International Journal of Electrical and Electronic Engineering & Telecommunications

ISSN 2319 – 2518 www.ijeetc.com
Special Issue, Vol. 1, No. 1, March 2015
National Level Technical Conference P&E- BiDD-2015

Research Paper

DESIGN AND ANALYSIS OF BRUSHLESS D.C MOTOR FOR REDUCE COGGING TORQUE USING FINITE ELEMENT ANALYSIS

Ananthan N[1]*, Vimalraj N[1] and Ganesh Kumar A[1]

*Corresponding Author: Ananthan N, ✉ jananthan1991@gmail.com

The aim of this paper is to evaluate the magnetic field and motor performance of an exterior-rotor brushless DC (BLDC) motor based on two approaches, i.e., the magnetic circuit method and the Finite-Element Analysis (FEA). An equivalent magnetic circuit model is applied to analytically estimate the magnetic field of a BLDC motor, while the validity is verified by the two-dimensional FEA. Due to the restriction of the simplified mathematical model, the FEA is further employed to be an assistant tool for the detailed design of the pole shoe of this BLDC motor. Four design cases with different pole shoe dimensions are proposed, and the one that possesses the largest electromagnetic torque as well as the smallest cogging torque and torque ripple is further prototyped for electric bicycle applications.

Keywords: Finite element analysis, BLDC-Brushless DC Motor

INTRODUCTION

Today's motors for traction in electric vehicles are most often induction motors. In recent years, PM-motors have become interesting, as the efficiency can be increased. This is very important in battery applications. Based on the computer program, some designs and the influence of certain parameters as the number of poles or the airgap length are discussed. The design that uses the stator of the induction motor that shall be replaced is of special interest. In addition, a compact design is presented Now-a-days two approaches are widely used for the Computer Aided Design of electrical machines, identified as analysis and synthesis method. In the analysis method, the dimensions, type of construction and details of the materials used are provided by the designer as the input data. The designer calculates the performance characteristics, and uses his experience to alter the design towards meeting the specifications by the CAD package software.

[1] EEE, Arunai College of Engineering, Tiruvannamalai, India.

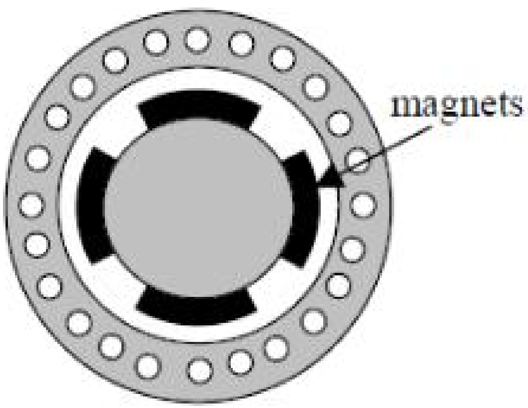
This process is repeated until the design specifications are met. In synthesis method, the logical decisions required to modify the initialdesign are incorporated in the CAD package. The main advantage of the synthesismethod is that it allows non-resident expertise to be utilized. In the thesis, theanalysis method has been used for the motor design.

PERMANENT MAGNET BRUSHLESS DC MOTOR

The Permanent Magnet Brushless DC motor have high power output to size ratio, better efficiency, high torque per ampere, effective power factor and does not use brushes for commutation. Moreover the power winding is on the stator, where its heat can be dissipated more easily, and the rotor loss is extremely small. These factors combine to keep the torque/inertia ratio high in small motors. The PMBLDC motors are mostly used in fractional kW applications.The stator of a BLDC motor consists of stacked steel lamination with windings placed in the slots that are axially cut along the inner periphery, and it resembles that of an induction motor. Rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate north and south poles.

Rotor is chosen depending upon the application requirements. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Neodymium Iron boron is used as (permanent) magnet.

