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PERFORMANCE OF BRUSHLESS PERMANENT MAGNET DC MOTOR WITH DIFFERENT ROTOR POSITIONS USING ANSYS

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ABSTRACT

Electrical machines with both industrial and home applications required improvement at less cost. This can be achievable by simulating them in a computer with the use of some software using measured data from the laboratory. ANSYS and MATLAB are few of the software that perform this kind of simulation. In this case, the machine is configured in ANSYS-Maxwell environment before the desired results are generated it does finite element analyses (FEA).

Key words: Brushless D.c motor, permanent magnet synchronous motor, ripple torque, ansys,FEA.

I INTRODUCTION

BLDC motors uses magnet without brush and commutator for commutation . The benefit of this machine is that, it enjoys less brush wear, but the demerit is that they need electronic current-phase commutation. The working principle of BLDC motors are like that of shunt wound motor with field flux gotten from the magnet instead of currents from the winding. The materials used for making the permanent magnet are from rare earth of high energy neodymium responsible for magnetic field generation

The usage of BLDC motor is becoming enormous as a small horsepower control motor. The physical appearance resembled that of a 3-phase PMSM whose input is from an inverter that is responsible of converting a direct current (dc) voltage to a 3-phase ac voltages with frequency corresponding to instantaneous speed to the rotor. The input and output terminals characteristics of the this machine which required an inverter resembled a dc shunt machine when it is operating; hence the name *brushless dc motor is* appropriate. [1] stated that BLDC is an improved PMSM with a back emf in form of a trapezium instead of sinusoidal as in the case of PMSM.

Some of its merits are: they have higher power to weight and torque to current ratios compared to induction, DC, and PM synchronous motors (PMSMs), noiseless operation, rugged construction and excellent speed to torque are some of its wonderful features. Apart from that, these motors are simpler to control than induction and PMSM. Efforts had been made by researchers to lower torque ripple as one of its drawback, and to see how to make the motor stable when loaded and speed improvement by proper commutation of windings. BLDC machines are noisy because of the torque ripple effect which makes it unstable and unusable for position control applications [2],[3]. But they still find relevance in areas such as industrial automation, medical, computer, automobile (EV, HEV), aerospace, military, and transportation industries, others that used this kind of motor includes public facilities, information technology, home appliances etc.

Authors in [4] worked on outer rotor BLDC motor for low cogging torque using ANFOT-Maxwell. In their work, they discovered that the cogging reduced with lower number of poles and slot opening, but [5] considered the slot of the stator in their design and the switching angle using RMxprt in ANSYS. In their work, they concluded that, when the correct stator slot and switching angle are chosen, maximum efficiency was obtained.

Brushless DC machines which are grouped based on the rotor structural design and rotor flux direction. Rotor are classified based on rotor structures as reported in figure 1 [6]. When magnets are placed on the rotor surface, it is called surface mounted rotor. This process is cheap and easy. For cogging torque to be reduced, magnets are easily skewed in this type. The demerits of this type is that the reluctance torque is minimized and the mounted magnets may detach from the rotor at high speed. In the surface mounted rotor BLDC motors, the armature field reaction is small and the stator winding inductance is low since the permeability of the magnetic of PMs is near that of air [7],[8].

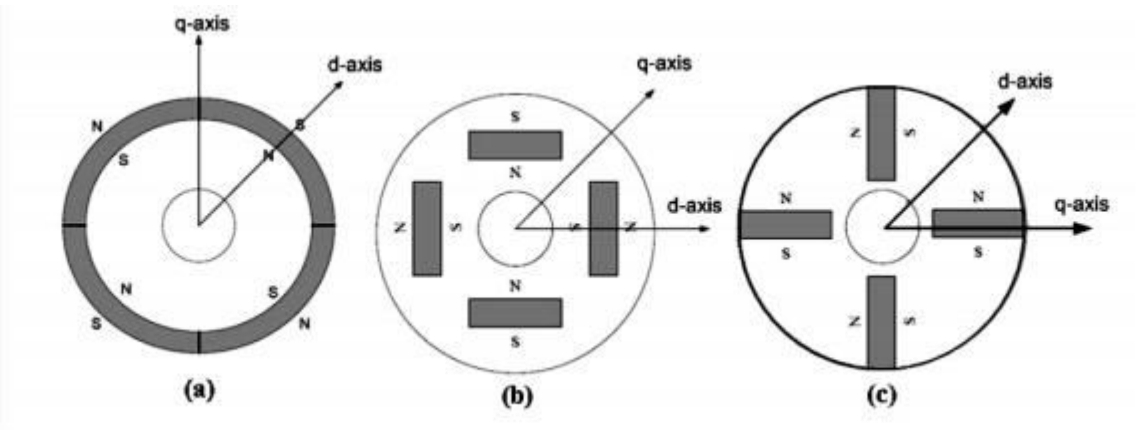


Figure 1: BLDC rotor structures (a) surface mounted (b) interior mounted (c) Buried mounted magnets

As the name implies, rotors with inserted magnets are called the interior mounted as reported in figure1(b) In this case, the speed is high and reluctance torque appreciated. The only difference between figure 1 (b) type and the buried magnet type is that in the buried as reported in figure 1 c, fluxes flows through the motor shaft which can be prevented using a non-magnetic shaft. Flux direction is another way of classifying BLDC motor as reported in figure 2. The other classification are Axial and radial flux direction presented in figure 2.

