MATERIAL SELECTION ANALYSIS AND MAGNET SKEWING TO REDUCE COGGING TORQUE IN PERMANENT MAGNET GENERATOR

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Abstract

Cogging Torque is a pounding (torque opposite the direction of rotator generator) when rotating the rotor that causes the rotor is difficult to rotate by hand and can interfere with the rotation of the generator at the start, causing vibrations and disturbing sounds. Cogging is a characteristic attached to a permanent magnet generator (GMP) caused by the geometry of the generator. Cogging torque may affect start ability, generate noise and mechanical vibrations when GMP is installed in wind turbines. Therefore cogging GMP should be made as small as possible (coggingless), one way is to tilt (Skewing) permanent magnet. Simulation using magnet software to know the magnitude of the cogging torque caused by the rotation of the rotor on the generator. The cogging torque simulation results are further validated by the starting torque on the GMP testing method using material changes and magnetic skewing. The best magnetic slope is achieved when the magnetic slope is 7.5 °, because in this position also the highest cogging torque (9.951905191 x 10^{-5} Nm) is found in model 3 material A skewing magnet (7.5º) with Cr-10 core material and NdFeb magnetic magnet, while the lowest cogging value (1.17512009 x 10^{-5}Nm) is found in model 3 material A magnetic skewing (7.5º) with core material M250-35A and permanent magnet NdFeb.

Keywords: Generator, Cogging, Skewing, Torque

1. INTRODUCTION

Development and research continues to be done in the field of entrepreneurship to get new alternative energy sources that are healthy, environmentally friendly, efficient and cheap. This problem also affects the need of electric energy in Indonesia which is increasingly increasing day. For that required alternative energy as a producer of electrical energy. One of them is the utilization of wind energy. This energy must be balanced with the generating technology of a generator.

The development of generator technology is dependent on the material that has high efficiency generated by existing generators. Therefore the motor / generator used must meet the standards and have a small torque even as small as small. The existence of software to design the generator to help the researchers in designing and designing so that when making the process of generator has a high success rate and able to know the cost used in 1 time the generator, but many researchers previously conducted research and generator manufacture using try and error method in other words directly make the generator which is designed manually and using mathematical calculation manually.

Cogging is a tug (a torque opposite the rotary direction of the generator) when rotating the rotor causing the rotor is difficult to rotate by hand and can reduce the efficiency of the generator, causing vibrations and disturbing sounds. Cogging is a characteristic attached to a permanent magnet generator (GMP) caused by the geometry of the generator. Cogging torque may affect start ability, generate noise and mechanical vibrations when GMP is installed in wind turbines. Therefore cogging GMP should be made as small as possible (coggingless), one way is to tilt the permanent magnet. Simulation using energy variation method to know the magnitude of cogging torque caused by magnetic rotation. The cogging torque simulation results are further validated by the starting torque on the GMP testing method using the torque arm. The best magnetic slope is achieved when the pole width is 21 mm or the inclination angle is 3.88 ° (58% of the flow range) because in this position the cogging torque and the smallest starting torque are generated.

With these problems came the idea to analyze cogging, designing and designing a generator with the help of magnetic infolityca software. Software used specifically for analyzing, designing and designing generators and motors, but this software still has weaknesses in its devices so that for the design of complex forms must use other software to perform designing such as solidwork, autodesk and autocad. The existence of this research is expected later when there is doing the making, designing and research generator and motor do simulation first so that expected result fulfilled.

II.METODOLOGY

2.1 Place and Time of Research

The author applied the previous problem when the practice at the research site and the development of renewable energy in LenteraAngin Nusantara (LAN), Ciheras, Kab.Tasikmalaya, West Java and the data obtained continued in the laboratory ITP padang, processing using magnet software and other supporting software on personal computer (PC) Asus with Intel processor spek (R), Pentium (R), Cpu 2177U, 1.80Ghz, Ram 2 GB, 64bit, windows 7 ultimate, service pack 1.

2.2 Method of Calculation

The calculation and analysis of generator design based on the basic law of generator design, where the aid of magnet software and other calculation software can facilitate the calculation. The numerical method used refers to the equation of energy stored in the air gap, where the cogging torque (Tcog) is a derivative of the amount of energy stored in the air gap W to the angle of the rotor rotation (α) at the velocity ωt. The cogging torque is analyzed on three skewing positions (magnet), ie: straight, maximum (slope of a range of grooves) and between the two positions to obtain the most optimum magnetic position at what position will be. Material selection in the design of the generator is also required by combining 2 pieces of core material M250-35A and Cr-10 and its magnetic material Ndfeb and Smco.

