Design and Analysis of Electric two/three-wheeler bike Hub-Motor using Ansys Motor-CAD

Swathi Munnur, Sagarkumar Rathod and Deepika Masand

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Ms Swathi Munnur
dept of Electrical and Electronics Eng
Visvesvaraya Technological University
Global Academy of Techology
Bangalore ,India
0000-0002-8823-3639ORCID

Mr SagarKumar Rathod
Research and Development
MANDO Softtech
Gurugram,Hariyana, India
0000-0001-9478-5416ORCID

Dr Deepika Masand
dept of Electrical and Electronics Eng
Visvesvaraya Technological University
Global Academy of Technology
Bangalore,India
0000-00022-2563-8305ORCID

***Abstract*— In order to encompass greener transportation needs, electrical vehicle technology has come a big way. The Indian Automotive sector is also undergoing a breakthrough, with electric vehicles as one of the most promising options towards a cleaner and greener world. Presently Brushless DC Motors are considered as the best choice for electric vehicles due to their compact size, reliability and maintenance free operations. Brushless dc motors with inner and outer rotors are popular these days, and they are employed in electric bikes. The benefits of BLDC motors are numerous (like higher efficiency smaller size), which has resulted in an exhaustive investigation by researchers to further improve its performance. The Lab model analyses, E-Magnetic analysis since the motor is coupled to the wheels of the vehicle, thermal and magnetic analysis are essential while developing an outer rotor BLDC Hub motor. It differs from a petrol engine motorcycle because the engine and the wheel are separate on a petrol engine motorcycle. As a result, any heating of the engine would not heat the wheel; but, because the hub motor and the bike wheel are not separated, heating of the hub motor would induce a similar type of heating in the wheels of an electric bike. If the hub motor's temperatures and total magnetic flux density rise above typical levels, the electric motorcycle may not start at all. This paper emphasizes on the E Magnetic analysis, Lab model analysis, and Thermal and Magnetic analyses on a 45 slot, 50 poles outer rotor BLDC motor developed in Ansys Motor-CAD. The paper clearly displays all of the E Magnetic plots and Lab plots acquired from the analysis. The various views of the model, including axial, radial, and schematic views, are also clearly depicted. This study project demonstrates how to properly examine a motor E-magnetically, which is the first and most significant step in analyzing the thermal and mechanical models in Ansys motor CAD.**

Keywords*— *Finite element analysis (FEA), brushless Direct current (BLDC), Electric vehicle (EV), ANSYS.

I. Introduction

Electric vehicles are the most viable solutions to achieve a cleaner, greener world. They offer zero-emission, efficient and smart transportation system. The advantages of Electric vehicle over conventional internal combustion energy automobiles are enormous. Electric vehicle technology effectively minimizes air pollution, and greenhouse emissions can also be reduced on a large scale. Dependency on non-renewable fossil fuels is considerably minimized using Electric Vehicles. Appropriate choice of motors in electric vehicles plays a vital role in its performance. Conventional DC motors are highly efficient, and their characteristics make them suitable for use in traction specially two-wheeler EV vehicles. However, their only drawback is that they need a commutator and brushes which are subjected to wear and require maintenance. When solid state switches implemented the functions of commutator and brushes, maintenance free motors were realized. These motors are hence known as brushless DC motors. The function of magnets is the same in both brushless motor and the dc commutator motor. Magnets serve the same purpose in brushless motors and dc commutator motors. Brushless arrangement has a number of advantages, the most notable of which is the elimination of brushes. Brush care is no longer necessary, and many brush-related issues are eliminated. The brushless design has the advantage of allowing more cross-sectional area for the power or armature winding on the rotor inside the stator. At the same time, heat conduction through the frame produces more particular torque. The efficiency is likely to be higher than that of a comparable commutator motor, and the lack of brush friction helps even more.

