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Different Magnetic Orientation for Torque Angle Control in Scan Mirror Systems for Satellite Applications

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ABSTRACT

This paper presents the comparative evaluations of different brushless motor that is used to tilt the scan mirror in a static torque angle. Limited angle control orientation in forward and reverse directions for the developed torque is used for the precise control. The step process in the design equation for the brushless machine is presented and few different magnetic orientation models are evaluated for its improve torque density and reduced harmonic loading. It is found that the brushless machine with bread loaf structure.The motor constant square density for the proposed model is increase by 14.5% compared to that of the conventional model. Also as seen from the range of operation for the angle (+15 to -15) is constant and hence control is highly easier with that of the control circuit.

Keywords: Space, Scan Mirror, Limited Angle Brushless Torque Motor, Brushless Motor

1. INTRODUCTION

For the positioning mechanism such as the scan mirror application in the satellite applications requires precise position with greater fidelity. Weight of the system is an important factor in the aerospace systems, therefore the weight of the application system is considered more important than the configuration. For obtaining a system comprising of a low maintenance cost and optimized life, brushless motors are used instead of brushed motors. Besides these the brushless motors have many other advantages but the complexity of building up the power electronic commutation circuitry for driving the motor is inevitable. Very often brushed DC motors are replaced with brushless motors for various applications recent times and space applications such as this utilized one [1]. The brushless direct current motor (BLDC) comprises of a permanent magnet rotor and an armature stator with electronic commutation circuitry fitted with a rotor position sensor. The implementation of the BLDC is the most economical, and less maintenance cost demanding solution [2].The purpose of scan mechanism in the satellite is the rotation at positive and negative selectable scan positions. To meet the requirements of torque in the system, the software tool based on Finite Element Analysis is used for the optimized and proper designing and modeling of the motor. The provision of rate and position command is to be made possible through the software [3]. Figure 1 shows the scan mirror mechanical model typically employing two motors for the precise control as used in the satellite mirror scan applications [4].

Figure 2 shows the spread of the operation required both in the forward and reverse motoring to facilitate the scan mirror to tilt in two different angle (± θ) with constant torque. The motor armature design encompasses four winding on the stator base. In order to ensure ±θ degree uniformity in torque four magnets are mounted on stainless steel ring. The choice of the magnet determines the orientation

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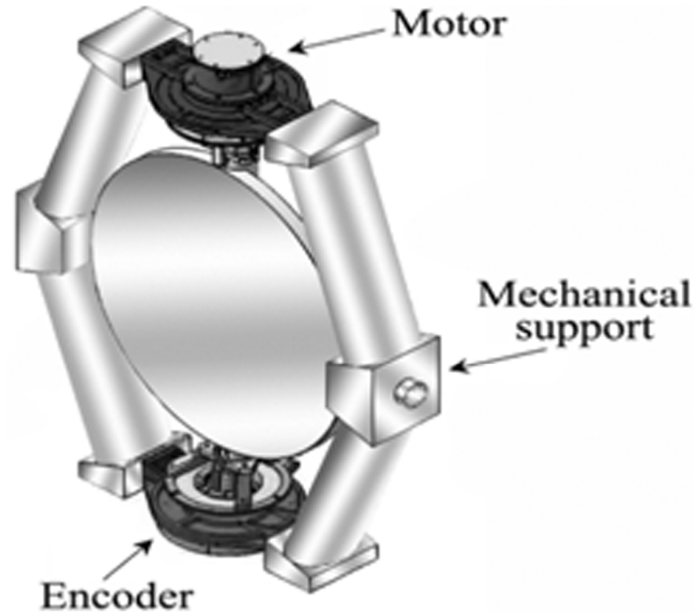