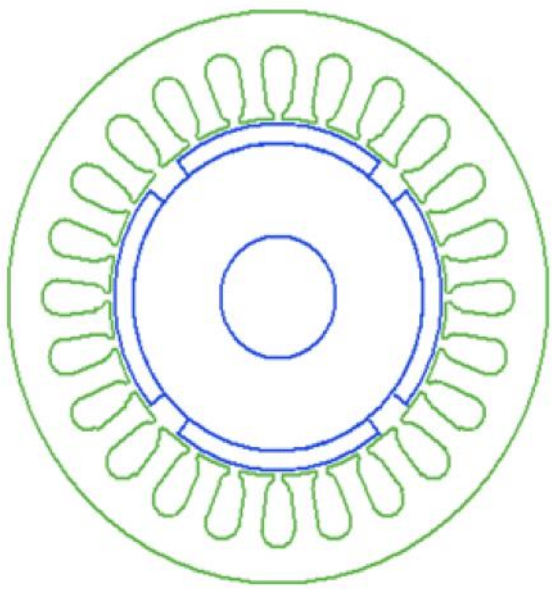
Figure 1: Structure of BLDC



CAD PACKAGE OVERVIEW

In computer aided approach the design goes hand in hand with the motor design-engineering environment. In our CAD package Finite-Element Analysis (FEA) is the basic numeric-analysing tool. In electromagnetic field analysis FEA is particularly valuable in optimizing the design of electromagnetic devices such as motors, generators, solenoids and so on. It is used to study the field configurations in integrated circuits and electronic beam devices.

Figure 2: BLDC Motor

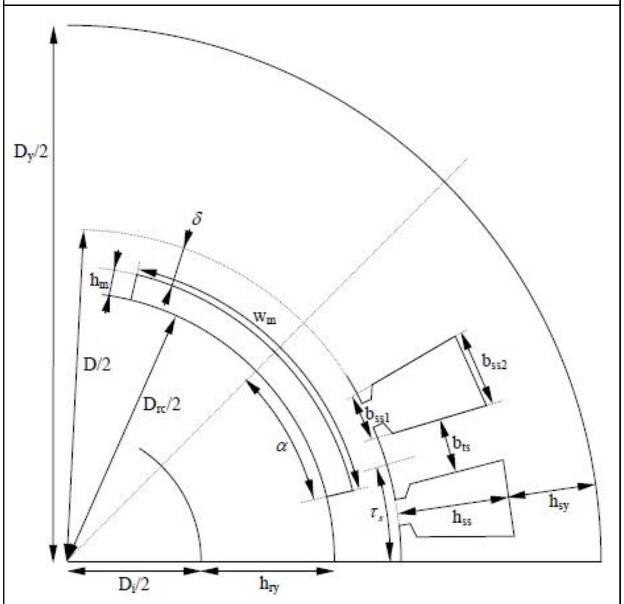


ANALYTICAL DESIGN

Here concentrates on the analytical design of a SMPM. Specific parameter coherences are shown and general design reflections are outlined. An adequate analytical loss model is derived and used in the design process. Additional considerations on the armature reaction and the magnet protection are also discussed. the design of the surface-mounted PM-motor. It is the simplest type of the PM machine design. There are several aspects that must be taken into considerations when designing a PM-machine.

Essential criterions such as the choice of magnets, their arrangement (salient/non-salient rotor) and the protection against demagnetisation (regarding overload and thermal capability) are discussed.The design process starts with the definition of the constraints and the requirements of operation. In this study, the design specifications are: A rated torque of 60 Nm at a rated speed of 1500 rpm is required.

Figure 3: Angle of Rotor and Stator Pole



The field-weakening range should be up to 3, corresponding to a maximum speed of 4500 rpm. Some constraints and target values are listed below: The inverter output line-to-line voltage is roughly limited to a rms-value of UL-L = 35 V.

That corresponds to a peak value of the phase voltage Û of about 28.6 V (Û U L-L = √2/√3). The outer dimensions of the SMPM drive are restricted to the dimension of the induction motor that shall be replaced. the total length is restricted to l = 0.34 m the outer stator diameter is restricted to Dy = 0.24 m. The frame and the bearings are included in the outer dimension and reduce the effective motor dimension to l = 0.165 m.

The magnet characteristics are assumed as follows:

remanence flux density Br = 1.1 T

demagnetisation flux density BD = –0.2 T

relative magnet permeability μr = 1.05

A Reasonable Design has the Following Flux Densities: Fundamental airgap flux density ¢ $\hat{B}$ ≈ 0.85-0.95 T-maximum flux density in the rotor yoke Bry ≈ 1.4 T-maximum flux density in the stator yoke Bsy ≈ 1.4 T-maximum flux density in the stator teeth Bst ≈ 1.8 T (near to saturation).