2.3 Prototipe Design

GMP specifications are 100 W, 220 / 380V, 10000 rpm, NdFeB magnetic type with pole number p = 18. Magnetic skewing and configuration method of combination of 2 core materials and permanent magnet. The magnetic slope (skewing) is determined in 3 positions 0º, 15º and 7.5º. One generator is formed by 3 magnetic laying shapes whose position can be shifted to obtain the optimum slope of the image (3). The main parameters used for cogging torque analysis are obtained from the prototype design specifications. The 3D design model of the GMP rotor is shown in FIG. 4 with a dimension of one magnet, length x width x thick.

Table 4.1 Generator Dimension

Desain	Ukuran Dimensi
Di(diameter luar magnet)	65 mm
Da(diameter dalam magnet)	60 mm
Da (diameter luar rotor)	65 mm
Db (diameter luar stator)	120 mm
Dc (diameter dalam stator)	66.5 mm
De (diameter dalam lubang slot)	110 mm
Lm (tebal magnet)	7,5 mm
Lh (panjang magnet)	20 mm
La (tebal core)	40 mm
δg (air gap)	$\frac{1,5}{4} = 0,375\ mm$
P (jumlah magnet)	8 Pole
Qs (jumlah slot)	12 slot
Qc (jumlah coil)	24 turn
Ltg (jarak antara slot)	2 mm
Lt (tinggi teath)	0,5 mm
Lw (panjang teath)	20 mm

III. RESULT AND DISCUSSION

A. Result

In this paper, the following magnetic skewing position is determined as the angle between the midpoint of the magnet and the midpoint of the stator gear in a single pole, as shown in Fig. 1,

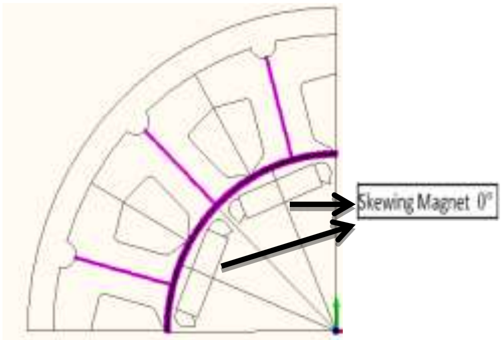


Figure 1.Magnet skewing 0^0

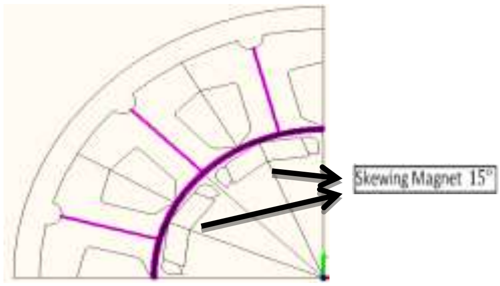


Figure 2.Magnetskewing 15º

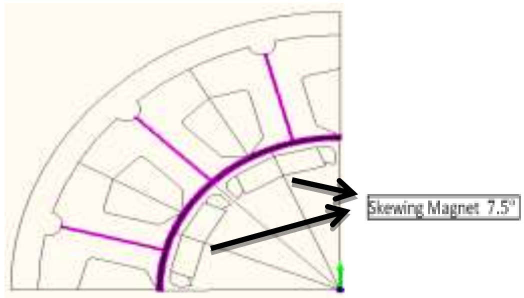


Figure 3.Magnet skewing 7.5º

The analysis is limited to the distribution of the magnetic field in the air gap in 1D (one dimension) ie the direction of radial magnetization to the generator shaft. When stationary, position one mid-magnet against the mid-tooth of the stator in one pole. The magnet used is considered to have the same dimensions and characteristics, and its relative permeability is equal to that of air.

The result of simulation and analysis of this calculation to find out how big the cogging torque on generator design and the effect that will be generated to achieve the reduction of cogging value and the desired generator efficiency.

