Case History	Modal Balancing Method of Flexible Rotor in Active Magnetic Bearings	Rotating machinery
Forced		

Object Machine

Flexible rotor in active magnetic bearings

Fig.1 shows the structure and specification of the experimental apparatus. The rotor is flexible one having the second bending critical speed Nc4 within the rated rotational speed (250 rps).

Observed Phenomena

After applying the conventional modal balancing method, the rotor passed the second bending critical speed. However, balancing was performed again because the rotor might be in contact with the protection bearings due to the following factors:

(1) The unbalance vibration amplitude at the first bending critical speed Nc3 was large (Fig.3 (4)).

(2) The vibration amplitude showed a sudden increase after passing the second bending critical speed Nc4 (Fig.4 (4)).

Cause Presumed

(1) The first bending mode balance was not sufficient.

(2) The influence of the third bending mode unbalance after passing Nc4 was not taken into account.

Analysis and Data Processing

(1) Bending first mode balance

Since the vibration amplitude of the first bending critical speed Nc3 in Fig.3 (4) was large (150 μm), the first bending mode balancing was performed again. Here consideration was given not to affect the rigid body and the second bending mode already balanced, as well as the third bending mode unbalance, and five-sided balancing was applied according to the following procedure.

● To calculate the mass ratio of correction weights.

The calculation of the mass ratio included up to the third bending eigenmode φ_5 shown in Fig.2, so as to be able to offset only the first bending mode unbalance, whose calculation results were indicated in Fig.3 (1).

● To derive the influence coefficient (influence vector).

Based on the mass ratio thus obtained, rotation tests were conducted with trial weights attached as indicated in Fig.3 (2). As a result, the vibration amplitude of Nc3 changed from A to B as shown in the polar diagram in the said Fig.3 (2). The "AB ->" is an influence vector.

● To perform balancing.

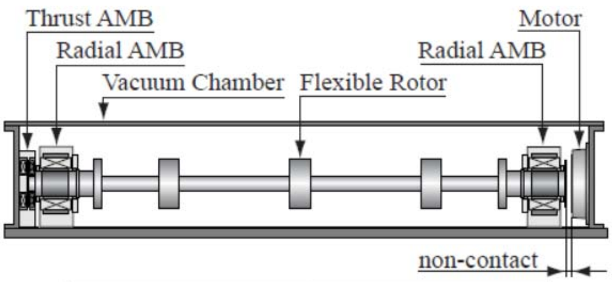
Balancing was performed by calculating the correction weights and the mounting angle so that the influence vector thus derived would turn toward the original point. After rotation tests were conducted with the correction weights mounted as shown in Fig.3 (3), only the vibration amplitude of Nc3 was able to be reduced from A (150 μm) to C (90 μm) as indicated in the polar diagram in the said Fig.3 (3) and Fig.3 (4).

(2) Third bending mode balance

By performing the third bending mode balancing at the area of the rated rotational speed (236 rps), an attempt was made to reduce the third bending mode unbalance vibration after passing Nc4.

The mass ratio of the correction weights was able to be obtained by considering up to the third bending eigenmode φ5 shown in Fig.2, which is illustrated in Fig.4 (1). On the basis of the calculated mass ratio, rotation tests were conducted using the trial weights mounted as shown in Fig.4 (2) to derive the influence coefficient. Finally, as a result of rotation tests with the correction weights mounted as in Fig.4 (3), the vibration amplitude at the rated rotational speed was successfully reduced from A (95 μm) to C (40 μm) as shown in Figs.4 (3) and 4 (4).

Countermeasures and Results	(1) As indicated in Fig.3 (4), this balancing method succeeded in reducing the unbalance vibrations for each first bending mode. (2) As indicated in Fig.4 (4), the third bending mode balancing succeeded in reducing the vibration amplitude after passing Nc4, thus allowing the rotor to reach safely the rated rotational speed.
Future Issues	In addition to performing the third bending mode balancing, studies shall be made to introduce Ncross control for reducing Q value (resonance magnification) and effort shall be made to pass the third bending critical speed Nc5.
Keyword	Active magnetic bearing, flexible rotor, unbalance, modal balancing, bending critical speed



Total mass	31.5 [kg]
External form	φ37×1310 [mm]
Rotational speed	250 [rps]
Material	SUS304

