

The Comparison Study of Orbital Electro Motor Patent IDP00201300116 with BLDC Motor Construction to the Force and Torque of the Electric Motor

Rahmat Doni Widodo, Widya Aryadi, Ahmad Rozikin
Department of Mechanical Engineering, Universitas Negeri Semarang, Indonesia

Keywords: Orbital Electric Motor, BLDC Motor, Magnetic Simulation, Force, Torque

Abstract: This study aims to compare the force and torque generated between orbital electric motor patent IDP00201300116 with BLDC electric motor. This research was conducted based on magnetic simulation modelling method using software. Coil wire material using Copper: $5.77e7$ Siemens with dimensional cross-section area of 5x3 cm, iron core using Miscellaneous Steel Material 20PNF1500 with dimensional cross-section area of 6x2 cm, and permanent magnet using Neodymium Iron Boron 28/23 material with dimensional cross-section area of 6x2 cm. Simulations are carried out on six rotor magnet position stages which represent the rotor rotation motion. The simulation results produce the greatest force data that can be generated by orbital electric motor of 180 N compared to the greatest force of BLDC motor of 159 N, while the greatest torque capable of being produced by orbital electric motor is 3.58 Nm compared to the torque produced by BLDC motors of 2.79 Nm. The average force that can be generated by the orbital electric motor is 106.57 N compared to the BLDC motor of 132.83 N, the average torque produced by the orbital electric motor is 1,619 Nm compared to the BLDC motor of 1,623 Nm. Based on these data, it can be concluded that the construction of orbitals electric motor at certain test points produces greater force and torque than the BLDC motor, but BLDC motors have a higher average force and torque.

1 INTRODUCTION

The use of electric motors as a generator of mechanical motion is currently widely used, to become the most popular energy conversion system to produce clean mechanical energy. In the future, the application of electric motors has a big challenge, especially the development of electric motor technology that can produce large power and large torque efficiently. Many patents were created to make this happen. The invention proposed by Douglas F. McFarland US 4473763 A entitled "Solenoid motor", describes a solenoid motor consisting of a crankshaft with a number of selenoids surrounding it (Mc. Farland, 1984). This invention uses translational motion to rotate the crankshaft so that it is less efficient. In addition the invention of electric motors was also stated by Michael John Werson US Patent 5986376 A entitled "Brushless DC motors", which consists of rotors made of permanent magnets and stator with iron core and installed windings facing each other with the rotor (Werson, 1999). This

invention is less capable of producing large torque due to the direction of the magnetic field produced by the stator to the rotor or vice versa not in the toroid core of the magnetic field. This happens because the location and direction of the stator winding does not really circle the rotor.

In the construction of the electric motor that is currently not able to produce large torque due to the direction of the magnetic field produced by the stator to the rotor or vice versa is not in the direction that produces maximum performance. This happens because the location and direction of the stator winding does not really circle the rotor or vice versa. Based on the weakness of the use of magnetic field force in the types of electric motors that exist, the researchers developed the concept of electrical orbital motors where the rotor construction is right at the center of the toroid magnetic field or in the center of the coil so that the maximum output energy is obtained. The concept of orbital electric motor has been registered for patent by the State University of Semarang in 2013 and has obtained a patent

certificate in 2017 with a patent number ID P00201300116.

Brushless DC motor (BLDC) is an electric motor that consists of rotors and stators that have front facing faces. One of the parts consists of a permanent magnet that is arranged parallel in one axis and has the same distance between one and the other. The iron core is one of the surfaces that deal with magnets. Iron cores are arranged in certain angles and have the same distance. The wire coil is wrapped around the iron core where when the windings flow with an electric current with a certain amount, it will produce torque which will rotate the rotor (Werson, 1999). Illustration of BLDC magnet construction can be seen in the following figure.

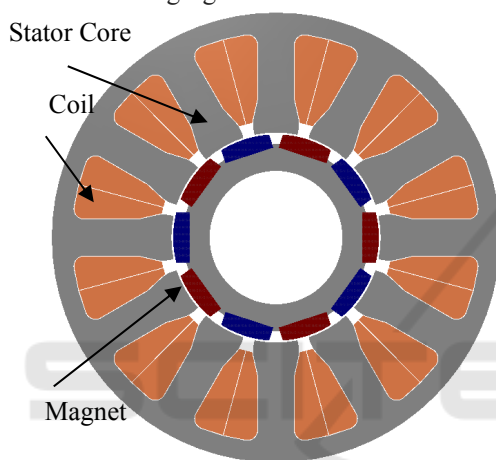


Figure 1: BLDC motor construction with permanent magnet rotors.

