Modelling Of Half Leg Phase Converter For The Active Magnetic Bearing Drive

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Abstract

Active magnetic bearings (AMB) are predominantly utilized in rapid apparatus due to their contactless activity. One of the primary inconveniences of AMB is its huge size. Conservative AMBs with higher load conveying limit might be considered for better usage of accessible space and material. Considering this, an endeavor has been made to design conservative AMBs to accomplish higher burden conveying limit. Two fundamental boundaries for example state of the leg and post winding example are thought of and their impact on the heap conveying limit and size of the AMB have been assessed. This paper likewise presents the reproduction of AMB in Finite Element Method Magnetics (FEMM) programming in which the powers are determined by weighted pressure tensor technique. AMB with crown shape leg with trapezoidal winding example has been found to be the most minimal in size.

Keywords: magnetic, bearing drive, tensor technique, AMB, FEMM, electromagnetic actuators

1. Introduction

The design of an Active Magnetic Bearing framework has been begun in the Laboratory of Electromagnetic Fields. The Active Magnetic Bearing (AMB) use electromagnets to hold the heap stable. (Agarwal .P.K and Chand .S, 2011) The AMB is a bearing without actual contact between the revolving and the fixed part. In this manner the grating and misfortunes of rubbing can be completely dispensed with. Without this actual contact, higher activity speed can be reached, and the gadget requires less support, thus the lifetime can be expanded, as well. Tragically, the AMB requires ceaseless power supply for the electromagnets, and for the controlling electronic. Active Magnetic Bearings (AMBs) are electromagnetic actuators. AMB chips away at the guideline of electromagnetic suspension. AMB framework comprising of an electromagnet gathering, a bunch of force enhancers which supply current to the electromagnets, a controller, and hole sensors with related gadgets to give input expected to control the place of the rotor inside the hole. When the current is applied to the loops, an attractive magnetic power is produced between every one of the stator shafts also, rotor. This attractive power increments as the distance between the two surfaces diminishes. In this manner the shaft stays unsound. So to settle the shaft position, constant input via air hole sensors

ought to be shipped off the controllers to give suitable curl flows from power speaker. AMBs are essentially utilized in fast hardware because of their benefits of no mechanical contact, no requirement for oil, high accuracy activity, and capacity to work at high rotational paces and at high temperatures.

It has been seen that in numerous applications minimal magnetic bearing with higher burden conveying limit is expected for better usage of accessible space and material. Thusly, there is a need to design reduced AMB with higher burden conveying limit. Eight-post AMB gives 2.414 times higher burden conveying limit when contrasted with four-shaft AMB for same sources of info like current, number of turns, post region and air hole. (Bíró, 1999)This higher burden conveying limit brings about decrease of stator external measurement by 24% . Eight-post AMB gives the minimized size when contrasted with three-shaft AMB yet three-post AMB requires just three power intensifiers so their underlying expense is less when contrasted with eight-shaft AMB.Geometrical boundaries like rotor distance across, shaft width, stator breadth and bearing hub length chooses the size of the AMB. So there is a need to improve these boundaries to accomplish the higher burden conveying limit at a least volume of the whole bearing construction. Transformative calculation like hereditary calculation is utilized to design ideal AMB. Super durable magnet one-sided AMBs are proposed to lessen the size and limit the power utilization of the AMB for controlling the moving rotor. This paper presents the design of AMB for higher burden conveying limit and re-enactment of recreation of AMB in limited component strategy magnetic (FEMM) programming. Variety of motion thickness along the post and in the air hole between the shaft and rotor has additionally been assessed and introduced in this paper. At last conservative AMB has been designed with higher load conveying limit.

2. Active Magnetic Bearing Model

2.1 Geometrical model of AMB

The math of the eight-shaft AMB is displayed in FIGURE1 in which all posts are viewed as indistinguishable in shape and quantities of pivot each post are equivalent. So the quantity of turns and shaft region for all posts are given by (1) and (2)

$$\mathbf{A_1 = A_2 = \cdots = A_8 = A}$$

$$\mathbf{N_1 = N_2 = \cdots = N_8 = N}$$

In magneto static issues, at consistent state 1 2 3 8 0 g g g = = = = =. Consequently the magnetic motion thickness Bi along th I shaft is given by (3)