BLDC motors are high-performance motors capable of providing large amounts of torque over a vast speed range. The major advantages include:

• High-Speed Operation — in both loaded and empty circumstances, a BLDC motor may reach speeds of over 10,000 rpm. • Quick acceleration and responsiveness – inner rotor Brushless DC motors have a low rotor inertia, which enables them to fast accelerate, decelerate, and reverse direction.• High Power Density - Of all the DC motors, BLDC motors have the highest running torque per cubic inch. • High Reliability - Because BLDC motors lack brushes, they are more dependable and have a life expectancy of over 10,000 hours. These also result in fewer instances of replacement or repairs and thus reduce the outage time of the motor. Apart from an appropriate motor the major components in an electric vehicle are a battery pack, battery management system and a controller. Fig. 1 shows the basic diagram of a typical electric vehicle.

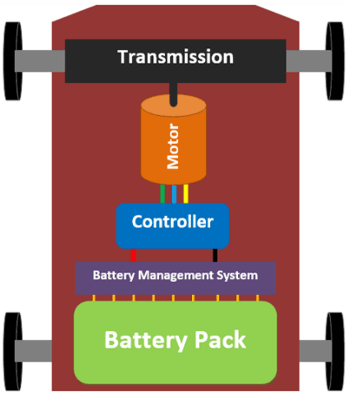

Fig. 1 Basic Block Diagram of an Electric Vehicle

The current paper focuses on the Electromagnetic, Thermal and Mechanical Model & Analysis of BLDC Hub Motor using ANSYS MOTOR CAD TOOL.ANSYS is a power full simulation tool to design and optimize the next generation of EV's. The motor under study is 2000W, 350rpm, input voltage 72Vand current 25A. Referred the QS motors data sheet.

II. Electromagnetic Model:

Electromagnetic modelling is the process of precisely determining the electric fields, magnetic fields, and currents by solving Maxwell's equations in many industrial or scientific applications, computing the electromagnetic fields throughout space and time can provide a more detailed knowledge of the underlying physical processes. There are numerous advantages to having a precise understanding of the electromagnetic fields in a system:

1) Determine the amount of power deposited in the load and its spatial profile using induction heating.2) Ascertain that systems will meet or exceed magnetic field strength requirements.3) for scientific applications, a thorough understanding of field strength and gradients is required.

The input data of stator and rotor are given in Table 1 and 2 respectively. Table 3 provides other important parameters required to design the electromagnetic model of the hub motor. Using the Ansys tool Analysed results of BLDC hub motor can be observed in the output figures. Where fig.2.shows radial view, fig.3. Shows axial view, and fig.4. Shows 3D view of hub motor. From these figures we can analyse complete geometry designing of the motor.fig.5. Shows the radial and linear pattern of windings.fig.6. Shows Finite element analysis (FEA) is done using Motor-CAD. Motor-CAD provides the ability to perform electromagnetic and thermal performance tests quickly and easily on prototype designs FEA model. Figures from 7 to 16 gives the input and output wave forms.fig.8. Current wave,fig.9. terminal voltage ,fig.10. back emf, fig.11. Flux linkage with o/c, fig.12. flux linkge with load, fig.13. Torque, fig.14. torque /speed curve, fig.15. power speed curve , fig.16 ELab Torqueand fig.17. Elab efficiency.

III. Thermal Model

The method of solving the heat equation for a given load and power density is known as thermal analysis. For industrial and scientific applications, a thermal simulation can be used to assess heat distribution and dissipation due to conduction, convection, or radiation. For induction heating applications in steady state, can give thermal 2D and 3D simulations as well as heat transfer studies for induction heating applications in steady state or transient conditions.The creation of heat owing to electromagnetically induced eddy currents in the load may be properly approximated using electromagnetic modelling. There are numerous advantages to having a precise grasp of the temperature distribution across the load: 1) Gain a thorough understanding of the load's temperature distribution.2) Calculate the heating profile over time and the heat penetration depth.3) Ensure that the uniformity of induction heating is within specifications or restrictions.

Temperature we set for 80 deg Celsius to design hub motor. Output result temperature can be seen in various part of radial and axial geometry of motor. Fig.17.radial temperature and fig.18. Axial temperature in hub motor.

