SUNON®

S U N O N T E C H N O L O G Y

MagLev Motor Fan

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Part I

Part II

MagLev Motor Technology
Win IEEE/IAS & CEFC Recognition

As a global leader of total thermal solution, Sunonwealth Electric Machine Industry Co., Ltd. (Sunon) has long been committed to offering nothing but the best products to the cooling industry. After investing significant funds and manpower, Sunon debut MagLev Motor Fan in the fourth quarter of 1999, the world's first-ever cooling fan are zero friction and no contact between the shaft and the bearing during operation.

Immediately following its launch, Sunon's MagLev Motor Fan became the favorite of large vendors around the world, due to its superior features such as low noise, high temperature endurance and super long life. As a cooling fan, its performance was evident from nearly 100,000,000 units being sold in its limited history, as well as orders from around the world.

In addition to receiving recognition from our customers, Sunon's MagLev Motor has its innovative underlying theory introduced to the academe in 2004, when Dr. Cheng-Tsung Liu and Dr. Tsung-Shiun Chiang - both from National Sun Yat-Sen University in Kaohsiung, Taiwan - and Alex Horng - Sunon's president - conducted a study entitled as "Three-dimensional Force Analyses of an Axial-flow Radial-flux Permanent Magnet Motor with Magnetic Suspension" to reason its superiority and published papers on IEEE (Institute of Electrical and Electronics Engineers) annual meetings.

Two papers were published on two IEEE annual meetings, including CEFC 2004 at Seoul, Korea in June 2004 and IEEE/IAS2004 Annual Meeting at Seattle, USA in October 2004, giving a comprehensive evaluation on the cooling fan in which the MagLev design was introduced. Results from actual examination were included to confirm that a motor fan consolidating Sunon's MagLev design would create a stable guidance force which absorbed the shaft in 360° direction, thereby minimizing the vibration effects that the rotor might introduce at any of its operational positions, and alleviating the radial force applied on the connecting bearing system. An adaptive magnetic equivalent circuit model was used to conduct the three-dimensional static/quasi-dynamic force analysis, deducting the result that Sunon's MagLev Motor Fan could run more stably and reliably than conventional motors did.

Recognized by engineers and scholars on the meetings, both papers ascertained how perfect that Sunon's MagLev design was and how it had contributed to the motor design. Here we recommend you to have an insight look on this innovative invention, which is well recognized by the global industry and academe.

Please see the attached for the full text papers presented by Dr. Cheng-Tsung Liu, Dr. Tsung-Shiun Chiang, and Mr. Alex Horng on CEFC 2004 and IEEE/IAS 2004 Annual Meeting.

If you have any question, please contact with sunon e-mail: sunon@email.sunon.com.tw

Attachment 1 : CEFC 2004*
-- The Eleventh Biennial IEEE Conference on Electromagnetic Field Computation
Date : June 6-9,2004 Place : Sheraton Grande Walkerhill Hotel, Seoul, Korea.
Subject : *Three-dimensional Flux Analysis and Guidance Path Design of an Axial-flow Radial-flux Permanent Magnet Motor*

Attachment 2 :IEEE/ IAS 39th Annual Meeting**
Date : October 3-7,2004 Place :Weatin Hotel, Seattle, Washington, USA
Subject : *Three-dimensional Force Analyses of an Axial-flow Radial-flux Permanent Magnet Motor with Magnetic Suspension*

Note: *CEFC 2004 web site : http://www.cefc2004.com
**IAS 39th web site: http://ewh.ieee.org/soc/ias/ias2004/index.htm

Three-dimensional Flux Analysis and Guidance Path Design of an Axial-flow Radial-flux Permanent Magnet Motor

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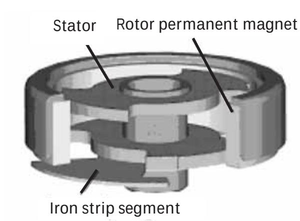
Abstract - This paper will provide a detailed field analysis of a specially designed axial-flow radial-flux permanent magnet motor for cooling fan applications. By implementing an iron strip segment at the stator base, this motor can provide a stable guidance force in its axial direction, such that the operational vibrations can be minimized and the undesired forces applied onto associated bearing system can be reduced. Supported by dynamic magnetic circuit modeling and three-dimensional finite element analysis, the motor operational fluxes and forces will be analyzed. Results showed that excellent performance and enhanced reliability objectives can all be achieved by this motor.

INTRODUCTION

The axial-flow radial-flux permanent magnet motor along with an iron strip segment, as shown in Fig. 1, has been developed for small-power cooling fan applications [1]. This motor is equipped with only one set of axial stator winding that can supply the desired radial flux through adequate stator pole design, and such structure design is quite promising for applications with limited spaces. With the undesired vibration forces mainly generated in the motor radial direction, the concept is to provide adequate flux path such that a passive magnetic suspension can be established.

An adaptive magnetic equivalent circuit (AMEC), as shown in Fig. 2, has been devised to provide a convenient and accurate mathematical model for the associated performance evaluations at all operational conditions. Supported by 3-D finite element analysis results as shown in Fig. 3, the satisfactory performance and flux guidance effects of the motor can be demonstrated. Results obtained from the AMEC, as shown in Figs. 4 and 5, clearly illustrated that the motor can provide a smoother torques and larger axial forces with same power inputs compared with those without ion strip segment implemented.

(a) Photograph of the stator base.



(b) Conceptual structure of the motor.

Fig. 1. An axial-flow radial-flux permanent magnet motor with a stator iron strip segment.

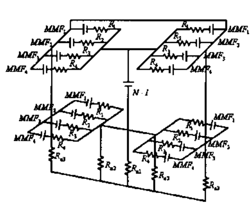


Fig. 2. Magnetic equivalent circuit of the axial-flow radial-flux permanent magnet motor.

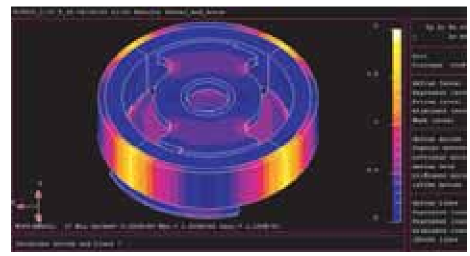


Fig. 3. Operational flux densities at the motor with rated input applied.

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[1] A. Horng, Direct current brushless motor of radial air-gap , US Patent No. 6,538,357, Mar. 2003.

[2] M. Moallem and G.E. Dawson, An improved magnetic equivalent circuit method for predicting the characteristics of highly saturated electromagnetic devices, IEEE Trans. Magn., vol. 34, no. 5, Sept. 1998, pp. 3632 3635.

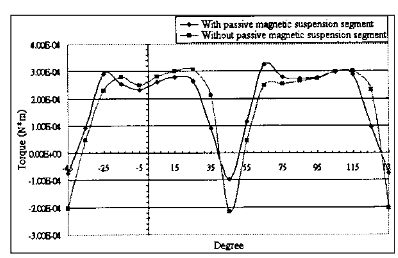

Fig. 4. Operational torques of the motor with rated source inputs.

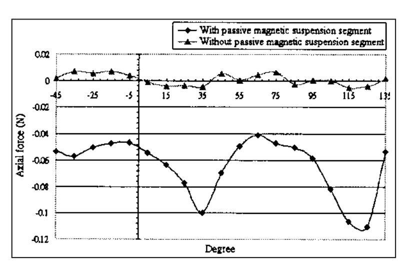

Fig. 5. Axial forces generated onto the rotor permanent magnets.

