DESIGN OF BLDC MOTOR USING MATLAB & AUTOCAD

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ABSTRACT

The idea of our project is based on design. Previously; design of machine was carried out of manually with complicated calculation. We can avoid human error & save time in calculation by use of MATLAB. AUTOCAD is used for design of BLDC motor. Now due to rapid development of electronic device, BLDC motor are widely used to replace conventional DC motor BLDC motor are ideally suited for manufacturing applications because of their high power density, good speed-torque characteristics, high efficiency BLDC motor are commonly used as pump, fan, spindle drives& servomotors for machine tool servo drives.

Keyword: - *MATLAB,autoCAD,BLDC motor.*

1. INTRODUCTION

During the last decade, modern control system design methods, involving advanced mathematical techniques and time-consuming calculations have been greatly aided by design software MATLAB & AUTOCAD.

Conventional DC motors have many attractive properties such as high efficiency and linear torque-speed characteristics. The control of DC motor is also simple and does not require much complex hardware. However, the main drawback of the dc motor is the need of periodic maintenance. The Brushes of the mechanical commutator eventually wear out and need to be replaced. The mechanical commutator has other undesirable effects such as sparks, acoustic noise and carbon particles coming from the brushes. With rapid developments in power electronics, power semiconductor technologies, modern control theory for motors and manufacturing technology for high performance magnetic materials, the Brushless DC (BLDC) motors have been widely used in many applications. BLDC Motor have many advantages over conventional DC motors like: Long operating life, High dynamic response, High efficiency, Better Speed vs. Torque characteristic, Noiseless operational Higher speed range and high torque.

A BLDC Motor is a permanent synchronous motor that uses position detectors and an inverter to control the armature currents. Its armature is in the stator and the magnets are on the rotor and its operating characteristic resembles those of a DC motor. Instead of using a mechanical commutator as in the conventional DC Motor, the BLDC motor employs electronic commutation which makes it a virtually maintenances free. The BLDC motor is driven by DC voltage but current commutation is done by solid-state switches.

1.1 Problem statement

- *Direct current motors was chosen for the speed control applications due to the control simplicity on the intrinsic decoupling between flux & torque.*
- *As the name implies, there are physical limitation to speed & life time because of brush wear. However, BLDC have been produced to overcome this problem.*
- *Since, there are no carbon brushes to wear out; a BLDC motor can provide significantly greater life being now only limited by bearing wear.*
- *This advantage make BLDC motor becomes popular in the industry but this motor is a non- linear system hence, need more complex speed controller than the dc motor.*

1.2 Aims and objectives

To design and analysis of mathematical model for BLDC motor using MATLAB. And design of BLDC motor using AUTOCAD.

To improve speed performances and control of BLDC motor such as reduces overshoot; reduce rise time and steady state error .

2. DESIGN ANALYSIS

1.) **main dimension** :-

Rated speed, $W_m = \frac{2N\pi}{60}$

Torque, $T = \frac{P}{W_m}$

Lenghth of motor, $L = \left(\frac{4 \times T \times ar^2}{ktrv \times sr^2 \times 10^{-3}}\right)^{\frac{1}{3}}$

Stator outer diameter, $D_{so} = \frac{L}{ar}$

Rotor outer diameter, $D_{ro} = D_{so} \times sr$

2.)**magnet design**:-

Electrical speed, $W_e = \frac{N_m}{2} \times W_m$

Fundamental electrical frequency, $F_e = \frac{W_e}{2 \times \pi}$

No. of stator slot per pole per phase, $Nspp = (N_s/N_m/Nph)$

No. of turns per coil, $nc = lcm(N_s, N_m)$

$$magnet\ fraction, \alpha_m = \frac{\frac{nc}{N_m} - 1}{\frac{nc}{N_m}} + 0.02$$

$\alpha_p = \frac{\alpha_{m \times 360}}{N_m}$

$flux\ concentration\ factor, C_{\phi} = \frac{2 \times \alpha_m}{1+\alpha_m}$

$length\ of\ magnet,\ l_m = 10 \times l_g$

3.)**stator design**:-

$no.of\ stator\ pole\ per\ phase, N_{sp} = \frac{N_s}{N_{ph}}$

$angular\ pole\ pitch,\ \theta_p = \frac{2 \times \pi}{N_m}$

$angular\ slot\ pitch,\ \theta_s = \frac{2 \times \pi}{N_s}$

$rotor\ outer\ radius,\ R_{ro} = \frac{D_{ro}}{2}$

$stator\ outer\ radius,\ R_{so} = \frac{D_{so}}{2}$

$phase\ voltage,\ E_{ph} = \frac{V}{N_c}$

$phase\ current, I_{ph} = \frac{P}{ef \times V}$

$a_c = \frac{ktrv}{2 \times B_g}$

$no.of\ turns\ per\ phase,\ T_{tph}$=(ktrv×π×Dro)/(4×Bg×m×Iph×1000)