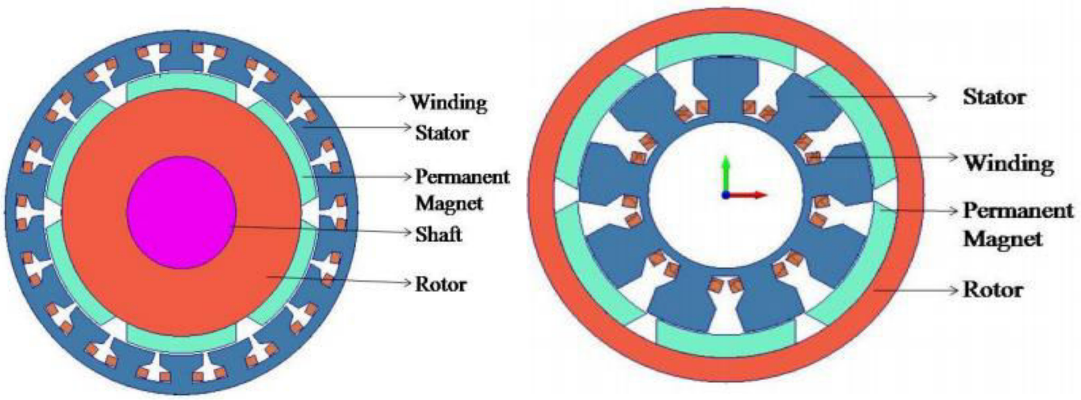


Figure 2: (a) Radial Flux BLDC (b) Axial Flux BLDC

II MODE OF OPERATION

When the stator phases in a BLDC motors are powered by a 3-phase voltage inverter as reported in figure 3, this voltage is rectified to dc voltage and the output of the rectifier is use to feed the dc link filter, which may be simply an LC filter. The filtered rectifier output dc voltage source is again inverted by the inverter, which drives the PMSM. As can be seen, rotor position is an input to the controller. The controller detects the switching states of the inverter semi-conductors with the help of some inputs and the rotor position. A flux is generated in the stator that interacts with the rotor magnetic flux whose angles must remain at 90 degrees to produce maximum torque. The torque speed ratio shows that the torque is maximum when the machine is stationary and decreased when the speed linearly improved. The method used for rotor position of a BLDC motors are sensors and sensorless methods. changing the applied voltage can control the speed of BLDC motors [9],[10]. This is achievable with the sensor based method with the pulse obtained from pulse width modulation (PWM)

There are a various types of BLDC motor drives. Fig 4 describes the step by step block for the drives. It consists of a power converter, a PMSM sensors, and a control algorithm. The power converter converts power to ac voltage that will drive the machine which in turn turns the electrical energy to mechanical energy. The brushless dc machine just like the switched reluctance machine, PMSM have a rotor position sensor. Because of this feature, a control algorithm can be written based on the command that dictates the signal of the gate to each semiconductor in the power converter.

The winding configurations depend on the speed require for a particular purpose, for instance, if high speed is expected, the windings can be configured in delta which operates at low torque, but the reverse is the case where the configuration is in Wye connections

