Case History	Vibration due to Unbalance of Coupling	Rotating machinery (turbine & generator)
Self-Excited Vibration		

Object Machine

Power generation test turbine 100,000 rpm (Fig.1)

Observed Phenomena

As this was the first speed-up operation, the test turbine was accelerated gradually under an adequate monitoring, but at 88,000 rpm, the high speed pinion shaft experienced a sudden increase in shaft vibrations. However, after maintaining the speed for several minutes, no change in vibration was noticed.

Cause Presumed

Since shaft vibrations of the high speed pinion shaft suddenly increased and their major component was rotating speed component, it was estimated that unbalance increased at a resonance point not taken into account or due to any other reason. Thus, the calculation results were reviewed, together with checking of natural frequencies of the peripheral parts and possible causes of increase in unbalance.

As a result of overhauling of each part in search of factors for increased unbalance, no specific abnormality was identified, except for peeling off in a spotty fashion of coupling paint.

At this stage, however, as we had no confidence to identify that peeling off of paint was the cause of vibration, resonance points were checked and reconfirmation was made on the basis of calculation that there would be no resonance points around 88,000 rpm. Natural frequencies around the peripheral parts had no resonance points, either, that are likely to be the cause.

Therefore, on an assumption that the coupling was the cause, investigation was made again to clarify the following three points, and we have come to a conclusion that the cause of increased vibration is peeling off of coupling paint.

(1) Although the coupling was specified to operate at 100,000 rpm, the maximum rotating speed attained by the manufacturer was only 60,000 rpm.
(2) Single unit balancing was conducted with due care, but the test turbine was delivered after final paining was applied after balancing.
(3) The rotational acceleration on the coupling periphery was as high as 130,000 to 260,000 G, which is large enough to cause paint peel off.

Analysis and Data Processing

The test turbine is a world-class rotating machine in terms of shaft system vibration and bearing performance, with the highest rotating speed of 100,000 rpm, thus adequate review was made from the design stage.

In particular, the peaks at 71,250 rpm and 80,300 rpm during acceleration shown in Fig.5 are in fairly good agreement with the results of preliminary analysis of bending-torsion coupled vibration. As there should be no calculation-based peak at 88,000 rpm, a cause investigation was conducted after obtaining the frequency analysis result (Fig.4) on the spot.

Countermeasures and Results

After washing away all the paint on the coupling, residual unbalance on the single unit was reduced from 0.045 g·mm to 0.015 and 0.010 g·mm on both sides. As a result, the shaft vibration amplitude at 100,000 rpm was 15 μm P-P, making stable test operations possible.

Lesson Learned

Vibrations of high speed rotating machinery may be caused by unexpected reasons, thus requiring deliberate treatment to be made for high speed operation.

This is an example of increased vibrations caused by unbalance, which is one of the most classical phenomena. However, this case has problems specific to high speed rotating machinery in that the causes were "peeling off of paint due to centrifugal force" and "uneven coating of extremely thin finish paint".

This is also a special case that may not be a problem at all for general intermediate and low speed rotating machinery, but is a problem to occur naturally in view of the manufacturers' mentality to deliver their products finely painted.

References

Nothing in particular.

Keyword

High speed rotating machinery, coupling, unbalanced vibration

★ Since centrifugal force is a function of ω2, it may be a difficult task to adjust a balance weight because of too large centrifugal force of a high speed rotating body. It is thus necessary, in principle, to improve the damping characteristic of the entire system. (The use of squeeze film damper should be considered.)

