PERFORMANCE IMPROVEMENT OF THREE PHASE INDUCTION MOTOR USING SUPER MAGNETIC MATERIAL

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Abstract—In this paper, a comprehensive computer-aided design (CAD) procedure for three phase induction motor is presented and then finite-element analysis is carried out for standard induction motor to validate the designs. The paper presents a new solution to improve the performance of poly phase induction motor by applying superior magnetic material like hiperco50. The operating flux density of hiperco50 is higher than conventional magnetic materials .The finite element analysis (FEA) of three phase induction motor using conventional magnetic material M19 and superior magnetic material hiperco50 is carried out to analyze the influence of superior magnetic material on size and performance of the three phase induction motor .The size of three phase induction motor is reduced and performance is improved with application of super magnetic material.

Index Terms—computer aided design (CAD), finite element analysis(FEA), Hiperco50, induction motor

I. INTRODUCTION

Electrical motors are extensively used in commercial and industrial applications. Electrical motors are an important part of any electrical system as they consume about 65% to 70% of all electricity generated. The increased interest in induction motors is because of its merits over the other types of industrial motors. These merits are simplicity, ruggedness, less initial cost and ease of maintenance etc. It is very essential to increase efficiency of induction motor and improve the other performance parameters also to minimize the energy consumption and to contribute to environment friendly society. The performance improvement through better motor design becomes a major concern. This paper proposes a novel technique to reduce size and enhance the performance of induction motor using superior magnetic materials.

Hiperco50 consist of Iron–cobalt (Fe–Co) alloys with Co contents ranging from 15 % to 50 % have the highest saturation magnetic flux density, about 2.4 T at room temperature. They are the natural choice for applications demanding compactness and high performance standards. The Computer Aided Design (CAD) of Three Phase Induction Motor is done using M19 and superior magnetic material Hiperco50. The FEA is also done to validate CAD result influence of usage of Hipeco50 on compactness and performance [1].

II. DESIGN OF STANDARD INDUCTION MOTOR

The main purpose of designing an induction motor is to obtain the complete physical dimensions of all the parts of the machine and performance estimation to satisfy the customer specifications. Following are important design stages:

A .Main Dimensions Calculation
B. Stator Design
C. Rotor Design

D. Performance Estimation.

KVA rating of machine of a 3- phase induction motor is

$$Q = 3E_{Ph} \times I_{Ph} \times 10^{-3} \quad kVA \tag{1}$$

Where,

E_{ph} =Induced emf per phase.

I_{ph} =Current per phase.

The output equation of 3-phase induction motor is,

$$Q = C_0 D^2 L n_s \quad kVA \tag{2}$$

$$Where, C_0 = Output\ Co-efficient = 11 \times 10^{-3} B_{av}\ ac\ K_w\ \eta$$

B_{av}=Specific magnetic loading

ac=Specific electric loading

L=Stack length

D=Stator bore Diameter

K_w =Winding Factor

n_s=Synchronous speed in r.p.s.

So, from equation (2)

$$D^2 L = \frac{Q}{C_0 n_s} \tag{3}$$

D and L are calculated based on certain assumptions. Dimensions of magnetic circuits are calculated based on flux and permissible flux density of magnetic materials. Numbers of turns per phase are calculated according to voltage rating and conductor size is calculated according to current rating. Performance estimation is carried out considering design details. Algorithm is developed for CAD design of three phase induction motor[3]. Design of 2.2 kW ,415 V, 50 Hz,4-pole,3-phase induction motor using M19 magnetic material is done and CAD output is shown in Table I.

Table I

CAD OUTPUT USING M19 MAGNETIC MATERIAL

Stator outer diameter(mm)	206.1
Stator inner diameter(mm)	105
Number of turns	427
conductor's cross section area(mm)	0.674
Depth of stator core(mm)	13
Width of stator teeth(mm)	7
Stack length(mm)	125
Length of air gap(mm)	0.43
Total loss(kW)	0.488
Output power(kW)	2.2
Input power(kW)	2.688
Full load efficiency(%)	81.83

The accuracy of the developed CAD program is established by conducting FE analyses of the designed motors.

