

Answer List for Reviewer

Dear Reviewer,

First of all, we would like to express our deep gratitude to you, who has spent a lot of time reading our paper and give us valuable advice. We also hope that we will receive your contribute in our future researches. Basing on your comments and questions, we have been tried our best to revise the manuscript. We would like to list here the questions and our answers.

1. A In the abstract, you state that the forces are axial forces, however, from your paper, it becomes clear that you have designed a radial / axial force mb. Please correct

Answer:

In our research, we deal with only radial translation along x and y axes and the axial translation is mechanically constrained. So we have corrected this mistake in the abstract.

2. I did not understand the meaning of "proper minute distance", please maybe rephrase

Answer:

We use phrase "proper minute distance" to imply that is enough small distance. Based on your recommendation, the phrase "enough small gap" is utilized in our paper. It is shown in page 2.

3. The verdict "However, the AGBM has low power density and efficiency because of the axial flux motor principle." cannot be generalized. There are beneficial and non-beneficial arrangements.

Answer:

We agree that this sentence is not totally exact so following the reference [7] we have changed to: "However, the axial gap has usually lower torque density and higher material cost than the radial flux motor [7]". It is shown in page 2

4. I did not understand the meaning of "This combination makes the motor size zooming out continuously", please maybe rephrase.

Answer:

We have changed to: "This combination makes the motor size smaller". It is shown in page 2.

5. Please replace "energy loss." with "loss energy."

Answer:

It has been checked and edited. The result is shown in page 3

6. In Fig.5, you give the currents for forces, torques, and combined force/torque. However, the current directions of 5)b and 5)c are identical while the force arrows, e.g. of d- c- phase are different in 5)b and 5)c. This seems to be wrong, please correct

Answer:

Based on the recommendation of the reviewer, we recheck both formulae and Fig. 5. We found that the Fig. 5 is correct, however the formulae (14) and (15) is not exactly correct.

The correct current which generates torque is:

$$\begin{cases} i_{a,d}^T = \pm A_m \cos(\phi_m) \\ i_{b,e}^T = \pm A_m \cos(\phi_m + \pi/3) \\ i_{c,f}^T = \pm A_m \cos(\phi_m + 2\pi/3) \end{cases} \quad (14)$$

And the total current which is supplied to the motor is:

$$\begin{cases} i_{a,d} = i_d \cos(\psi) + i_q \sin(\psi) \pm A_m \cos(\phi_m) \\ i_{b,e} = i_d \cos(\psi - 2\pi/3) + i_q \sin(\psi - 2\pi/3) \pm A_m \cos(\phi_m + \pi/3) \\ i_{c,f} = i_d \cos(\psi - 4\pi/3) + i_q \sin(\psi - 4\pi/3) \pm A_m \cos(\phi_m + 2\pi/3) \end{cases} \quad (15)$$

The Fig. 5 shows the currents and forces in one case when we assume that $\theta_0 = 0$, $\psi = 0$, $\phi_m = -\pi/4$, $i_q = 0$ and $A_m > i_d$, then the bearing currents become:

$$\begin{cases} i_{a,d}^f = i_d \\ i_{b,e}^f = -i_d/2 \\ i_{c,f}^f = -i_d/2 \end{cases}$$

And the torque currents are:

$$\begin{cases} i_{a,d}^T = \pm A_m \cos(-\pi/4) \\ i_{b,e}^T = \pm A_m \cos(-\pi/4 + \pi/3) \\ i_{c,f}^T = \pm A_m \cos(-\pi/4 + 2\pi/3) \end{cases}$$

It is easy to see that the Fig. 5 is correct with these currents

As the result the equations (14) and (15) are changed in the page 5

7. Eqn.(11): parentheses missing and eqn. (29): please use parenthesis in the numerator

Answer:

It has been checked and edited. The result is shown in page 5 and 7

8. Please correct: "In order to the total force acting ON the rotor not be zero"

Answer:

The sentence is changed to "In order for the total force acting on the rotor not to be zero". The result is shown in page 5

9. Please take a look at (19). You are adding an angle (Φ_0), another angular portion ($\pi/4 * z/l_t$), and a rational depending on the phase number. This does not make sense to me. Missing a factor 2π for the middle term?