$$\mathbf{B_i = \frac{u_0 N I_i}{g_0}}$$

Load carrying capacity of the AMB is defined as the maximum force that the bearing can generate in any given direction. So the load carrying capacity of the AMB along vertical axis is given by (4) [2]

$$\mathbf{F_{max} = \sum_{i=i}^{n} \frac{B_i A}{2u_0} Sin\theta_i}$$

Where, Bi is the magnetic flux density along th i pole, µ0 is the permeability in air, n is the number of poles and θi is the pole orientation of th i pole from horizontal axis as shown in figure 1.The area of pole and number of turns required for maximum load carrying capacity can be found from equation (3) and equation (4) as shown in equation (5) and equation (6)

$$\mathbf{A} = \frac{\mathbf{F_{max}}}{\sum_{i=i}^{n} \frac{\mathbf{B_i^2}}{2\mu_0}}$$

$$\mathbf{N} = \frac{\mathbf{g_0 B_{max}}}{\mu_0 \mathbf{I_{max}}}$$

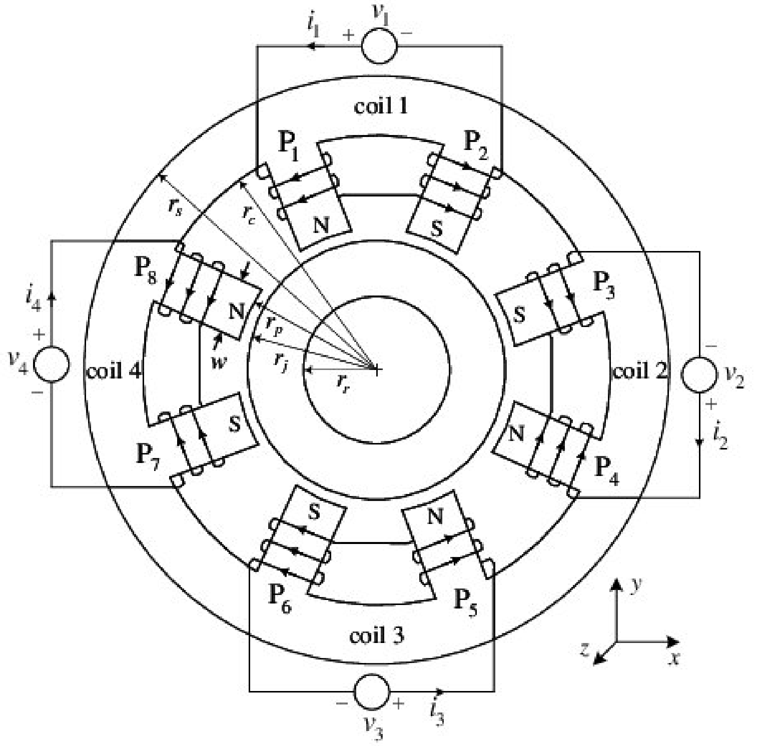

Figure : 1 Geometry of eight- pole AMB

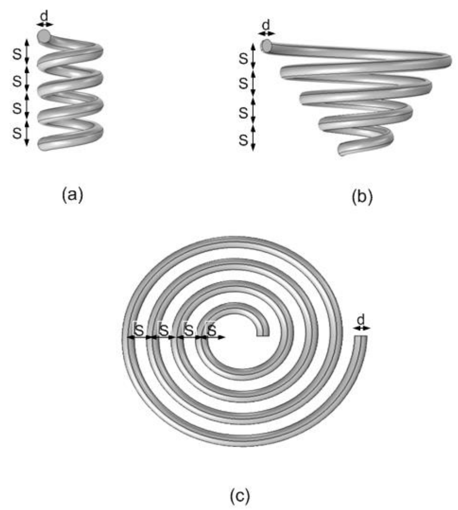

Figure: 2 Geometry of the coil

The nitty gritty calculation of single loop is displayed in fIGURE2. (.S.C., , 2002)The most extreme winding width Ww chooses the size of the loop. The winding width ought to be not exactly or equivalent to greatest twisting width to keep away from covering of nearby electromagnets. The twisting width of loop is given by (7) .

$$\mathbf{w_w = B_i\left[\left\{(r + g_0)\cos\left(\frac{a_1}{2}\right) + t\right\}\tan\left(\frac{1}{2}a_1 + a_2\right) - \frac{1}{2}\right]w_p}$$

