Case History / Resonance	Secondary Critical Speed of Centrifugal Fan	Rotating machinery (compressor)

Object Machine

Centrifugal fan (See Fig.1 for its rotor outline.)

Observed Phenomena

Around the rated speeds, rotor vibrations increased, resulting in trip. Checking of the phenomenon revealed a large portion of asynchronous component in the rotor vibration components. This fan was planned to be of an under-critical design, and also judging from the balancing test result performed during the manufacturing stage, it was not likely that the vibrations were caused by a general unbalance.

Cause Presumed

At the planning stage, the bearing support stiffness was estimated to be under completely fixed condition, but in view of the installation status, it was considered necessary to perform a re-evaluation of the bearing supports. It was fully possible that, because of an incorrect estimation of the bearing stiffness, the natural frequency of the bearing system largely differed. The bearing system had a very small damping as the ball bearing supports were employed. In addition, as the fan shaft had a keyway for impeller shrink fit, the cross section profile had an asymmetrical flatness, which was liable to cause secondary critical speed to develop.

Analysis and Data Processing

A frequency analysis was conducted of the rotor vibrations around the rated speed to examine the vibration components.
In order to check the bearing support stiffness, a hitting test was performed. A re-evaluation was made of the natural frequency of the bearing system reflecting the hitting test result.

1. The frequency analysis results confirmed that rotor vibrations arising as something like a resonance phenomenon near the rated speed (Fig.3) indicated the growing component of twice the synchronous component (Fig.4).
2. It has become clear that the natural frequency of the bearing system reflecting the bearing support stiffness (48,560 kg/mm) obtained by the hitting test corresponds to the primary 1,472 rpm, which is about twice the rated speed (750 rpm).
3. After checking the structure of the bearing system, it was understood that the fan shaft and the impellers had a shrink fit construction, and that, because of a keyway, the shaft cross section had an asymmetrical flatness (Fig.2).
4. Furthermore, at the time of system planning, the bearing system natural frequency was estimated on the basis of the bearing support stiffness being completely fixed. Thus, the planned stiffness was significantly different from the installation status.
5. In addition, results of vibration response calculations in consideration of the shaft cross section confirmed the occurrence of a peak at about 750 rpm (Fig.5).

From the above, it has been judged that the vibrations arose because the secondary critical speed of the shaft system coincided with the rated speed.

Countermeasures and Results

By means of fan shaft tuning (body slenderizing－scraping off resulting in reduction of the cross section by about 35% [Fig.2]), the shaft system natural frequency was adjusted, thus successfully reducing the vibrations near the rated speed. As per the calculations, the primary would be 1,292 rpm, so that the natural frequency was detuned from twice the rated speeds, thus avoiding the secondary critical speed (Fig.3).

Lesson Learned

In case the shaft cross section has flatness due to a keyway or else, it is necessary to design the shaft system by fully taking into account the secondary critical speed.

References

Tanuma. *Mechanical Dynamics*: Kitamori Publishing
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Keyword

Centrifugal fan, rotor vibration, bearing support stiffness, secondary critical speed, asymmetrically flat shaft

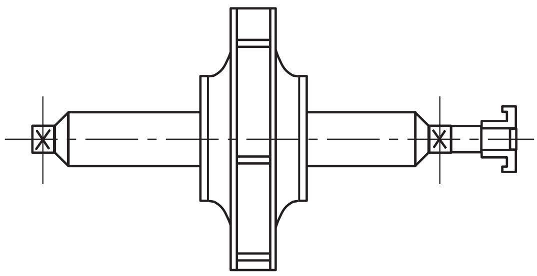

Fig.1: Rotor of centrifugal fan

★ In case of an asymmetrical shaft, excitation force due to gravity acts two times per one rotation, thus generating a frequency that is twice the rotational speed.
★ It is generally not advisable to reduce shaft stiffness. However, it may be an effective means if detuning could solve the problem.