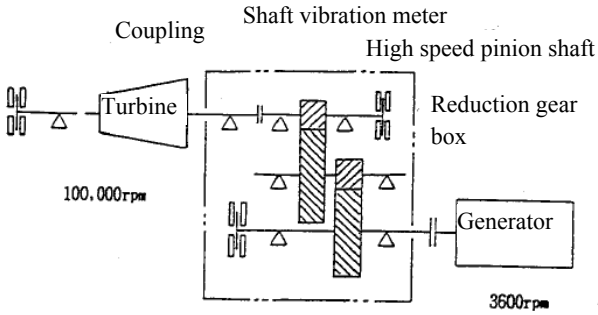

Fig.1: Generator test turbine

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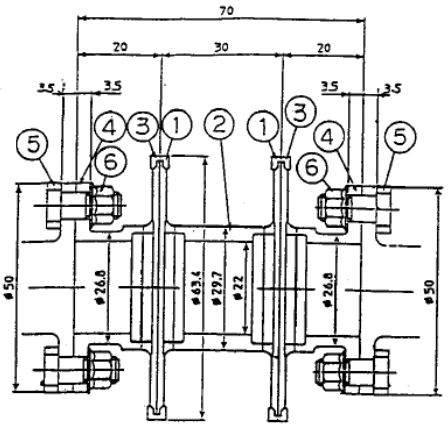
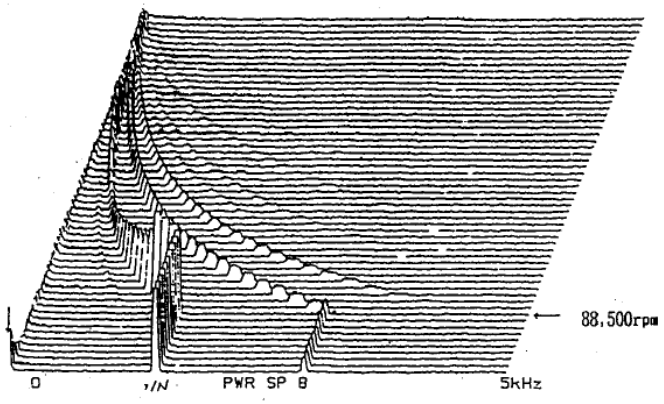


Fig.2: Flexible coupling



Frequency

Fig.3: Changes in high speed shaft & shaft vibration at top speed

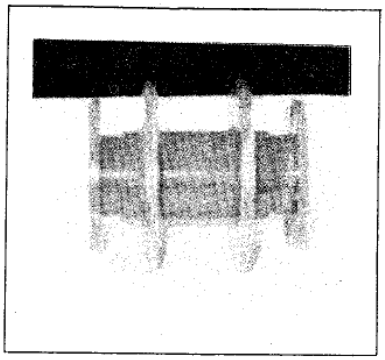


Fig.4: Photograph showing splash of paint

Peeling off of paint -> occurrence of unbalance

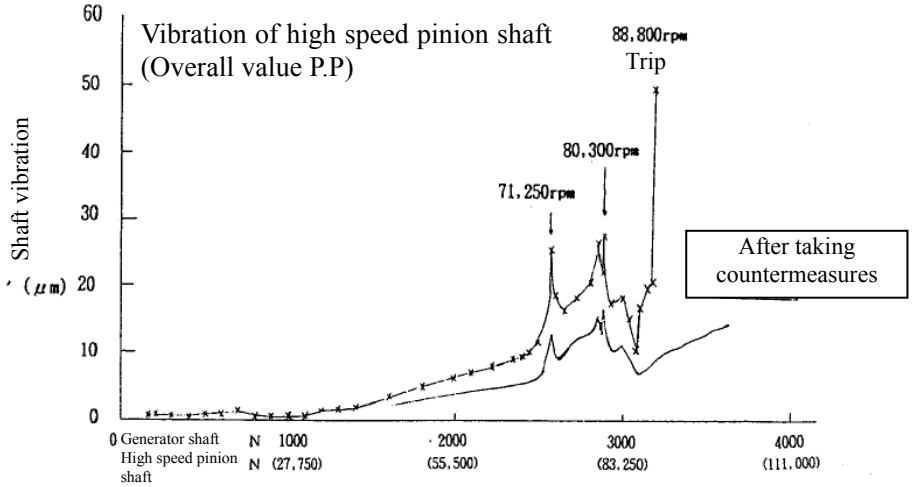


Fig.5: Vibration of high speed pinion shaft (O.A)