A Novel PM Bearing and Its Application in Permanent Maglev Turbine Machine

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Abstract: A prototype of permanent maglev turbine machine was developed. The device has a rotor and a stator, both have two PM rings with a diagonal surface (bevel plane). All rings were magnetized axially and the rotor rings have opposite magnetized direction compared with the stator rings. Their diagonal surfaces are face to face and reject each other, producing a rejection force perpendicular to the diagonal surfaces. The rotor is suspended in such way radially and axially by these two PM bearings. First experiment demonstrated that the rotor maximal eccentric distance, measured by 4 Hall sensors, would be smaller than the gap between the rotor and the stator, if the rotating speed was higher than 1800rpm, indicating that the rotor had no contact with the stator and thus was levitated stably.

Keywords: PM Bearing, Permanent Maglev, Turbine Machine, Eccentric Distance of the Rotor

Introduction

Electric and supper conductive magnetic bearings have no mechanical friction and thus have no mechanical wear, can improve the endurance of the machines thereafter. In spite of that, their applications have been limited in industry, because of their complicity and high costs [1, 2]. Passive magnetic(PM) bearings have advantages of simplicity and low costs, need neither position detection and feed-back control like electric magnetic bearings, nor bulk cooling system as super conductive bearings, have been therefore extensively studied in high speed train and heart pumps[3,4]. Because of Earnshaw’s theory (1939), however, permanent maglev technology by use of merely PM bearings has been considered being difficult to achieve stable equilibrium, its development has been also limited [5, 6]. Investigators use thus PM bearing together with other bearings to achieve equilibrium stability [7,8].

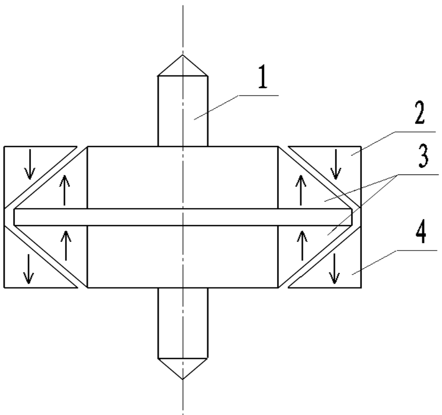
This paper presents a novel PM bearing and its application in permanent maglev turbine machine, the stable equilibrium of the suspended rotor was proved by detecting rotor position with 4 Hall sensors. This result may prompt the extended applications of permanent maglev technology in engineering.

Methods

A schematic drawing of the prototype of permanent maglev turbine machine is shown in Fig.1 (left). On the stator and the rotor, two PM bearings were devised, all the PM rings with diagonal surfaces (bevel plane) were magnetized axially, but the rotor PM rings 3 have opposite direction compared with the stator PM ring 2 and 4. These 4 PM rings are concentric with axis 1, their diagonal surfaces are face to face and reject each other, producing a rejection force perpendicular to the diagonal surfaces. The reason why the rejecting force between PM rings will be perpendicular to their diagonal surface is explained in Fig.1 (right). This rejecting force has a radial and an axial component. The rotor is suspended in such way both radially and axially by rejecting force components of these two PM bearings in 6 degrees of freedom.

The gap between two diagonal surfaces of PM rings can be used to adjust the bearing force because the magnetic force is inversely proportional to the square of the distance between two magnets: the smaller the gap, the larger the bearing force; the larger the gap, the smaller the bearing force.

The angle (0 to 90 degree) of the diagonal surfaces with the rotating axis can be designed to adjust the ratio of axial component to radial component of rejecting force between two diagonal surfaces: the larger the angle, the larger the axial component and the smaller the radial component; inversely, the smaller the angle, the smaller the axial component and the larger the radial component.