Three-dimensional Force Analyses of an Axial-flow Radial-flux Permanent Magnet Motor with Magnetic Suspension

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Abstract - This paper will provide a thorough evaluation of a specially designed axial-flow radial-flux permanent magnet motor for cooling fan applications. With a passive magnetic suspension segment implemented, the design objective of this motor is to provide a stable guidance force in its axial direction, such that the vibration effects at the entire rotor operational positions can be minimized and the net radial forces applied onto associated bearing system can be alleviated. Supported by dynamic magnetic circuit modeling and static/quasi-dynamic three-dimensional finite element analyses, the operational forces of such motor, either with or without magnetic suspension, at its respective radial, axial, and tangential directions will all be evaluated. Results show that the motor, which being implemented with a low-cost passive magnetic suspension segment, can supply excellent operational characteristics and thus enhance the operational reliability

Keywords- Adaptive magnetic equivalent circuit; finite element analysis; operational vibration; permanent magnet motor.

I. INTRODUCTION

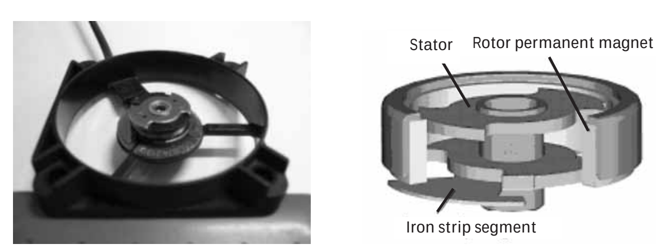
The axial-flow radial-flux permanent magnet motor along with a passive magnetic suspension segment, as shown in Fig. 1, has been developed for small-power cooling fan applications [1]. This motor is equipped with only one set of axial stator winding that can supply the desired radial flux through adequate stator pole design, and such flat structure is quite promising for applications with limited spaces.

As can be observed from Fig. 1(b), the magnetic fluxes generated from the motor stator winding will first flowing through its stator center shaft, getting out of the stator pole pairs at its top/bottom part, and then coming back to the bottom/top part stator pole pairs after passing through the corresponding rotor magnets. With the pole pairs on the stator top and bottom parts being perpendicular to one another, undesired vibration forces mainly generated in the motor radial direction will be exhibited. The resultant frictions applied onto motor bearing system will certainly generate extra heat and energy losses, and thus reduce the reliability and lifetime of this motor.

This work is supported in part by the National Science Council of R.O.C. under NSC 92-2213-E-110-052 and the Sunonwealth Electric Machine Industry Co., Ltd.

The major concerns on cooling fan motor manufactures are low construction/maintenance cost and high operational reliability [2]. In addition to satisfy these construction prerequisites, it is also desired that the overall performance of such motors can preserve their market competitions without implementing complicate sensor and driver control devices. To achieve the aforementioned low cost and simple/reliable structure objectives, as illustrated in Fig. 1(b), the design concept of installing a passive magnetic suspension segment directly on the stator bottom part of the motor has been proposed in one of the commercialized products [1]. This design idea has claimed that a magnetic suspension will be established through the extra flux path being provided. Though it is anticipated that the attraction force between the rotor permanent magnet and the passive magnetic suspension segment will be induced to stabilize the rotor vibrations, intuitively it is also suspected that this segment with high permeability might yield the motor rotational performance.

To evaluate the overall performance of this axial-flow radial-flux permanent magnet motor and investigate the effects contributed from the generated axial force, with and without the passive magnetic suspension segment being implemented, a thorough system electromagnetic field analysis is essential. In addition to the three-dimensional (3-D) finite element analysis (FEA), this paper will present an adaptive magnetic equivalent circuit (AMEC) which can provide a convenient and accurate mathematical model for the related performance evaluations at all of the operational conditions.



(a) Photograph of the stator base. (b) Conceptual structure of the motor.

Fig. 1. An axial-flow radial-flux permanent magnet motor with a stator passive magnetic suspension segment.

II. Modeling The Axial -flow Radial-flux Permanent Magnet Motor System

By referring to the 3-D structure of the motor system as shown in Fig. 1(b), due to the stator pole shape, the cross-sectional view of the motor along with a magnetic equivalent circuit illustrating part of its stator and rotor regions are depicted in Fig. 2. Therefore, based on the physical structure and geometric symmetry of the motor, without the passive magnetic suspension segment, the entire system magnetic equivalent circuit is illustrated in Fig. 3(a). To provide a convenient and accurate mathematical model for the associated performance evaluations at all of the operational conditions, the relative reluctances and magnetomotive forces in the magnetic equivalent circuit must be continuously adjusted according to the rotor positions. Such an adaptive magnetic equivalent circuit (AMEC) can be systematically devised, with the flux flowing through the stator center shaft being expressed as [3]:

$$\varnothing_c=\varnothing_{th}+\frac{NI}{R_{th}} \qquad (1)$$

$$\text{with } \varnothing_{th}=2\left\{\frac{MMF_1}{R_{a1}}+\frac{MMF_2}{R_{a2}}+\frac{MMF_3}{R_{a3}}+\frac{MMF_4}{R_{a4}}\right\} \text{ and}$$

$$1/R_{th}=1/+R_{a1}1/+R_{a2}1/+R_{a3}1/+R_{a4}$$

Among which it can be observed that NI is the applied stator winding magnetomotive force, and the branch reluctance R_{ai}, i= 1~4, is a rotor position dependent function, which can be calculated using the common expression: $R_{ai}=(lai / \mu \text{ ai Aai})$. By referring to Fig. 2 and assuming that the permeability at machine stator and rotor cores are much larger than that at the air gap, it is obvious that the averaged air-gap lengths $l_{a1}= l_{a2}$, $l_{a3}= l_{a4}$, and $l_{a1}> l_{a3}$. While the averaged area of each branch, A_{ai}, i= 1~4, can be determined by the rotor radius and the corresponding arc spanned at different rotor positions. The equivalent magnetomotive force of permanent magnet at each branch, MMF_i, i= 1~4, can be determined by the intersection of material magnetization curve and the operational load line. In here if the thickness of the permanent magnet is l_m, due to structure symmetry, a general assumption that the branch magnetomotive force will be fully applied to its corresponding reluctance can be made, hence the operational load line can be expressed as [4]:

$$\frac{B_m}{H_m}=-\frac{l_m}{A_m R_{ai}} \qquad (2)$$

As for the passive magnetic suspension segment, which being implemented at the bottom part of the stator, it is expected that extra flux paths will be produced. As the air gaps among stator and rotor poles are comparable shorter than the distance between the rotor and the passive magnetic suspension, a reasonable assumption that the major interaction contributed from the rotor permanent magnet will be still taken place among the stator and rotor can be made. The added elements, which can represent the effects of the passive magnetic suspension segment, along with their circuit connections to the original AMEC are thus illustrated in Fig. 3(b).

