PERFORMANCE ANALYSIS OF 3 PHASE INDUCTION MOTOR USING ANSYS

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Abstract : It is well known that an induction motor is very reliable, robust and efficient machine used for various industrial applications under various loading conditions. This paper throws light on design and Performance analysis of 17 years old 4-pole induction motor by using ANSYS Maxwell software. The Simulation Results has been studied, analyzed and compared with the results of actual motor as well as with theoretical calculations. Performance of electric motor can be improved by proper material selection and accurate design. The analysis of this machine is executed employing FINITE ELEMENT METHOD at steady state level. The tools used for analysis are ANSYS MAXWELL 2D and ANSYS RMxprt.

Keywords—ANSYS RMxprt, ANSYS Maxwell 2D, Induction motor, Finite element method.

I. INTRODUCTION

In this paper 3 phase 4 pole 5 HP (i.e. 3.7 kilowatt) Induction Motor from laboratory is considered for performance analysis. The motor selected for study of performance analysis is squirrel cage type of motor.

Induction motor is robust in nature and as well as efficient and hence it is used for many industrial applications like stirrer motors in chemical Industries, pumping applications and also in sugar industries. For some common applications like drive mechanism, locomotives etc Induction motors are mainly used[3]. In these Industries these Motors are used for many years so because of using it for many years it's life gets deteriorated or reduced and also efficiency of motor gets affected.

Different parameters of the magnetic core, such as Voltages, Currents, core, yoke, flux, inductances in teeth coil etc can be described by proper electromagnetic calculation. By using “ANSYS Maxwell” electromagnetic parameters in a visually convenient form and calculation model can be made. [7]. A. Kachin and A.Kiselev presented the use of “ANSYS Maxwell” for the research of the synchronous electric motor drive system [4].

So in this paper the same kind of motor which is used for longer Time i.e. 17 years is selected for the study purpose. The design and analysis of same motor is done by the ANSYS software. The results of the ANSYS are compared with the practical results and performance parameters of the motor are analyzed.

To design the motor in ANSYS the tools used are RMxprt and MAXWELL 2D. In RMxprt the geometry of the machine is created with the help of some theoretical calculations and practical design parameters. The most important benefit of RMxprt tool is the ability of the package to build a complete Maxwell Project (2D/3D) including all parameters such as geometry, material and Boundary Conditions. RMxprt provides fast analytical calculations of machine performance and 2-D and 3-D geometry creation for detailed finite element and mesh calculations [1]. Various types of electrical machines are simulated and analyzed with the help of RMxprt tool [2].

Design of RMxprt is converted into 2D with the help of Maxwell 2D tool. Transient results (i.e. with respect to time) can be analyzed well with the help of Maxwell tool. ANSYS Maxwell is the premier low frequency electromagnetic fields simulation software in which we can design and analyze devices like motors, actuators, transformers etc.

This paper focuses on comparison of practical motor results that are obtained from performing practical tests in Laboratory with that of results obtained from simulation of the same motor by using ANSYS RMxprt software. This software tool is used for material selection, machine design and obtaining performance characteristics of three-phase induction motor and linking the same geometry with Maxwell 2D in order to get Transient Results with respect to Time(t) specified by user and obtaining the graphical result for the set Time(t) to analyze the various electrical parameters of the induction motor.

II. MOTOR SPECIFICATIONS

1. Output Power (P)	3.7 kW
2. Rated Voltage (V)	415 V
3. No. of Poles	4
4. Speed(S) (rpm)	1480
5. Frequency(Hz)	50
6. Current(I)	7.8 Amp
7. Winding Connections	Delta