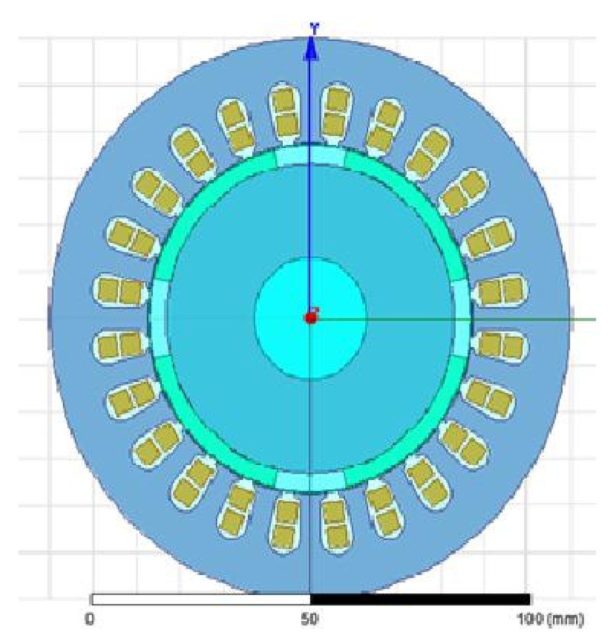
To prevent high temperatures and insulation problems, the maximum current density J should be lower than 7 A/mm^2. This value is relevant for a motor without forced cooling. Depending on the way the motor is cooled, higher current densities can be possible.

DESIGNING OF SM BLDC

The finite element method is a numerical method for solving electromagnetic field problems, which are too complex to be solved using analytical techniques, especially those involving non-linear material characteristics. FEA is a computer based numerical technique for calculating the parameters of electromagnetic devices. It can be used to calculate the flux density, flux linkages, inductance, torque emf, etc. In finite element method, the large electromagnetic device is broken down into many small elements. The behaviour of an individual element can be described with a relatively simple set of equations. Just as the set of elements would be joined together to build a whole device, the equations describing the behaviours of the individual elements are joined into an extremely large set of equations that describe the behaviour of the whole device.

The computer can solve this large set of simultaneous equations. From the solution, the computer extracts the behaviour of the individual elements. The spatial variation of magnetic potential throughout the motor is described by a nonlinear partial differential equation derived from Maxwell's equations. Application of the finite element method to machine design involves three stages,

Figure 4: Structure of Proposed Module



It involves in the division of the rotor cross-section into a set of triangular elements (2-D solutions) or the division of the motor volume into bricks. Modern mesh generation is carried out using the internal specialist drafting facilities of the finite element software. Specialist mesh generation software calculates the coordinates required to define the motor geometry. The cross section is usually split up into regions representing different materials such as current carrying conductors, air, steel, and magnets. Each region may define a different component used in the construction of the motor for example, the shaft, rotor core, magnets, stator lamination, airgap, etc. In most cases it is beneficial to split the components further into smaller polygons along the lines of symmetry.

Stator lamination can be created by reflection followed by multiple rotational copies of half a slot pitch. This procedure reduces the amount of data needed to 30 specify the geometry, and reduces the chance of errors. When rotation of the motor rotor is to be modelled, it is essential to define the airgap using a sliding surface is to be defined and is splitted at least two layers. One of these layers is fixed to the rotor and one to the stator. The node spacing on the central sliding surface is set to a constant such that it is possible to rotate the rotor by any multiple of this constant. Figure 4.1 shows a mesh in which the airgap region is divided into two layers and the sliding surface is central to the air gap.

RESULT

Once the model has been completed the field solution package is invoked and the program automatically assembles the stiffness matrix, modifies it to include the boundary condition and solves the system of N-equation in the N unknown potential values. The solution of the discretized partial differential equation uses a specialized mathematical algorithm. The algorithm is often based on the minimization of energy functional. The discretisation transforms the partial differential equation into