The BLDC motor is a type of synchronous motor because the magnetic field generated by the stator and the magnetic field generated by the rotor rotates at the same frequency (Y.S Jeon, 2000). In the brushless DC motor, polarity reversal is performed by power transistors switching in synchronization with the rotor position. Therefore, BLDC motors often incorporate either internal or external position sensors to sense the

actual rotor position (Madhurima, 2012). Theoretically BLDC motor is a constant torque machine but torque ripple exists practically due to current ripple, emf waveform imperfections and phase current commutation to the electric motor. The effects of torque pulsation in BLDCM are audible noise and visible vibration in the high precision application (Babu, 2017). Besides the torque ripple and vibration, there are more disadvantages from BLDC motor as shown at Table 1 below.

2 TEST METHOD

2.1 Orbital Electric Motor

This patent is a construction of an electric motor system circuit that is able to optimize the relative magnetic force between the stator magnetic field and the direction of the rotor motion or vice versa. This patent electric motor construction has a rotor that is located inside the stator winding cavity, where in the winding cavity there is a toroid magnetic field center. Construction and performance is designed by using a rotor in the form of a ring gear without a shaft. The use of rotor construction without shaft allows the windings to be perfectly formed around the rotor. To get mechanical motion, the inner teeth of the rotor ring are connected to the sun's gear. This sun gear shaft is then used as an output in the form of mechanical rotational energy. When the motor is working, the ring gears orbiting on the sun gear, this is why this patent is named orbital electric motor. Orbital electric motor construction can be seen in the following figure.

The principle of using the magnetic field center in the coil as motion energy can also be proven in other types of motors, including electric axial flux permanent magnet machines (AFPM) and Tubular moving-magnetic linear oscillating motors (TMML OM). Axial flux permanent magnet machines become one

Table 1. Advantages and disadvantages of different types of motors (Naser, 2016).

Motor Type	Advantage	Disadvantage
BLDC	High Power density, High efficiency	Limited speed range, High cost, High stator core los at high speed
Induction Motor (IM)	High speed range, High reliability, Low cost, Rigidity in hostile Environments	Low efficiency, Thermal problem at high speed
Switched Reluctance Motor (SRM)	Desirable torque speed characteristics, High reliability, Low cost, Rigidity in hostile Environments	High torque ripple and noise, Low power density, Low efficiency

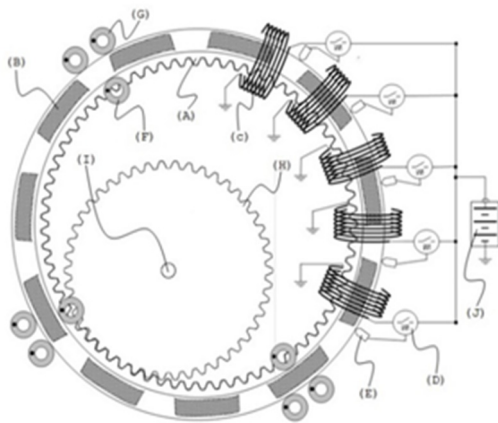


Figure 2: Orbital electric motor construction design.

type of motor that allows to achieve high motor performance. AFPM motors have high energy, and light weight. AFPM motor is very suitable to be applied to the in wheel drive and also the in line drive on electric vehicles (Emran, 2017). sTMMLOM is an actuator that works linearly with a high alternating frequency. The advantages of this tool are efficiency, performance and simple structure so that it can be applied to many uses. This tool works without using a crankshaft so it has an efficiency of 20-30 percent compared to an electric motor that works with the principle of rotation on the compressor refrigerator application (Xuensong,2018).

2.2 Simulation and Analysis

The method used in this study is finite element analysis using software. Finite element analysis is performed for getting torque, force and flux density distribution waveforms in static condition. The most used performance characteristics obtained from the analysis (Emran, 2017). Testing parameters using software are based on materials commonly used to make electric motors. The parameters for testing simulation using software are as follows.