IV. Mechanical Model

When we include the mechanical parts, however, the picture becomes more convoluted. A revolving disc, as shown in fig.19, can be used to represent the motor in the mechanical domain.

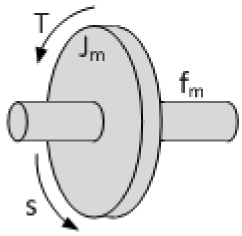

Fig.19.Mechanical simple Model

The moving element of the motor (the rotor) has some moment of inertia (Jm) and some friction in this simplified model (fm). The letters 'T' and's' on the graphic stand for the torque on the motor and rotational velocity or speed, respectively. Because a perfect motor has no losses, fm is equal to 0. Because of its linear behaviour, most beginning texts employ viscous friction to simulate mechanical losses in the motor. We are assuming Simulation: 2D FEA – Plane stress condition and Materials used is Homogeneous and Isotropic.Loadsare Rotation only No temperature effect No manufacturing effect and Contacts is Bonded. Mechanical strength of machine is seen in fig .20. Mechanical model

Table 1: Stator Design

Sr No	Parameter	Value and unit
1	Slot Type	Parallel Tooth
2	Slot Number	45
3	Armature Dia	280mm
4	Air gap	0.7mm
5	Tooth Width	8.5mm
6	Slot Depth	21mm
7	Slot Corner Radius	1mm
8	Tooth Tip Depth	1.2mm
9	Slot Opening	2.6mm
10	Tooth Tip Angle	14mm
11	Sleeve Thickness	0
12	Axle dia	216mm
13	Axle hole diameter	0

Table 2: Rotor Design

Sr No	Parameter	Value and unit
1	Pole number	50
2	Black iron thickness	7mm
3	Magnet thickness	3.4mm
4	Magnet arc ED	180mm
5	Magnet segment	1mm

Table 3: Other Parameters for Motor Design

Sr No	Parameter	Value and unit
1	Motor Length	50mm
2	Stator Lam Length	32mm
3	Magnet Length	32mm
4	Magnet Segments	1mm
5	Rotor Lam Length	280mm
6	Winding Type	automatic
7	Path Type	Upper/lower
8	Winding Layers	2
9	Phases	3
10	Turns	7
11	Throw	1
12	Parallel Paths	1
13	Stator Lam	M350-50A
14	Armature Winding	Cupper(pure)_hub motor
15	Rotor Lam	M350-50A
16	Magnet	N40H-Brl 1.435

Table 4 input data

Sr NO	Parameter	Value and unit
1	Shaft Speed	350 rpm
2	Line Current Definition	RMS
3	RMS Current	25A
4	DC Bus Voltage	72V
5	Phase Advance	15 E dge
6	Drive Mode	Sine
7	Winding Connection	Star connection
8	Magnetisation	Parallel
9	Winding / Magnet Temperature	65

Table 5: Output data

Sr No	Parameter	Value and unit
1	Voltage	72 V
2	Current rms	25 A
3	Phase advance	15A
4	Max Shaft torque	54.097 Nm
5	Current peak	35.36A
6	Efficiency	92.57%
7	Input power	1932.2w
8	Output power	1789w
	Total loses	143.11w
9	Winding losses dc cupper losse	98.56w
10	Magnet losses	7.556w
11	Stator and Rotor iron losses	37.02w
12	Mechanical losses	0

