World-unique Permanent Maglev Turbine Reaches a Speed Over 30,000 rpm

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Abstract

The author's former works on developing a permanent maglev heart pump have been questioned because the rotor of the heart pump has only ca. 20g weight and there is liquid in the pump. To levitate a heavier rotor with passive magnetic(PM) bearing and to avoid the possibility that a fluid bearing may act on the levitation of the rotor, the author applied the passive magnetic bearing in turbine machine.

A prototype of permanent maglev gas turbine was developed. The device has a rotor and a stator, both radial and axial PM bearings were used to support the rotor weighing over 2kg. The gap between the rotor and the stator was 1mm, thereby no possible air bearing can be built up to support the rotor together with the PM bearings. First experiment by a model permanent maglev turbine demonstrated that the rotor's 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 under the action of PM bearing alone. In more extensive experiments with this prototype, the rotating speed of the device reached 30,773rpm, a value approaching that in practical application.

It can be concluded that PM bearing can merely support the rotor of a gas turbine being suspended fully and stably in the stator, same as that in blood pump; this result may overturn the principle acknowledged worldwide for hundreds years that permanent maglev could not be stable.
Key words: PM bearing, Permanent maglev, Turbine machine, Eccentric distance of the rotor

1 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.

2 Methods

A prototype of permanent maglev gas turbine was developed. The device has a rotor and a stator, both radial and axial PM bearings were used to support the rotor weighing over 2kg. The gap between the rotor and the stator was 1.0 mm in radius, thereby no possible air bearing can be built up to support the rotor together with the PM bearings. Figure.1 demonstrates a traditional radial PM bearing and a patented novel axial PM bearing developed by the author [9]. Figure.2 and 3 show the rotor of the permanent maglev turbine and it was in testing respectively.

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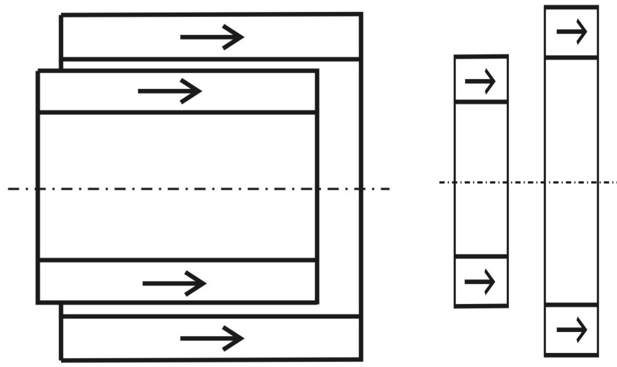

Figure 1: PM bearings used in this work: the left is a traditional radial bearing and the right is the author's novel axial bearing.

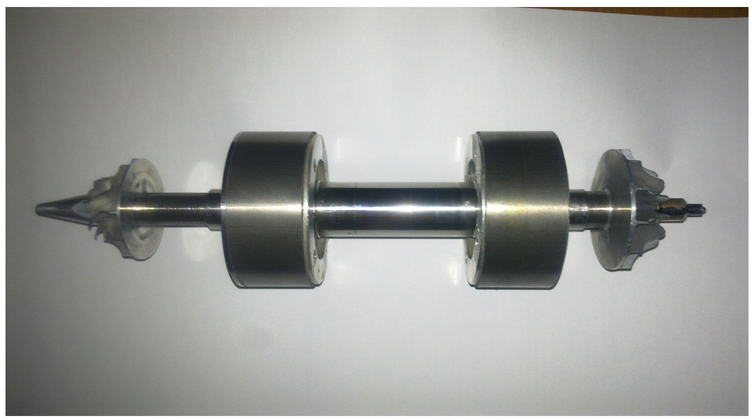

Figure 2: The rotor of permanent maglev turbine machine.