Figure 5: Flux Density

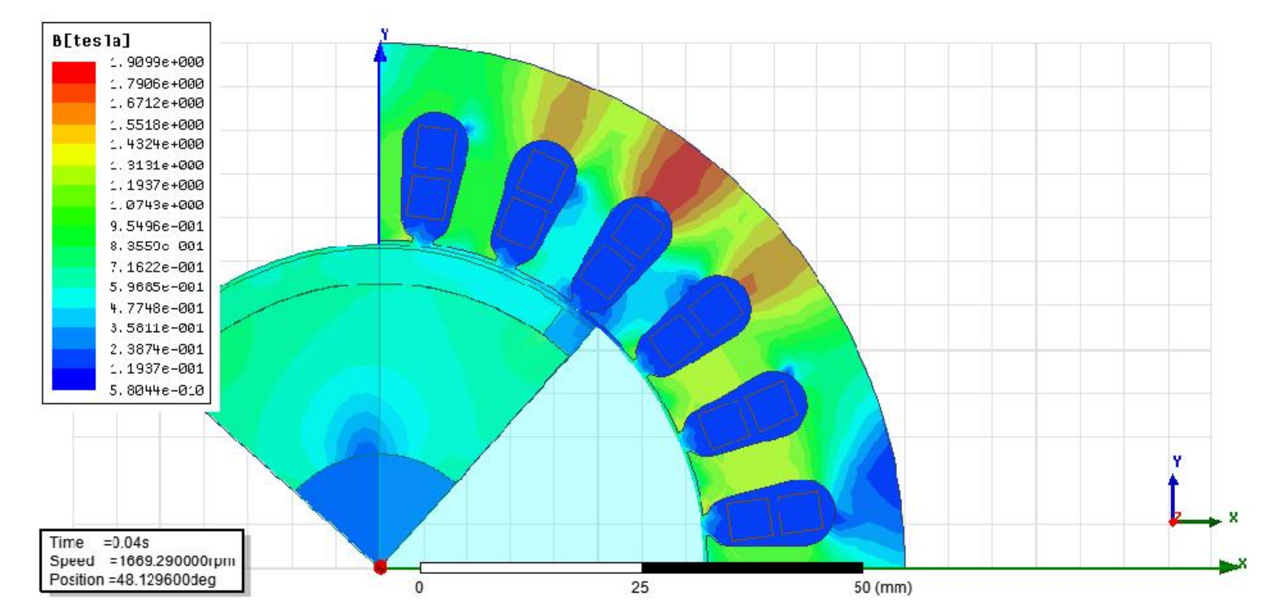


Figure 6: Efficency Versus Speed

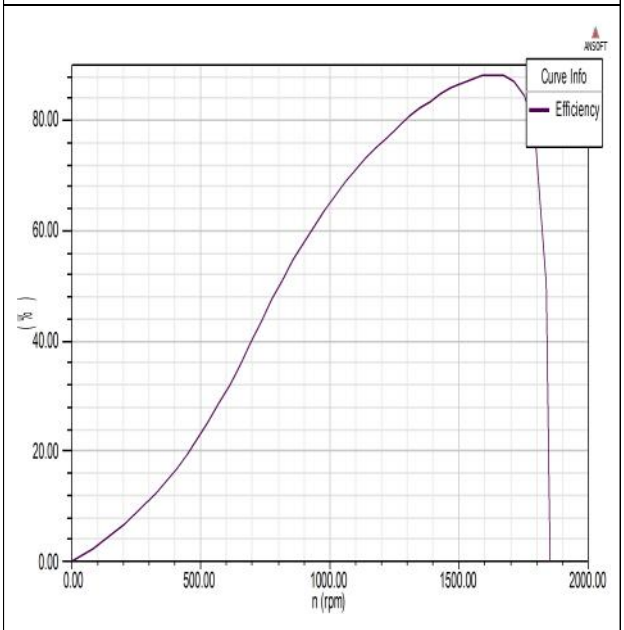
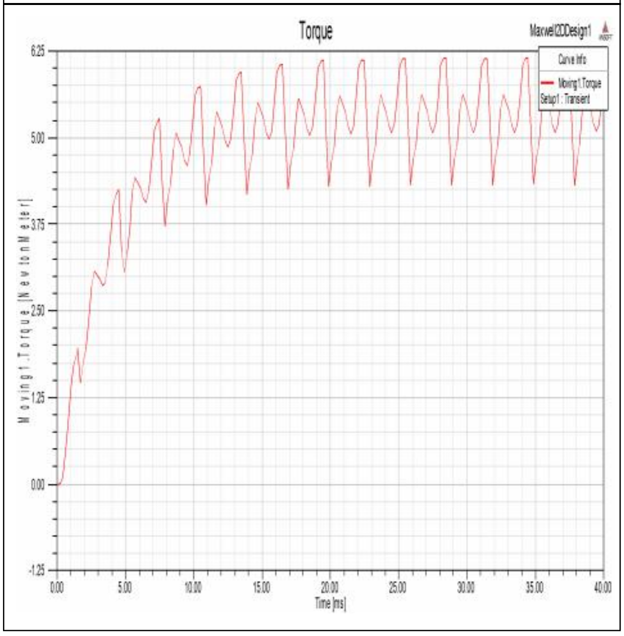