III. DESIGN DETAILS

1.STATOR DESIGN-

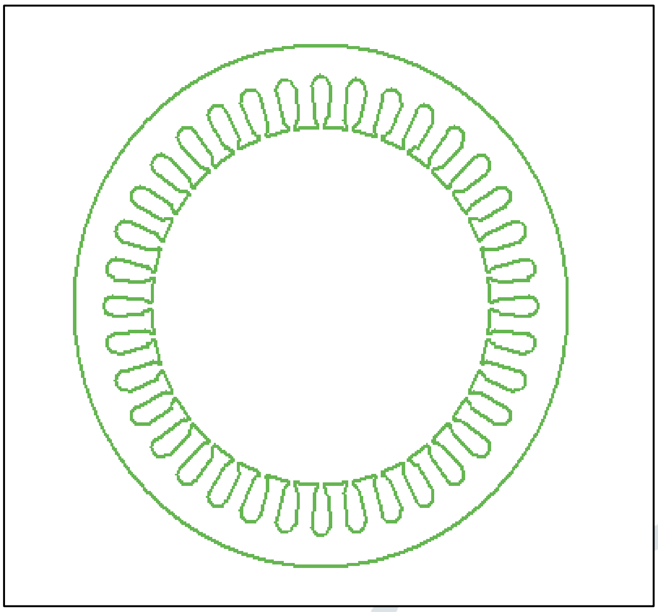


Fig.1 Stator model of 36 slots developed in RMxprt tool

Major Stator design data-

No. of Stator Slots	36
Stator Outer Diameter(mm)	204
Stator Inner Diameter (mm)	140
Stator Core length (mm)	135
Stator Core Stacking Factor	0.95
Steel Type	D21_50
No. of Parallel Branches	1
Coil Pitch	8
No. of Conductors per Slot	50

2. Stator slot details-

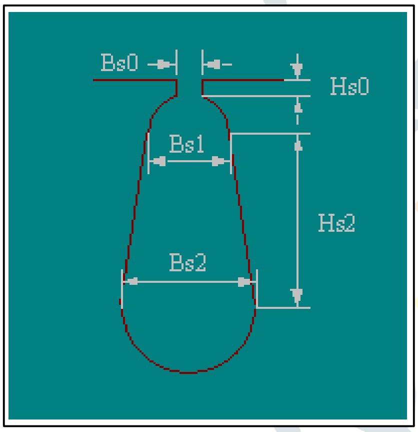


Fig.2 Stator slot design in RMxprt

Stator Slot Dimensions: -

Parameter	Value(mm)
bs0	3
bs1	6.3
bs2	8.3
hs0	0.6
hs2	12.7

3. ROTOR DESIGN-

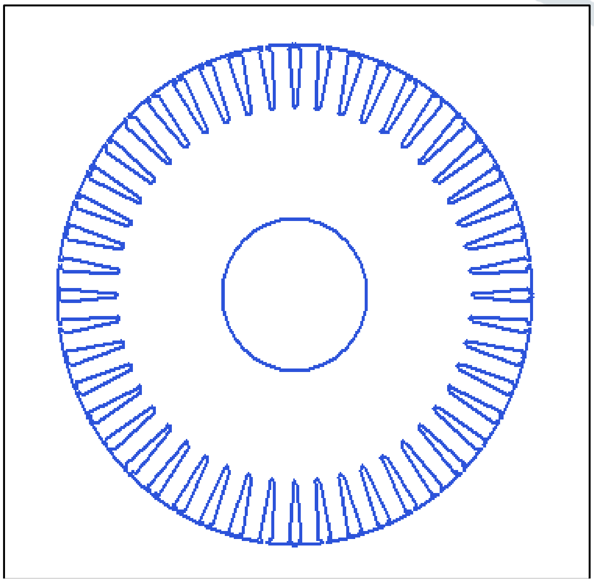


Fig.3 Rotor model of 48 slots developed in RMxprt tool

Major rotor design data-

Rotor Inner Diameter(mm)	43
End Ring Height(mm)	20
End Ring Width (mm)	7
Rotor Slot Type	4
Rotor Length (mm)	135
Rotor Core Stacking Factor	0.95
Steel Type	D21_50
No. of Rotor Slots	48
Air Gap (mm)	0.65
End Length of Bar (mm)	7