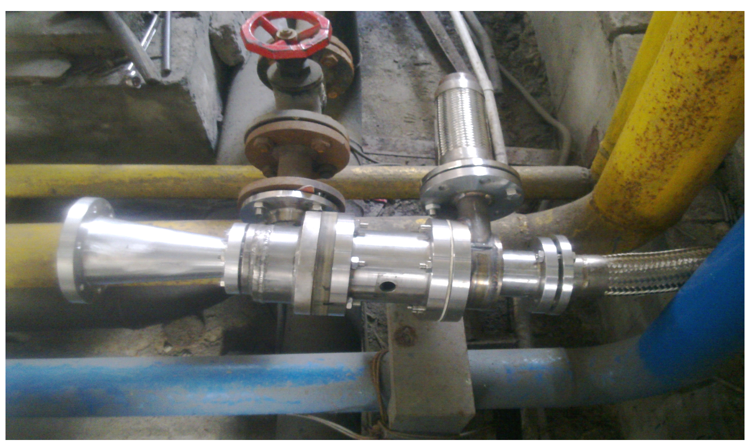

Figure 3: Permanent maglev turbine machine was in testin

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 a model turbine stator (Figure.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 0,15 mm, the gap between the rotor and the stator of the turbine machine model in radius, the rotor can be considered to have no contact with the stator, that is to say, the rotor is suspended.

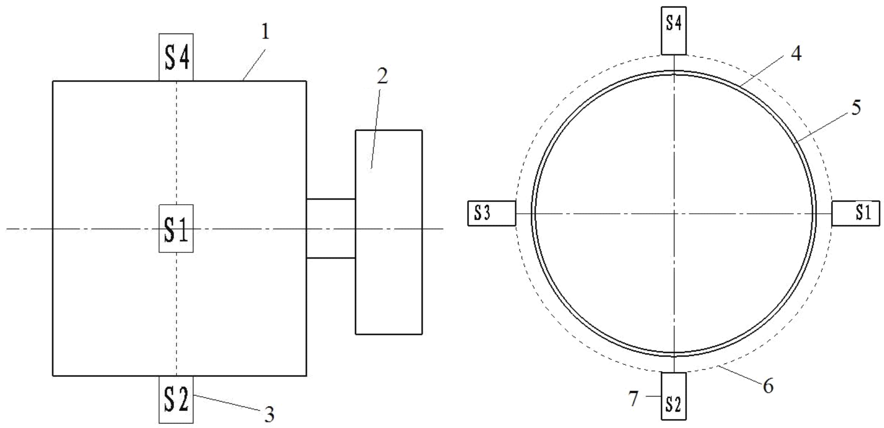

Figure 4:The rotor position, namely, the rotor eccentric distance, was detected by 4 Hall sensors, which were devised along the periphery of the stator evenly. Any change of the distance between the rotor PM rings and the Hall sensors will result in variations of inductive voltage in Hall sensors, they 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.

3 Results

The instantaneous eccentric distance of the rotor of model permanent maglev turbine is shown in Fig.5. The rotor was driven to rotate by a compressor and then the compressor was removed. In first 500ms the maximal rotor eccentric distance is significantly smaller than 0,15mm, that is, 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). Figure.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.

Figure.6 exhibits the changes of rotor average eccentric distance every 4 ms and rotating speed of the rotor along with the time. Corresponding to first 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 Figure.5.

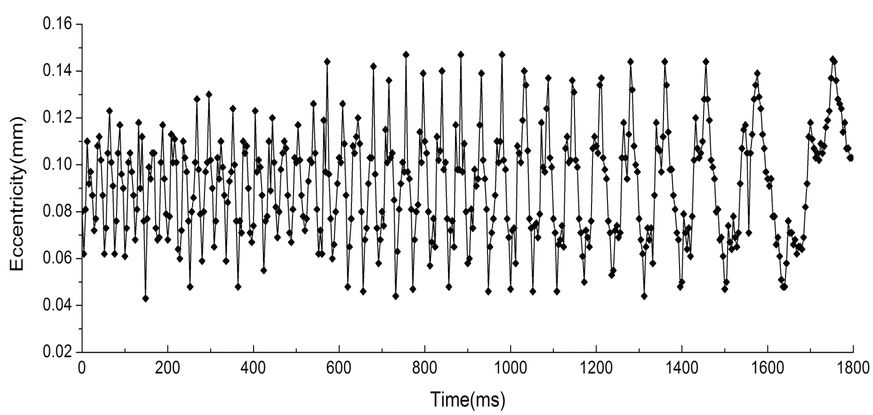

Figure 5: The instantaneous eccentric distance and vibration amplitude of the rotor. During first 500ms the eccentric distance is smaller than 0,15mm, the gap between the rotor and the stator, indicating the rotor has no contact with the stator, with another words, the rotor is suspended.

