

Case History	Thermally Induced Bending Vibration Experienced in High Speed Balancer	Rotating machinery
Forced Vibration		

Object Machine The object machine is an industrial compressor rotor, which has compressor impellers on both sides. Bearings (two units) are located in such a way as to support the overhung impellers, while drive pinion gears are provided at the rotor center. Overall length of the rotor is 1,450 mm, shaft diameter of the bearing section is ϕ 90 mm, the bearing span is 600 mm, and the rated rotational speed is 19,294 rpm. The bearings used are of the five-pad tilting-pad type, with a directed lubrication system (Fig.1).

Observed Phenomena When the rotor was placed on a high speed balancer (HSB) and was kept running at 13,500 rpm, periodic fluctuations were observed in the vibration amplitude of rotational frequency component. The phenomenon was remarkable particularly when in transition of speed from the deceleration to the retention state. A spiral curve appeared in the polar plot (Nyquist diagram) (Fig.2).

Cause Presumed First, it was considered that a thermally induced bending vibration was caused by contact with the stationary part. However the bearing side-seal that was the only part likely to be in contact, The rotor had no trace of such contact. Thus, it was estimated that the thermally induced bending vibration due to the bearings (Morton effect)⁽²⁾ was the cause.

* The Morton effect refers to a thermal bending phenomenon that occurs due to uneven heating (circumferential direction) of the shaft at the bearing, which does not involve contact with a stationary part. For example, when the shaft largely whirls inside the bearing, oil film tends to be thin at a location of maximum whirling (corresponding to the high (temperature) spot in the case of thermal bending by contact, hereinafter referred to as "high spot"), so that heat generation in such a location increases. As a result, thermal bending will occur. Especially in case of an overhung rotor, the Morton effect is easy to occur as the thermal bending at the bearing part and leads to a large unbalance.

Analysis and Data Processing Since the bearing of the object machine was a directed lubrication type where oil is fed from the bearing pad surface, the pad back side has a lubrication pipe, which is connected to the pad through an O ring (Fig.1). In order to see any changes when replacing such a specific type of lubrication bearing with a conventional bearing (flooded, oil tank type, Fig.3), bearing replacement was made, with the test result given in Fig.4.

Countermeasures and Results It is observed from Fig.4 that, in case of a conventional bearing, the polar diagram exhibited no vibration fluctuation for any rotational speed (19,300, 17,360, 14,500, 13,500, 13,000 rpm) maintained, and thermal bending vibration disappeared. Judging from the fact that replacement of the bearing prevents the thermal bending, the Morton effect was considered to be the cause. Therefore, replacement with a conventional one was determined as the countermeasure. The reason why the Morton effect occurred easily with the bearing before replacement was considered that since this bearing was used under a low load as in the case of a balancer, there was no sufficient force to tilt the bearing pad, so that the O ring used for connection with the lubrication pipe could not be squashed, thus resulting in the bearing pad being pressed to the shaft. As a consequence, the oil film on the high spot became thin, leading to increased heat generation and resultant thermal bending.

Lesson Learned When using tilting pad bearings under low load conditions, the bearing structure should be considered not to restrain the movement of the bearing pad (tilting mechanism).

- References**
- (1) Newkirk. B.L. "Shaft Rubbing". *Mechanical Engineering*, Vol.48, No.8, August 1926: pp.830-832
 - (2) de Jongh, F.M.; and P.G. Morton. "The Synchronous Instability of a Compressor Rotor due to Bearing Journal Differential Heating". *ASME Paper* 94-GT-35

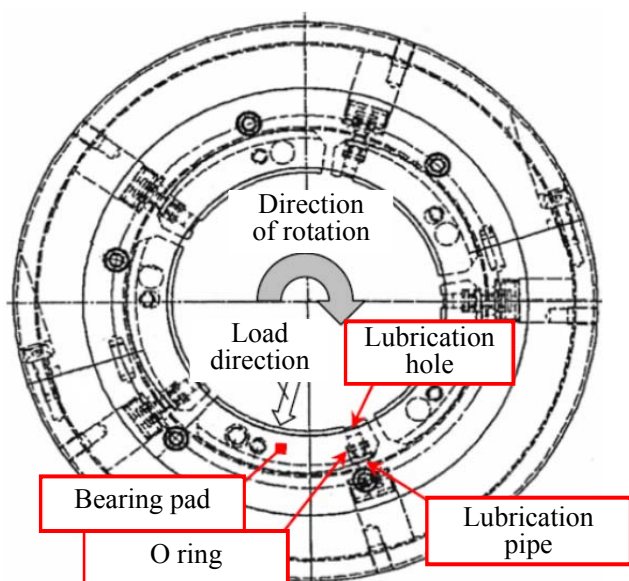


Fig.1 Bearing of the object machine (before replacement)