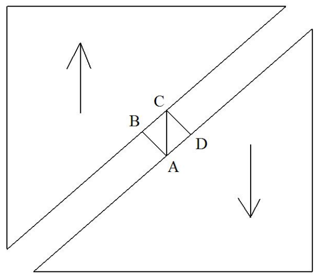


Fig.1: Schematic drawing of permanent maglev turbine machine (left). 1. axis; 2. stator PM ring; 3. rotor PM rings; 4. stator PM ring. The diagonal surfaces of the rotor PM rings3 and the stator PM rings2,4 are face to face, producing a rejecting force perpendicular to these diagonal surfaces, the rotor is supported by the components of this rejection in radial and axial directions. The right of Fig.1 explains why the rejecting force between PM rings will be perpendicular to their diagonal surfaces: according to the magnetized direction, the magnetic lines of force at point A will reject that at point C, but the magnetic lines of force at point A scatter also to point B. Because the magnetic force is inversely proportional to the square of the distance between two magnets, the rejecting force between A and B is stronger than that between A and C; the rejecting force between C and D is also stronger than that between A and C. For this reason the strongest rejection between two diagonal surfaces will be everywhere perpendicular to these surfaces.

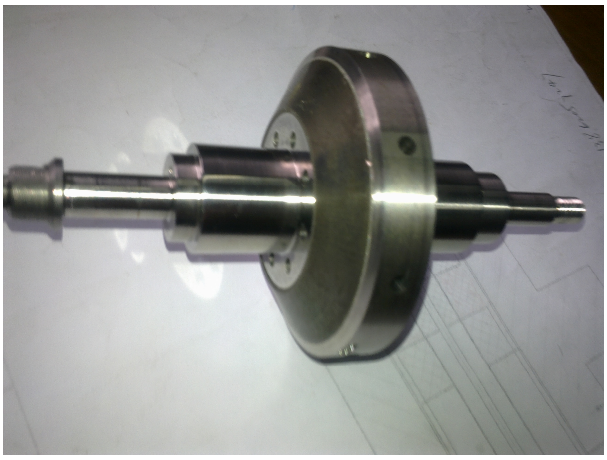


Fig.2: The rotor of the permanent maglev turbine machine.

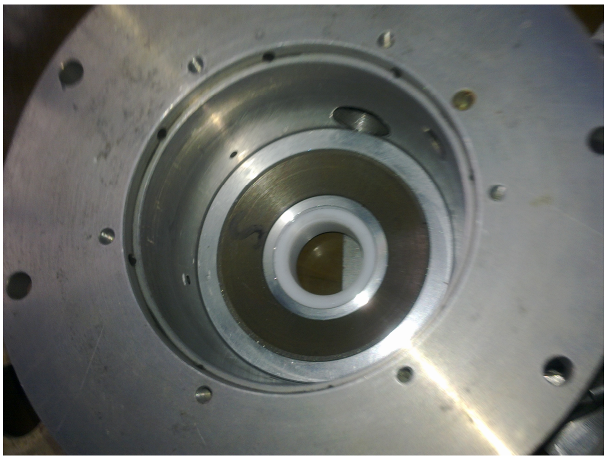


Fig.3: The stator(bottom) of the permanent maglev turbine machine.

Fig.2 and Fig.3 show the rotor and the stator (bottom) of the permanent maglev turbine machine, the stator (top) is similar to its bottom.

In order to make clear whether the rotor is really levitated stably, the rotor position was measured. 4 Hall sensors were devised evenly along the periphery of the turbine stator (Fig.4), any change of the distance between the rotor PM rings and Hall sensors will result in variations of the induced voltage in Hall sensors. After calculation by computation, the eccentric distance of the rotor can be obtained instantaneously. If the maximal eccentric distance of the rotor is smaller than 0,15mm, the gap between the rotor and the stator of the turbine machine in radius, the rotor can be considered to have no contact with the stator, that is to say, the rotor is suspended.