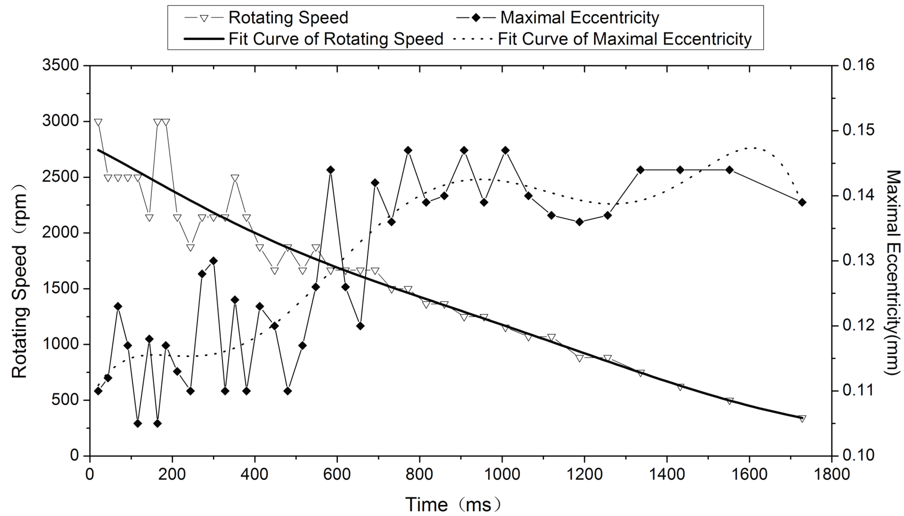

Figure 6: The average eccentric distance every 4ms and rotating speed of the rotor. At time point of 500ms the rotating speed is 1800rpm; As the rotating speed is larger than this value, the eccentric distance is smaller than 0,15mm and the rotor is considered being suspended. Therefore, 1800rpm is a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

The prototype of permanent maglev turbine was tested and its rotating speed reached 30,773 rpm, a value approaching that in practical application.

4 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 [10,11]. Permanent maglev will have more extended application in industry and engineering because of its simplicity and low cost.

References

[1] Eastham AR, Hayes WF: Maglev systems development status. IEEE Aerospace and Electronic Systems Magazine, #(1):21-30, 1988.

[2] Davey K: Analysis of an electro-dynamic Maglev system. IEEE Trans. On Magnetics. 35(5):4259-4267, 1999.

[3] Okada Y, Ueno S, Ohishi T, Yamane T, Tan CC: Magnetically levitated motor for rotary pumps. The 4th Congress of the International Society for Rotary Blood Pumps. Waseda Univ., Tokyo,Japan,August,1996.

[4] Qian KX, Jing T: Use of PM bearings in permanent maglev centrifugal pumps for stability investigation. IEEE Conference on Bio-Medical Engineering and Informatics, Vol. 2, 535-538, 2008.

[5] Earnshaw S: On the nature of molecular forces which regulate the constitution of luminiferous ether. Tran. Camb. Phil. Soc. 7, 97-112, 1839.

[6] Sinha PK: Electromagnetic suspension: dynamics and control'', IEEE Control Eng. Ser., 30, 1987.

[7] Marion-Pera M.-C. , Yonnet J.-P. , d'Heres SM : Axial bearings using superconductors and permanent magnets. IEEE Transactions on Magnetics. Volume: 31(3):2112 – 2114, 2002.

[8] Thompson M.T: Practical issues in the use of NdFeB permanent magnets in maglev, motors, bearings, and eddy current brakes. Proceedings of the IEEE. 97(11): 1758 – 1767, 2009.

[9] Qian K.X., Magnetic spring and magnetic bearing. IEEE Trans. Magnetics. Volume 91, No 1, pp559-561, 2003

[10] Qian K.X: Gyro-effect stabilized unstable permanent maglev centrifugal pump. J Cardiovascular Engineering: An International J. Mar;7(1):39-42.. 2007.

[11] Simon MD, Heflinger LO , Ridgway S.L: Spin stabilized magnetic levitation[J]. American Journal of Physics, 65: 286-292, 1997.