$Z_{ph} = 2 \times T_{tph}$

$stator\ yoke\ width,\ W_{sy} = \frac{\pi \times R_{ro} \times B_g}{N_m \times K_{st} \times B_{ry}}$

$rotor\ yoke\ width,\ W_{tb} = \frac{2 \times \pi \times R_{ro} \times B_g}{N_s \times K_{st} \times B_t}$

$stator\ back\ iron\ radius,\ R_{sb} = R_{so} - W_{sy}$

$stator\ inner\ diameter,\ R_{si} = R_{ro} + l_g$

$rotor\ inner\ diameter,\ R_{ri} = R_{ro} - l_m - W_{ry}$

Angular pole pitch, tavp=$R_{si} \times \theta_p$

Coil pole fraction, $\alpha_{cp} = \frac{round\ (Nspp)}{Nspp}$

Coil pitch, tavc=$\alpha_{cp} \times tavp$

Slot pitch, tavs=$R_{si} \times \theta_s$

slot bottom width, $W_{sb}=(R_{sb} \times \theta_s)$-$W_{tb}$

total slot depth, d_s=R_{sb}-R_{ro}-l_g

$d_1=\frac{\alpha_{sd}\times W_{tb}}{2}$

$d_2=\frac{\alpha_{sd}\times W_{tb}}{2}$

conductor slot depth, $d_3=d_s$-(d_1+d_2)

$W_t W_s=\frac{2\times\pi\times R_{ro}}{N_s}$

slot opening, $W_s=\frac{W_t W_s}{5}$

teeth opening, $W_t=(W_t W_s)$-W_s

conductor cross sectional area, $As=d_3\left(\theta_s \times \left(R_{sb}-\frac{d_3}{2}\right)-W_{tb}\right)$

slot width beyond shoe, $W_{si}=\left(\left(R_{si}+(\alpha_d \times W_{tb})\right)\times\theta_s\right)-W_{tb}$

slot fraction, $\alpha_s=\frac{W_{si}}{W_{si}+W_{tb}}$

4.)**losses:-**

slot turn resistance, $R_s=\frac{res\times ns^2\times L}{K_{cp}\times A_s}$

slot end resistance, $R_e=\frac{res\times ns^2\times tavc\times\pi}{2\times K_{cp}\times A_s}$

phase resistance, $R_{ph}=N_{sp}(R_s+R_e)$

copper loss, $P_{cu}=N_{ph\times}I_{ph}{}^2\times R_{ph}$

stator volume, $V_{st}=[(p_i\times(R_{so}{}^2-R_{so}{}^2))$-$(N_s\times A_s)]\times[(L\times k_{st})]$

iron loss, $P_{iron}=(V_{st}\times R_{ho}\times B_{max})$

friction and windage loss, $P_{fw}=\frac{(fwl\times P)}{100}$

total losses, $P_{loss}=P_{cu}\times P_{iron}\times P_{fw}$

Efficiency, $\eta = \frac{P}{P+P_{loss}} \times 100$

airgap inductance, $L_g = \frac{ns^2 \times 4 \times \pi \times 10^{-7} \times 1.05 \times L \times tavc \times 0.9656}{4 \times (l_m + (1.05 \times l_g))}$