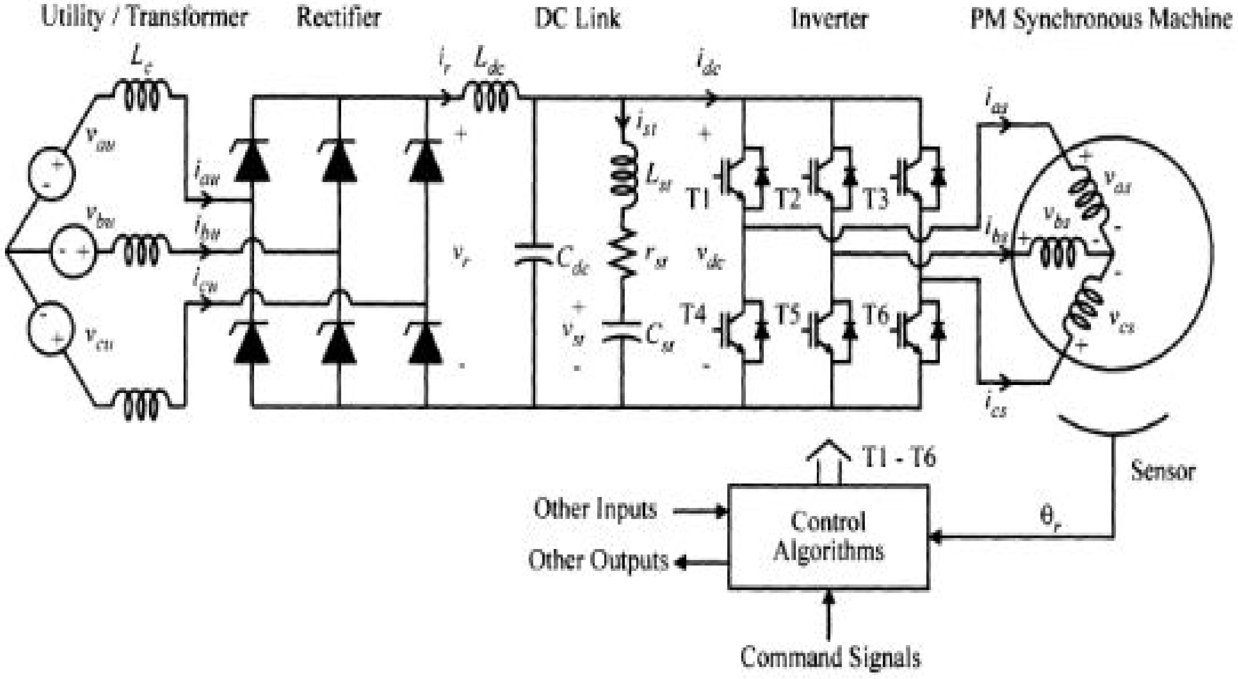


Figure 3: Voltage source inverter fed- brushless dc motor drive [11]

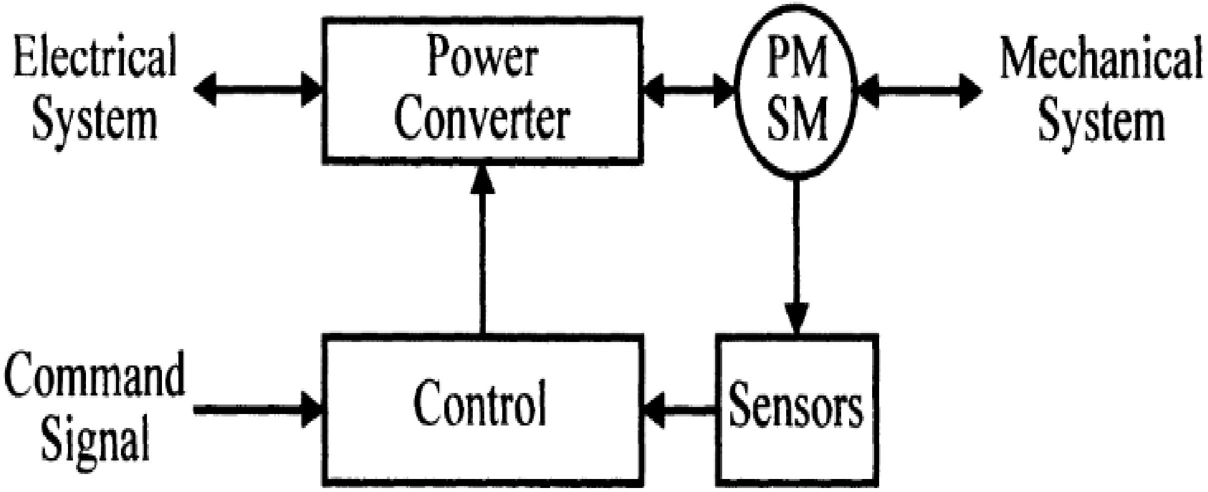


Figure 4: Brushless dc drive [11]

III MACHINE DATA FOR DESIGN

Table 1: Machine parameters for PMBLDC

FULL LOAD DATA FOR OUTER ROTOR DESIGN	**FULL LOAD DATA FOR INNER ROTOR DESIGN**
Average Input Current (A): 41.1313 Root-Mean-Square Armature Current (A): 38.8169 Armature Thermal Load (A^2/mm^3): 156.4 Specific Electric Loading (A/mm): 29.6539 Armature Current Density (A/mm^2): 5.27416 Frictional and Windage Loss (W): 44.4362 Iron-Core Loss (W): 0.00211345 Armature Copper Loss (W): 135.644 Transistor Loss (W): 179.21 Diode Loss (W): 14.7527 Total Loss (W): 374.046 Output Power (W): 1600.26 Input Power (W): 1974.3 Efficiency (%): 81.0543 Rated Speed (rpm): 543.566 Rated Torque (N.m): 28.1131 Locked-Rotor Torque (N.m): 278.236 Locked-Rotor Current (A): 732.738	Average Input Current (A): 45.5008 Root-Mean-Square Armature Current (A): 47.9314 Armature Thermal Load (A^2/mm^3): 650.373 Specific Electric Loading (A/mm): 79.8913 Armature Current Density (A/mm^2): 8.14072 Frictional and Windage Loss (W): 29.0027 Iron-Core Loss (W): 0.00185341 Armature Copper Loss (W): 412.226 Transistor Loss (W): 202.381 Diode Loss (W): 31.1119 Total Loss (W): 674.724 Output Power (W): 1600.32 Input Power (W): 2275.04 Efficiency (%): 70.3423 Rated Speed (rpm): 576.545 Rated Torque (N.m): 26.506 Locked-Rotor Torque (N.m): 151.213 Locked-Rotor Current (A): 385.985