With all of the magnetic circuit elements and their adaptive scheme being defined, the associated flux and flux density at every branch of the motor system can be derived. Thus, by using virtual works and assuming magnetic linearity, the system coenergy, $W_c(r, s, z)$, at different rotor positions and stator magnetomotive forces can be systematically calculated from the AMEC as:

$$W_c\,(r,\theta,z)=4x\sum_{i-1}^{4}W_{ci}+W_s, \qquad (3)$$

$$\text{with } W_{ci}=\frac{1}{2\mu_0}\int_{r_i}^{r_i+l_{ai}}B_i^2\cdot A_{ai}\,dr=\frac{1}{2\mu_0}\int_{r_i}^{r_i+l_{ai}}(\varnothing_i^2/A_{ai})dr, \text{ and}$$

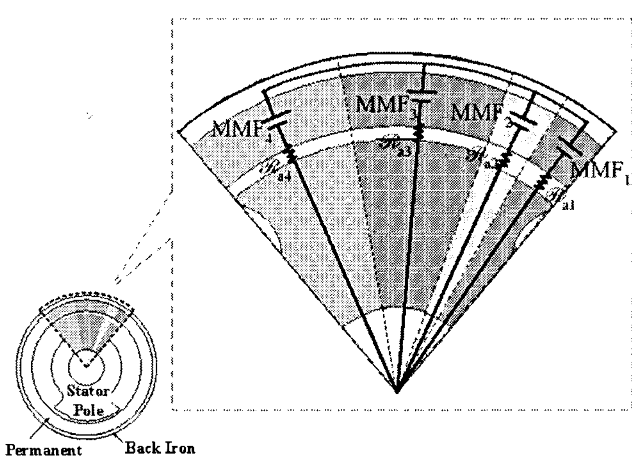
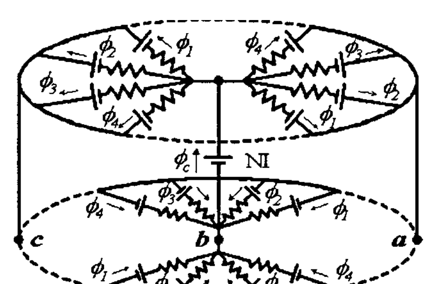
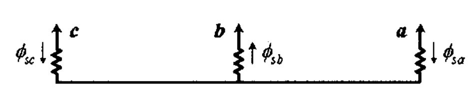


Fig. 2. Cross-sectional view of the motor system and part of the magnetic equivalent circuit representation.



(a) Without the passive magnetic suspension segment implemented.



(b) Extra circuit elements to represent the passive magnetic suspension segment implementation.

Fig. 3. The magnetic equivalent circuit of the axial-flow radial-flux permanent magnet motor system.

$$W_s=\sum_{j=a}^{c} W_{sj}=\sum_{j=a}^{c}\frac{1}{2\mu_0}\int_{hj}^{hj+zj}(\phi_{sj}^2/A_{sj})dz.$$

Hence the related motor electromagnetic forces and torque can then be expressed as:

$$Fr(r,\theta,z)=\lim_{\Delta r\to 0}[(Wc(r+\Delta r,\theta,z)-Wc(r,\theta,z))/\Delta r],$$

$$Te(r,\theta,z)=\lim_{\Delta\theta\to 0}[(Wc(r,\theta+\Delta\theta,z)-Wc(r,\theta,z))/\Delta\theta],$$

$$Fz(r,\theta,z)=\lim_{\Delta z\to 0}[(Wc(r,\theta,z+\Delta z)-Wc(r,\theta,z))/\Delta z]$$

In which $Fr(r,\theta,z)$, $Te(r,\theta,z)$, and $Fz(r,\theta,z)$ are respectively the radial force, the electromagnetic torque, and the axial force of the motor system.

III. 3-D Field Analysis and Verifications

To verify the convenience and adequacy of the devised AMEC, a thorough 3-D finite element analysis (FEA) will be performed. By using a commercialized software package [5] and setting appropriate operational conditions, the 3-D finite element meshes of the motor system is depicted in Fig. 4. The physical dimension of the motor is provided in Table I, and the selected mesh sizes of Fig. 4 are illustrated in Table II. The magnetic material used for constructing the stator is H60 with a relative permeability of 6,000, while the material for rotor permanent magnet is bonded ferrite.

By applying a magnetomotive force of 30A t to the stator winding, without the bottom passive magnetic suspension segment, the flux paths of the motor system are depicted in Fig.

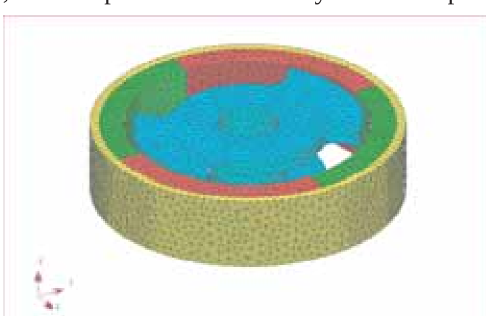


Fig. 4. 3-D finite element meshes of the axial-flow radial-flux permanent magnet motor.

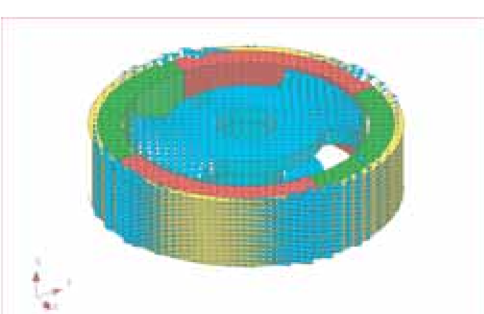


Fig. 5. Magnetic flux paths of the axial-flow radial-flux permanent magnet motor at one rotor position.

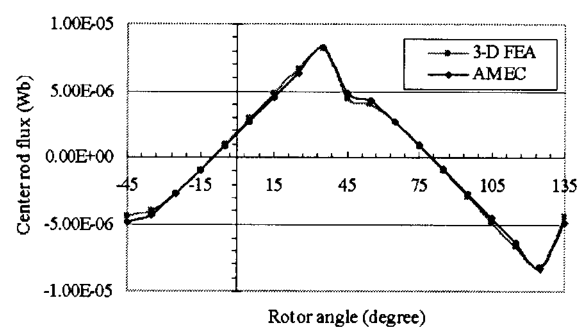
TABLE I
PHYSICAL SIZES OF THE AXIAL-FLOW RADIAL-FLUX PERMANENT MAGNET MOTOR SYSTEM

Symbol	Sizes	Parameter Descriptions
L_s	15.0mm	diameter of stator pole
W_s	10.0mm	diameter of stator axis
H_s	1.0mm	thickness of stator pole
P_s	80^o	stator pole arc
P_s	20^o	arc of the stator truncated pole
L_s	14.5mm	diameter of the stator truncated pole
D_c	4.0mm	inner diameter of stator center rod
L_c	0.5mm	thickness of stator center rod
H_c	4.8mm	height of stator center rod
D_r	15.8mm	inner diameter of rotor
H_r	4.8mm	height of rotor
L_m	1.6mm	thickness of rotor permanent magnet
L_b	0.6mm	thickness of rotor backiron

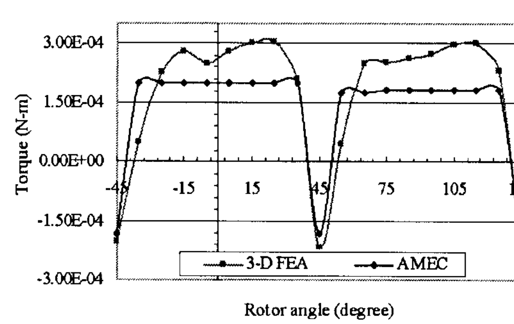
TABLE II
SELECTED MESH SIZES FOR 3-D FEA OF THE MOTOR SYSTEM

Subdomain	Mesh Sizes
outer boundary	5.0mm
outer air	4.0mm
interior air gap	0.2mm
stator pole	0.5mm
rotor permanent magnet	0.5mm
rotor backiron	0.5mm

5. A thorough study has been performed based on both the 3-D FEA and the AMEC schemes, and the flux flowing through the motor center shaft with different rotor positions, as well as the total generated electromagnetic torque of the motor system is depicted in Fig. 6 for comparison. Obviously, from these



(a) Flux ϕ_c at the stator center rod.



(b) Electromagnetic torque T_e.

Fig. 6. Calculated center shaft fluxes and total electromagnetic torques of the motor system with different rotor positions.

investigation results, a reasonable assumption can be made that the AMEC scheme will provide an accurate enough analyzing results in the averaged basis with small enough rotor increment angle. Therefore, it is confident that the predicted operational performance as derived from the AMEC scheme will supply a convenient and satisfactory index for evaluating the overall steady-state characteristics of the motor.