Where 1 α π = / n ,α α 2 1 = Ki and 2 w t H = β . Constant β1 is used to prevent the interference between the adjacent electromagnets whose value is taken as 0.9 for most of cases. Value of β2 is taken as 0.1 for most of cases. Width of the pole and height of the winding are given by (8) and (9).

$$\mathbf{w_p = 2(r + g_0)\sin\left(\frac{a_1}{2}\right)}$$

$$\mathbf{H = \left[\left(R - w_p\right)^2 - \left(\frac{w_p}{2} + w_w\right)^2\right]^{\frac{1}{2}} - (r + g_0)\cos\left(\frac{a_1}{2}\right) - t}$$

The connection between the accessible region and region expected to winding is given by (10)

$$\mathbf{(w_w - t_c)(H_w - 2t_c) = \frac{N\pi_w^2}{w_f}}$$

Where w r is the sweep of the loop wire ,wf is the winding variable whose worth is thought of as 0.7 , c t is the loop packaging thickness and Hw is the winding level. So at last the stator external distance across of the AMB is given by (11)

$$\mathbf{D = 2\left(r + g_0 + t + H_w + w_p\right)}$$

2.2 The FEM model of AMB

The magnetic field is thought to be 2-D and fixed. The estimation of powers in active magnetic bearing depends on Maxwell's situations of electromagnetism. For the low-recurrence issues tended to by FEMM, just subsets of Maxwell's situations are adequate. Low - recurrence issues are those issues where removal flows can be disregarded (Chen S.L and Hsu .C.T, 2002.). In Magneto static issues fields are time-invariant. For this situation, the field power (H) and transition thickness (B) should comply:

$$\Delta \times \mathbf{H} = \mathbf{J}$$

$$\boldsymbol{\nabla}.\,\mathbf{B} = \mathbf{0}$$

$$\boldsymbol{\nabla}.\,\mathbf{J} = \mathbf{0}$$

On the off chance that the material is straight, the accompanying connection ought to comply:

$$\mathbf{H} = \frac{\mathbf{B}}{\boldsymbol{\mu}}$$

In the event that a material is nonlinear (for example soaking iron or alnico magnet), the piousness is really an element of B:

$$\mathbf{H} = \frac{\mathbf{B}}{\boldsymbol{\mu}(\mathbf{B})}$$

Magnetic field in FEMM that fulfils (12)- (15) is determined through a magnetic vector likely methodology. Since the magnetic motion thickness is without dissimilarity, there exists a magnetic vector possible A, Such that B A = ∇× [11] which gives the possible definition.

$$\boldsymbol{\nabla} \times \left(\frac{\mathbf{1}}{\mathbf{uB}} \boldsymbol{\nabla} \times \mathbf{A}\right) = \mathbf{J}$$

For direct isotropic material (and expecting the Coulomb gauge,∇ = . 0 A), then the eq.17 is diminished to

$$-\frac{\mathbf{1}}{\mathbf{u}} \boldsymbol{\nabla}^{2} \mathbf{A} = \mathbf{J}$$

It is assumed that the typical part of the magnetic motion thickness evaporates on the limit, which can be recommended by the limit condition [11]

$$\mathbf{A} \times \mathbf{n} = \mathbf{0}$$

3. Design of AMB and simulation in FEMM

The AMBs are designed to get higher burden conveying limit. Load conveying limit of AMB can be expanded by changing various boundaries like expanding current, number of turns, shaft region. (D. Meeker, 1999)So state of the leg is viewed as in present work to increment load conveying limit. There are a few impacts which we have disregarded for straightforward numerical conditions to design AMB. The calculation of the bearing that utilized for limited component examination is displayed in table1.

Parameter	**Value**
Air gap	2 mm
Pole width	11.17
Axial Length	41 mm
Turns per leg	81 turns
Saturation Flux Density	1.3 Tesla
Rotors Radius	26 mm
Shaft Radius	16 mm
Outer Radius Of bearing	61.17 mm

Table: 1 Design parameters of AMB

The B-H bend of material (silicon-iron) as displayed in the figure 3 is viewed as bearing material. Its immersion transition thickness is 1.2 Tesla. Immersion transition thickness is characterized as the most extreme utilizable motion thickness in bearing material for getting most extreme burden conveying limit for example $B_{sat} \cong B_{max}$. Overlaid silicon steel is viewed as whose overlaid thickness is 0.632mm (25 inches).The examination have been finished by passing most extreme current in upper horseshoe posts, half of the greatest (predisposition) current through side horseshoe shafts which are set along x-pivot and zero current in lower horseshoe post for example i_1 =6A, i_2=12A, i_3=6A, i_4=0.In the limited component examination the absolute region is partitioned into little three-sided region as displayed in Figure : 3