Coil material	: Copper:5.77e7 Siemens/meter
Distace	: 5cm
Iron Core material	: Miscellaneous Steel Material 20PNF1500
Magnet material	: Neodymium Permanent Magnet Material Neodymium Iron Boron28/ 23
Coil cross section size	: Lenght 5 cm, width 3 cm
Magnet size	: Lenght 6 cm, width 2 cm

Iron Core size : Lenght 6 cm thick 2 cm
Current : 2 A 60 hz

Testing simulation using software is represented by single segment of the electric motor, consisting of a permanent magnet as a moving part, and one pair of coils and an iron core. To determine the change in magnetic force that occurs in one segment of the electric motor, it is simulated that the magnet motion moves closer to the coil until it reaches the center of the coil core, starting from step 1 of the magnet position farthest from the coil, until step 6 the magnet position in the center of the coil. The simulation was carried out on two different electric motor construction, namely BLDC motor construction and motor Solenoid construction to be analyzed for the results of the differences of the two motor construction.

3 RESULTS AND DISCUSSION

3.1 Simulasi BLDC Motor

BLDC motor construction generally places the coil and iron core on the center of the electric motor, and places a permanent magnet on the outside of the motor. This kind of construction allows the BLDC motor to work without using a brush. BLDC motor simulations are performed on single segment of the electric motor consisting of a permanent magnet, coil and iron core. Simulations were carried out on six stages of magnetic motion from step 1 to step 6 to simulate the motion of the electric motor rotor. The results of magnetic force simulation using software obtained at the following graph.

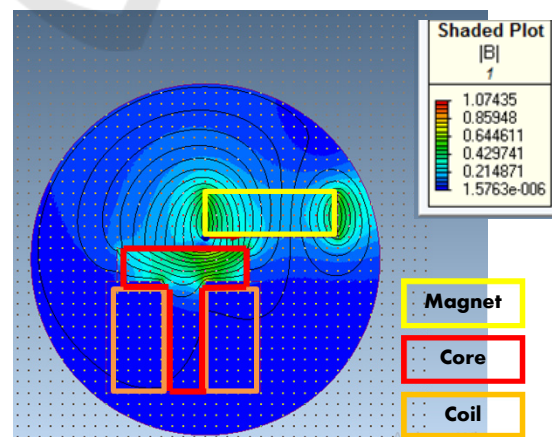


Figure 3: Magnetic flux simulations on BLDC motor segments.

Table 2: Simulation of magnet position against magnetic force on the BLDC motor.

Simulation	part	Force				Torque			
		X	Y	Z	Magnitude	X	Y	Z	Magnitude
Step 1	Coil 1	34	27.2	0	43.6	0	0	-0.883	0.883
	Magnet	-134	-84.8	0	159	0	0	2.3	2.3
Step 2	Coil 1	31.6	71	0	77.7	0	0	0.982	0.982
	Magnet	-69.5	-96.5	0	119	0	0	-1.78	1.78
Step 3	Coil 1	14.9	88.5	0	89.7	0	0	0.117	0.117
	Magnet	-65.5	-119	0	134	0	0	-0.591	0.591
Step 4	Coil 1	0.995	90	0	90	0	0	-1.45	1.45
	Magnet	-49.9	-142	0	150	0	0	0.765	0.765
Step 5	Coil 1	-9.67	97.5	0	98	0	0	-2.61	-2.61
	Magnet	3.36	-118	0	118	0	0	2.79	2.79
Step 6	Coil 1	-18.8	84.4	0	86.4	0	0	-1.5	1.5
	Magnet	6.95	-117	0	117	0	0	1.51	1.51

Based on the illustration in Figure 3, it can be seen that the magnetic force lines formed between the coil. It create an attractive force to make the magnet approach the magnetic center of the coil to produce magnetic force and torque. The simulation results of magnetic force and torque from different position of the magnet from step 1 to step 6 are summarized in Table 2 below

Based on the data shown in Table 2, the strongest magnetic force simulation results are generated in step 1 with a force of 159 N. The highest torque is in step 5, which is 2.79 Nm.

3.2 Simulation of Orbital Electric Motor

Simulations on orbital electric motor use the same method as simulations on BLDC motors. Simulations on the orbital electric motor used only one motor segment consisting of magnet, coil and iron core. The three parts are made to have dimensions that are not different from the BLDC type motor but have different construction. Simulations on the motor solenoid also use 6 stages of motion to simulate rotor motion. The simulation results of the motor solenoid construction using software can be seen from the illustration of the following simulation results.