Since the major factor for motor operational vibration is contributed from the unbalanced radial forces applied to the rotor bearing, by using the AMEC and 3-D FEA schemes, the net radial forces of the motor system when the rotor rotates to different positions have been systematically analyzed. These net forces are calculated by subtracting the generated rotor radial forces at certain angles with the ones being 180^o mechanically apart. Fig. 7 depicts the schematic diagram that has been used to calculate the net radial forces of the motor system with the rotor rotates to a reference angle of 0^o, and the resultant net forces are illustrated in Fig. 8. Theoretically, if there is no vibration effect, the net radial force of the motor at every rotor position must all be zero.

IV. EFFECTS OF THE PASSIVE MAGNETIC SUSPENSION SEGMENT

To alleviate the vibration effects at operations, such that the motor overall reliability can be enhanced and the lifetime can be extended. By implementing a passive magnetic suspension segment at the stator base of the motor, the extra cost compared to the total construction expense of the motor is negligible. While for the motor operational performance, with and without the passive magnetic suspension implemented, the generated electromagnetic torques of the motor are first provided in Fig. 9 for comparison. It can be observed that though slightly more severe notches will be occurred when the rotor being rotated to the positions with negative torque generations, the two torque patterns are closed enough in the overall averaged point of view.

As for the net radial forces of the motor system, with the same operational conditions as that shown in Fig. 8, the generated electromagnetic forces are illustrated in Fig. 10 for comparisons. At first glance, it is obvious the passive magnetic suspension segment will not behaved as the design objective, but will even deteriorate the already exhibited net radial forces. As for ideal case, the net radial forces applied to all the rotor positions must be all zeros. By taking the standard deviations as the statistical indices, the summarized results of the net radial forces at different rotor angles are provided in Table III. The results still showed that a passive suspension segment will provide an up to about 30% larger net radial force to the motor system.

However, for the generated axial forces of the motor system,

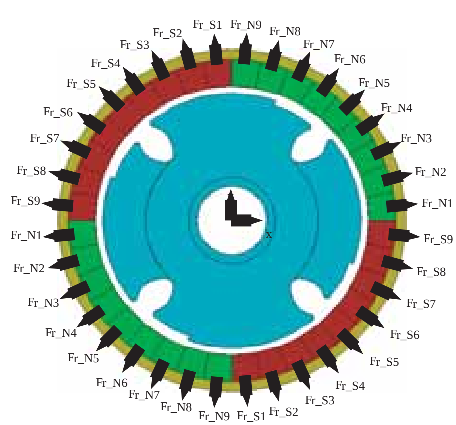


Fig. 7. Schematic diagram for calculating the net radial forces of the motor system with the rotor located at a reference angle of 0^o

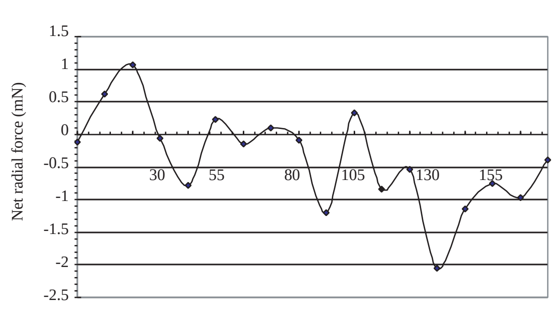


Fig. 8. Calculated net radial forces applied onto the rotor at a reference rotor angle of 0^o.

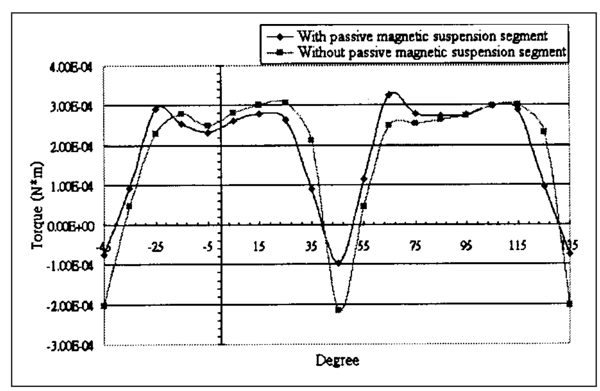


Fig. 9. Calculated total electromagnetic torques of the motor system with different rotor positions.

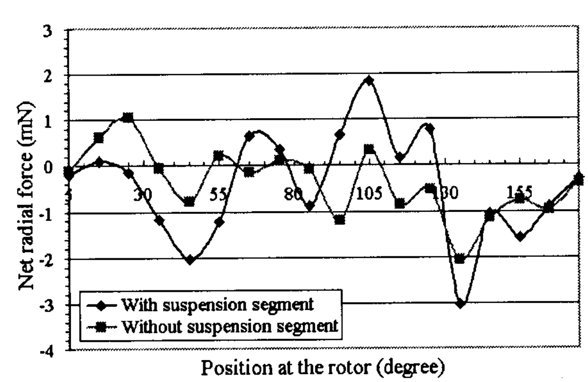


Fig. 10. Calculated net radial forces applied onto the rotor with/without the suspension segment implemented at a reference rotor angle of 0^o.

as can be clearly observed from Fig. 11, the additional attracted forces contributed from the passive magnetic suspension segment are clearly illustrated. Since these induced axial forces are in the negative z direction, and they are in the orders of about 50 times of the motor radial forces, the combined force vectors in the motor radial directions will be insignificant. From such observations, the effects of those extra flux paths among the rotor and the passive magnetic suspension segment will supply adequate guidance forces to stabilize the motor operations are evident.

V CONCLUSION

The operational characteristics of an axial-flow radial-flux permanent magnet motor, with an extra passive magnetic suspension segment implemented on its stator base, for cooling fan applications have been thoroughly investigated. The adequacy and convenience of using the proposed AMEC scheme for continuous/dynamic motor system performance analysis have been verified by 3-D FEA. By introducing extra axial forces to guide the motor rotation with alleviated radial force, the analyzing results clearly illustrated the effects of motor operational stability enhancement through the implementation of passive magnetic suspension segment.

ACKNOWLEDGMENT

The authors wish to express their gratitude to the valuable technical suggestions from Mr. W. Wu and W. Chen of the Sunonwealth Electric Machine Industry Co., Ltd.

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[4] C.-T. Liu and K.C. Chuang, "On the design of a disc-type surfacemounted permanent magnet motor for electric scooter application," in Proc. IEEE IAS 37th Annual Meeting, vol. 1, Pittsburgh, PA, U.S.A., 2002, pp.377-383.

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TABLE III
STANDARD DEVIATIONS OF THE NET RADIAL FORCES AT DIFFERENT ROTOR REFERENCE ANGLES

Degree	Without Iron Strip Segment	With Iron Strip Segment
0	0.8157	1.1238
30	0.6785	0.8353
60	0.4253	0.4533

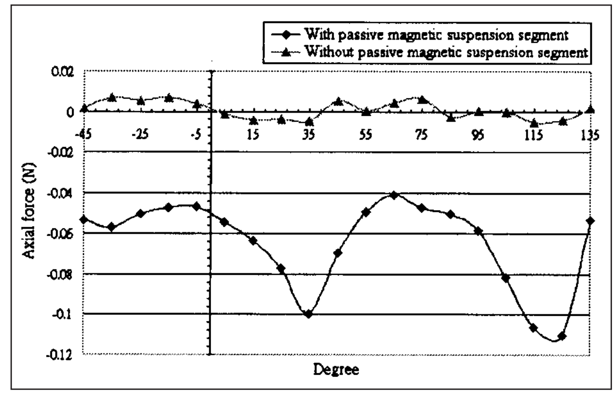


Fig. 11. Calculated total axial forces of the motor system with different rotor positions.