Magnetic Flux den city	Magnetic Flux Intercity
0.3	2000
0.4	300
0.5	4000
0.6	5000
0.7	6000
0.8	7000
0.9	8000

Table: 2 B-H curve of bearing material (Silicon steel)

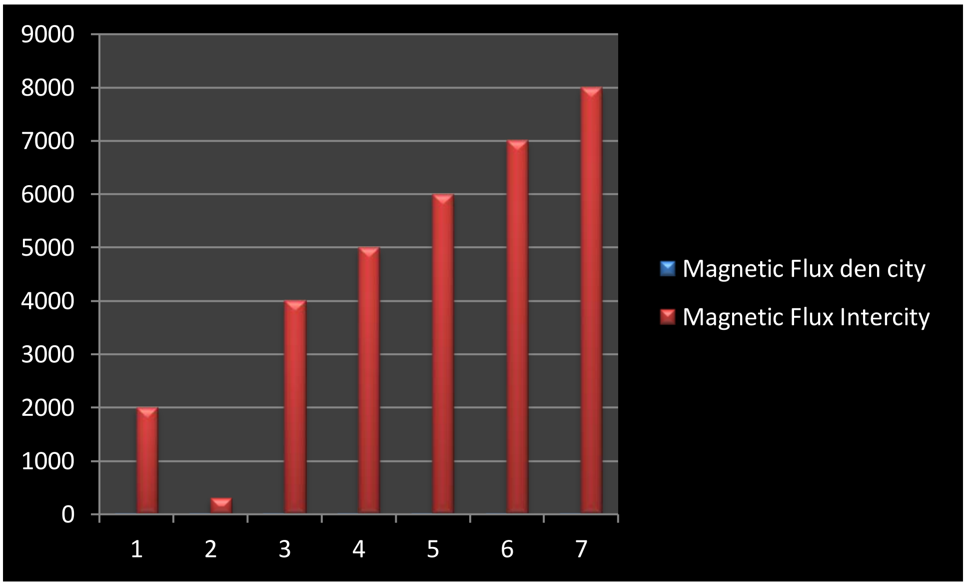

Figure: 3: B-H curve of bearing material (Silicon steel)

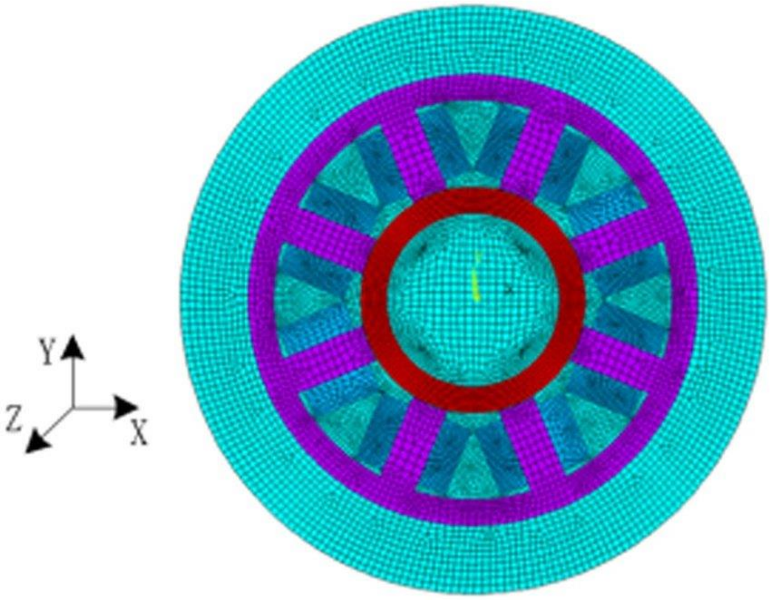

Figure: 4 Finite element model of AMB

Powers are gotten by Finite Element Method Magnetics (FEMM) through "weighted pressure tensor" strategy volume vital. FIGURE5 shows the recreation results for most extreme vertical power. It has seen that the heap conveying limit is greatest along certain y-hub.