4. Rotor Slot Design

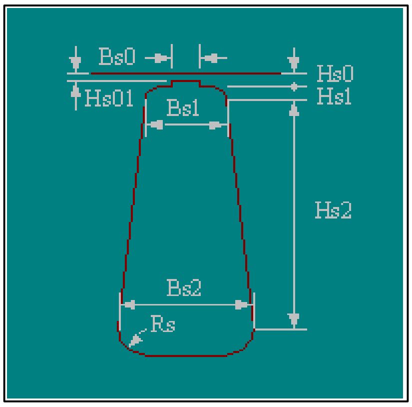


Fig.4 Rotor slot design in RMxprt

Rotor Slot Details-

Parameter	Value(mm)
bs0	1.1
bs1	3.8
bs2	1.5
hs0	0.6
hs1	0.5
hs2	16

3. WINDING ARRANGEMENTS

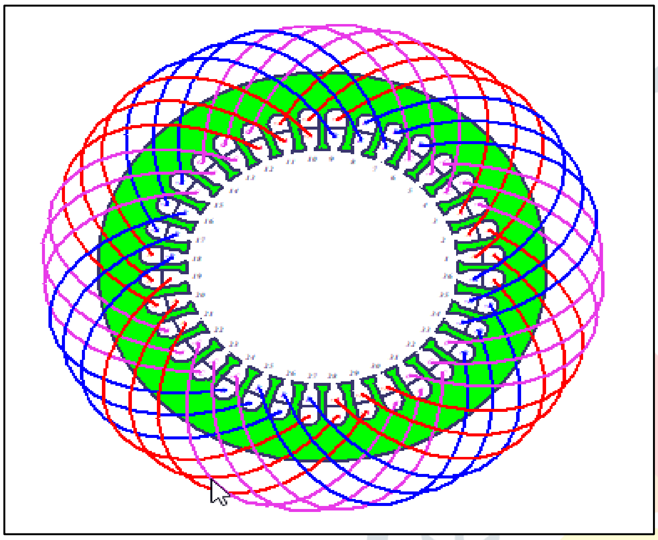


Fig.5 Winding arrangement view in RMxprt tool

Angle per slot (elec. degrees)	20
Phase-A axis (elec. degrees)	100
Arrangement of the 3-phase, two-layer winding in 9 slots is	AAAZZZBBB
First slot center (elec. degrees)	0

IV. PERFORMANCE OF MOTOR-

RATED-LOAD OPERATION	
Rated Shaft Speed(S) (rpm)	1460.87
Stator Phase Current(I) (Ampere)	4.79153
Rotor Phase Current(I) (Ampere)	3.33252
Stray Loss (Watts)	37
Stator Resistance (Ω)	5.75115
Iron-Core Loss (Watts)	164.308
Total Loss (Watts)	719.779
Input Power(P) (kW)	4.41947
Rotor Resistance (Ω)	2.99271
Efficiency (%)	83.7135
Rated Slip(s)	0.0260876
Stator Winding Copper loss(Watts)	396.118
Rotor Winding Copper loss (Watts)	99.7081
Output Power(P) (kW)	3.69969
Power Factor	0.734641

NO LOAD OPERATION	
No Load Rotor Resistance (Ω)	2.99256
No Load Slip(s)	0.000146488
No Load Stator Resistance (Ω)	5.75115
No Load Iron- Core Loss (Watts)	180.587
No Load Input Power(P) (Watts)	433.381
No Load Stator Phase Current(I) (Ampere)	3.33741
No Load Power(P) Factor	0.0953968
No Load Shaft Speed(S) (rpm)	1499.78

BREAK DOWN OPERATION	
Break Down Torque(T) Ratio	4.24047
Break Down Phase Current(I) (Ampere)	24.8458
Break Down Torque(T) (N.m)	102.551
Break Down Slip	0.32

V. PERFORMANCE CHARACTERISTICS

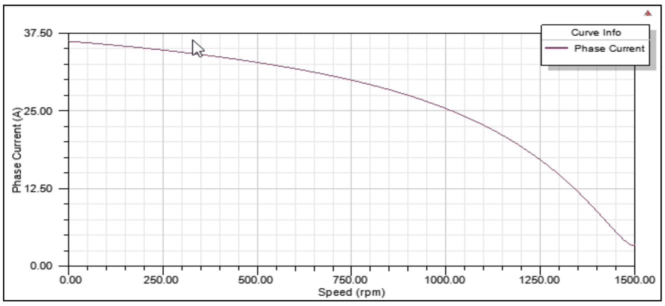


Fig 1. Phase Current(I) v/s Speed(S)

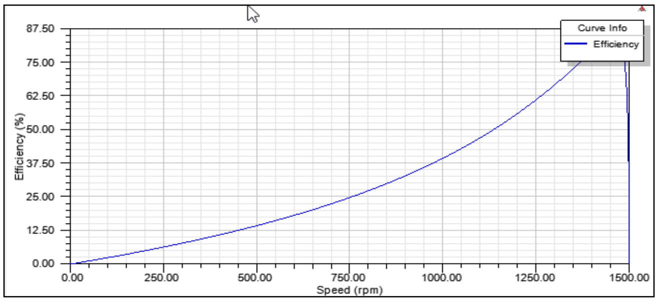


Fig 2. Efficiency v/s Speed(S)

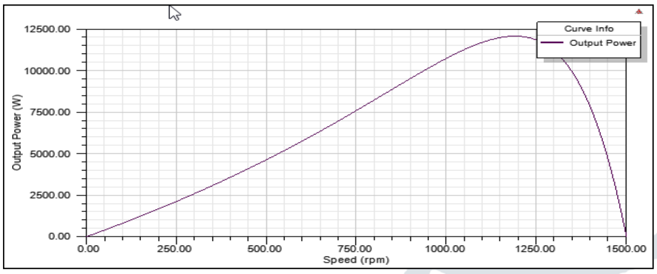


Fig 3. Output Mechanical Power(P) v/s Speed(S)