The test / simulation result of 100 watt generator design using infolytica magnet software with generator design specification as shown in chapter 2 obtained the results include:

B. Energy

The energy in the simulated generator 3 model 3 material is the energy stored or owned by each material from the core, in other words the generator before use has the energy stored in it for:

Tabel 2 Result of Energy and Co-energy

No	Parameter	Energy	Co-Energy	Satuan
1	Model 1 Material A	-9.87	9.87	Joule
2	Model 1 Material B	-7.34	7.34	Joule
3	Model 1 Material C	-9.87	9.87	Joule
4	Model 2 Material A	-9.79	9.79	Joule
5	Model 2 Material B	-7.28	7.28	Joule
6	Model 2 Material C	-9.78	9.78	Joule
7	Model 3 Material A	-9.95	9.95	Joule
8	Model 3 Material B	-7.4	7.4	Joule
9	Model 3 Material C	-9.94	9.94	Joule

The energy in the simulation result of the generator is the energy stored or owned by each material from the nucleus, in other words the generator before use has the energy stored in it, the greatest energy is in the third model that is magnetic skewing (7.5º) with M250- 35A and permanent magnetic Ndfeb of -9.95 joule energy and 9.95 joule co-energy. As for the lowest energy is the second model of magnetic skewing (15º) with core material

M250-35A and permanent magnet SmCo of -7.28 joules of energy and 7.27 joule co-energy.

C. Result: 3 Generator Model with 3 Different Material

1. Generator model with no skewing

In this model the generator corresponds to the initial shape and specification without any skewing, but the research is done by changing the shape of core material and permanent magnet following material:

A. Corepart : M250-35A, permanent Magnet (PM) : Ndfeb

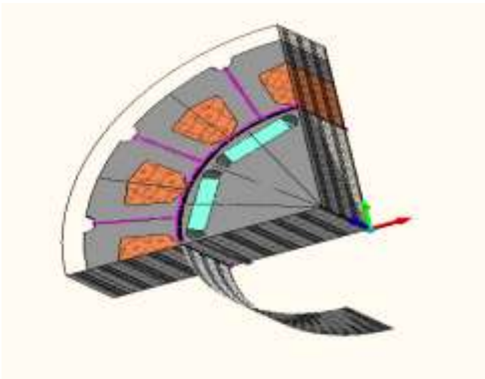


Figure 4. Model ¼ of core material generator : M250-35A, permanentmagnet (PM) : Ndfebskewing 0^0

B. Core part: M250-35A, permanent Magnet (PM) : Samarium Cobalt

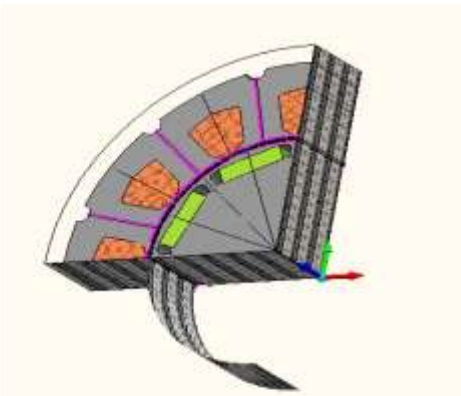
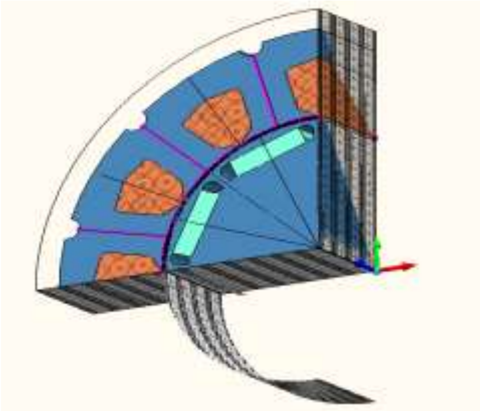


Figure 5. Model ¼ part of Core material generator : M250 - 35A, permanentmagnet (PM) : samarium cobalt 0 degree slope

C. Core part: CR10, permanen Magnet (PM) : Ndfeb



Gambar 6 Model ¼ part ofcore materal generator : CR-10, permanen Magnet (PM) : NdFeb 0 degree slope

2. Generator model of 15^o skewing

In this model the generator changed its magnetic position in skewing 15 degrees upward, but the research also changed the shape of magnetic material and core materials and materials:

A. Core part : M250-35A, permanenMagnet (PM) : Ndfeb

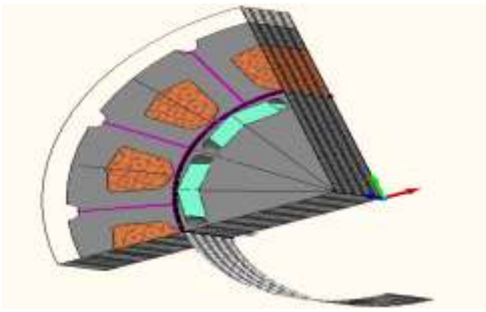


Figure 7. Model ¼ part of core material generator : 250M-35A, permanen Magnet (PM) : NdFeb
skewing 15 degree

B. Core side : M250-35A, permanent Magnet (PM) : Samarium Cobalt

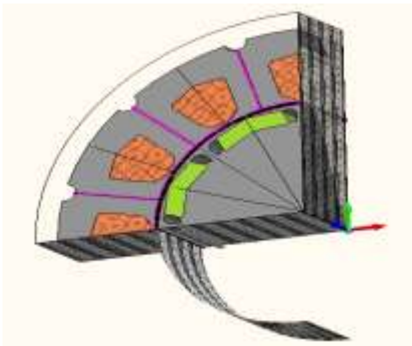
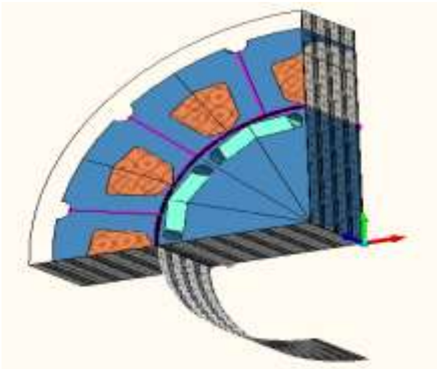


Figure 8. Model ¼ Core material generator part : M250-35A, permanen Magnet (PM) : samarium cobalt 15 degree skewing

C. Core part : CR10, permanentmagnet (PM) : Ndfeb



Gambar9 ¼Part Model of generatormaterial core: CR-10, permanen Magnet (PM) : NdFeb15^0 magnet skewing

3. Model Skewing MagnetGenerator 7.5derajat

In this model the generator changed its magnetic position in skewing 7.5 degrees upward, but the research also changed the shape of magnetic material and core materials:

A. Core part : M250-35A, permanentmagnet (PM) : Ndfeb

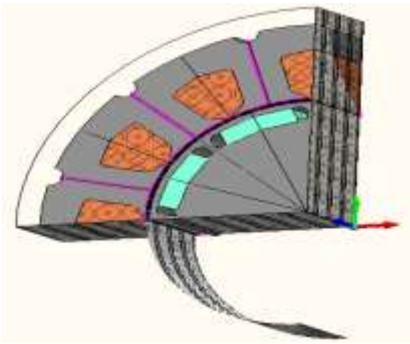


Figure 8. Model ¼ core material generatorpart: CR-10, permanen Magnet (PM) : NdFeb 15 degree skewing magnet

B. Core part : M250-35A, permanentmagnet (PM) : Samarium Cobalt

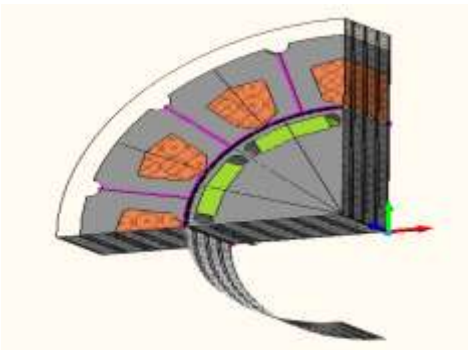


Figure 11. Model ¼core material generator part : CR-10, permanen Magnet (PM) : NdFeb15 degree magnet skewing

C. Core : CR10, permanen Magnet (PM) : Ndfeb

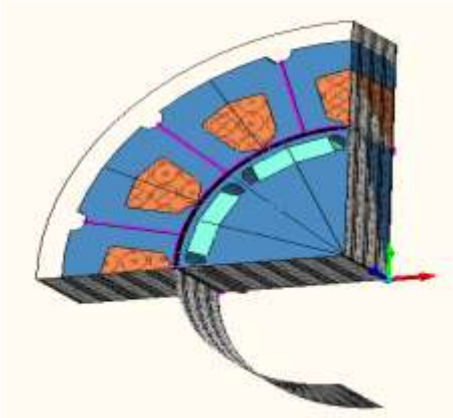


Figure 12. Model ¼partgenerator Core : CR-10, permanen Magnet (PM) : NdFeb magnet skewing 7.5 degree