Fig.1: Structure of experimental apparatus

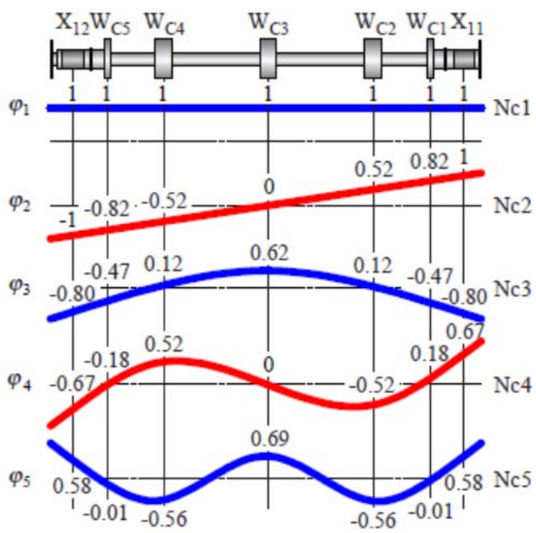


Fig.2: Eigenmodes of flexible rotor

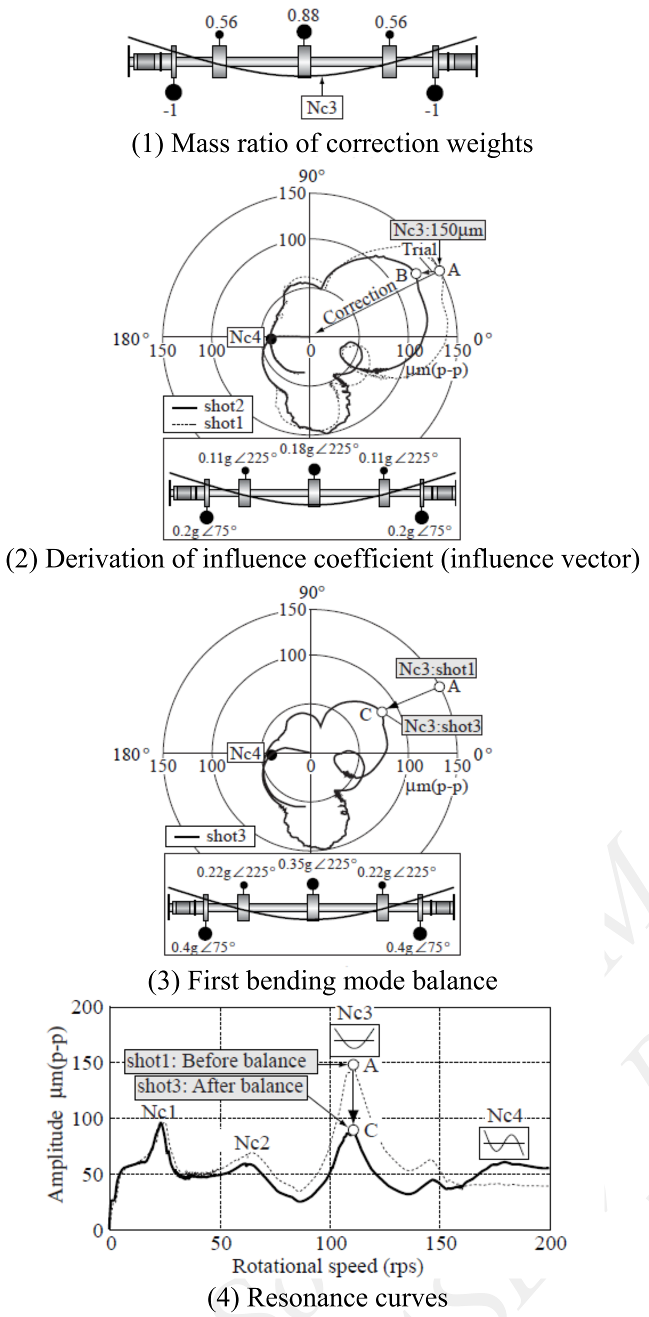


Fig.3: First bending mode balance

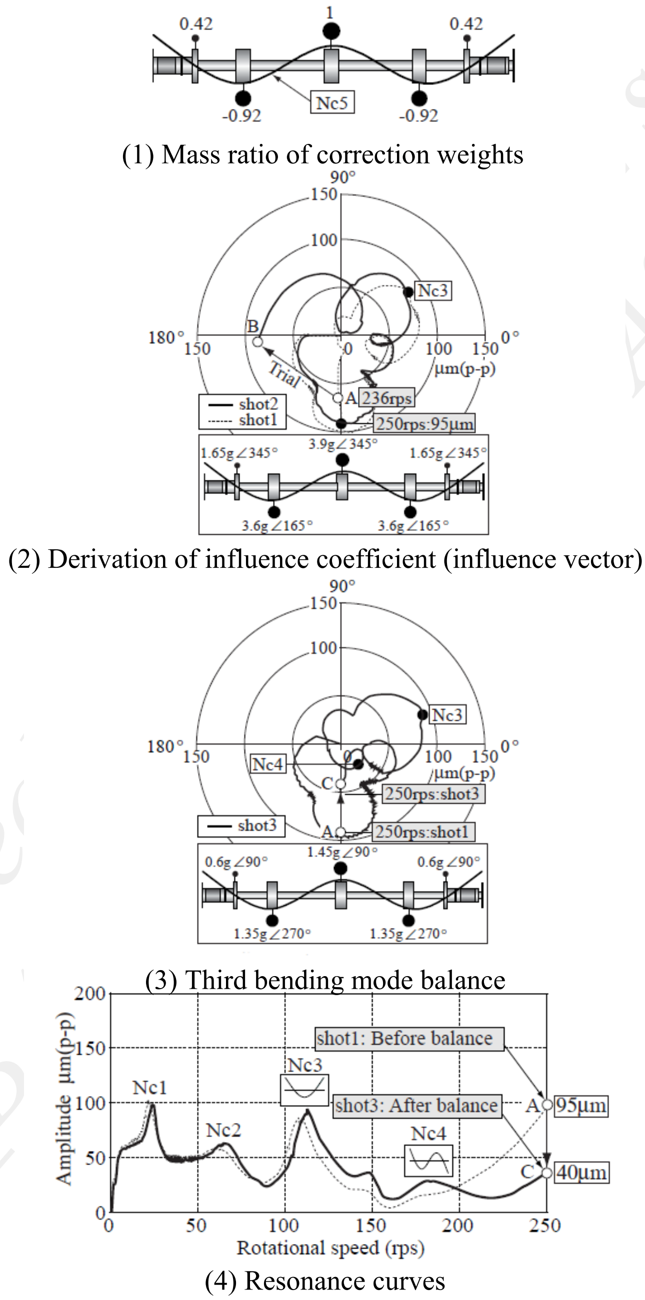


Fig.4: Third bending mode balance