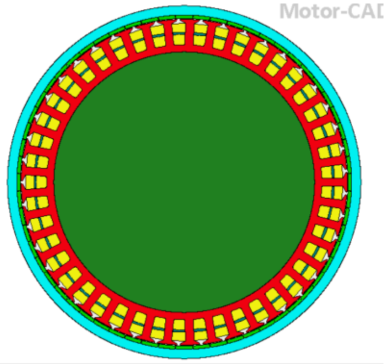

Fig.2.Raidial view

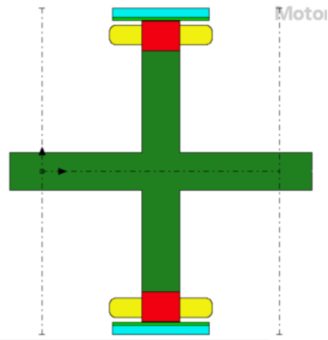

Fig. 3. Axial view

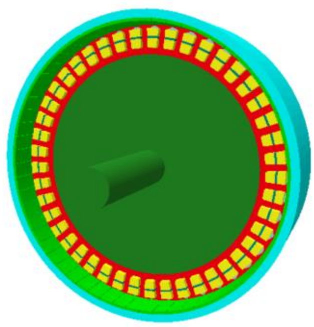

Fig.4. 3D view of motor

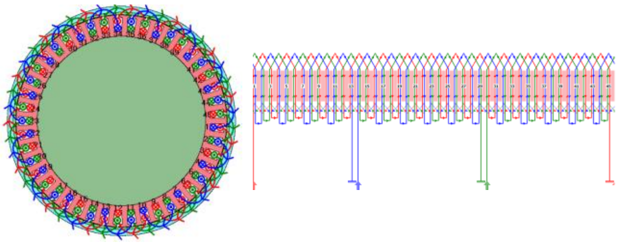

Fig.5. Radial and linear pattern of windings

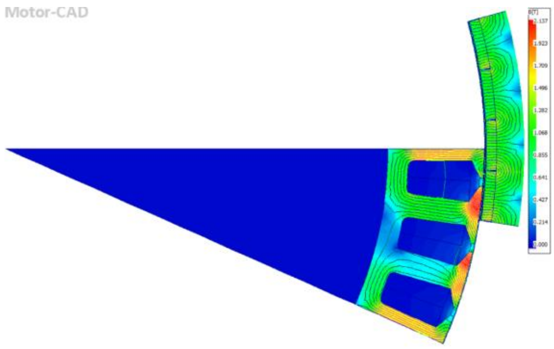

Fig.6. FEA of flux density

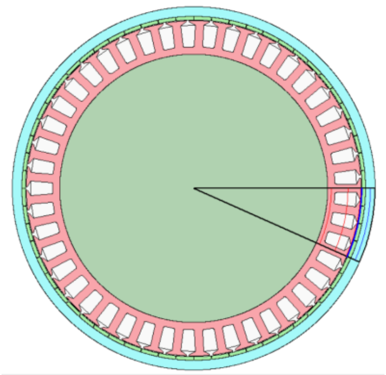

FIG.7. FEA PATH

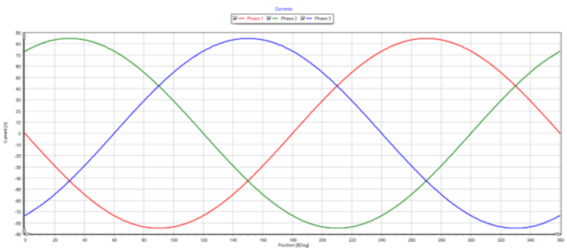

Fig.8.current wave

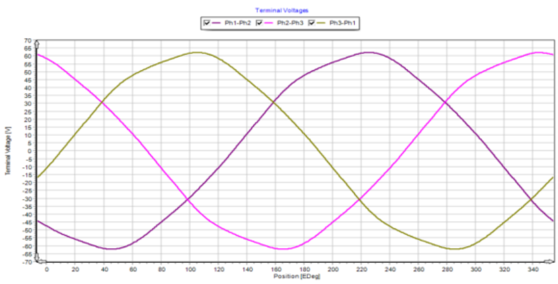

Fig.9. terminal voltage

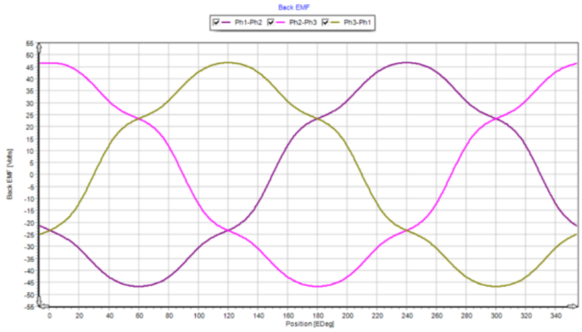

Fig.10. back emf