The wind wheel, fixed on the axis of the rotor, was blown by a compressor. The rotating speed reached over 3000rpm, then the compressor stopped and the wind wheel reduced speed gradually due to air resistance. The voltage in 4 Hall sensors was measured and uploaded together with the rotating speed into computer. The rotor eccentric distance was calculated every 4 ms and recorded.

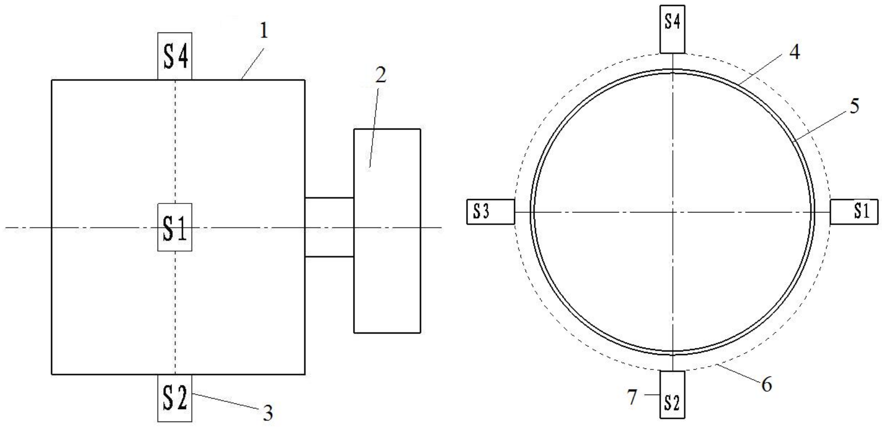


Fig.4: The rotor position, namely, the rotor eccentric distance, was detected by 4 Hall sensors, which were devised along the periphery of the stator evenly. Any change of the distance between the rotor PM rings and the Hall sensors will result in variations of inductive voltage in Hall sensors, they can computed into the value of the eccentric distances of the rotor. 1. stator; 2. wind wheel; 3. Hall sensors; 4. Internal circle of the stator; 5. Outer circle of the rotor PM rings; 6. Outer circle of the stator; 7. Hall sensors.

Results

The instantaneous eccentric distance of the rotor is shown in Fig.5. In first 500ms this value is significantly smaller than 0,15mm, the gap between the rotor and the stator. Then this value reaches 0,15mm occasionally. Meanwhile the vibration amplitude of the rotor is about 0,06mm (from 0,06mm to 0,12mm) in the first 500ms, and then it reaches 0,11mm (from 0,04mm to 0,15mm). Fig.5 indicates that the rotor has no contact with the stator in the first 500ms after moving away the compressor; that means the rotor is levitated in this period. Besides, the rotor has smaller vibration during suspension than it is not suspended.

Fig.6 exhibits the changes of rotor average eccentric distance every 4 ms and rotating speed of the rotor along with the time. Corresponding to 500ms time point the rotating speed is 1800rpm; if the rotating speed is larger than 1800rpm, the eccentric distance is smaller than 0,15mm and the rotor can be considered to be levitated. This result coincides with that in Fig.5.

Conclusion and Discussion

A novel PM bearing was applied to a prototype of permanent maglev turbine machine. This bearing has both axial and radial restore forces, the rotor of the device can be thus levitated either axially or radially. The position measurement of the rotor demonstrated that there is a minimal rotating speed 1800rpm, above which the rotor can be levitated stable. A rotator with a high speed will have a so-called Gyro-effect, which stabilized the unstable levitator [9,10]. Permanent maglev will have more extended application in industry and engineering because of its simplicity and low costs.