Table II

FEA result using M19 Magnetic material

Stator outer diameter(mm)	206.1
Stator inner diameter(mm)	105
Number of turns	427
Conductor's cross section area(mm)	0.674
Depth of stator core(mm)	13
Width of stator teeth(mm)	7
Stack length(mm)	125
Length of air gap(mm)	0.43
Total loss(kW)-	0.490
Output power(kW)	2.2
Input power(kW)	2.68
Full load efficiency(%)	81.80

A comparison of CAD and FE results is given in Table 3. It is observed that the results are within the acceptance tolerance; however, the minor difference between the two can be attributed to the empirical design coefficients and formulae used in the CAD program.

Table III

A comparison of CAD and FEA USING M19 Magnetic material

Performance	CAD	FEA
Full load efficiency (%)	81.83	81.80
Power factor	0.80	0.814
Total loss(kW)	0.488	0.490
Output power(kW)	2.2	2.2
Input power(kW)	2.688	2.68
Flux density in stator core(Wb/m^2)	1.30	1.12
Flux density in stator teeth(Wb/m^2)	1.60	1.62
Flux density in rotor teeth(Wb/m^2)	1.30	1.35
Flux density in air gap(Wb/m^2)	0.45	0.44

The Figure 1 shows the flux density plot of induction motor using M19 magnetic material.

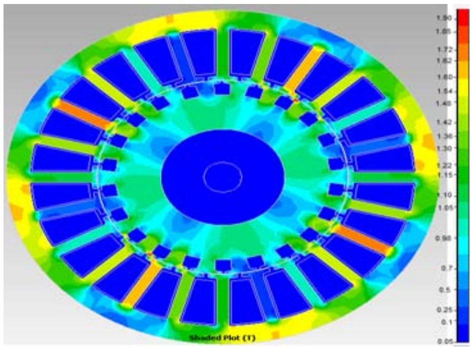

Figure 1 Flux Density plot of IM using M19 magnetic material

III. Application of superior magnetic material Hiperco50

Hiperco50 consist of an alloy of 49% Cobalt, 2% Vanadium and balance Iron. Hiperco50 has the highest flux density of all soft-magnetic alloys. Hiperco50 maintains its strength after heat treating making it best choice for applications that experience high rotational forces.. The specific mass density of Hiperco50 is 8120 kg/m^3, modulus of elasticity 207 GPa, electric conductivity 2.5 × 106 S/m, thermal conductivity 29.8 W/(m K), Curie temperature 940^{0}C, specific core loss about 76 W/kg at 2T, 400 Hz and thickness from 0.15 to 0.36 mm. [2].The below table shows the comparison of physical properties of hiperco50 with conventional M19 magnetic material.

Table IV

Comparison of Hiperco50 with conventional M19 magnetic material

Sr.No	Property	Hiperco50	M19-29
1	Saturation flux density, T	2.44	2.0
2	Relative permeability	10000	8300
3	Curie temperature, ^{0}C	940	760
4	Electric conductivity, S/m	2.38	2.00
5	Core losses at 60 Hz and 1.5 T, W/kg	1.73	3.08
6	Core losses at 400 Hz and 1.5 T, W/kg	17.47	44

The B-H curve of M19 material is shown in Figure 2.

Figure 1 B-H curve of M19 Magnetic Material

The B-H curve of Hiperco50 material is shown in Figure 3.

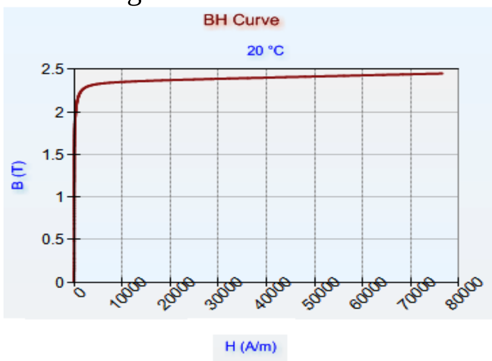

Figure 3 B-H curve of Hiperco50 Magnetic Material

Hiperco50 operates at flux density of 2.4 Wb/m^2 without saturation while 1.9 Wb/m^2 is the saturation flux density of M19 magnetic material. The CAD and F.E.A. using hiperco50 considering 2.4 Wb/m^2 flux density in stator core and stator teeth with application of hiperco50 superior magnetic material. Design of 2.2 kW, 415 V, 50 Hz,4-pole,3-phase induction motor using hiperco50 magnetic material is done and CAD output is shown in Table V.