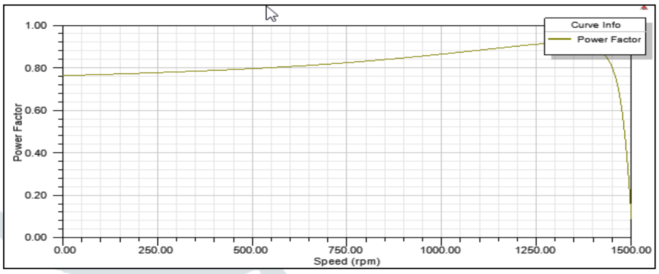


Fig 4. Power(P) Factor v/s Speed(S)

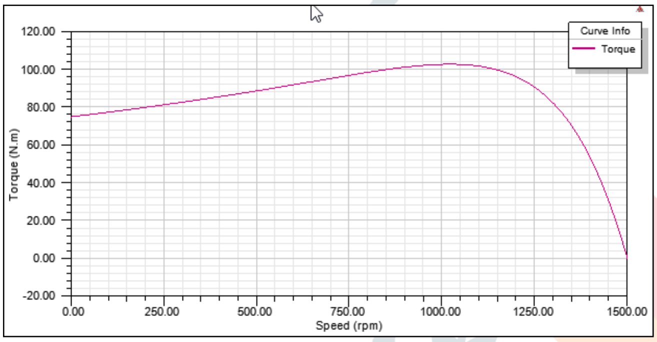


Fig 5. Torque(T) v/s Speed(S)

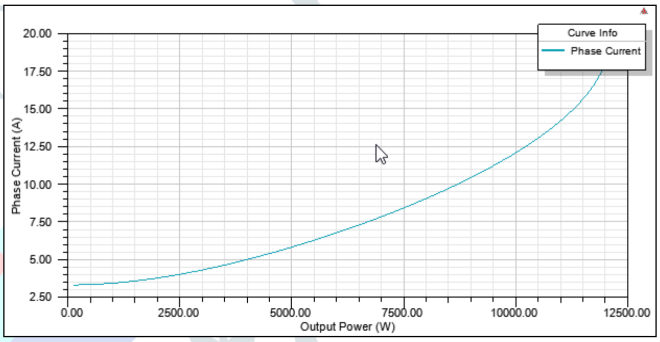


Fig 6. Phase Current(I) v/s Output Power(P)

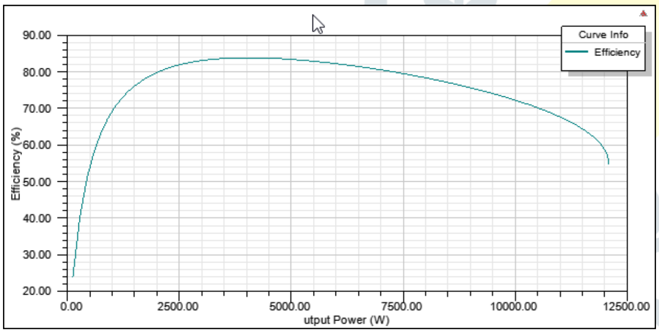


Fig 7. Efficiency v/s Output Power(P)e

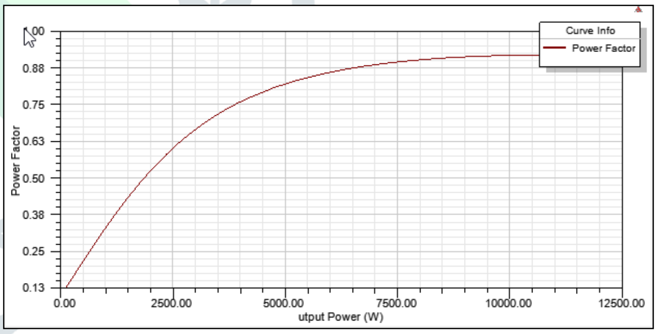


Fig 8. Power factor v/s Output Power(P)

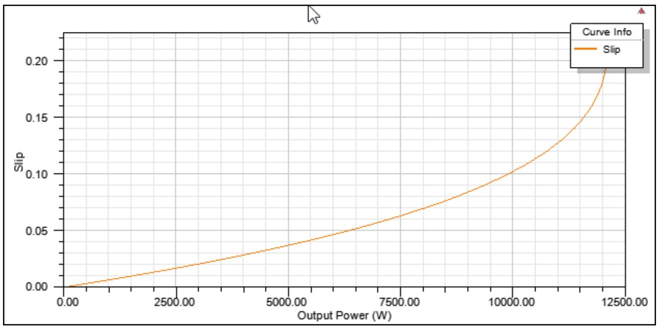


Fig 9. Slip(s) v/s Output Power(P)