From the fIGURE 3 and fIGURE4 it has been plainly seen that transition levels are higher in the center and diminishing towards the tip of shaft. Assuming that we check the transition values at the center of any upper posts it gives 1.59 Tesla. In the focal point of air holes of any upper shafts, the most extreme transition thickness is 1.12 as displayed in the fIGURE5. This is going on a direct result of misfortunes of motion through the sides of shafts because of untimely immersion of posts Different leg shapes as displayed in the figures (9-11) have been considered for reproduction. (Fan .Y, 1997.) We found that level crown shape and crown shape at the lower part of the post gives practically equivalent burden conveying limit for direct B-H bend of materials (relative porousness is 4416).

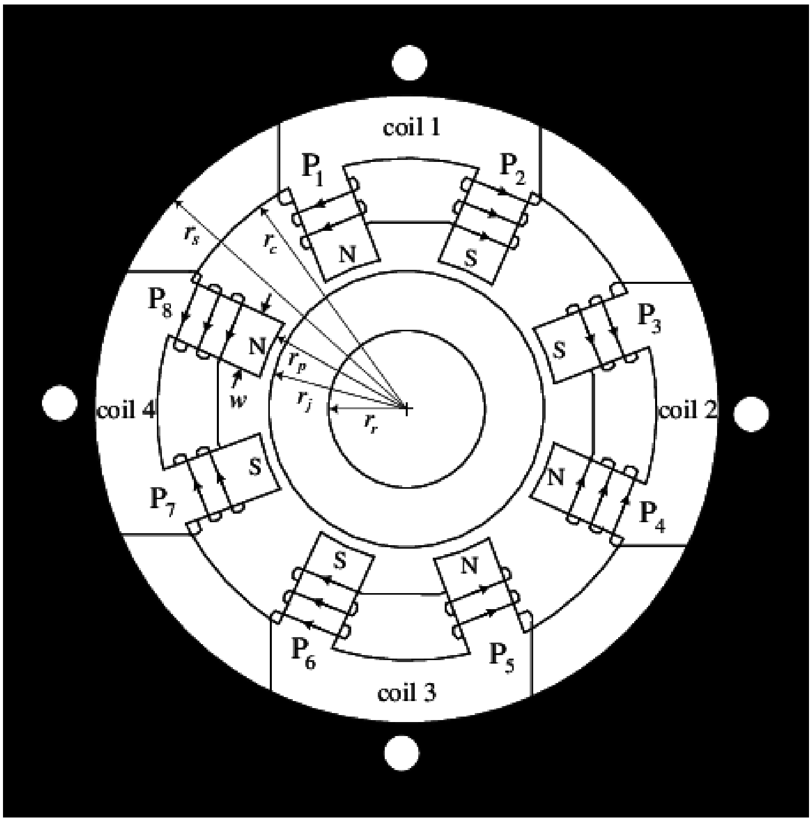

Figure: 5 Upper poles of eight pole magnetic bearing

Length (cm)	Magnetic Flux Density
0.1	1.1
0.2	1.2
0.3	1.3
0.4	1.4
0.5	1.5
0.6	1.6
0.7	1.7