By using equations. In this design to find 1 peak and 1 valley cogging 12 slot / 8 pole is valid for all models 1 - 3 which has 12 slots and 8 poles because it got the formula to calculate 1 wave full of cogging

$$\theta_m = \frac{360}{12} = 30\ degree$$

$$\theta = \frac{30}{8} = 3.75\ degree\ \ (half\ wave)$$

$$\theta_{1wave} = 3.75\ x\ 2 =$$

$$7.5\ \ degree\ (full\ wave)$$

coggingequatio :

$$Tcog = -\frac{1}{2}\phi\frac{2}{g}\frac{tR}{d\theta}$$

D. Models of Generator

Gambar 13 Curve of torque produced by generator core material parts: M250-35A, permanentmagnet (PM) : Ndfeb 0 degree skewing

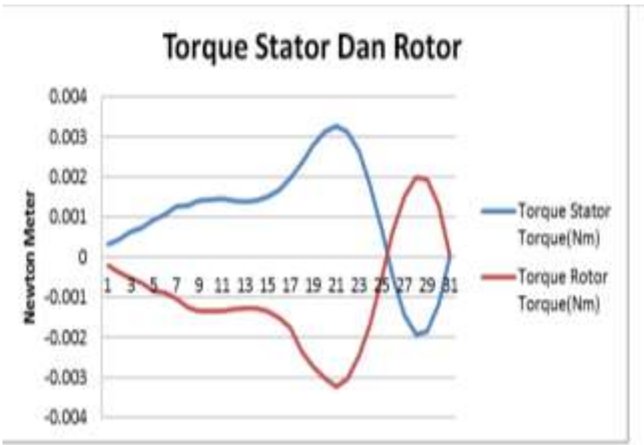


Figure 14.permanentmagnet (PM) : Ndfeb15^{o} skewing