IV RESULTS FOR MACHINE GEOMETRY I

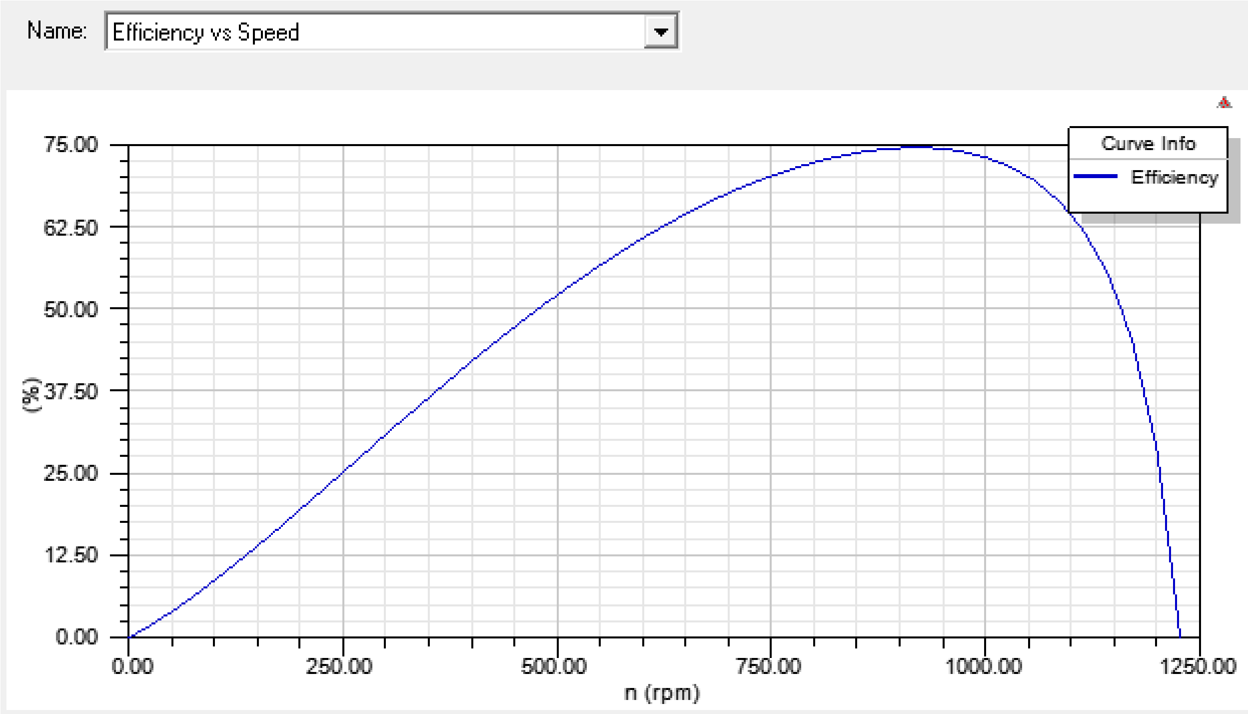


Figure 5: Waveform of efficiency versus speed