The innovative concepts of MagLev

For decades, friction and noise have been the root disadvantages for Traditional fan motors. After long term operating, rubs between the shaft and the inner surface of the bearing cause abrasions, in turn creating the noise and sway common in many fans.

Sunon has been dedicated to the development of a new motor structure to breakthrough this barrier and root out the defects of Traditional fan motors.

From this commitment and background MagLev(Magnetic Levitation System) blossomed.

About MagLev

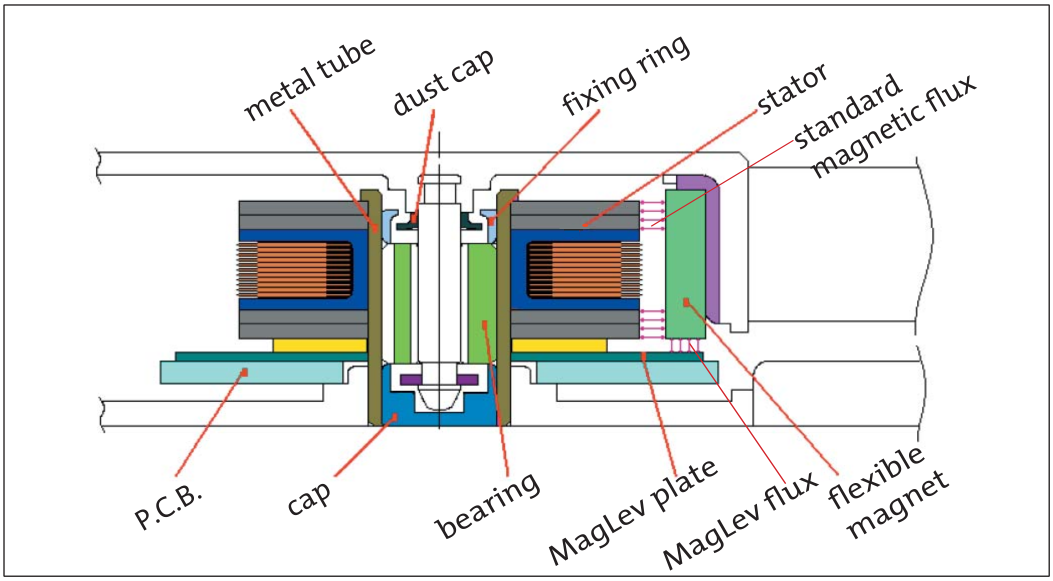
A fan born out of dreams-" MagLev".

The name MagLev is derived from Magnetic Levitation System, the industry-leading fan that was first introduced by Sunon in the 4th quarter of 1999. In 2003, Sunon unveils the newly renamed MagLev to more concisely convey the meaning of the product. With MagLev, you enjoy the high level of precision that comes with this technology, but with a new simplified name.

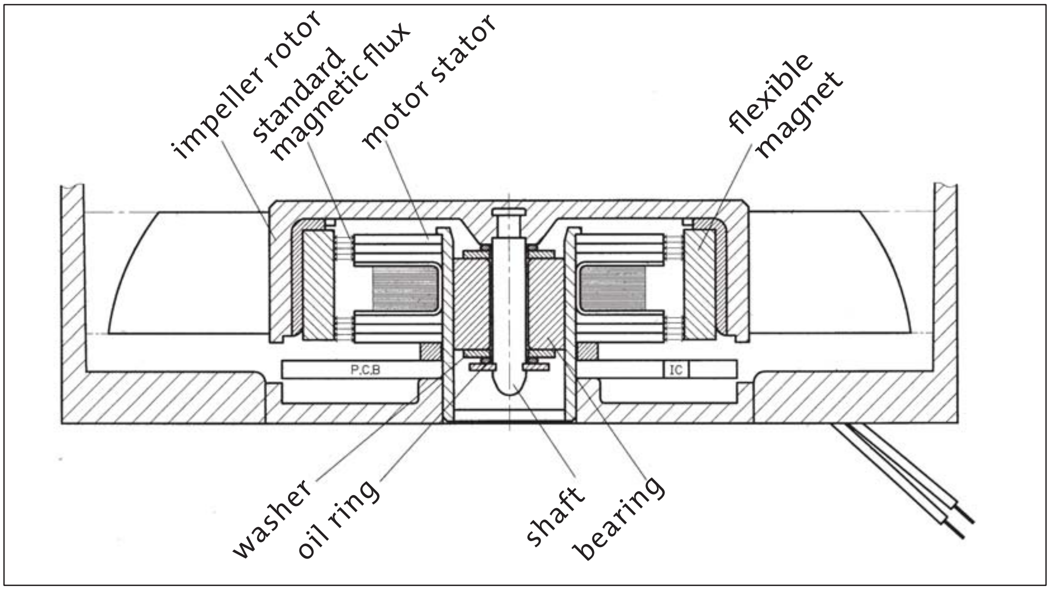
MAGLev® Fan & Blower by SUNON

MagLev Motor Fan Structure

MagLev Motor Fan Structure

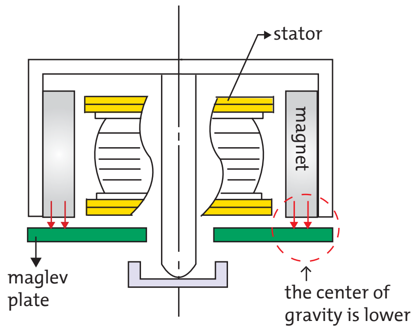
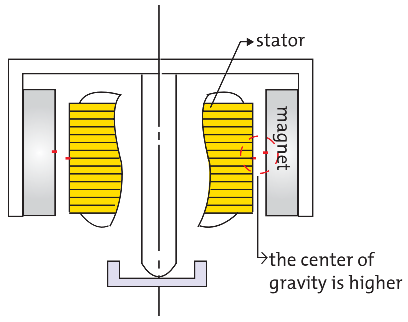


General Fan Structure



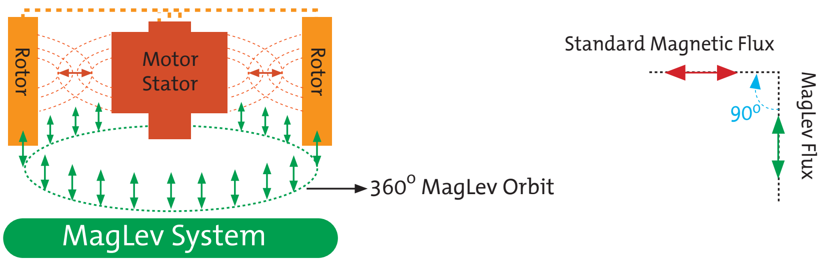
MagLev® Law

Comparison between MagLev and General Motor Fans

(A) Sunon MagLev Fan	(B) General Fan
	
Possesses 3 important factors: the maglev plate, the magnet and the stator	**2 factors: the magnet and the stator**
The resulting interaction between the maglev plate and the magnet pulls the rotor downward along the entire 360-degree surface. Due to the lower center of gravity, the rotor runs in a more stable consistent orbit.	The general fan utilizes a deviating magnetic center to attract the rotor downward. This technology causes the rotor to vibrate violently, due to the lack of a consistent orbit as well as a deviation of the magnetic center.

MagLev Law

1. The rotor is attracted along the entire 360 degree surface by the MagLev system,which results in stable rotation.
2. Standard magnetic flux perpendicular to MagLev flux.