Figure 1: Scan Mirror Mechanism Model

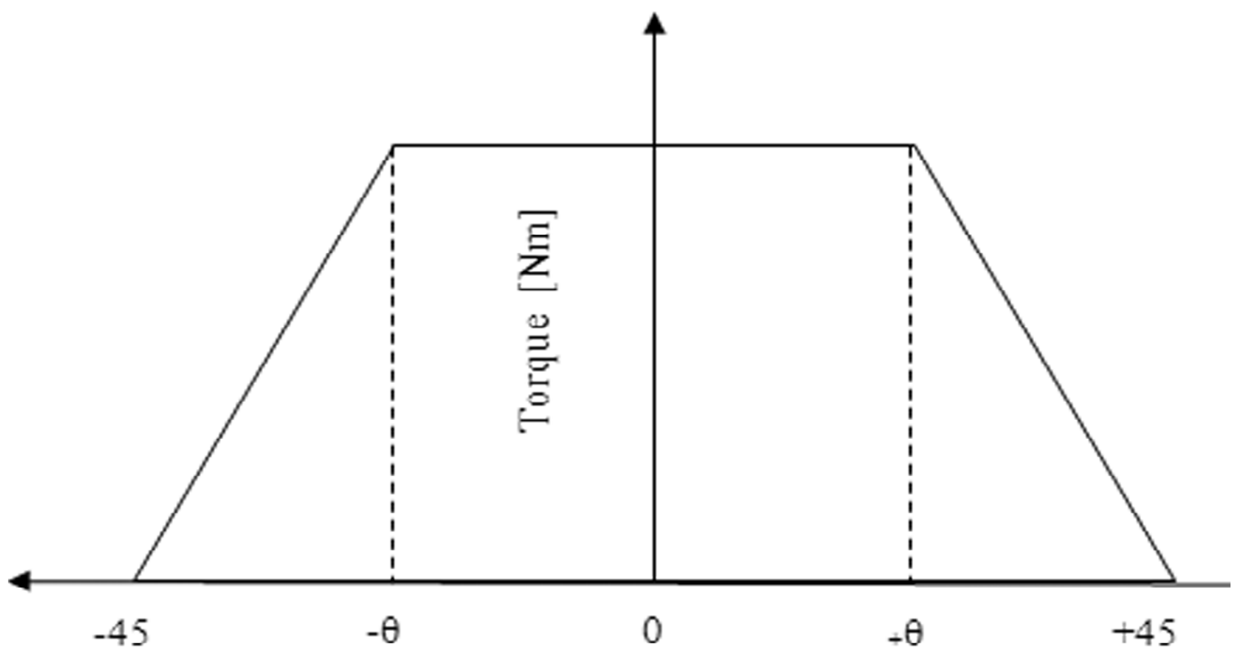


Figure 2: Torque Angle Characteristics

and hence the flux density and hence the torque of the machine. The application as such one required the torque design slab (as seen in the dotted lines) to be constant both in the forward and the reverse condition. Figure 3 shows the block diagram representation of the research approach used in this analysis. Seven different type of orientation is taken with both surface and interior magnet structure are used for analysis for their torque characteristics and harmonic component. All the machine structure is done for the same volume in order to have the fair comparison. Also the magnetic loading and the electric loading is kept the same with the net magnet volume being the same in all of the configuration. The machines are designed based on the design procedure used in [5-7] and are analyzed for electro-magnetic and electro-mechanical performance. The best model is then chosen and is compared with that of the conventional model [4] with resized to the volume chosen in this analysis for their torque performance.