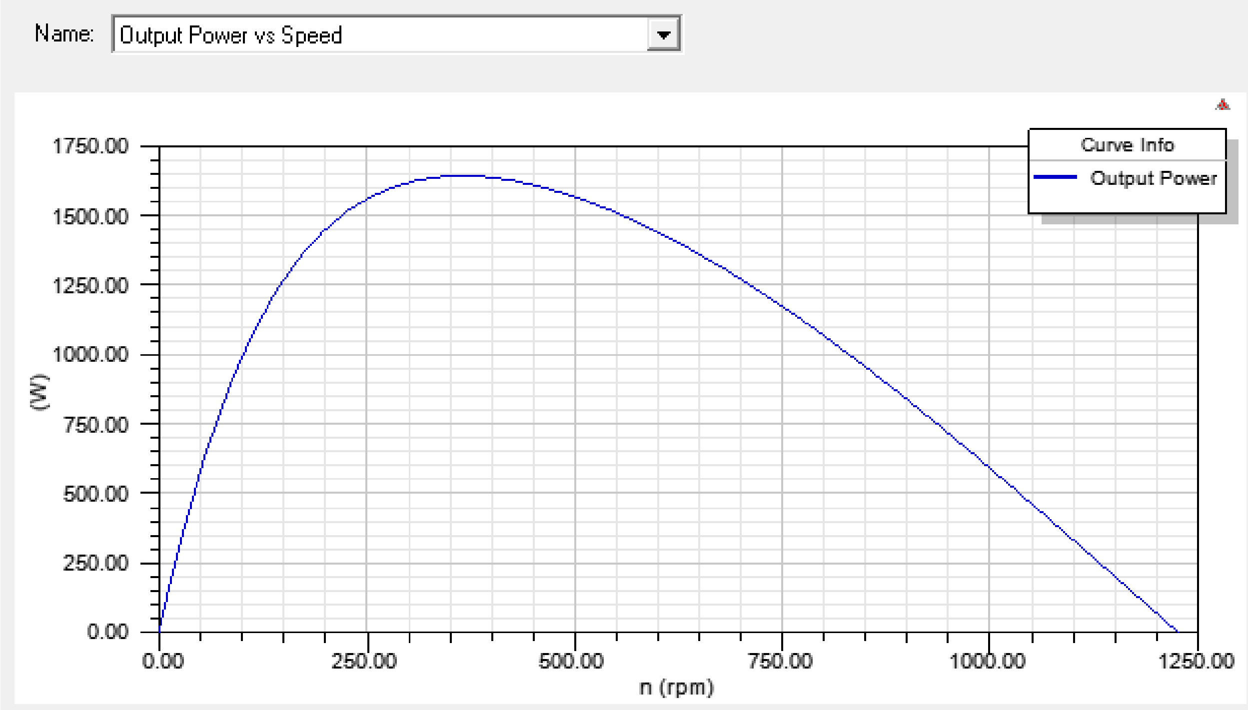


Figure 6: Waveform of output power versus speed

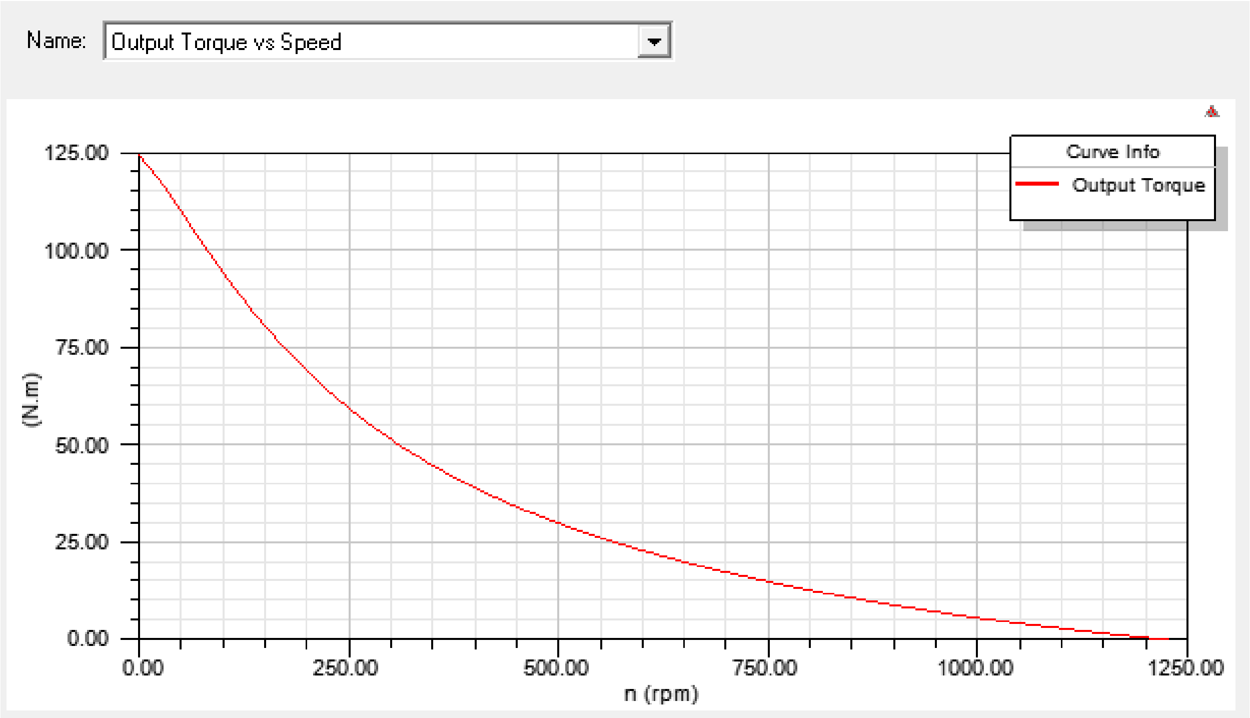