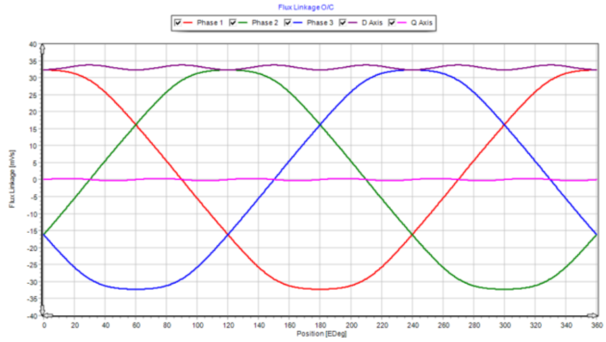

Fig.11.flux linkage with o/c

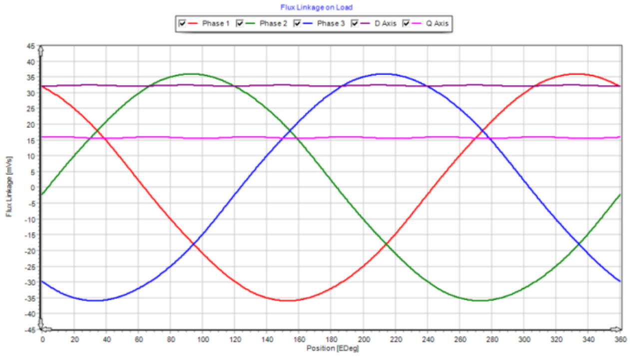

Fig.12. flux linkge with load

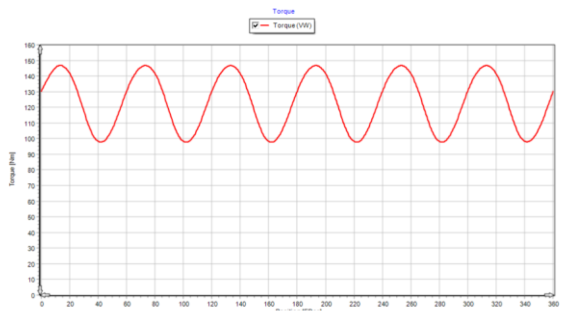

FIG.13OUTPUT WAVE FORM OF.TORQUE

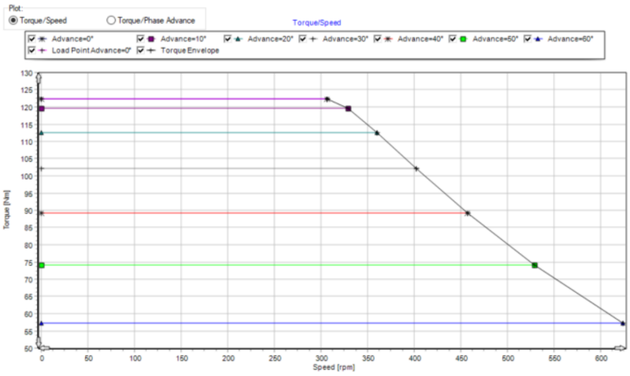

FIG.14.TORQUE /SPEED CURVE

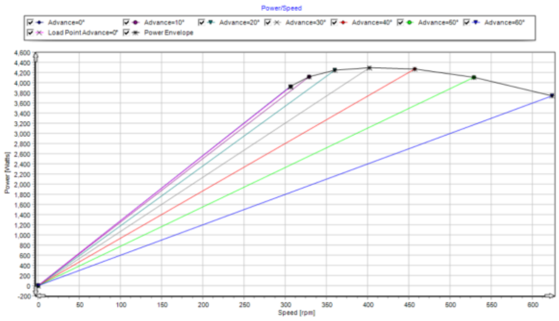

Fig.15 power speed curve

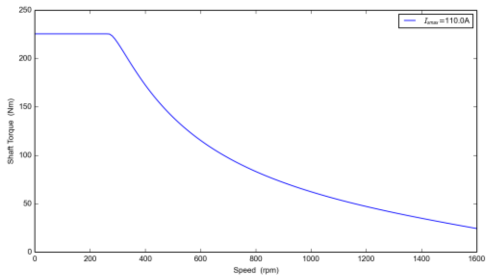

Fig 16 ELab Torque

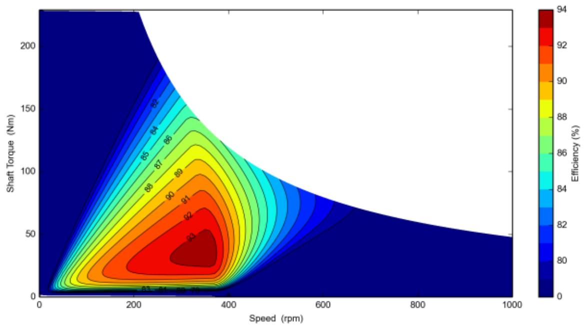

FIG.17. ELAB EFFICIENCY

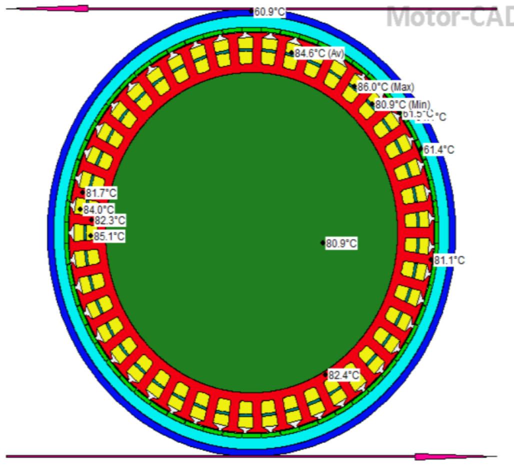

FIG.18. RADIAL TEMPERATURE

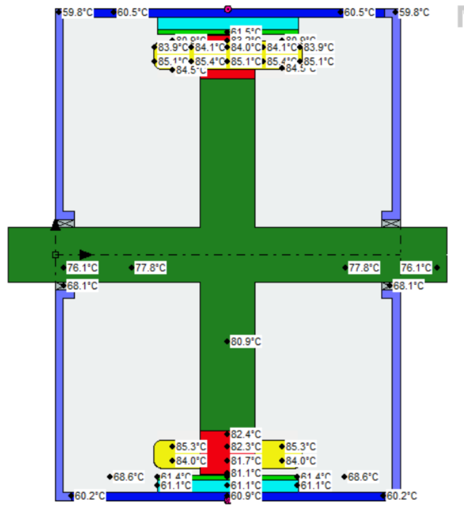

FIG.18. AXIAL TEMPERATURE

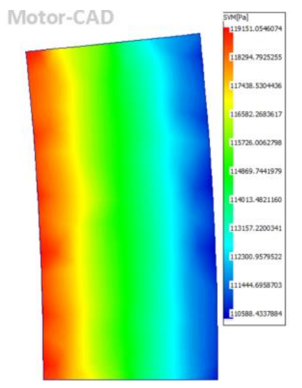

Fig.19. Mechanical Model

V CONCULSION

The basic design concept of a Permanent Brushless DC Hub Motor is presented in this study. First, the fundamentals of magnetic, thermal, and mechanical circuits are discussed, followed by the necessary basic data for design and output as demonstrated. In this work, a 2000W BLDC hub motor with 350 rpm is designed which used in an electric car. This study demonstrates that the motor has a high efficiency at rated torque and rated speed.

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