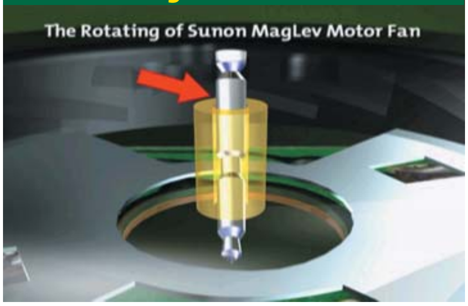


MagLev =Standard Magnetic Flux + MagLev Flux

Advanced Features of MagLev Motor Fan

Comparison between MagLev and General Motor Fans

MagLev Motor Fan

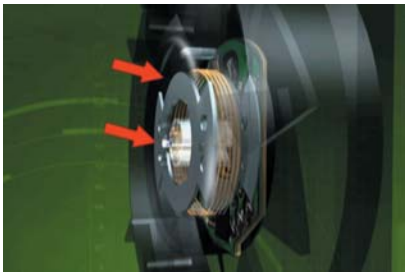


General Fan

The MagLev Motor Fan's rotation is fully exerted by Sunon's patented 360^0 MagLev Orbit, which prevents it from slanting and swaying. No friction or noise can occur, resulting in an extremely long lifespan for the fan.

With no magnetic control exerted over the blade trajectory, a traditional fan tends to produce irregular shuddering and vibrations. After long-term use, the shaft will cause severe abrasion on the bearings, distorting them into a horn shape. The worn-out fan will then start to produce mechanical noises and its life will be shortened.

MagLev Motor Fan Suitable for any position or angle



360^0 MagLev Orbit design

MagLev Motor Fan

The MagLev Motor Fan rotates, fully exerted by Sunon's patented 360° MagLev Orbit. The shaft and bearing have no direct contact during operation, and so will experience no friction, no matter how the fan is oriented.

General Fan

With no control exerted over the blade trajectory, the fan tends to produce irregular swaying and slanting. After long-term use, the shaft will cause severe abrasion on the bearings, and this different orientation will cause severe mechanical noise and shorten the fan's life.

How and Why MagLev Meets Your Needs

How and Why MagLev Meets Your Needs:

Low Noise
- No friction with good balance

High Temp. Endurance
- No friction and keep low temperature between shaft and bearing.
- Consists of temperature resistance material.

Long Life
- No friction, stable operation,
- Prevents dust penetration, increases lubrication circulation

Multi-Orientation
- Runs along the entire 360o surface
- Suitable for multiple-orientation with no noise occured.

Good Balance
- Lower center of gravity,
- Runs along the entire 360o surface.

Low Power Consumption
- One coil winding results in low current

Since SUNON MagLev was launched in Q4 1999.

MagLev Motor fans have been shipped over

276 Million units

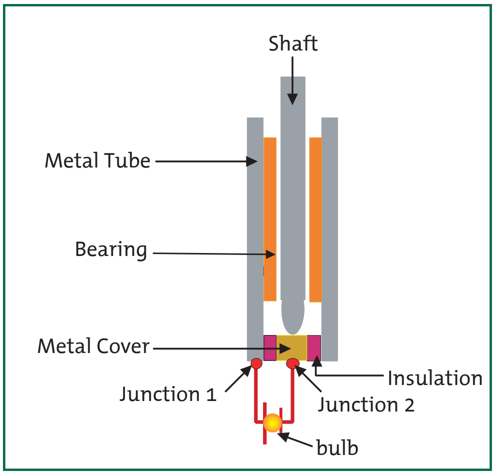
to worldwide renowned customers.

MagLev Experiments

To further demonstrate the MagLev system's quality , we have performed the following two experiments:

MagLev Experiment 1

The purpose of this experiment is to demonstrate that there is no friction between the shaft and the bearing during operation of the MagLev Motor fan.

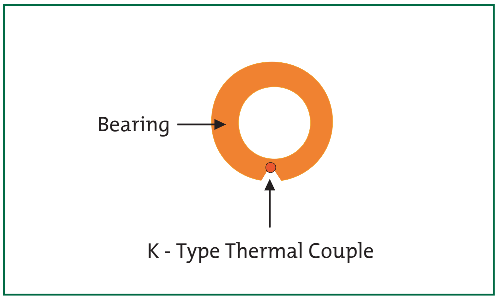


The shaft and bearing are made of metallic materials. We use an insulator to separate the shaft from the bearing at the bottom, and run wires to the metal at the two ends of the insulator. When the fan is powered on and operating, the bulbs next to the fan will light up if the bearing comes into contact with the shaft.

When we turn on the power, we see that other fans cause the bulb to stay on, due to continuous contact between the shaft and bearing, while the bulbs attached to Sunon's MagLev Motor fan are off, due to lack of contact and friction between the shaft and bearing.

MagLev Experiment 2

This proves that in the absence of friction between shaft and bearing, the temperature inside the MagLev motor will be lower during operation.



We installed a temperature sensor inside the bearing to detect the temperature variation.

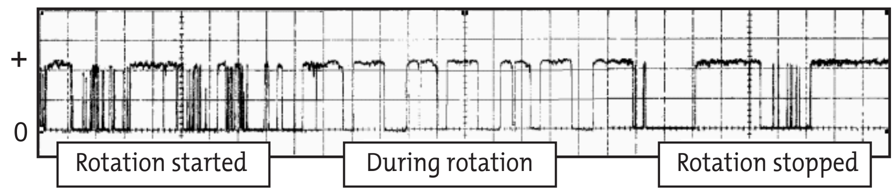
After a period of time, the temperature inside the bearings of other fans rises faster than that of the MagLev Motor fan. The internal temperature of other fans is higher by more than 10 degree Celsius.

MagLev Experiment

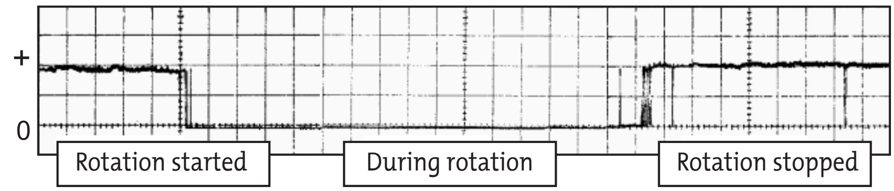
Model: 40x40x20mm

MagLev Fan Motor-- No friction during rotating

- **General Fan Motor**
  There is friction b/w shaft and bearing from time to time during rotation. Hence, the fan is very unstable.



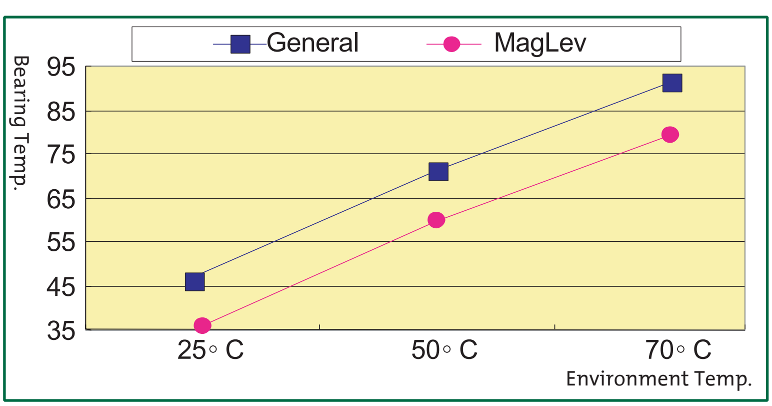
- **MagLev Fan Motor**
  There is no friction b/w shaft and bearing during rotation for MagLev fan; therefore, it shows an open circuit.