Figure 7: Waveform of output torque versus speed

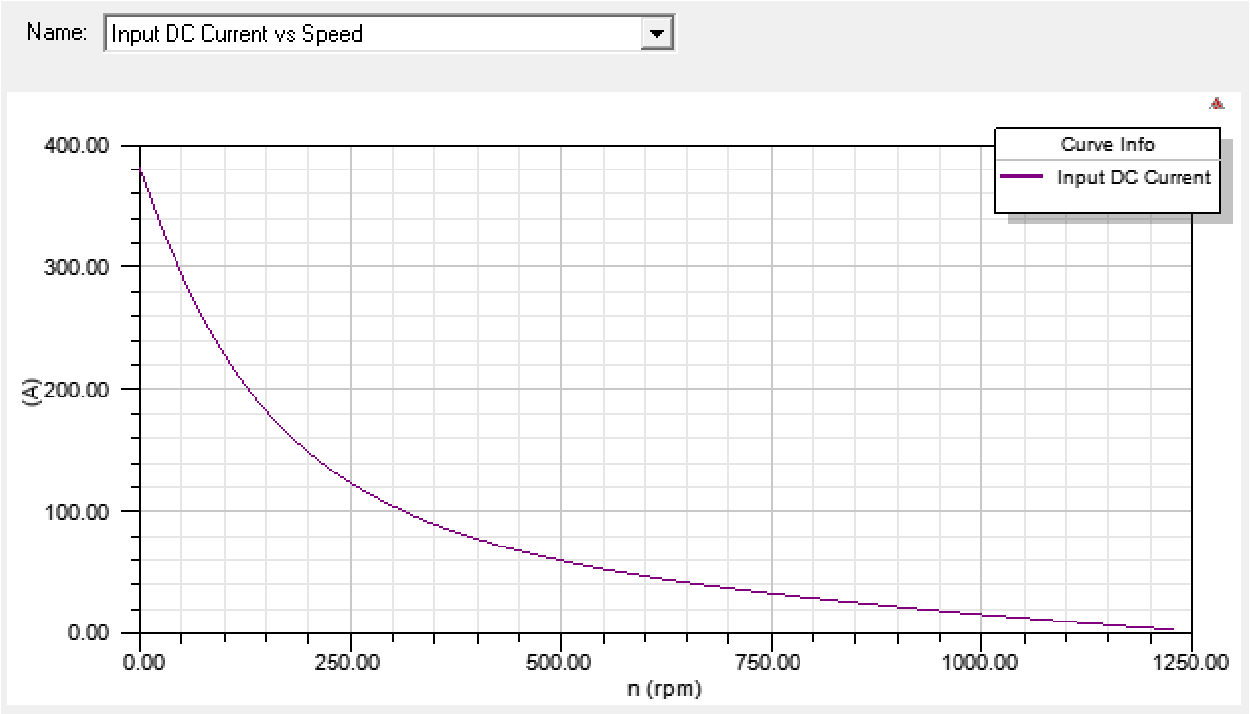
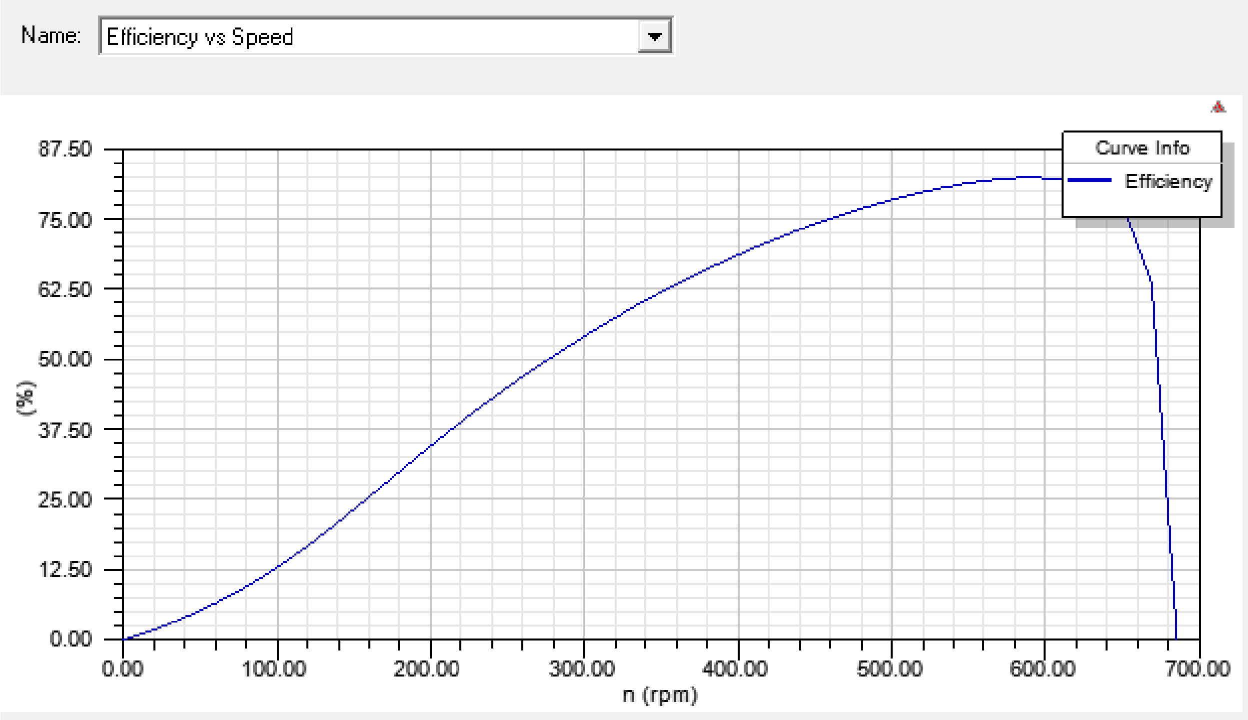