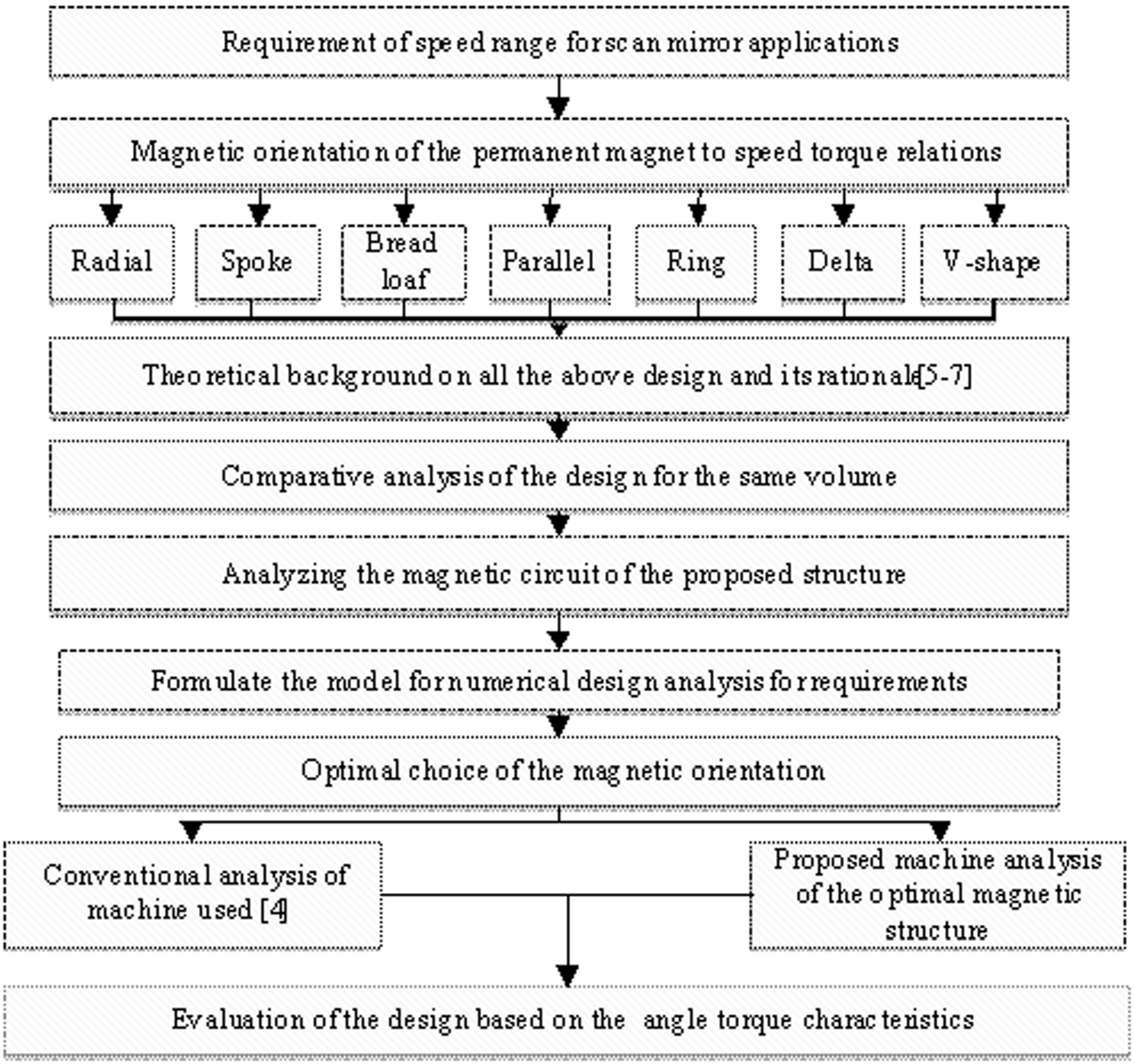


Figure 3: Models used in this investigation

2. DESIGN ARCHITECTURE

The capability of the machine T is as shown in the Equation (1)

$$T = KD^2L \tag{1}$$

where, K is motor constant, D is airgap diameter, L is stack length .The force F and therefor the torque is expressed as in Equation (2)-3

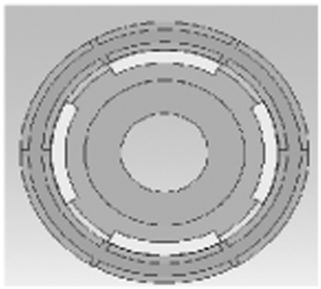
$$F = B_g I L_a \tag{2}$$

$$T = F R \tag{3}$$

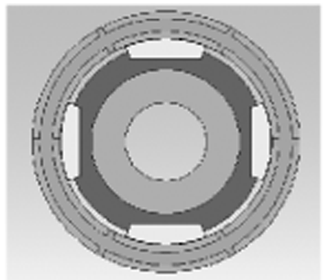
where B_g is the Air gap flux density, I is the winding current, L_a is the active length of conductor, R is the radius.There fore if P is the number of poles the torque developed in the motor is given as in Equation (4)

$$T = PB_gIL(D/2) \tag{4}$$

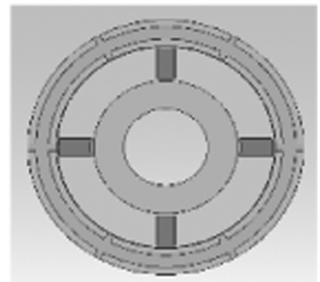
Figure 4 shows the seven model chosen in this design for comparative analysis and are modelled for the same volume and the net energy loadings. It is found that the bread-load surface with partial embedded magnetic orientation produces better linearity than the other models [8]. Figure 5 shows the proposed machine with bread- loaf rotor magnet. The machine has three phase armature winding, having four pole of bread-loaf magnet mounted on the surface of the rotor. Since the torque angle characteristics requires a smooth and constant it's more reliable to use the proposed machine for space applications improvement.