The Comparison of Thermal Increase of Bearing During Fan Rotation

	Ambient Temp. 25 C	Ambient Temp. 50 C	Ambient Temp. 70 C	Ambient Temp. 90 C
Bearing temp. of General	48.0	71.2	91.3	
Bearing temp. of MagLev motor	35.9	59.7	79.2	99.5
△T (=T (General) - T (MagLev) (C)	12.1	11.5	12.1	

Since there is no friction b/w shaft and bearing of MagLev motor during rotation, the temperature of the MagLev motor is at least 10°C lower than that of general one.



The Reliability and Performance

Shock Test

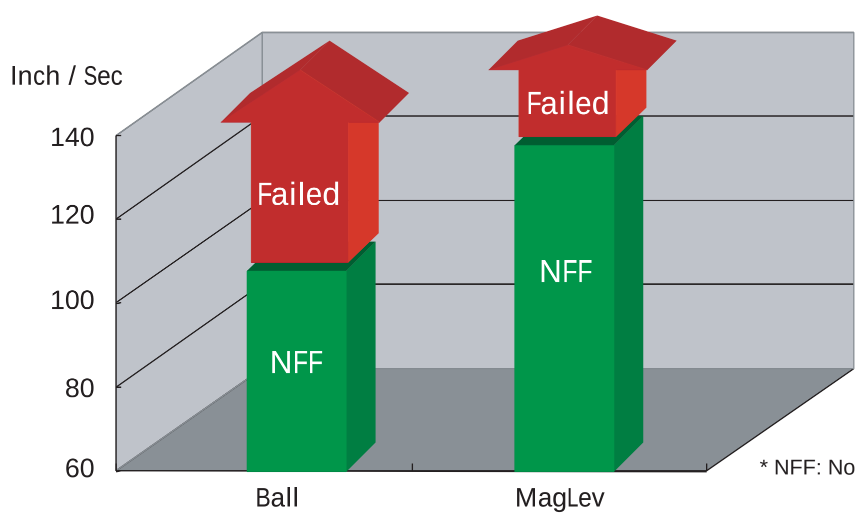
Model:40x40x20mm

Units power : Off
Wave Form : Half Sine
Pulse Form : 3ms
Velocity Change : The test start from 60 inch/sec increase impact velocity to units failure occur by 10 inch/sec.
Shock Orientation : All six-unit face

Imapct Level	60in/Sec						70in/Sec						80in/Sec						90in/Sec				
Orientation	Bottom	Top	Front	Rear	Left	Right	Bottom	Top	Front	Rear	Left	Right	Bottom	Top	Front	Rear	Left	Right	Bottom	Top	Front	Rear	Left
No.1(VAPO)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
No.2(VAPO)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
No.3(VAPO)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
No.1(BALL)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	Note 1	PASS	PASS	PASS	PASS	Note 1				
No.2(BALL)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	Note	Note 1	PASS	PASS	PASS	PASS	Note 1				
No.2(BALL)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

Imapct Level	100 in/Sec						110 in/Sec						120 in/Sec						130 in/Sec				
Orientation	Bottom	Top	Front	Rear	Left	Right	Bottom	Top	Front	Rear	Left	Right	Bottom	Top	Front	Rear	Left	Right	Bottom	Top	Front	Rear	Left
No.1(VAPO)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	Note 1				
No.2(VAPO)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1				
No.3(VAPO)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	Note 1				
No.1(BALL)	Note 1						Note 1	Note 1	Note 2	T/S	T/S	T/S	T/S						T/S				
No.2(BALL)	Note 1						Note 1						Note 1						T/S				
No.2(BALL)	Note 1						Note 1						Note 1						T/S				

- Note 1 : Noise level increace and fan keep running as no mechanical structure damaged.
- Note 2 : Fan no function.
- T / S : Test stop .



* NFF: No Failure Found

The Reliability and Performance

Drop Test (fan stand alone stress test)

Model : 40x40x20mm

MagLev+Vapo Bearing

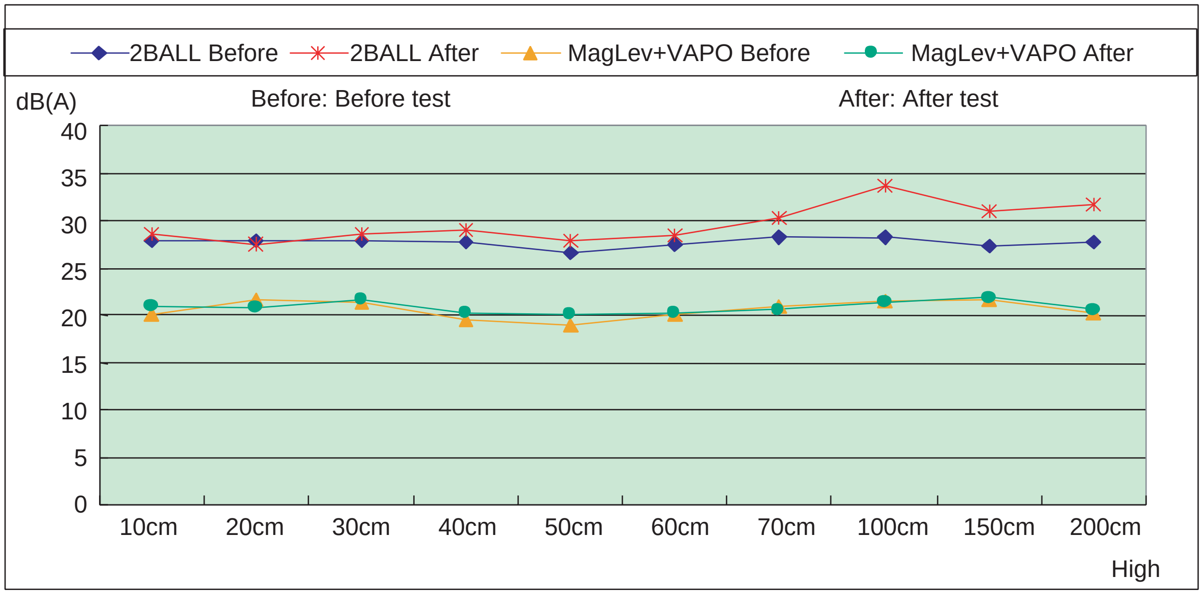
Model	KD1204PKV2(MagLev+Vapo)													
Item	Current			Speed			Noise			Vibration				
Unit	AMP			RPM			1MdB(A)			mm/sec			Noisy	
Spec	0.070 ±15%			6200 ±1000			21.0 Max 24			1.80			by ear	
Drop height	Before	After	Var.	Before	After	Var.	Before	After	Var.	Before	After	Var.	Before	After
10cm	0.066	0.064	3.1%	5771	5890	2.0%	20.0	20.9	0.9	1.17	0.78	0.39	OK	OK
20cm	0.065	0.065	0.0%	5917	5884	0.6%	21.6	20.8	0.8	1.17	0.78	0.39	OK	OK
30cm	0.064	0.063	1.6%	5982	6064	1.4%	21.3	21.6	0.3	1.17	1.17	0.00	OK	OK
40cm	0.071	0.069	2.9%	5500	5698	3.5%	19.4	20.1	0.7	1.17	0.78	0.39	OK	OK
50cm	0.069	0.069	0.0%	5630	5661	0.5%	19.0	20.0	1.0	1.17	0.78	0.39	OK	OK
70cm	0.067	0.067	0.0%	5848	5811	0.6%	20.0	20.2	0.2	1.17	1.17	0.00	OK	OK
100cm	0.066	0.066	0.0%	5957	5966	0.2%	20.9	20.6	0.3	0.78	0.78	0.00	OK	OK
120cm	0.069	0.07	1.4%	6034	6006	0.5%	21.4	21.3	0.1	1.56	1.17	0.39	OK	OK
150cm	0.067	0.067	0.0%	6104	6123	0.3%	21.6	21.9	0.3	0.78	1.17	0.39	OK	OK
200cm	0.065	0.065	0.0%	5843	5843	0.0%	20.1	20.5	0.4	0.78	0.78	0.00	OK	OK