Table: 3 Decrement of flux density along pole

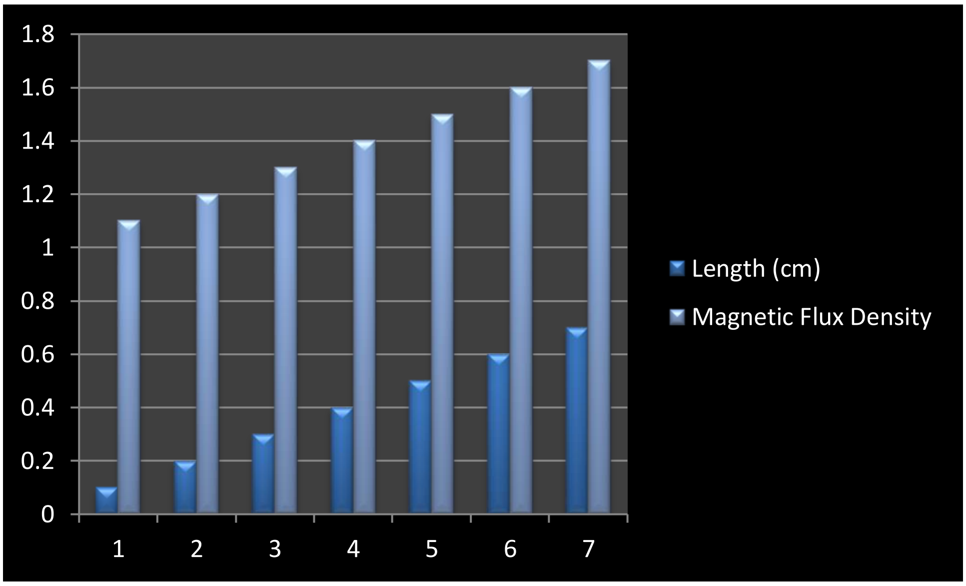

Figure: 6 Decrement of flux density along pole

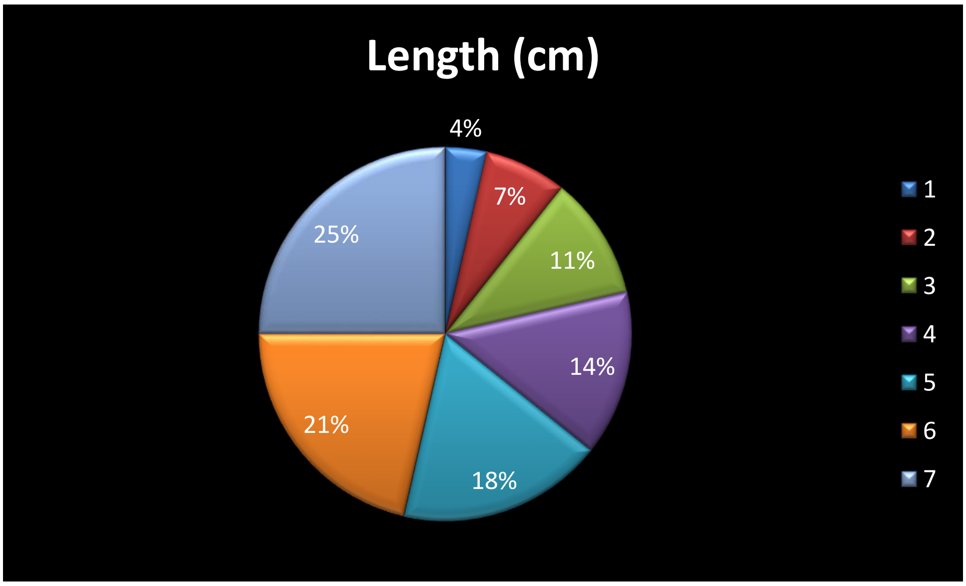

Figure: 7 Decrement of flux density along pole

4. Effect of various parameters on size of AMB

The size of AMB relies upon different boundary. In this paper we have thought about state of the leg, winding example and thickness of back iron.

4.1 Effect of leg shape on the size of AMB

Eight-shaft AMB without crown at the lower part of the post gives the most extreme burden conveying limit of 458 N yet when crown is given 1 mm thickness then it gives most extreme burden conveying limit of 819 N. This higher burden conveying limit brings about decrease of stator external distance across by 13 %. The came about aspects of AMBs are displayed in table 2 and the subsequent setups of designed AMBs are plotted in the fIGURE13 and fIGURE14.

4.2 Effect of twisting example on the size of AMB

Winding example concludes the quantity of loop turns that can be obliged in the accessible space between two nearby shafts. There are two sorts of winding examples for example equal winding and trapezoidal winding.

In trapezoidal winding example more number of turns are occupied in less space in view of better use of space accessible between the shafts. Consequently the general size of the AMB decreases. In the current work for AMB with crown shape both winding examples are thought of and correlation of the AMB size for both the case is given in Table 3. It is found that AMB with trapezoidal winding example gives 7% more modest stator outside breadth contrasted with AMB with equal winding example. AMB with crown shape designed with equal winding example and trapezoidal winding example are displayed in fIGURE15 and fIGURE16.