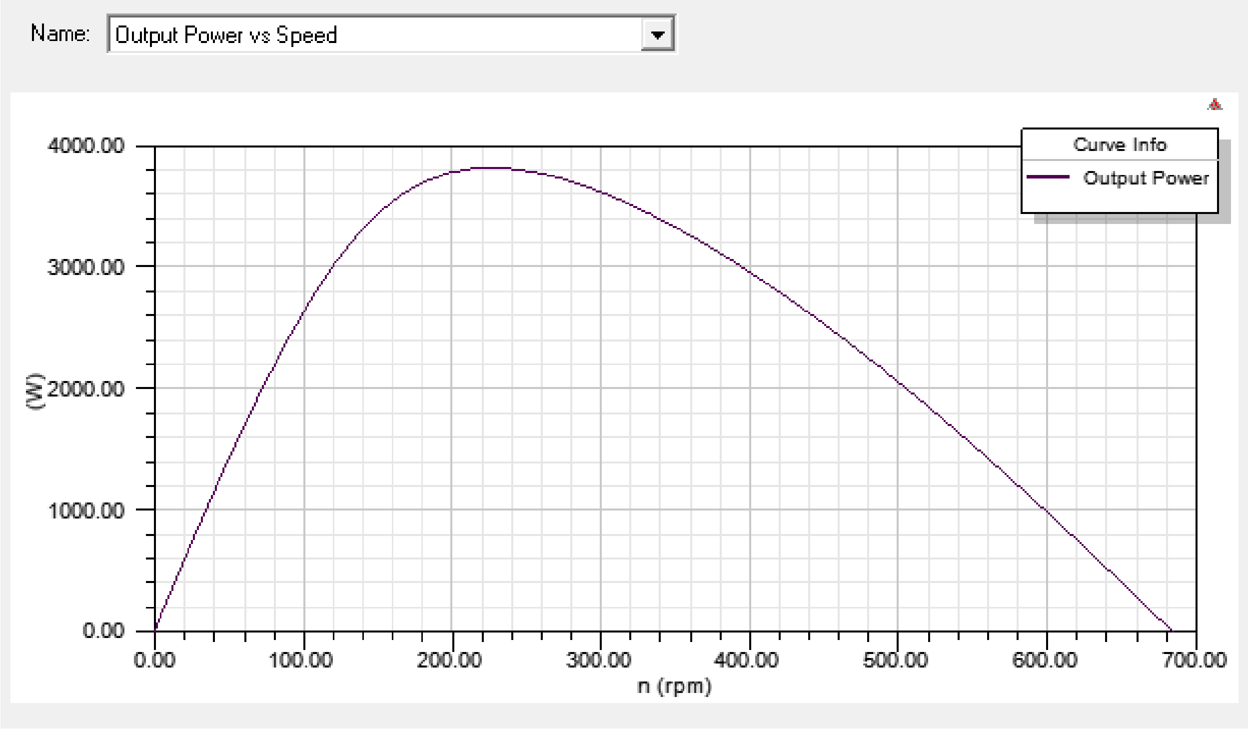
Figure 8: Waveform of input DC current versus speed