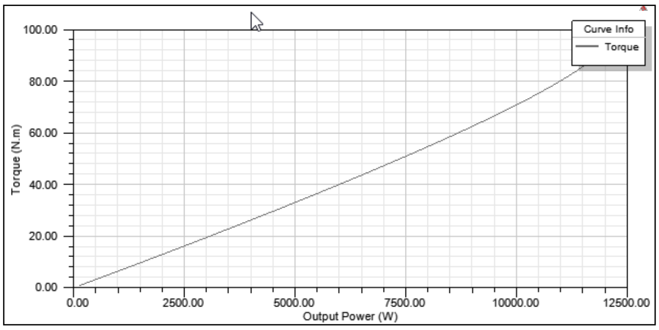


Fig 10. Torque(T) v/s Output Power(P)

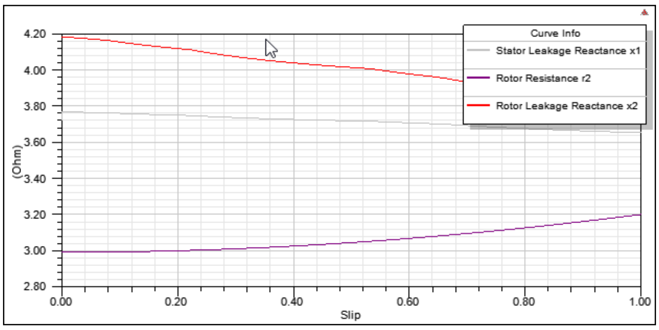


Fig 11. Leakage Impedance(Z_L) v/s Slip(s)

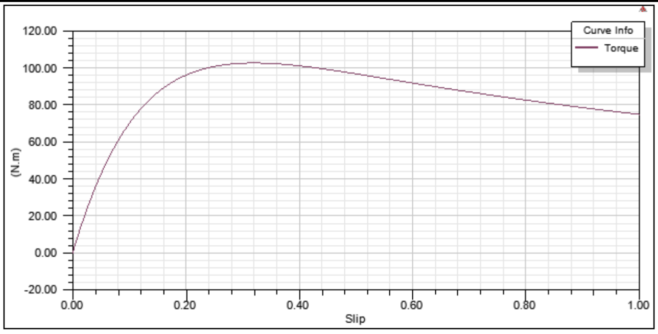


Fig 12. Torque(T) v/s Slip(s)