Parameter	AMB Without Crown	AMB with crown
Stator Outer Diameter	121	105
Axial Length	41	41

Table: 4 AMB size comparison with and without crown

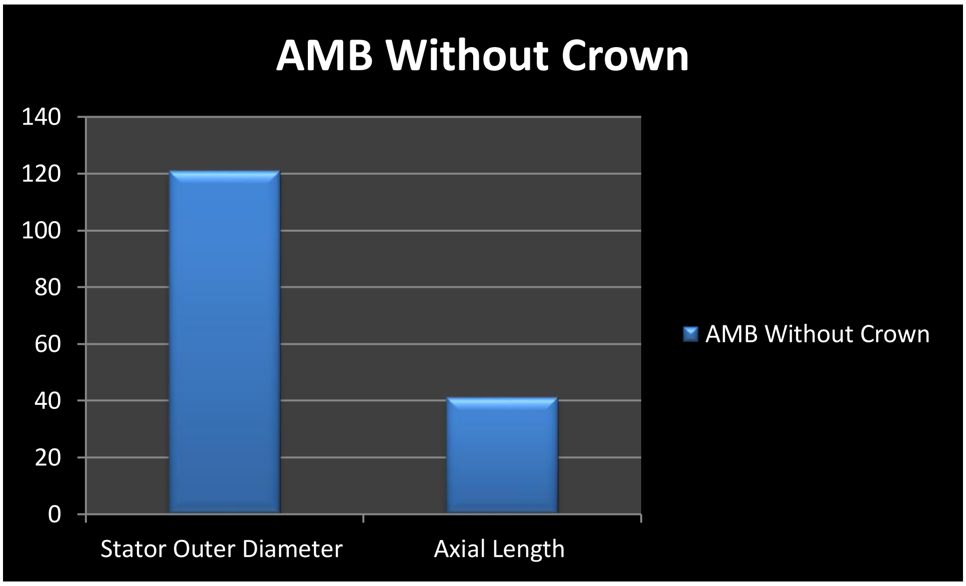

Figure: 8 AMB size comparison without Crown

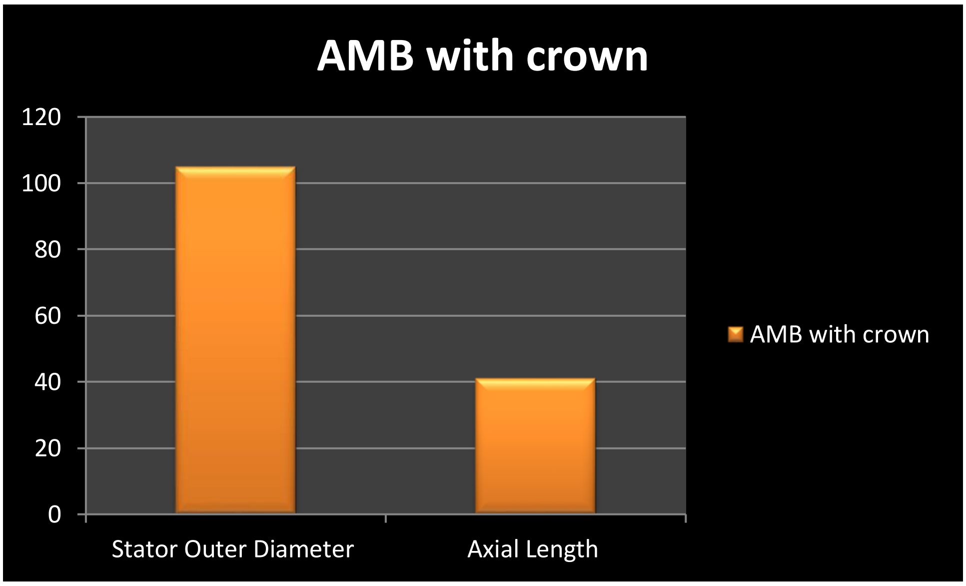

Figure: 9 AMB size comparison with Crown

5. Conclusion

The tentative arrangement is to fabricate the AMB, and to design a controller to appropriately work the gadget. Prior to building the plan, further nonlinear recreations should be considered, the nonlinear qualities of the stator and of the shaft will be considered by a straightforward opposite digression type bend, and the nonlinear halfway differential condition will be addressed by the decent point cycle strategy (Hantila, 1975)The higher burden conveying limit due to crown shape brings about decrease of the stator external width by 13 % and trapezoidal winding example results 7 % decrease in stator measurement.

Further, the bearing can be made more minimal by utilizing back iron thickness equivalent to 70% of shaft width. AMB with crown shape leg with trapezoidal winding example has been viewed as the most minimized in size

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