Based on the simulation illustration of the magnetic force in figure 4, the magnetic force line can be seen in the middle between the upper and lower coils which is very dense so that it is depicted in red indicating a large magnetic force. It is used to draw a permanent magnet which is positioned in the middle of the coil so that a greater attraction is produced. Detailed data from each stage of the simulation of

changes in magnetic position from step 1 to step 6 can be seen in Table 3 below.

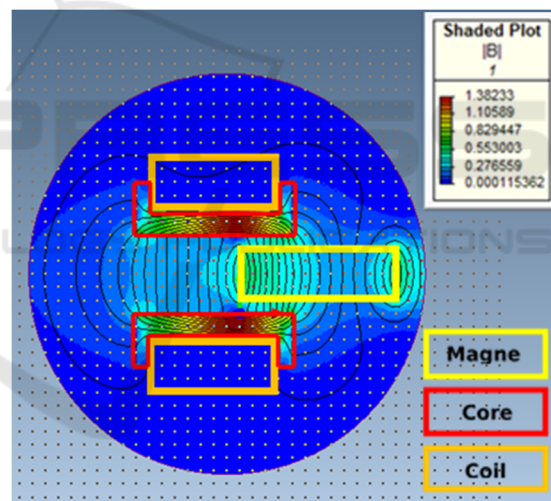


Figure 4. Magnetic flux simulations on orbital electric motor segments.

Based on the data shown in the Table 3, it can be seen that the greatest magnetic force generated is in step 2 with a magnetic force of 180 N. The biggest torque in the orbital electric motor simulation is generated in step 1 with a torque of 3.58 Nm.

3.3 Comparative Analysis of BLDC and Orbital Electric Motor

Based on the data in Table 4, BLDC motor has the greatest force 159 N and the smallest force is 117 N

Table 3: Simulation of magnet position against magnetic force on the orbital electric motor.

Simulation	Part	Force (N)				Torque (Nm)			
		X	Y	Z	Magnitude	X	Y	Z	Magnitude
Step 1	Coil 1	53	-46.5	0	70.5	0	0	-0.749	0.749
	Coil 2	54	45.9	0	70.9	0	0	-1.38	1.38
	Magnet	-179	0.49	0	179	0	0	3.58	3.58
Step 2	Coil 1	51.5	123	0	133	0	0	0.155	0.155
	Coil 2	52.9	124	0	134	0	0	-1.19	1.19
	Magnet	-180	6.84	0	180	0	0	2.09	2.09
Step 3	Coil 1	24.5	-168	0	169	0	0	-0.399	0.399
	Coil 2	24.9	167	0	169	0	0	-0.325	0.325
	Magnet	-109	-0.002	0	109	0	0	1.63	1.63
Step 4	Coil 1	-5.64	-181	0	181	0	0	0.661	0.661
	Coil 2	-5.67	180	0	180	0	0	-0.441	0.441
	Magnet	-44.7	0.137	0	44.7	0	0	0.889	0.889
Step 5	Coil 1	-31.5	-164	0	167	0	0	-0.101	0.101
	Coil 2	-31.5	164	0	167	0	0	1.07	1.07
	Magnet	47.9	-0.284	0	47.9	0	0	-0.737	0.737
Step 6	Coil 1	-43.3	-118	0	126	0	0	8.1	8.1
	Coil 2	-43.6	118	0	126	0	0	-7.23	7.23
	Magnet	78.8	-0.06	0	78.8	0	0	-0.789	0.789

with an average force value 132.8 N. The biggest force produced by orbital electric motor is 180 N and the smallest force is 44.7 N with an average force of 106.6 N. The minimum torque produced by the BLDC motor is 0.591 Nm and the greatest torque is 2.79 Nm with an average torque of 1.623 Nm. The minimum torque produced by the electric motor orbitals is 0.737 Nm and the greatest torque is 3.58 Nm with an average torque of 1,619 Nm.

Figure 5 shows that the force generated by the BLDC motor tends to be stable with an average force of 132.8 Nm. Orbital electric motor shows a graph of unstable force with peak force with the lowest force having a difference of 135.3 N with the pattern of force on the orbital electric motor tends to decrease when approaching the center of selenoid which simulated in step 6

Table 4: Comparative analysis of BLDC and orbital electric motor.