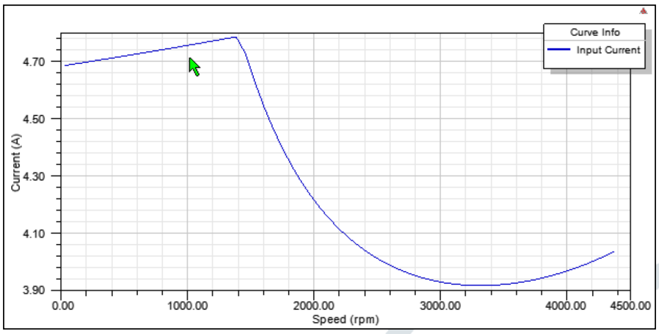


Fig 13. Input Current(I) with Flux Weakening Control

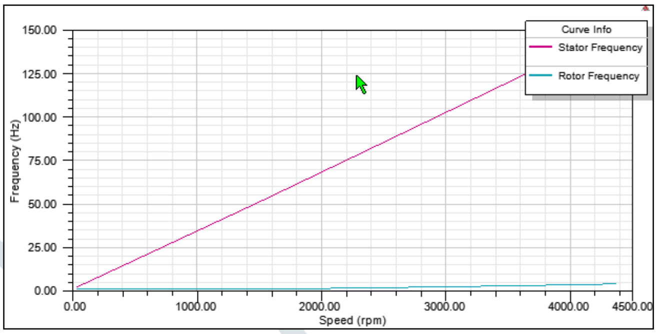


Fig 14. Frequency with Flux Weakening Control

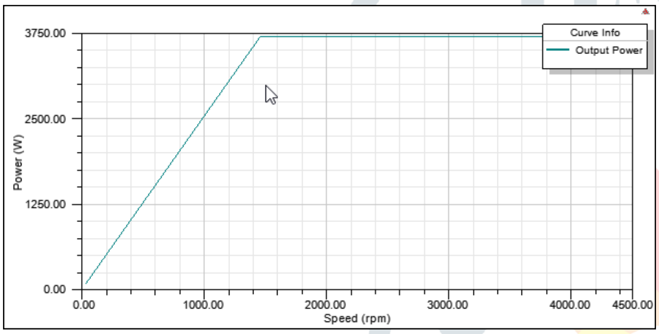


Fig 15. Output Power(P) with Flux Weakening Control

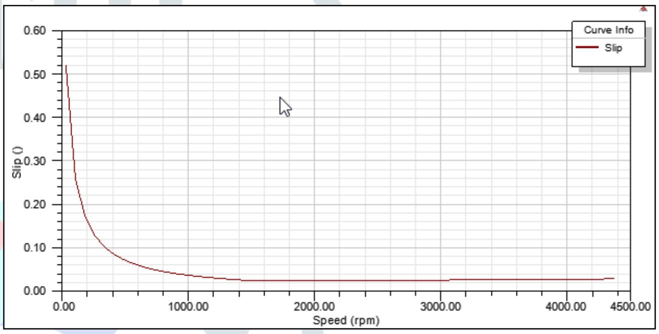


Fig 16. Slip(s) with Flux Weakening Control

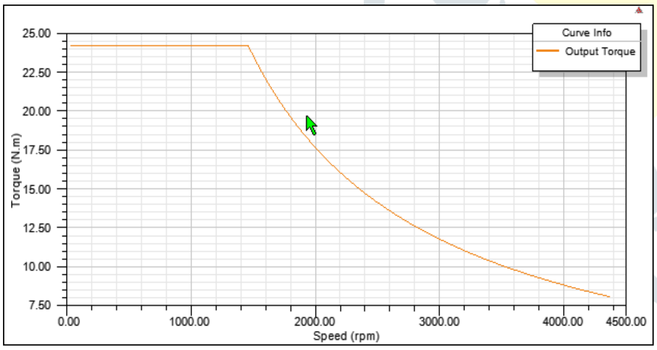


Fig 17. Output Torque(T) with Flux Weakening Control

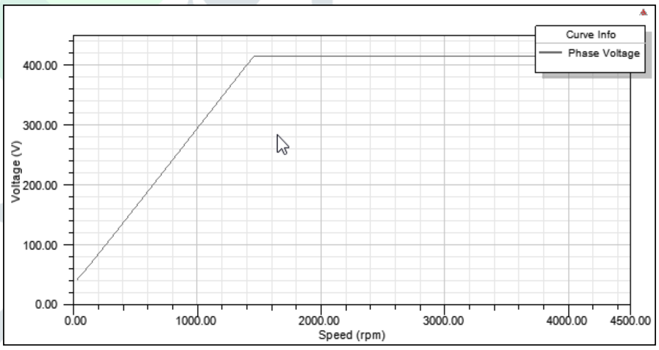


Fig 18. Phase Voltage(V) with Flux Weakening Control

VI. MAXWELL 2D GEOMETRY:

Magnetic and Electric Finite Element Field Solvers Static and Transient (Time(t)-domain) solutions Linear and non-linear, isotropic, and laminated materialsCo-simulation with Simplorer Direct link from RMxprt Direct link to ANSYS Mechanical for Stress and Thermal analysis.