Figure 7: Torque



a large number of simultaneous non-linear algebraic equations containing the unknown node potentials. Iterative methods like Newton raphson and conjugate-gradient procedures are widely used. With linear elements the potential is assumed to vary linearly between the nodes and the flux density is constant within each element. Current density is also assumed to be constant within each element associated with a winding.

Figure 8: Cogging Torque

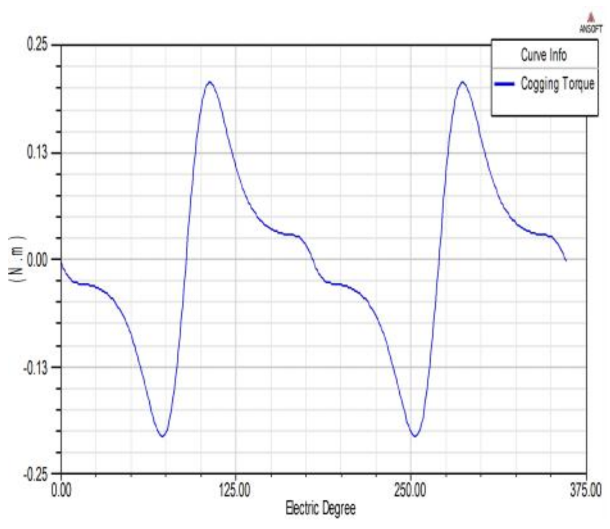
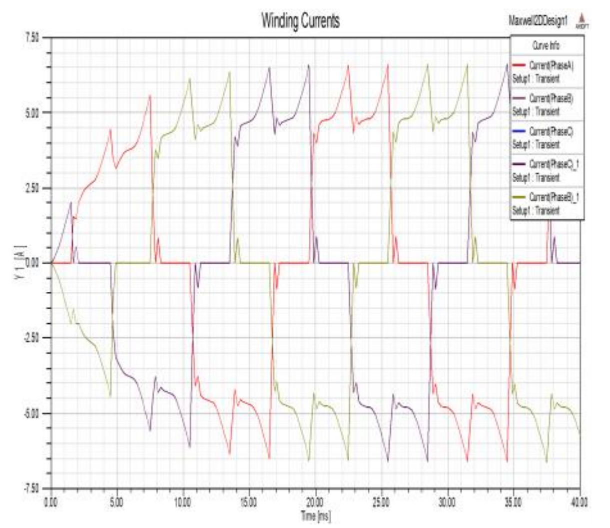


Figure 9: Winding Current



The field solution is expressed in terms of magnetic vector or scalar potential, but the design engineer needs quantities such as flux densities, force and torque. The extraction of these quantities from the potential solution is called post-processing. Ab good interactive graphics facility is important for that the essential information and b parameters canbe extracted from the large number of node potentials effectively and quickly.

CONCLUSION

The paper identifies the features of the powerful simulation FEM software for the analysis of the field. Analysis of various parameters like co-energy, flux linkages and torque plot reveals that different types of configurations of FSM can be modelled, and analysed for improving the performance. The simulated solutions have shown that the model is advantageous however in practical situations various other parameters have to be taken into considerations.

REFERENCES

1. IEEE Transaction on “New Class Magnet and Brushless DC Motors” (2008-10).
2. Krishnan R (2001), “Switched Reluctance Motor Drives Modelling, Simulation”, CRC Press, New York.
3. Miller T J E (1999), “Brushless Permanent Magnet and Reluctance Motor Drives”, Clarendon Press.
4. Nicola Bianchi (1999), “Electrical Machine Analysis Using Finite Element”, Clarendon Press.
5. Sawhney A K (1998) “Electrical Machine Designs”, Naveen Shahdra, Delhi.

6. Upadhyay K G and Mittle Arvindmittal V N (2009), "Design of Electrical Machines", Nai Sarak, Delhi.
7. www.uread_books.com/ BLDC/Ansoft's Maxwell