Posisi magnet	BLDC		Orbital Motor	
	Force Magnitude (N)	Torque Magnitude (Nm)	Force Magnitude (N)	Torque Magnitude (Nm)
Step 1	159	2.3	179	3.58
Step 2	119	1.78	180	2.09
Step 3	134	0.591	109	1.63
Step 4	150	0.765	44.7	0.889
Step 5	118	2.79	47.9	0.737
Step 6	117	1.51	78.8	0.789
min	117	0.591	44.7	0.737
max	159	2.79	180	3.58
average	132.8	1.623	106.6	1.619

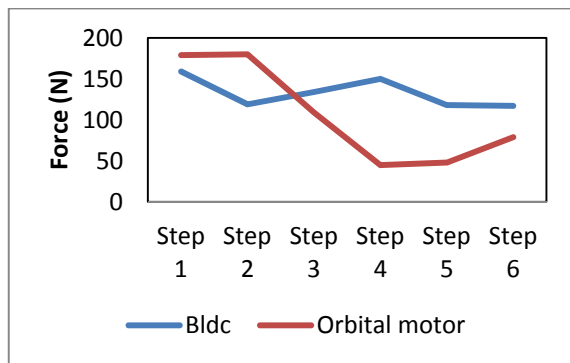


Figure 5: Comparison of BLDC and orbital electric motor force.

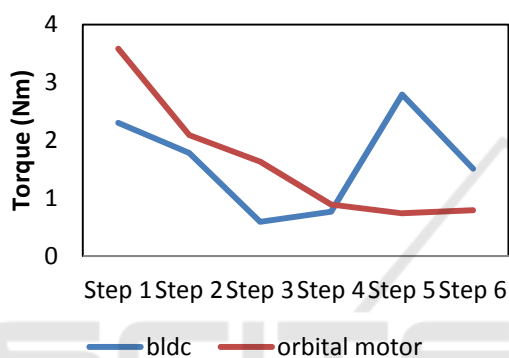


Figure 6: Comparison of BLDC and orbital electric motor torque.

Figure 6 shows that the torque generated by the BLDC motor fluctuates with an average of 1.623 Nm. The initial torque of the test on the orbital electric motor is greater than BLDC motor, but the resulting torque tends to decrease when approaching the selenoid center which is simulated in step 6. The maximum torque utilization in the electric motor orbitals can be obtained by regulating the switching of the solenoid current control.

4 CONCLUSION

Based on the comparison of simulation data using software, the force generated by BLDC motor tends to be stable with an average force of 132.8N while the orbitals electric motor produce a fluctuating force with an average of 106.6 N. The torque produced by BLDC motor fluctuates with the average value is 1.623 Nm while the torque on the Orbital electric motor decreases with an average value of 1.619 Nm.

Orbital electric motor construction on single electric motor segment produces a magnetic force and

torque greater than BLDC motor, this is based on the analysis of BLDC construction resulting in a force of 159 N compared to the force produced by Orbital electric motors of 180 N, while the greatest torque BLDC motor is capable of producing 2.79 Nm compared to the greatest torque of orbital electric motor 3.58 Nm.

ACKNOWLEDGMENT

The disseminating researchers were invited to the Engineering Faculty of Semarang State University which had supported the implementation of this research through a study center's research fund scheme at Engineering Faculty. Thanks to all parties who have played a role in the completion of the research.

REFERENCES

- Babu Ashok, Mahesh Kumar, 2017. Comparative analysis of BLDC motor for Different control topology. *1st International Conference on Power Engineering, Computing and CONTROL, PECCON-2017*, VIT University, Chennai Campus
- Emrah Cetin, Ferhat Daldaban., 2017. Analyzing distinctive rotor poles of the axial flux PM motors by using 3D-FEA in view of the magnetic equivalent circuit. *Engineering Science and Technology, an International Journal* 1421–1429
- Madhurima Chattopadhyay et al., 2012. *Procedia Technology* 4. 666 – 670
- Mc. Farland. 1984. *Solenoid Motor*. United States Patent. US 4473763 A
- Nasser Braiwish., 2016. *Design Optimisation of Brushless Permanent Magnet Synchronous Motor for Electric Vehicles.Thesis*. Cardiff University. United Kingdom
- Werson, Michael. 1999. *Brushless DC Motors*. Unites States Patent. US 5986376 A
- Xuesong LUO, et al. 2008. 2018. Modeling and analysis of mover gaps in tubular moving-magnet linear oscillating motors. *Chinese Journal of Aeronautics*, 31(5): 927–940
- Y. S. Jeon, H. S. Mok, G. H. Choe, D. K. Kim & J. S. Ryu, 2000. "A new simulation model of BLDC motor with real back EMF waveform", *IEEE CNF. On Computer and Power Electronics, COMPEL*