Research Article

Applications of Permanent Maglev Bearing in Heart Pumps and Turbine Machine

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Earnshaw's theorem (1839) stated that no stationary object made of magnets in a fixed configuration can be held in stable equilibrium by any combination of static magnetic or gravitational forces. What will happen by a moving body like a rotating passive magnetic levitator? Nobody has given an answer until now. The author applied a self-made passive magnetic bearing to radial pump and turbine machine and found that if the rotating speed could be higher than a critical value, 3250 rpm for a pump and 1800 rpm for a turbine, the rotors would be disaffiliated from stators and keep the rotation stable. It seems that the fast rotating levitator has a so-called "Gyroeffect" which makes the passive maglev rotator stable. These results have extended Earnshaw's theorem from static to dynamic equilibrium. In static state or by a speed lower than critical value, the passive maglev rotator cannot keep rotation stable; if the rotating speed is higher than critical speed, the passive magnetic levitator will have Gyroeffect and thereby stabilize its rotation.

1. Introduction

In 1893, an English scientist named Earnshaw proved theoretically that a magnetic body cannot be supported in a stable manner in the field produced by any combination of mere passive magnetic poles [1]. This means that, it is impossible for a pure permanent maglev to achieve a stable equilibrium because the force of attraction (or repulsion) between two magnetized bodies is inversely proportional to the square of their separation (distance). In more precise words, there is no point of equilibrium between two magnets; they will attract or repel each other until they are attached together or separate indefinitely far away from each other. From viewpoint of energy, the magnetic power in passive magnetic field has no minimal value point, at which any magnetic body changes its position needs energy increase.

Things will be changed if the magnetic body moves. A rotating magnetic object, for example, has not only passive magnetic energy but also dynamic energy. Could a passive maglev rotator achieve stable rotation? The author applied a patented novel passive magnetic bearing [2] in rotary pump and turbine machine and found that the rotors of these

devices could be levitated in a stable manner if the rotating speed were high enough.

This paper presents the permanent maglev pump and permanent maglev turbine model, demonstrates the stable levitation of the rotors, and discusses the mechanism why passive maglev can be stable in dynamic equilibrium.

2. Passive Magnetic Bearings

The author's bearing is shown in Figure 1 (Bearing B), which has two passive magnetic rings with different outer and inner diameters but same thickness; the smaller ring is located beside the bigger ring concentrically and both are magnetized same in axial direction.

Compared with the available passive magnetic bearing (Bearing A in Figure 1), which consists of two passive magnetic cylinders with same length but different outer and inner diameters and the smaller cylinder is located within the bigger one and both are magnetized same in axial direction [3], the Bearing B needs smaller axial occupation and has bigger axial magnetic bearing force; besides, the Bearing B

FIGURE 1: The available passive magnetic Bearing A (a) and the novel passive magnetic bearing B (b) Comparatively, the bearing B needs smaller axial occupation but has bigger axial bearing force; more importantly, the bearing B has better stability than bearing A. The arrows indicate the direction of the magnetic field.

FIGURE 2: Schematic drawing (a) of radially driven centrifugal pump. 1-Outlet; 2-Inlet; 3-Impeller; 4-Bearing B; 5-Motor coil; 6-Rotor magnets; 7-Bearing B; 8-Hall sensors. (b) showed the rotor maximal eccentric distances (maximum ED, ordinate) by different rotating speed (abscissa). It is clear, the maximum ED will go down to less than 0.15 mm when rpm is larger than 3250, that means the rotor has no contact with stator because the gap between rotor and stator is 0.15 mm.

has better stability than Bearing A, that means the rotor with Bearing B has smaller vibration amplitude than that with Bearing A under same conditions [4].

3. Permanent Maglev Pump

A radially driven centrifugal pump used a pair of Bearing B is illustrated in Figure 2. It is composed of a motor coil and an assemble of rotor magnets, the pump impeller is fixed onto the rotor. To verify whether the rotor was levitated in the stator, 4 Hall-sensors are devised at the end of the stator evenly in periphery. The distances between the rotor and the sensors are detected by voltage differences in the sensors. Then the maximal eccentric distance (maximum ED) and vibration amplitude of the rotor are calculated. The results indicate that these eccentric distances and vibration amplitudes by use of Bearing B would be under 0.07 mm and 0.05 mm, respectively, smaller than the gap between the rotor and the stator (0.15 mm), if the rotating speed is ≥ 3250 rpm

[4]. That means the rotor had no contact with the stator, that is, it was suspended in the stator.

4. Permanent Maglev Turbine

The author's permanent maglev pump was doubted by some people who insisted that the levitation in the pump was due to hydrodynamic forces rather than passive magnetic force. Therefore, a passive maglev turbine model was manufactured (Figure 3).

The device has a levitation structure similar to the one of the passive maglev pump, but its dimension is 4 times larger than the pump. The rotor position is detected by 4-Hall sensors. The propeller (at the top of the device) is driven to rotate by a compressor. Then the rotating speed is gradually decreased. Results demonstrate that the maximum ED will be smaller than the gap between the rotor and the stator if rpm is larger than 1800, indicating the rotor has no contact with the stator; if rpm is smaller than 1800, the maximum

FIGURE 3: Passive maglev turbine model and its rotor position detection. The model has the same levitation structure as passive maglev pump, but 4- time larger dimension than the pump. 4 hall sensors detect the position of the rotor. As the propeller is driven by a compressor to rotate, then the rotating speed will gradually decrease. It demonstrates the maximal ED is smaller than gap (0.15 mm) when rpm is larger than 1800; and maximum ED will reach 0.15 mm if the rpm is smaller than 1800.

FIGURE 4: Illustration of Gyroeffect. (a) a gyro can rotate on top of the hemisphere if its rotating speed is large enough, but will go down if it is in standstill or rotates not fast. The toy Levitron (b) has same property: the small magnetic ring can rotate above the large ring if the small ring has enough speed, but will fall off if its speed decreases to certain value [6].

ED will reach 0.15 mm, that means the levitation has been broken.

5. Discussion and Conclusion

Passive maglev rotary machines have advantages of simpler structure, lower costs and more reliability compared with other maglev devices [5]. The traditional concepts exclude the possibility of passive maglev because of Earnshaw's theorem. Actually, few of the people who disregard passive maglev know Earnshaw's theorem were deduced in static status. In dynamic status, it is impossible to have a field with pure passive magnetic forces. That is to say, Earnshaw's theorem is not valid for dynamic equilibrium of passive maglev. There should be another principle to answer the question whether a rotating passive magnetic levitator can achieve a stable equilibrium and why if it can. In Figure 4 there is a gyro standing up a hemisphere. It rotates stably when it has large enough speed, but it will go down the hemisphere if the gyro rotates slowly or in standstill. Just like a Levitron [6] in Figure 4, the small ring can contact-less

rotate above the large ring when its speed is large enough; by low speed, the small magnetic ring will fall over. The magnetized direction by Levitron is different from that in the author's bearing (Figure 1), this is due to less axial occupation by later as mentioned. High speed rotating object has a so-called "Gyroeffect", which enables the object to maintain the rotation stable. Gyroeffect can be understood as a function of inertia like something following Newton's First Law, as simple as riding a bicycle: with certain high speed the rider can avoid to fall over, though theoretically a two-wheel bicycle cannot achieve stable equilibrium. People may think a bicyclist can use the steering for control, but nobody can maintain a stable equilibrium of a bike in standstill.

The critical speed between unstable to stable equilibrium may change according to the rotating inertia of the system: with larger inertia the critical speed will be lower. More extensive study is desirable.

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