Table V

CAD output using Hiperco50 Magnetic Material

Stator outer diameter(mm)	161.15
Stator inner diameter(mm)	82.1
Number of turns	446
Conductor’s cross section area(mm)	0.674
Depth of stator core(mm)	13
Width of stator teeth(mm)	7
Stack length(mm)	125
Length of air gap(mm)	0.43
Total loss(kW)	0.488
Output power(kW)	2.2
Input power(kW)	2.64
Full load efficiency (%)	83.30

The accuracy of the developed CAD program is established by conducting FE analyses of the designed motors. The results of F.E. analysis of induction motor having hiperco50 magnetic material is shown in Table VI.

Table VI

FEA using Hiperco50 Magnetic Material

Stator outer diameter(mm)	161.15
Stator inner diameter(mm)	82.1
Number of turns	446
Conductor's cross section area(mm)	0.674
Depth of stator core(mm)	13
Width of stator teeth(mm)	7
Stack length(mm)	125
Length of air gap(mm)	0.43
Total loss(kW)	0.488
Output power(kW)	2.2
Input power(kW)	2.64
Full load efficiency (%)	83.33

A comparison of CAD and FE results is given in Table VI. It is observed that the results are within the acceptance tolerance; however, the minor difference between the two can be attributed to the empirical design coefficients and formulae used in the CAD program.

Table VII

A comparison of CAD and FEA using Hiperco50

Performance	CAD	FEA
Full load efficiency (%)	83.30	83.33
Power factor	0.80	0.814
Total loss(kW)	0.488	0.490
Output power(kW)	2.2	2.2
Input power(kW)	2.64	2.64
Flux density in stator core(Wb/m^2)	2.20	2.26
Flux density in stator teeth(Wb/m^2)	2.3	2.3
Flux density in air gap(Wb/m^2)	0.9	0.9

The Figure 4 shows the flux density plot of IM with hiperco50.

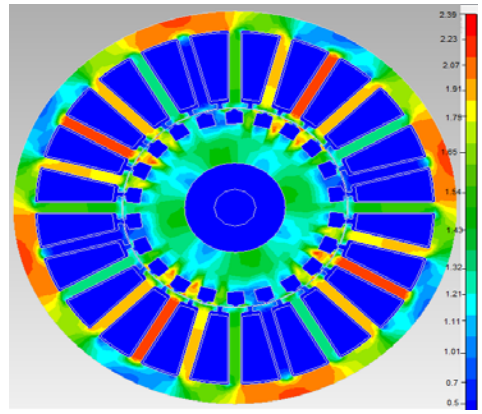

Figure 4 Flux Density plot of IM using Hiperco50 magnetic material

IV. PERFORMANCE COMPARISON OF STANDARD INDUCTION MOTOR USING M19 AND INDUCTION MOTOR USING HIPERCO50

The Table VIII shows the performance comparison between induction motor using M19 and induction motor using Hiperco50 magnetic material.

Table VIII

Comparison of Performance Parameters using M19 and Hiperco50 magnetic material

	M19-29	Hiperco50
Bore Diameter(mm)	105	82.1
Stack Length(mm)	125	96.7
Depth of stator core(mm)	13	8
Tooth Width(mm)	7	4
Torque(N.m)	15	15
Output Power(kW)	2.2	2.2
Input Power(kW)	2.68	2.64
Copper loss(kW)	0.308	0.308
Iron loss(kW)	0.0296	0.015
Efficiency(%)	81.8	83.3
RMS current(A)	4.91	4.91
Power factor	0.814	0.814
Flux Density in Airgap(Wb/m^2)	0.4	0.9
Flux Density in stator core(Wb/m^2)	1.35	2.26

Flux Density in stator teeth(Wb/m^2)	1.66	2.30
Rotor Core Mass	3.8	3.12
Rotor Bar Mass	0.234	0.181
Rotor End ring Mass	0.487	0.33
Stator Core Mass	10.8	6.0
Stator Winding Mass	3.28	3.20
Total Mass	18.601	12.831

It is observed that the bore diameter, stack length ,stator back iron depth and width of teeth reduced by replacing M19 material with Hiperco50. Overall size and weight reduced and efficiency increased due to application of Hiperco50.

V. CONCLUSION

CAD and FE analysis is carried out for three phase induction motor design using M19 magnetic material and superior magnetic material Hiperco50. The results of FE analysis and CAD are fairly matching. Hiperco50 is an improved iron- cobalt alloy specifically developed for electric machinery applications, where weight or space is at a premium. With application of Hiperco50, weight, size of the motor decrease and efficiency increases.

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