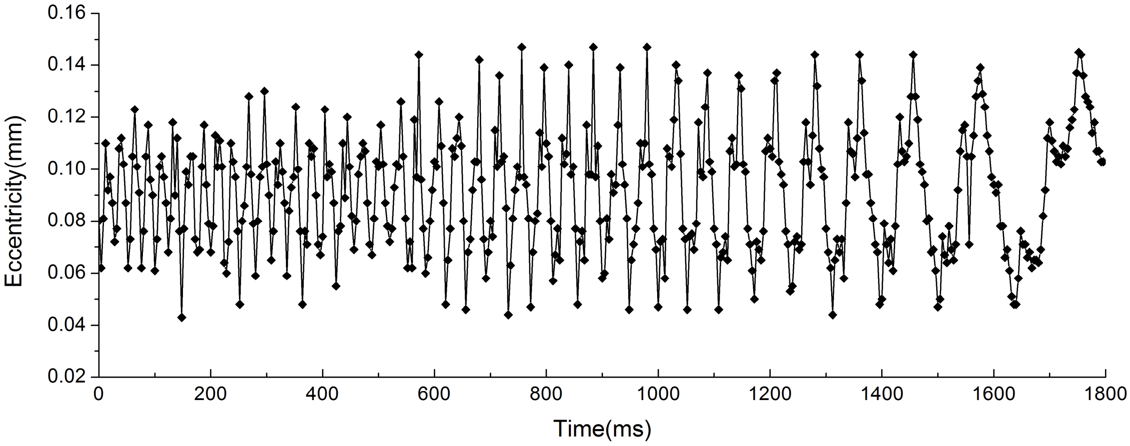


Fig.5: The instantaneous eccentric distance and vibration amplitude of the rotor. During first 500ms the eccentric distance is smaller than 0,15mm, the gap between the rotor and the stator, indicating the rotor has no contact with the stator, with another words, the rotor is suspended.

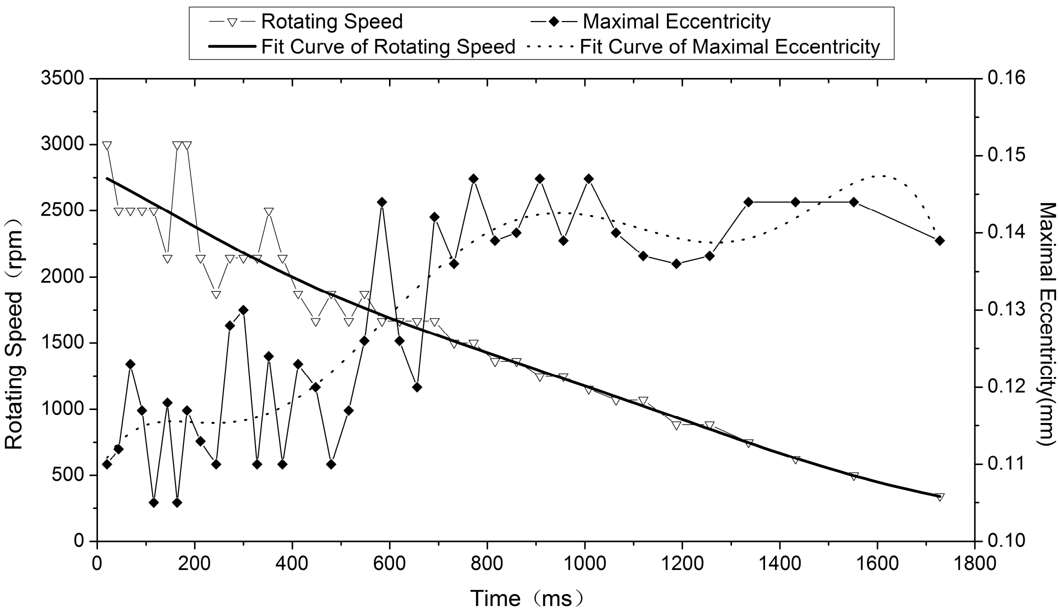


Fig.6: The average eccentric distance every 4ms and rotating speed of the rotor. At time point of 500ms the rotating speed is 1800rpm; As the rotating speed is larger than this value, the eccentric distance is smaller than 0,15mm and the rotor is considered being suspended. Therefore, 1800rpm is a minimal stable speed, above which the permanent maglev turbine is stable.

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