Slot leakage inductance, $L_s = ns^2 \times 4 \times \pi \times 10^{-7} \left[\left(\frac{d_3 \times L}{3 \times W_{sb}}\right) + \left(\frac{2 \times d_2 \times L}{W_s + W_{sb}}\right) + \left(\frac{d_2 \times L}{W_s}\right)\right]$

end turn inductance, $L_e = \frac{ns \times 4 \times \pi \times 10^{-7} \times tavc}{8} \times 2.303 \times log\left(\frac{tavc^2 \times \pi}{4 \times A_s}\right)$

phase inductance, $L_{ph} = N_{sp} \times (L_g \times L_s \times L_e)$

2.1 motor specification:-

Parameters	Values
ar(aspect ratio)	*0.2 – 0.4*
Sr(split ratio)	*0.4 – 0.7*
Ktrv(torque per unit voiume)	*15 – 50*
Bmax (maximum flux density)	*1.7 – 2.3*
Bg (airgap fiux density)	*Upto 0.9*
Br (residual flux density)	*1.25*
Urec (relative recoil permeability)	*1.05*
Kst (stacking factor)	*0.5 – 0.95*
αsd (shoe depth fraction)	*0.74*
Lg (Length of airgap)	*0.0005m – 0.002m*
Bsy (stator yoke flux density)	*1.24 – 1.55*
Bry (rotor yoke flux density)	*1.09 – 1.24*
Bt (stator teeth flux density)	*1.71 – 1.94*

2.2 Results:-

Parameters	Values
Wm(Rated speed)	*157.0796 rpm*
T(Tourque)	*0.9549 Nm*
L(Length of the motor)	*0.0419 m*
Dso(stator outer diameter)	*0.0681 m*
Dro(rotor outer diameter)	*0.0341 m*
We	*314.1593*
Fe	*50*
Lm(length of magnet)	*0.0037 m*
Rro(rotor outer radius)	*0.0170 m*
Rso(stator outer radius)	*0.0341 m*
Eph(phase voltage)	*6 v*
Iph(phase current)	*13.2668 mA*
ac(specific electric loading)	*15.6250*
Ttph(turns per phase)	*21*
Rsi(stotor inner diameter)	*0.0178 m*
Rri(rotor inner diameter)	*0.0039 m*
ds(total a lot depth)	*0.0086 m*
d1	*7.236e-04 m*
d2	*7.236e-04 m*
d3	*0.0071 m*
Efficiency	*87.43%*
Pcu(copper loss)	*19.60645 w*
Piron(Iron loss)	*1.0420 w*
Pfw(Friction and windage loss)	*0.60 w*
Ploss(total loss)	*21.5487 w*

3. PRINCIPLE OF OPERATION OF BLDC MOTOR

BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and rotor rotate at the same frequency. BLDC motor does not operate directly off a DC voltage source. It consists of a rotor with permanent magnets, a stator with windings and commutation that is performed electronically. Normally three Hall sensors are used to detect the rotor position and commutation is performed based on Hall sensor inputs. There are two types of stator windings variants which are trapezoidal and sinusoidal motors.

4. ADVANTAGES

Smaller motor: *Modern permanent magnets and no losses in the rotor enable BLDC motor to be smaller compared to both brush DC motors and induction AC motors.*

More efficient: *Permanent magnet in the rotor. Unlike AC induction motors, there are no core losses in the rotor.*

Higher speed: *No brushes to limit speed, lower speed losses by design. BLDC motors have been designed for speeds as high as 100,000 RPM. The problem of retention of magnets, in a rotor spinning at high speeds, has long been solved.*

No maintenance: *No brushes to replace, inspect or maintain*

Faster response: *Lower rotor inertia compared to a brushless motor or an induction motor*

Lower RFI (radio frequency interference): *no brushes*

Linear speed-torque characteristics: *Internal shaft position feedback. Permanent magnet design with internal shaft position feedback gives BLDC motors linear speed-torque characteristics when compared to "open loop" AC induction motor*

High starting torque: *Internal shaft position feedback gives BLDC motors higher starting and low speed torque when compared to "open loop" AC induction motors.*

5. APPLICATIONS

- *Uses in powering electric vehicles*
- *Uses in actuators for industrial robots*
- *Uses in heating and ventilation*
- *Uses in aerospace and instrumentation*
- *Uses in factory automation equipment*

6. SCOPE OF FUTURE WORK

The future research in BLDCM drives is expected to focus on sensorless starting, reduction of motor cost, controller cost reduction, comprehensive sensorless control, application specific controller design.

With the above objectives of BLDCM drives, the economic viability and performance of PMBLDC motor since a wide range of applications is expected to grow in the future.

7. CONCLUSIONS

The design modelling of BLDC motor and its validation in matlab have gave the platform for performance analysis and desired output.We can obtain complete design of bldc motor using autocad which will very helpful for combining different parts at the time of making model. All the design results are of theoretical aspect and can be utilized for practical implementation of BLDC motor.

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