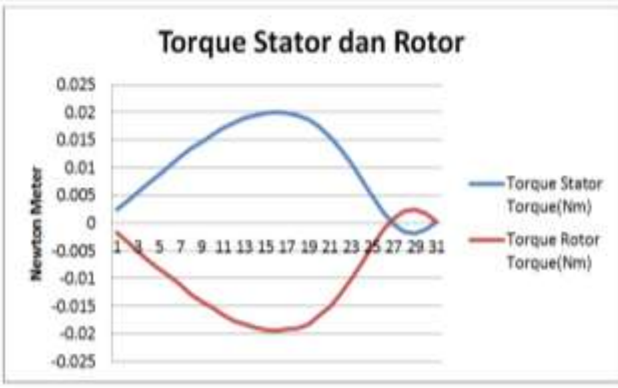


Figure 15 Core : CR-10, permanen Magnet (PM) : Ndfeb 0 degree slope

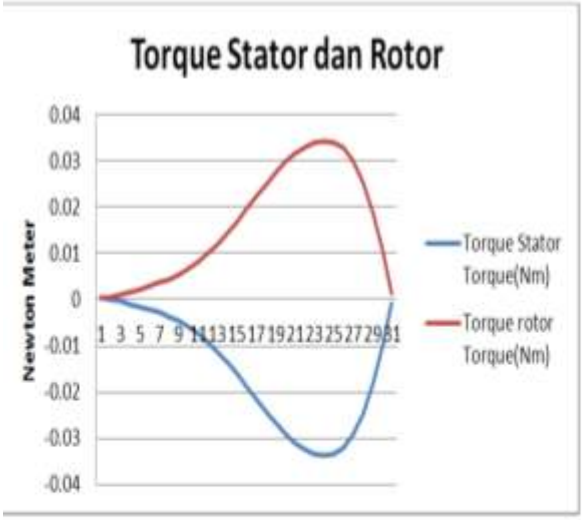


Figure 16 Core : M250-35A, permanentmagnet (PM) : Ndfeb 15 degree skewing

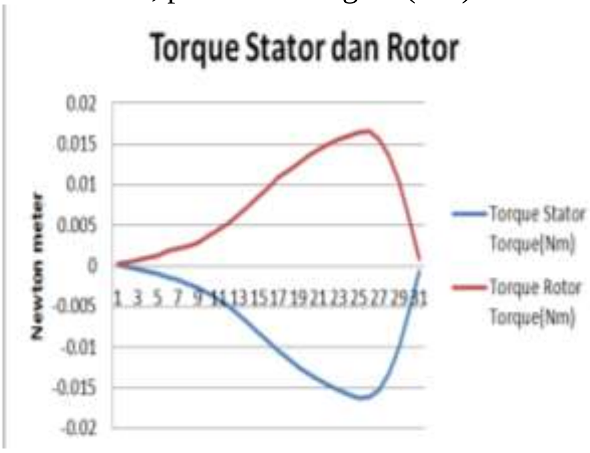


Figure 17. : smartium cobalt 15^{o} skewing

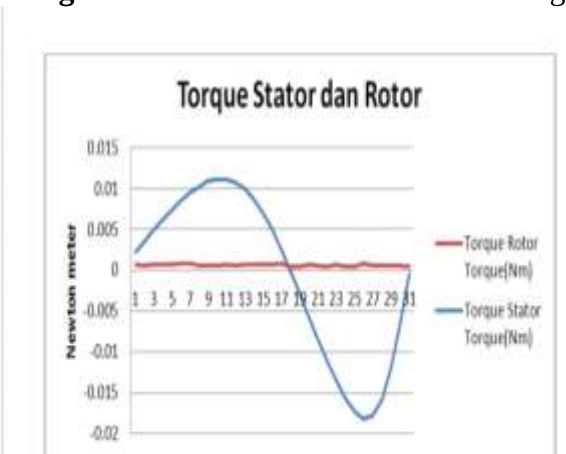


Figure 18 Core : 250M-35A, permanentmagnet (PM) : smartium cobalt 15 degree skewing

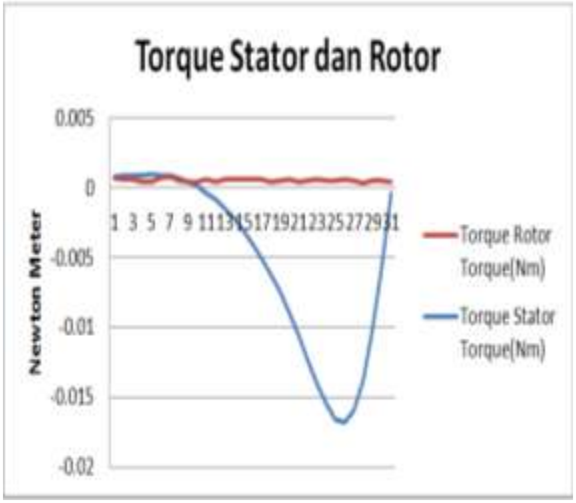


Figure 19 Core : 250M-35A, permanentmagnet (PM) : Ndfeb 7.5 degree skewing

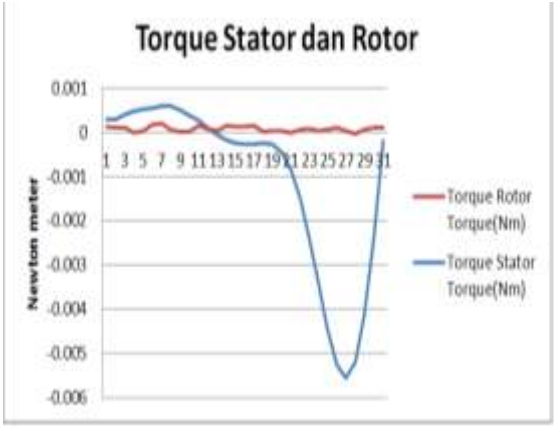


Figure 20 Core : M250-35A, permanentmagnet (PM) :samarium cobalt 7.5 derajat skewing