Answer:

In equation (19), $\frac{2m}{6} + \theta_0$ is the phase angular of the first component l_t of the m phase. The next angular of

the component l_t is calculated by $\frac{\pi}{4l_t} z$. The following figure describes how the equation is created:

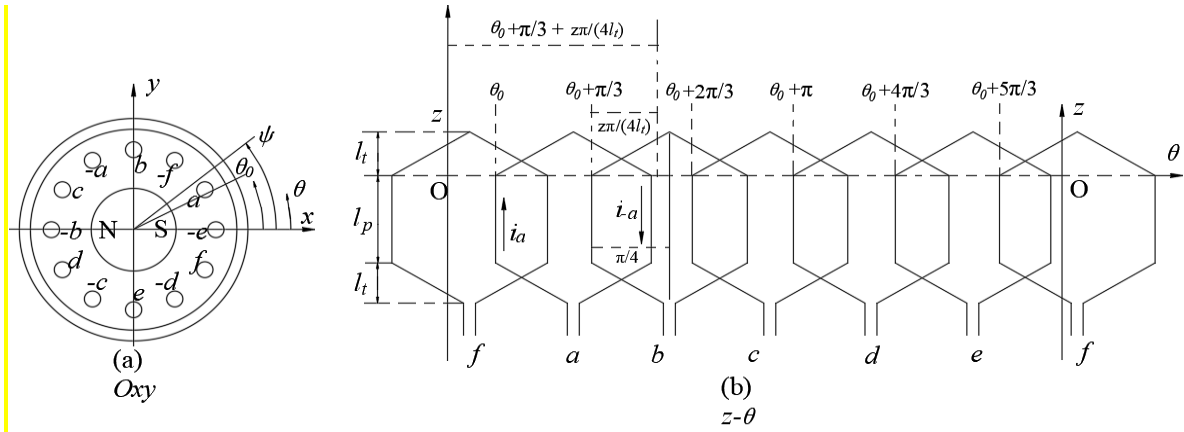


Figure 6. Coordinate axis

Basing on your comments and questions, we have finished the equation (19) and added more information on the Fig. 6 to make it clearer. The result was shown on the page 4 and 6.

10. Fig. 15(a): please use a different scaling (-+0,5 or -+1)

Answer:

Based on your comment, the scale of the displacement in Fig. 15 (a) was changed to ± 1 . The result is shown in page 11

11. Fig. 20(a) and 20(b): the time scale does not fit your events. Are these consistent measurements?

Answer:

We have done a lot of measurements when we write this manuscript, the results in Fig. 20(a) and 20(b) do not fit from each other because of our mistake. The correct Fig. 20(a) is replaced in this paper. It is shown in page 12.

12. You do not consider saturation which becomes a major problem for your linear system. Please comment

Answer:

Slotless Self-bearing Motor is an electromechanical actuator which can provide radial translation and rotation simultaneously. Moreover, the stator of Slotless Self-bearing Motor doesn't have an iron core. One of the benefits of using the SSBM is that there is no magnetic circuit saturation, which allows the system to work in a linear manner in large ranges. Therefore, saturation is not considered in this manuscript.

13. Properly describe the test setup.

Answer:

Basing on your comment, we have described the test bed more detail. The result is shown in page 9 and 10:

"To confirm the above mentioned control method, an experimental system is set up as shown in Fig. 13. It includes a PC, a dSPACE DS1104 board, a Sentec's displacement sensor, a power amplifier and a Slotless Self-bearing Motor attached a rotary encoder (Fig. 13). In this paper, only rotational motion along the z-axis and the horizontal translations along x and y axes of the rotor are considered; i.e. the axial translation along z axis is mechanically constrained. The permanent magnet of the rotor has a diameter of 22 mm. The magnetic flux density is sinusoidal, and its maximum amplitude is approximately 0.59T. The copper wire has a diameter of 27 mm and the number of turns is 55. The length of the parallel part l_p is 8mm and the length of the serial part is 6mm, respectively.

The control system uses a dSPACE DS1104 board dedicated to the control of electrical drives. It includes PWM units, general purpose input/output units (eight ADC and eight DAC), and an encoder interface. The

DS1104 reads the displacement signals from the displacement sensors via the A/D converter, and the rotor angle position and speed from the encoder via an encoder interface. The DSP calculates the stator reference currents and sends its command to the power amplifier through a D/A converter. The current source amplifier is used for supplying the stator current. When the starting current is limited to 1A, for the speed control, the pole value $s_{0\omega} = 5$ is chosen and the controllers' coefficients are: $k_{p\omega} = -0.0228$, $T_{I\omega} = 0.4$ and for position control the PID controllers' coefficients are $k_p = -1167$, $T_I = 0.0857$, $T_D = 0.0268$ when the pole value $s_0 = 35$ is chosen."

14. Clearly state what you have tested - the sentence "and the SSBM could operate stably in all working conditions." is highly misleading

Answer:

Based on your comments, the sentence is changed to "And the SSBM works stably in such modes as start, reverse, rotation load and external radial pulse forces....". It is shown in page 1 and 12