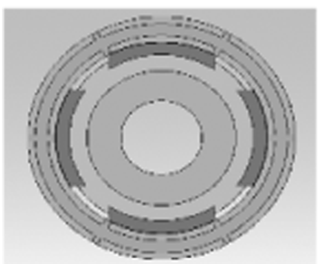
(a) Radial Surface



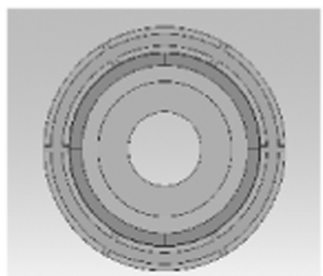
(b) Bread-loaf Surface



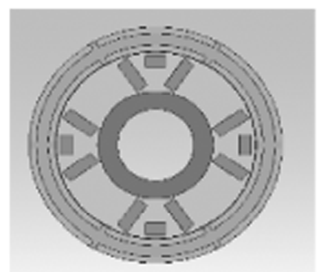
(c) Spoke Interior



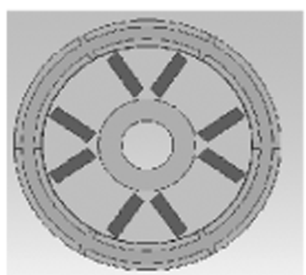
(d) Parallel Surface



(e) Full Ring Surface



(f) Delta Interior



(g) V Shaped Interior

Figure 4: Models used in this investigations

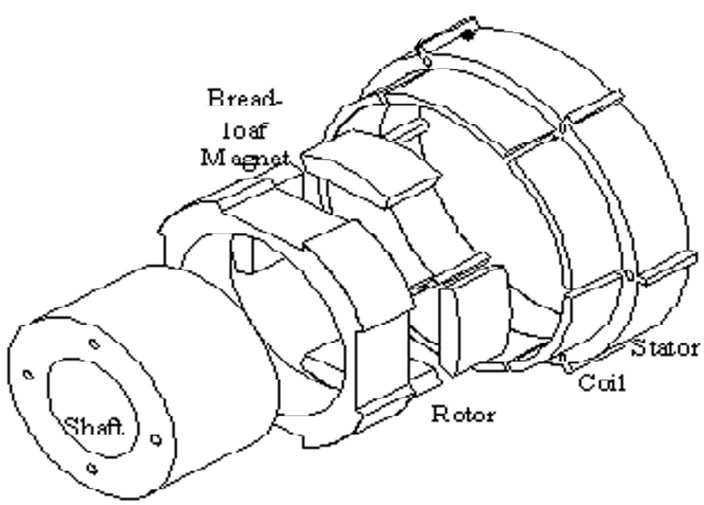


Figure 5: Proposed structural orientation

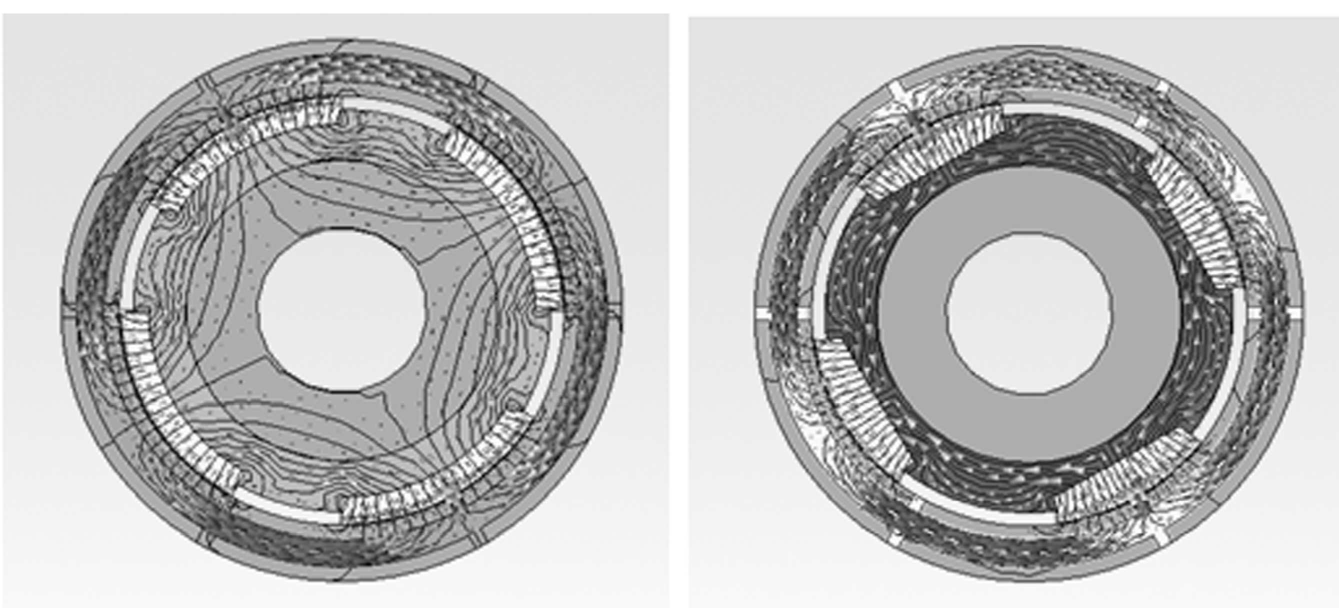
Table 1
Parameters of bread loaf structure

Parameter	*Value*
Rotor ring inner diameter	86 mm
Magnet rotor outer diameter	115 mm
Physical radial air gap	0.5 mm
Armature coil inner diameter	116 mm
Armature core inner diameter	124 mm
Armature core outer diameter	138 mm
Armature outer diameter	146 mm

Table 1 shows the parameter dimensions used for both proposed and existing model simulated in JMAG® software. As the proposed machine is designed to tilt the scan mirror into two different angles with no cogging torque. By using the JMAG® software the proposed and the exiting [4] models are simulated with performance of transient magnetic study and magnetic circuit analysis through FEA and numerical tools.

3. DESIGN EVALUATIONS