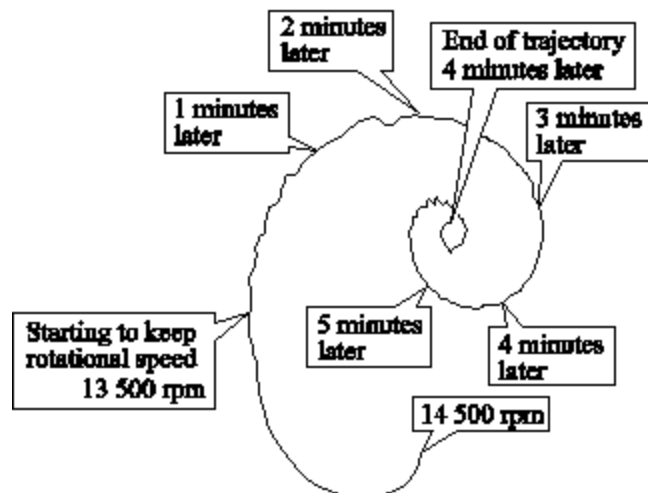


Fig.2 Polar diagram when holding the rotational speed (before bearing replacement)

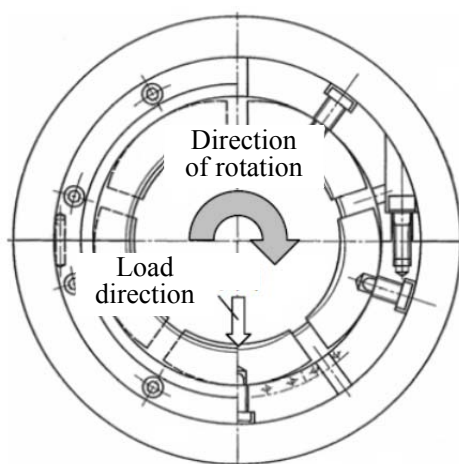


Fig.3 Bearing after replacement (conventional oil tank type)

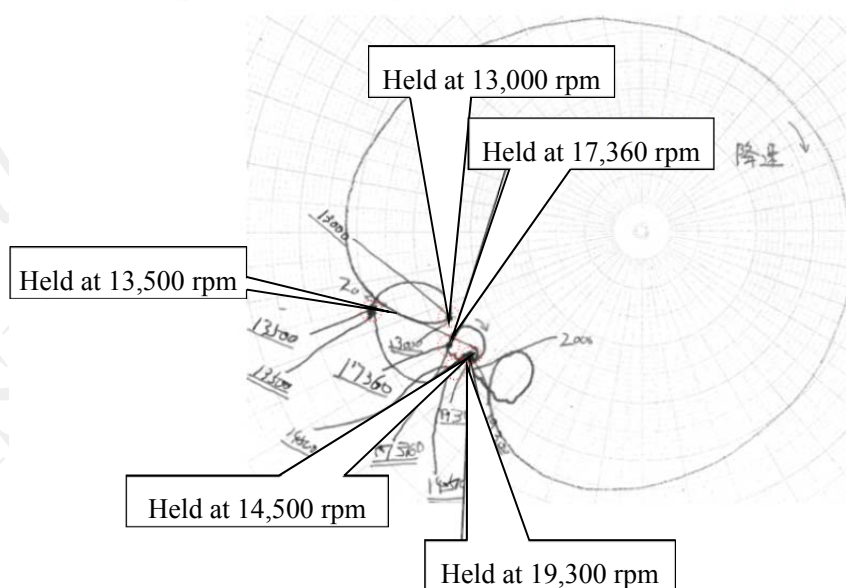


Fig.4 Polar diagram when holding the rotational speed (after bearing replacement)