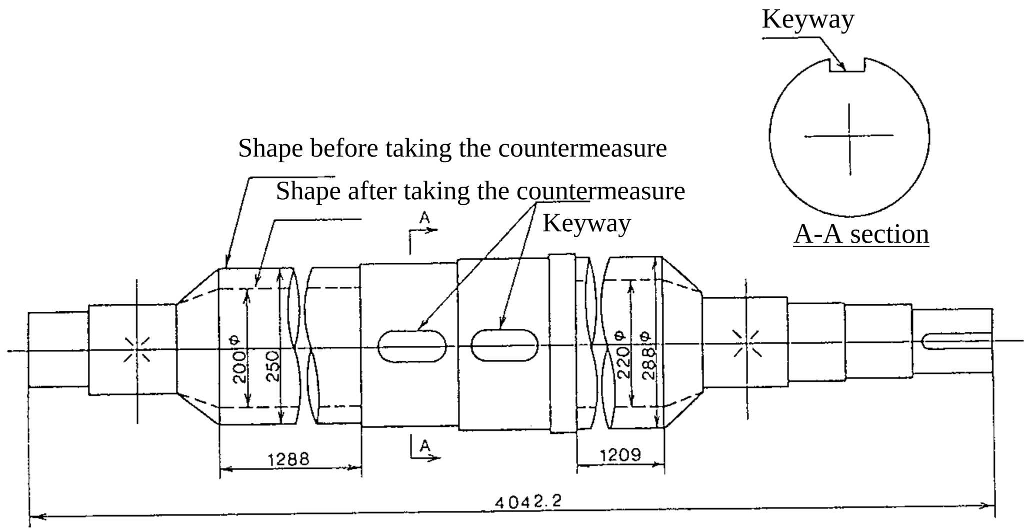

Fig.2: Shaft shape of centrifugal fan

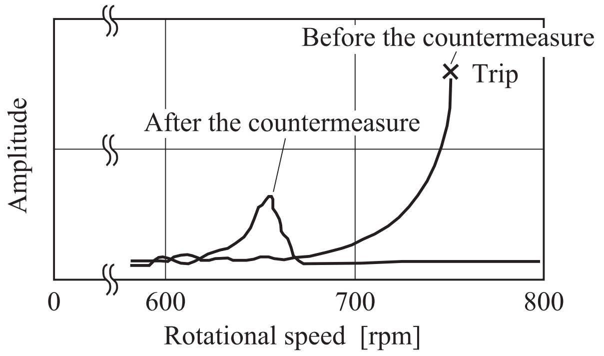

Fig.3: Result of vibration measurement

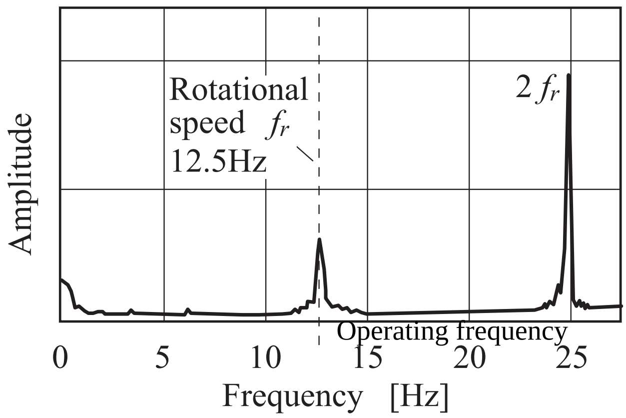

Fig.4: Result of frequency analysis upon occurrence of nonsynchronous vibration

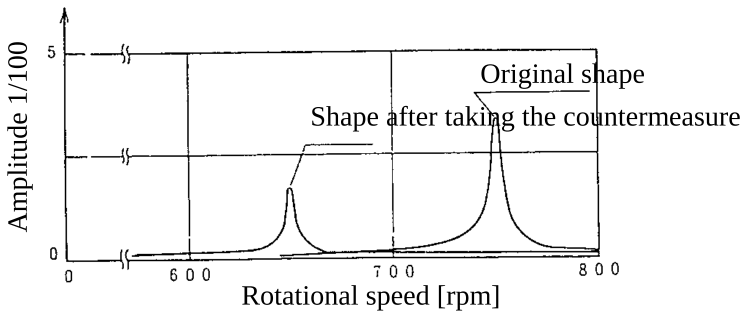

Fig.5: Result of calculation of vibration response