Figure 6(a) shows the flux linking in the proposed model is oriented well through the surface area of the yoke and it reduce the leakage in the conventional model (Figure 6(b)). Hence, the proposed machine is designed to enlarge the flux linkage generated in the air gap between bread-loaf magnet rotor and stator. Maximizing the linkage flux of the machine results a higher torque of the motor performance. In order to evaluate the machine on a comparative design factors motor constant square density is used in the analysis [9-13]. Table 2 shows the comparative evaluation of the machines for the torque density and the torque volume ratio of the conventional and that of the proposed model. As seen from the Table the motor constant square density for the proposed model is increase by 14.5% compared to that of the conventional model. Also as seen from the Figure 7 and Figure 8 the range of operation for the angle (+15 to -15) is constant and hence control is highly easier with that of the control circuit.



(a) Conventional Model **(b) Proposed Model**

Figure 6: Magnetic flux analysis

Table 2
Comparative evaluations

Parameter		*Bread-loaf Magnet*	*Radial Magnet*
I	[*A*]	5	5
V	[mm^3]	580156.9	582359.5
T_{avg}	[*Nm*]	0.27441	0.2322
K_t	[*Nm*/*A*]	0.054	0.046
Km	[$Nm/A/W^{-(1/2)}$]	2.16e-3	1.85-3
G	[$(Nm)^2/A^2/W^{-(1/2)}/mm^3$]	3.72E-9	3.18E-9