SETUP DETAILS:
Start Time(t): 0
Stop Time(t): 0.04
Time(t) step:0.000

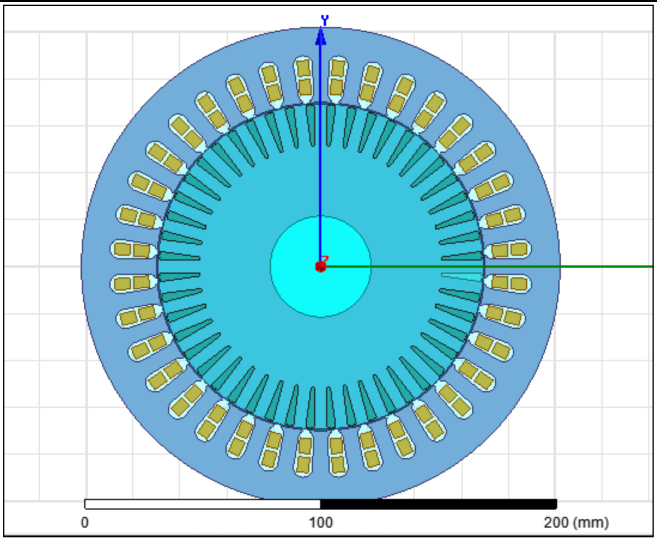


Fig 6. Geometry made in maxwell 2D

VII. Flux Distribution in Maxwell 2D

The below figure shows the flux distribution in motor

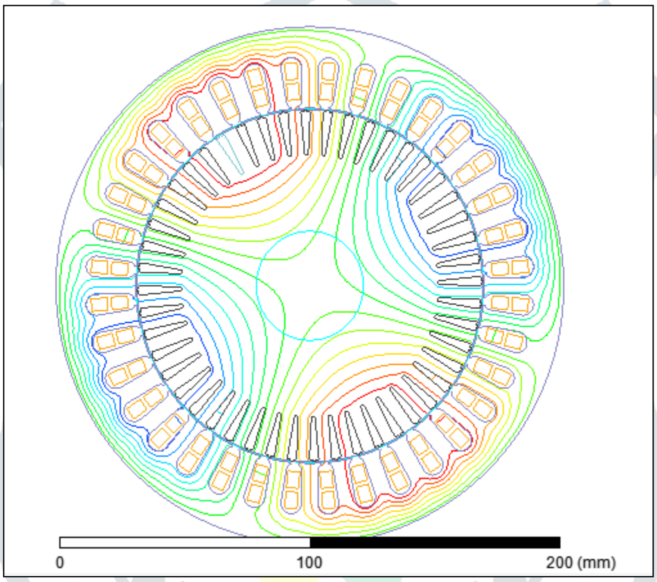
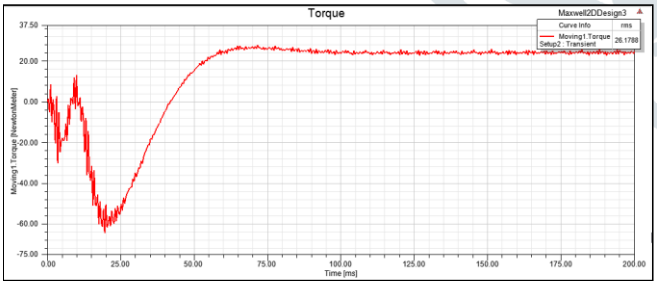
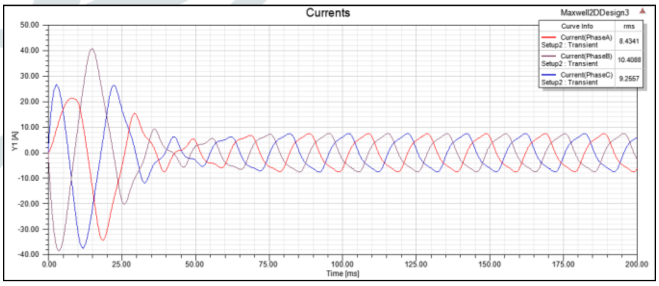


Fig. Flux Distribution

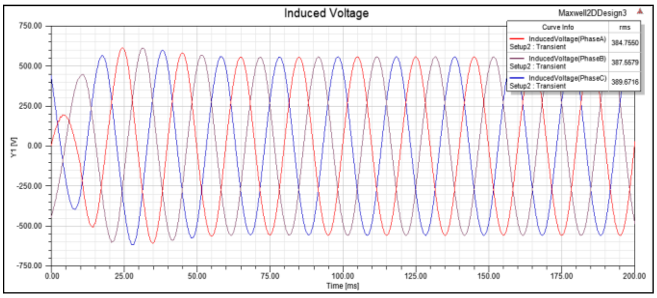
VIII. PERFORMANCE ANALYSIS IN MAXWELL 2D:



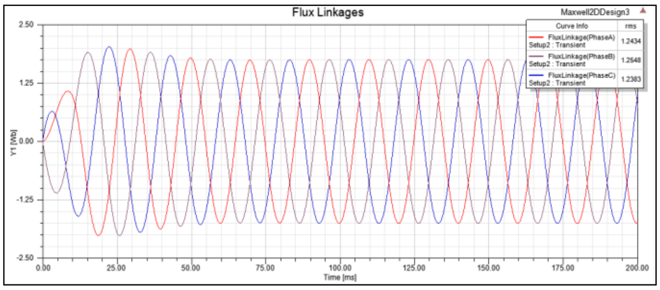
Graph A. Torque(T) v/s Time(t)



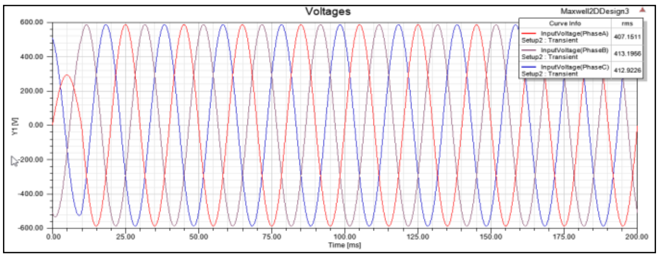
Graph B. Current(I) v/s Time(t)