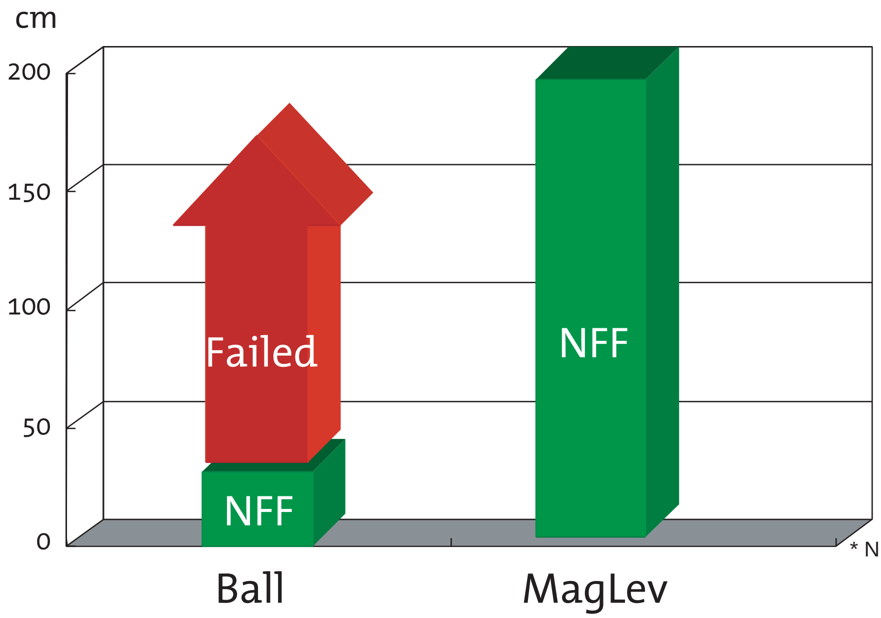
Ball Bearing

Model	KD1204PKB2(2)(2Ball-no MagLev)													
Item	Current			Speed			Noise			Vibration				
Unit	AMP			RPM			1MdB(A)			mm/sec			Noisy	
Spec	0.070 ± 15%			6500 ± 1000			29.0 Max 32			1.80			by ear	
Drop height	Before	After	Var.	Before	After	Var.	Before	After	Var.	Before	After	Var.	Before	After
10cm	0.073	0.071	2.8%	6378	6437	0.9%	27.9	28.6	0.7	1.95	1.17	0.78	OK	OK
20cm	0.073	0.072	1.4%	6345	6351	0.1%	27.8	27.5	0.3	1.17	0.78	0.39	OK	OK
30cm	0.071	0.072	1.4%	6468	6345	1.9%	27.8	28.5	0.7	1.17	0.78	0.39	OK	NG
40cm	0.072	0.072	0.0%	6499	6469	0.5%	27.6	28.9	1.3	0.78	0.78	0.00	OK	NG
50cm	0.072	0.072	0.0%	6243	6202	0.7%	26.6	27.9	1.3	1.17	0.78	0.39	OK	NG
70cm	0.072	0.072	0.0%	6311	6392	1.3%	27.5	28.4	0.9	1.17	1.17	0.00	OK	NG
100cm	0.072	0.072	0.0%	6476	6458	0.3%	28.2	30.1	1.9	1.95	1.95	0.00	OK	NG
120cm	0.073	0.074	1.4%	6645	6631	0.2%	28.1	33.6	5.5	1.17	1.17	0.00	OK	NG
150cm	0.073	0.074	1.4%	6348	6353	0.1%	27.2	30.9	3.7	0.78	2.34	1.56	OK	NG
200cm	0.072	0.072	0.0%	6371	6542	2.6%	27.6	31.6	4.0	1.17	1.17	0.00	OK	NG

The Reliability and Performance

Drop Test v.s. Noise (fan stand alone stress test) Model : 40x40x20mm





* NFF: No Failure Found

The Reliability and Performance

Anti-Dust Test

IEC60529 IP5X Standard.
Test duration : 8 Hours

Model:GC054009VH-8 P/N:V1.M.B237(MagLev+VAPO Bearing)with Dust Cap

NO.	Current			Speed			Noise			Vibration		Not Noisy	Remark
	before	after	Var	before	after	Var	before	after	Difference	before	after	Noisy by ear	
	AMP	AMP		Rpm	Rpm		1M dB(A)	1M dB(A)		mm/secRMS	mm/secRMS	Result	
OP	0.122	0.121	0.8%	4414	4481	1.5%	19.1	19.8	0.7	0.92	1.66	OK	
Non-OP	0.123	0.122	0.8%	4349	4395	1.0%	19.5	19.5	-	0.78	0.83	OK	

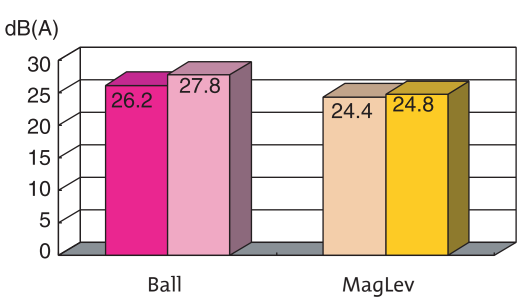
Model:GC054009BH-8 P/N:V1.M.B237(MagLev+BALL Bearing) without Dust Cap

NO.	Current			Speed			Noise			Vibration		Not Noisy	Remark
	before	after	Var	before	after	Var	before	after	Difference	before	after	Noisy by ear	
	AMP	AMP		Rpm	Rpm		1M dB(A)	1M dB(A)		mm/secRMS	mm/secRMS	Result	
OP: #1	0.123	0.121	1.6%	4341	4425	1.9%	19.0	24.8	5.8	0.66	1.66	OK	
Non-OP: #4	0.121	0.121	0.0%	4328	4377	1.1%	18.8	20.4	1.6	0.53	1.25	OK	

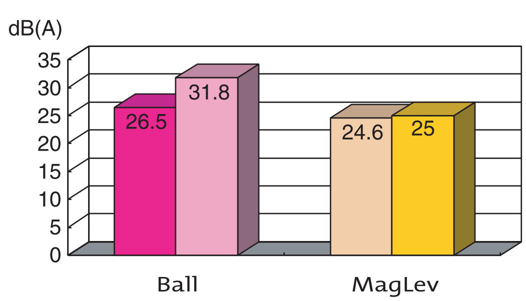
Before : Before making test.
After : Tested.
OP : Fan running during test.
Non-OP : Fan not running during test but check fan's performance before.

Anti-Dust Test v.s. Noise Test

Fan Non-Operation



Fan Operation



SUNON MagLev - the best choice for all applications

SUNON MagLev - the best partner for projector applications

- MagLev has broad applications, especially on projectors that operate in high-temperature environments over 70℃ (even up to 90℃~ 100℃) and on projectors that demand low-noise. Only Sunon MagLev motor fans can provide ultimate the thermal solutions for high temperature and low noise application. This is why well known projector makers make Sunon their first choice.

SUNON MagLev - the most silent partner for audio applications

- Cooling fans used in audio applications must be not only low noise, but also without resonance. Only Sunon MagLev motor fans can meet these criteria.

SUNON MagLev - the best choice for any application

- For portable applications such as notebooks and game consoles, Sunon MagLev motor fans are the ultimate solutions for noise and thermal problems.

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