V RESULTS FOR MACHINE GEOMETRY II



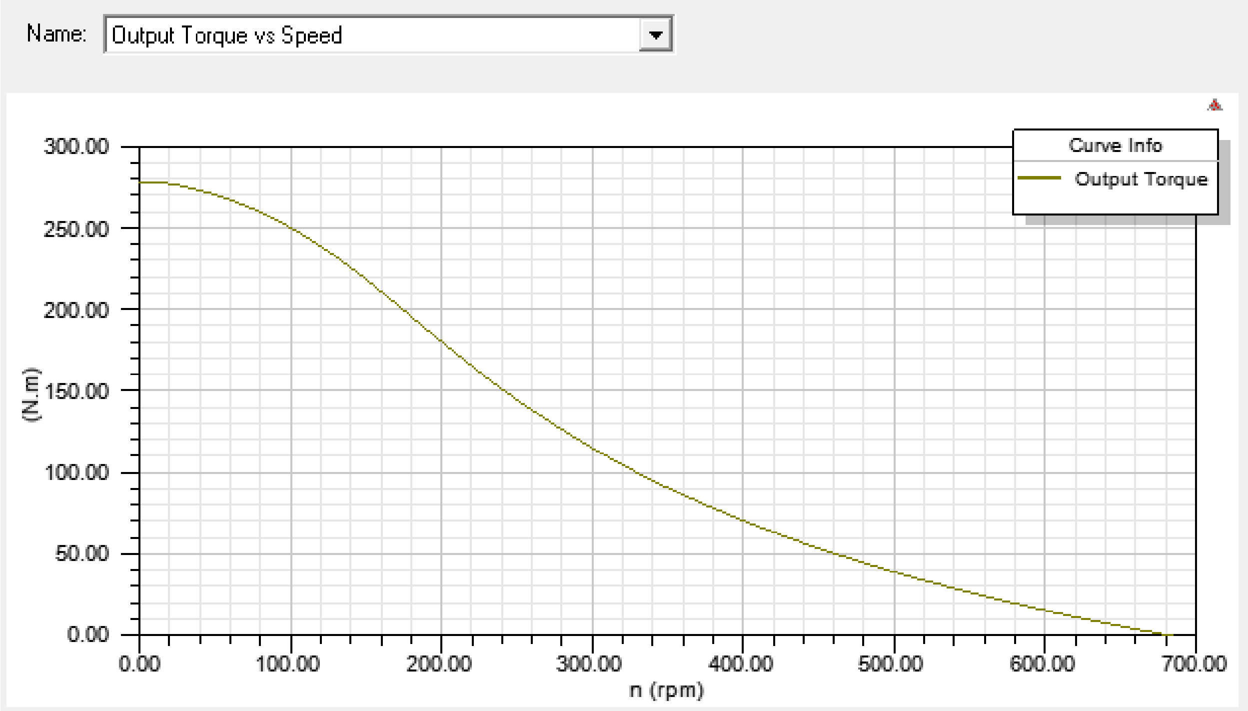
Name: Efficiency vs Speed

Figure 9: Waveform of efficiency versus speed



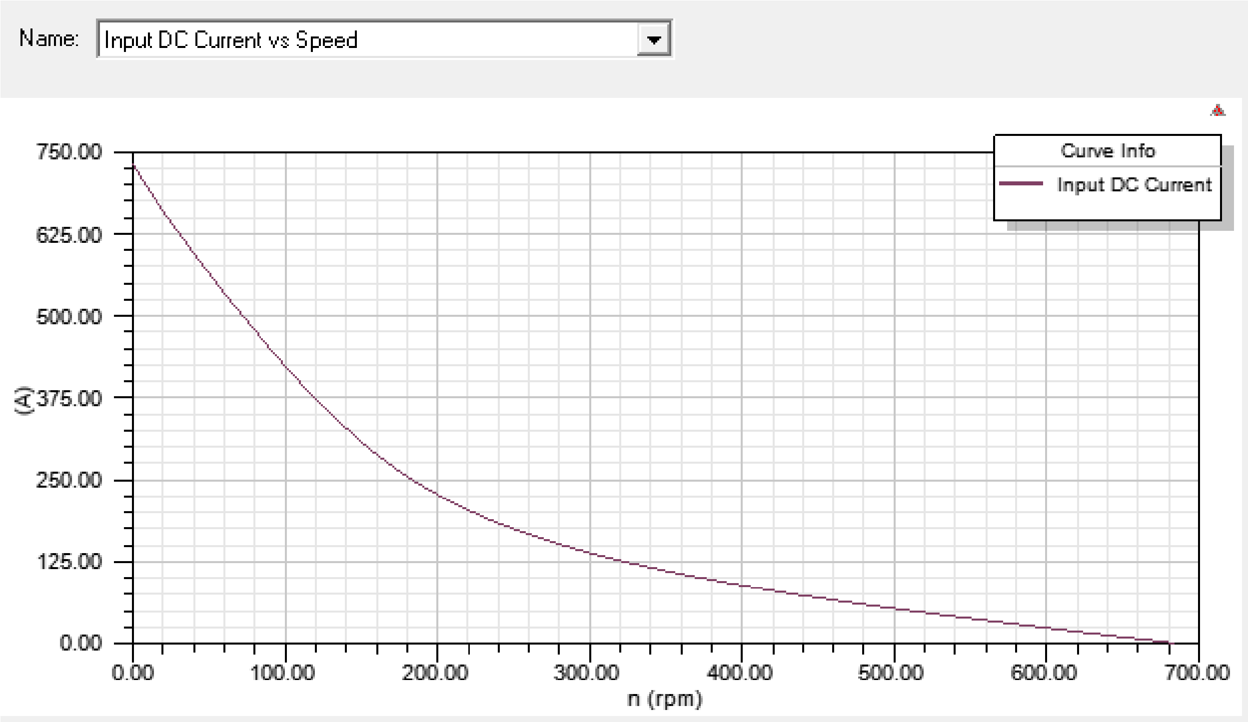
Name: Output Power vs Speed

Figure 10: Waveform of Output Power versus speed



Name: Output Torque vs Speed

Figure 11: Waveform of Output torque versus speed



Name: Input DC Current vs Speed

Figure 12: Waveform of input DC Current versus speed

IV DISCUSSION OF RESULTS

Table 1 presented the machine rated data with inner rotor and outer rotor configuration of the motors. In contains the rated load , the steady state parameters and the finite element analysis of the motor. The BLDC motor input parameters were obtained from the measured values in the laboratory. These data were used to configure the BLDC in ANSYS Maxwell environment. The machines were analyzed, simulated and results were generated.

Figures 5 to 8 presented the result of the inner rotor configuration while 9 to 12 represents results for the outer rotor configuration.

Figure 5 and 9 for both machines showed that when the rotor was stationary, no speed nor efficiency was recorded, when the machines rotors start rotating, speed and efficiency increased proportionally until they attained their peak efficiencies of 70% and 81% respectively at a corresponding speeds of 750 rpm and 600 rpm. Therefore, there was efficiency improvement of 13.5% even at a lesser speed.

Figure 6 and 10 compare the output power versus the speed. From the figures, it is obvious that, when the rotors were stationary, no output power nor speed was recorded. But when the rotor began to rotate, both quantities increased linearly until they reached their peak power output of 1650 W and 3800W respectively at a corresponding speeds of 340rpm and 200rpm. Again, it clear that more power output is given out at a lesser speed of the outer rotor BLDC motor.

Figure 7 and 11 compare the output torque against speed. At zero speed, the torques of both machines were very high (125 N-m and 275 N-m respectively). As the speed increased, the torques decreased until it becomes zero at speeds of 1250 rpm and 680 rpm respectively.

Finally, Figure 8 and 12 represented DC current versus speed. At their highest currents, the speeds were zeros. The waveforms showed that, these quantities were inversely proportional to each other

VII Recommendations

The performance of electrical machines can be access by changing some of its quantities like the air gap, size of stator slots, the skewing angle etc of a conventional type and their results compared with the prototype to check if there is improvement or not.

VII Conclusion

It is clear that the BLDC motor with outer rotor configuration perform better with improvement of 13.5% efficiency, the output power is higher than that of the inner rotor even at a lesser speed which is one of the important feature any electrical machine desires.

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