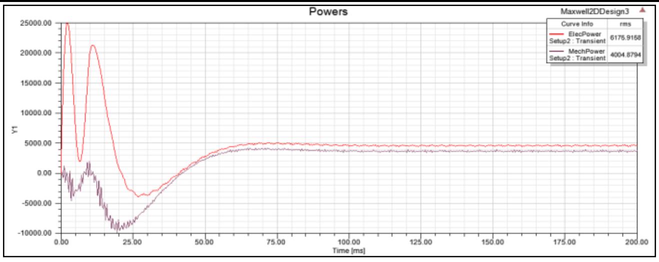
Graph C. Induced Voltage(V) v/s Time(t)



Graph D. Flux v/s Time(t)



Graph E. Voltage(V) v/s Time(t)



Graph F. Power(P) v/s Time(t)

IX. RESEARCH METHODOLOGY

To design and analyze the 3 phase induction motor theoretically, practically and on ANSYS Software we referred various data. So the things which we referred are as follows:

Data for theoretical calculations

For theoretical calculations we collected the ratings of motor from our college laboratory calculated the required parameters to design the motor as per given in the book by A. K. Sawhney and A. Chakrabarti, “A Course in Electrical Machine Design”.

Simulation on ANSYS

We attended the workshops of ANSYS software and designed the motor in ANSYS as per data obtained from theoretical calculations.

Practical readings and analysis

We took practical readings by referring some lab manuals in our laboratory and for analyzation purpose we went through some research papers on induction motor studies on any software (eg. Matlab) and by other research papers on ANSYS.

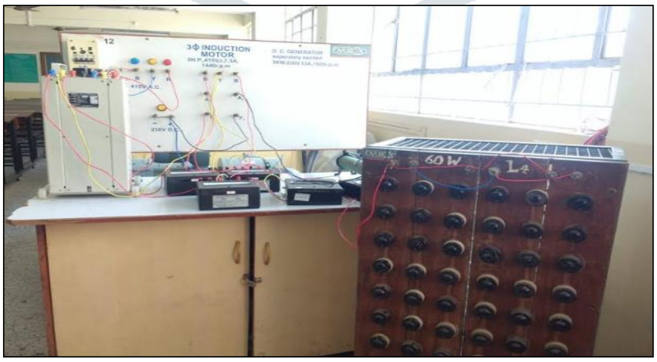
X. THEORETICAL CALCULATIONS

Done theoretical calculations of 3.7 kW, 415 V, 3-Phase 4 pole, 1500 rpm Induction motor and major results obtained from theoretical calculations are as follows.

PARAMETERS	VALUE
Efficiency	82.58%
Power factor	0.73
Slip (Full load)	0.029
Slip (No load)	0.009
Lossses (Watts)	780
Speed (rpm)	1457
Input Power (Watts)	4480
Output Power(Watts)	3700

XI. PRACTICAL TEST SETUP IN LAB.

Performed load test on Induction Motor in Lab. Laboratory



Test Setup In Laboratory.

Readings obtained:

Sr. No	Line Voltage(V)	Line Current(I)	W1	W2	Load Voltage(V)	Idc	Speed(S)
1	415	0.4	30	0	230	0	1426
2	415	6.4	630	180	184	10	1280

Perfromance Parameters Obtained after Calculations:

Efficiency: 63.09% Power Factor: 0.730
Slip (Full Load): 0.1466 Slip (No Load): 0.0493
Losses (Watts): 1418.113 Speed(S) (rpm): 1280
Input Power(P) (watt): 3843.113 Output Power(P) (Watt): 2425

XII. COMPARATIVE CHART:

Parameters	Practical Results	Theoretical results	Simulated Results
Efficiency	63.09%	82.58%	83.71%
Power Factor	0.730	0.73	0.7346
Slip (Full load)	0.1466	0.029	0.0260
Slip (No load)	0.0493	0.009	0.000146
Losses (Watts)	1418.113	780	719.779
Speed(S) (rpm)	1280	1457	1460
Input Power(P) (Watts)	3843.113	4480	4419.47
Output Power(P) (Watts)	2425	3700	3699.69

XIII. ACKNOWLEDGMENT

I have been very fortunate to work on this project under guidance of Prof. Mr. Y. B. Mandake. And I would also like to thanks our HOD Prof. Mr. D. S. Bankar for providing us machine from our college laboratory for study purpose.

CONCLUSION

In this paper, 3 phase 4 pole 5 H.P. Induction motor is designed and analyzed by using ANSYS Maxwell 2D and RMxprt software tools. Induction motor design and to analyze it. Practical results are obtained by performing the test on motor in laboratory from simulated results and practical results and theoretical calculation results, it is observed that motor performance got poor because of using it for many years. We observed that by developing the computer technology, the Finite Element Method tools are becoming more useful to analyze the machine. It provides the option of proper material selection, material consumption details, provides 2-D and 3-D geometry of designed motor and also allows to make any changes to optimize the design.

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