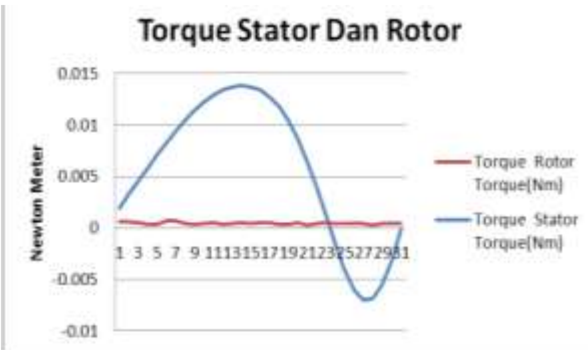


Figure 21 Core : CR-10, permanentmagnet (PM) :Ndfeb 7.5 degree skewing

E. Result of Cogging Torque

Table 3. Result ofCogging Torque

No	Parameter	Nilai	Satuan
1	Model 1 Material A	0.0005890413426	Newton meter
2	Model 1 Material B	-0.000159025706	Newton meter
3	Model 1 Material C	-0.0002049643614	Newton meter
4	Model 2 Material A	-0.000367627085	Newton meter
5	Model 2 Material B	0.0001402941686	Newton meter
6	Model 2 Material C	0.0002299853379	Newton meter
7	Model 3 Material A	−0.000117512009	Newton meter
8	Model 3 Material B	0.0001734388814	Newton meter
9	Model 3 Material C	0.0009951905191	Newton meter

Based on the above data can be analyzed, that the generator has a different magnetic skewing and different materials have different cogging torque values. The highest cogging torque is found in model 3 C magnetic skewing material (7.5º) with Cr-10 core material and NdFeb magnetic magnet, while the lowest cogging value is found in model 3 material A skewing magnet (7.5º) with material core M250-35A and permanent NdFeb magnets.

F. Result of Vdc Simulation Analysis of each Generator

Table4.32 Result of Generator Simulation

No	Parameter	Nilai	Satuan
1	Model 1 Material A	6.358489976	Vdc
2	Model 1 Material B	5.287196159	Vdc
3	Model 1 Material C	6.797324034	Vdc
4	Model 2 Material A	7.436507027	Vdc
5	Model 2 Material B	5.759280063	Vdc
6	Model 2 Material C	7.056347779	Vdc
7	Model 3 Material A	6.585886672	Vdc
8	Model 3 Material B	4.930994666	Vdc
9	Model 3 Material C	6.35279019	Vdc

The result of the voltage between the coil obtained the highest voltage of each phase using the absolute value to get the value of its Vdc voltage degan the angle of 0.24 - 7.44. Then the highest value of vdc is found in the model 2 material 1 is 7.436507027 vdc and the lowest value found in model 3 material 2 is 4.930994666 vdc.

F. ResultOf Rotor Speed (Rpm)

Because Cogging Torque does not take time to calculate the speed of play then the formula to find the rpm depends on many slots and poles on the generator because the generator models 1 to 3 have the same model then for frequency and speed of rotation (rpm) is also the same ie. Using the equation (2.61 to 2.65)..

$$\theta_{mek} = \frac{360}{24} = 15\ degree\ (mechanical)$$

$$\theta_{Ele} = \frac{8}{2} x\ 15 = 60\ degree\ (electric)$$

$$t_{Rt} = \frac{15}{90} = 0{,}16667\ secon$$

In this design the rotor is rotated every 3 ^ 0 with a time of 0.16667 ms = 0.00016667 s So to rotate by ⟦360⟧ ^ 0 takes 60ms = 0.006

$$F = \frac{1}{0{,}06} = 16{,}6667\ Hz$$

$\omega = 2\ x\ 3{,}14\ x$ 16,6667 = 104,6667 rad/s atau 1000 rpm

IV. CONCLUSION

A. Conclucion

After doing the designing and modeling system then perform testing and analysis, it can be taken some conclusions as follows:

How to reduce Cogging Torque with magnetic skewing is one way of reducing cogging torque with the magnitude of 15º and 7.5º, with M250-35A and CR-10 core materials while the Ndfeb and SmCo magnet material is permanent. Based on the results of the analysis that the generators have different magnetic skewing and different materials have different cogging torque values. The best magnetic slope is achieved when the magnetic tilt is 7.5 °, because in this position the highest cogging torque is generated (9.951905191 x ⟦10⟧ ^ (- 5) Nm) found in model 3 material A skewing magnet (7.5º) with material core Cr-10 and permanent NdFeb magnets, while the lowest cogging value of yaiu (1,17512009 x ⟦10⟧ ^ (- 5) Nm) is found in model 3 A magnetic skewing material (7.5 º) with core material M250-35A and permanent magnet NdFeb.

B.Suggestions

To get the design results and design of theappropriate generator and well should better understand the basic principles used by the generator as well as take into account everything such as magnetic slope material and generator dimensions are made. so get the appropriate diameter for the generator in the absence of a cogging torque or a coggingless call.

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