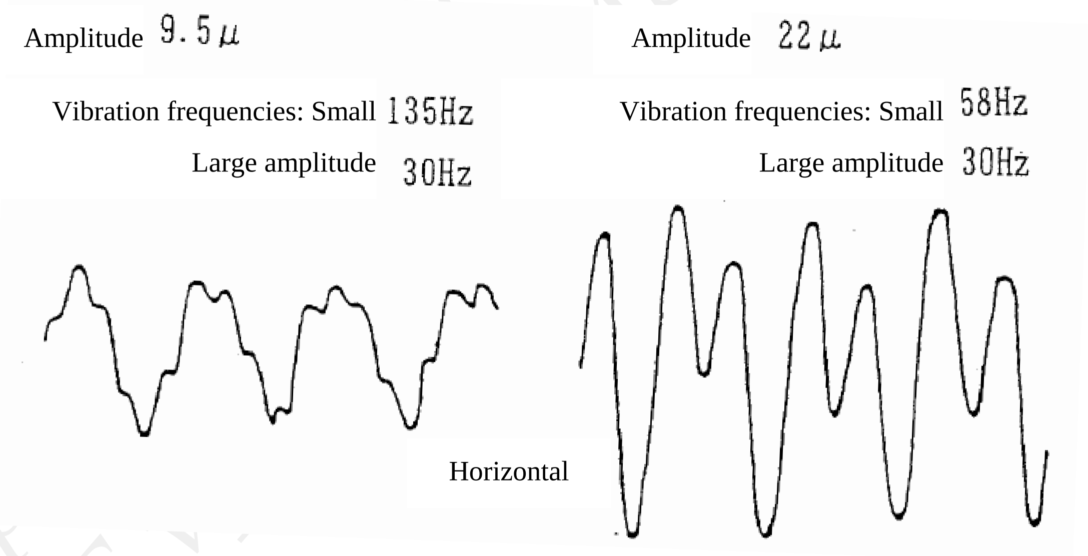

Fig.3: Vibration waveforms of turbine front bearing