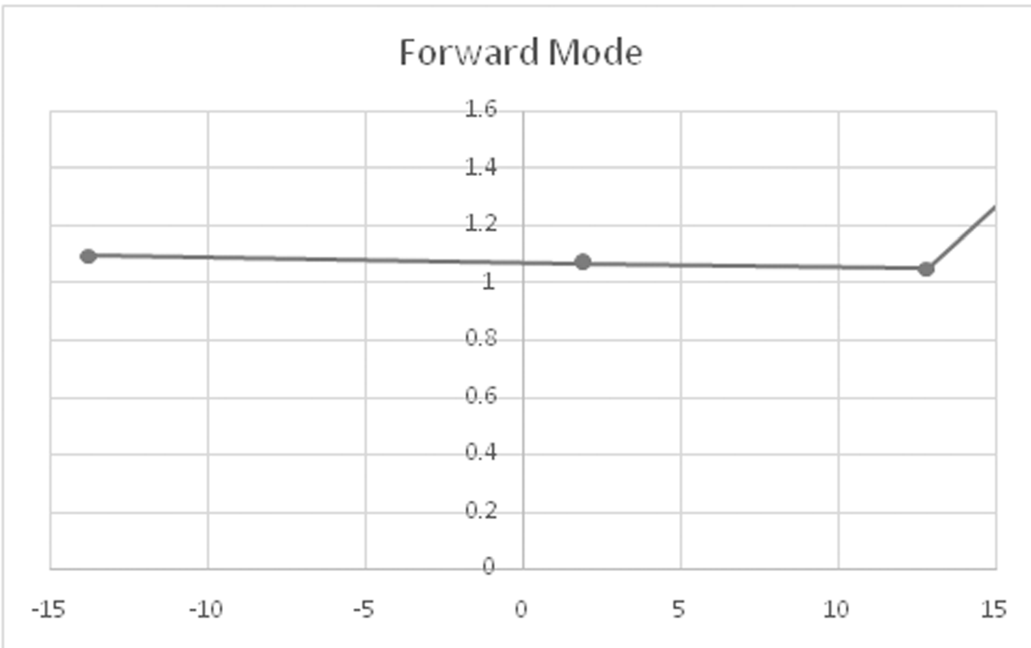


Figure 7: Magnetic flux analysis

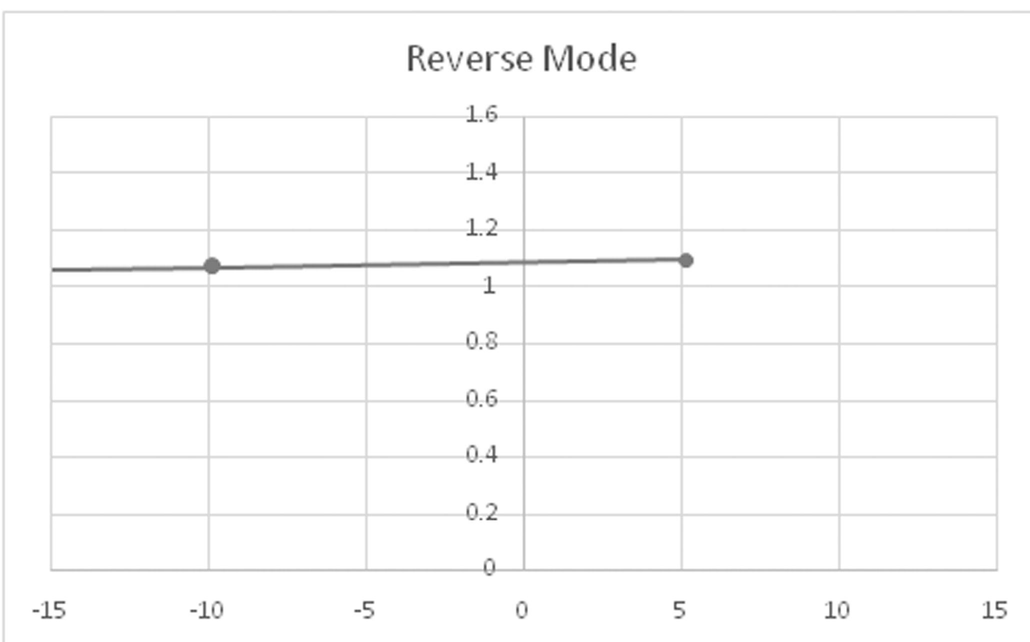


Figure 8: Reverse mode of the bread-loaf structure

4. CONCLUSION

The basic science behind scan mirror for satellite application is to get a stable torque which is achieved when the mirror is rotated in positive and negative region. The underlying reason of the research was to propose a new design of a motor for satellite space system. The motor constant square density for the proposed model is increase by 14.5% compared to that of the conventional model. Also as seen from the range of operation for the angle (+15 to -15) is constant and hence control is highly easier with that of the control circuit.

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