| Case History / Resonance | Blower Impeller Vibration Caused by Blade-Vane Interaction | Rotating machinery |
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**Object Machine**

Single-stage turbo blower
2,000 kW, 6,900 $min^{-1}$, steam turbine driven, speed control range (5,300 to 6,900 $min^{-1}$)

**Observed Phenomena**

A blower trip occurred due to excessive rotor vibration when seven years passed after commencement of operation of the blower. As a result of overhaul, it was found that one impeller was broken and other two had cracks (refer to Fig.1).

**Cause Presumed**

After checking the operating conditions, it has become clear that the operation speed was gradually increased due to facility expansion since about two years ago. Measurement of the natural frequency of the impeller blades exhibited no sign of the occurrence of resonance. Considering the fact that cracks developed simultaneously at three positions out of the 18 impeller blades, and that this blower had an inlet guide vane (hereinafter referred to as IGV) in front of the impellers, it was estimated that blade-vane interaction due to interference with this IGV was the cause (refer to Fig.2).

**Analysis and Data Processing**

Based on an FEM analysis, a natural frequency analysis and a frequency response analysis were conducted. The calculation included periodic fluctuating loads that were set with a relative phase difference between the impeller and IGV (refer to Fig.3).
Modes to generate resonance from among natural frequencies can be determined using the following equation (refer to Fig.4):

$$n \cdot Zs \pm k = m \cdot Zr$$

Zs: number of stator vanes, Zr: number of rotor blades, n: order of the rotating system excitation, k: number of nodal diameters, m: order of the stationary system excitation
The natural frequency and the rotational speed when resonating were considered as follows:
Impeller's natural frequency: 1,215 Hz
Impeller's rotational speed: 6,627 $min^{-1}$

$$n \cdot Zs \pm k = m \cdot Zr \quad \rightarrow \quad 1 \cdot 11 - 2 = 1 \cdot 9$$

Results of the frequency response analysis verified that large deformations took place on the impeller blades where defects and cracks developed in the above vibration mode (refer to Fig.5).

**Countermeasures and Results**

As an emergency countermeasure, the operation procedure was arranged so as to avoid the rotational speed causing resonance, while as a permanent countermeasure, the IGV was removed and only the rotational speed control was employed.

**Lesson Learned**

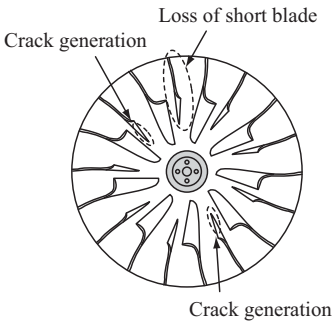
Even for blower class machines, resonance check for possible blade-vane interaction is essential.

**References**

Kubota et al. Vibration of Rotating Circular Plate with Blades due to Distributed Excitation Source on the Stationary Side. *Transactions of the JSME* (Edition C), Vol.49, No.439 (1983-3)

**Keyword**

Blower, blade-vane interaction, resonance



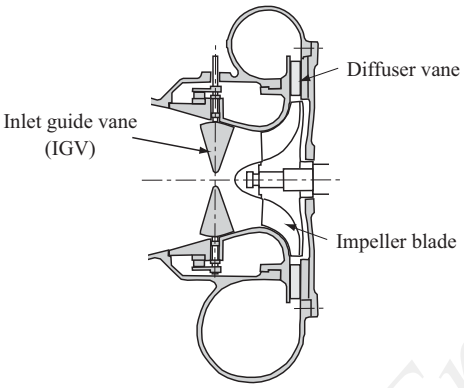




Fig.1: Condition of defects and cracks  Fig.2: Cross section view of blower

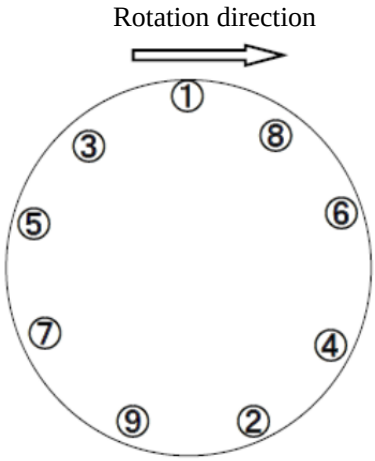



Fig.3: Order of periodic fluctuating loads

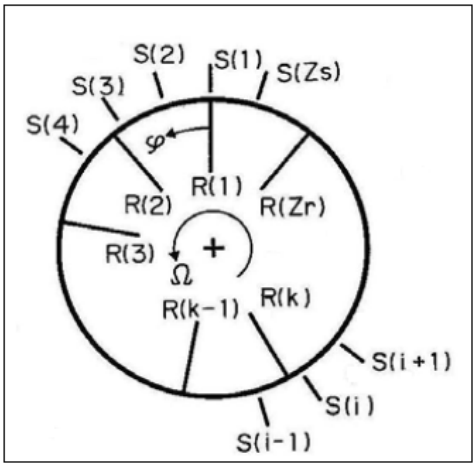



Fig.4: Chart illustrating the criterion formula of blade-vane interaction

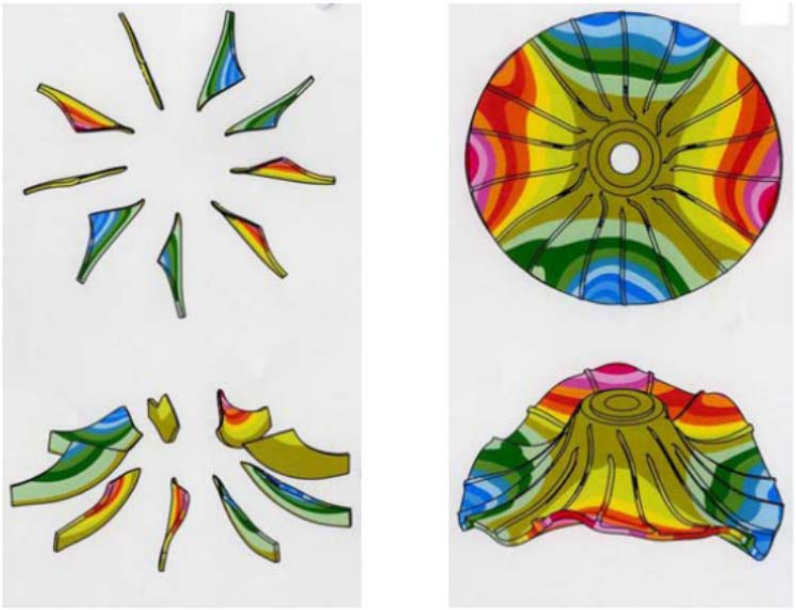


Fig.5: Deformation of blade and impeller when resonating