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Design optimization and development of energy efficient induction motor for industrial applications

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***Abstract*– This paper in this project, A detailed analysis of the energy efficiency of the industrial motors has been presented, The energy efficiency of industrial motors has been thoroughly examined. Energy efficient motor designs offer higher operating efficiency than standard designs, according to varying the motor design parameters presented in this project.**

Keywords: Optimization of induction motor, Energy Efficiency, Motor-Cad software, Air Gap length, Core length, Losses.

1. INTRODUCTION

In this project we optimize the standard motor by varying the design parameters to get an Energy Efficient Motor design with better efficiency and reduced losses, for this we are using a software called ANSYS Motor-CAD, ANSYS Motor-CAD is a dedicated electric machine design tool that allows for rapid multi-physics simulation over the whole torque-speed working range. This tool allows designers to examine motor topologies and concepts over their entire working range, resulting in designs that are optimal for performance, efficiency, and size. Electromagnetics, thermal, virtual testing laboratory, and mechanical are four integrated modules of Motor-CAD software that allow multi-physics calculations to be conducted fast and repeatedly, allowing users to go from concept to final design in less time. For the thorough study of electric motors, there is a one-of-a-kind analytical software package. The analytical-based algorithms in SPEED & Motor-CAD provide rapid computation speeds and real-time 'what-if' analysis.

Since its inception in 1887, the electric motor has undergone extensive improvement, with the majority of early efforts focused on increasing power and torque while lowering costs. During the late 1970s, the need for increased efficiency became obvious. The rising cost of energy necessitates energy conservation at every stage of the production process. Because electric motor-driven systems used in industrial processes consume more than 70% of all electricity used in industry, the most advanced technology is used to achieve the highest feasible efficiency levels. This PROJECT describes the various factors affecting the efficiency of motor and method to increase it on the basis of comparison with various standards. An incremental difference in the efficiency is also discussed.

The majority of motors are used at a lower load than their rated capacity. Because of the safety margin, desired size selection, and starting torque requirements, most motors operate at 60 to 80 percent of full load, and many will operate at very low load for a significant portion of their working life. High-efficiency motors must maintain their energy efficiency at these normal load factors, and the leading manufacturers typically design optimum efficiency motors at roughly 75% full load.

Within the first 500 hours of operation, an electric motor can consume enough electricity to pay for itself — that's only three weeks of continuous use or three months of single shift work. The motor's annual operating costs will range from four to sixteen times its initial investment.

It may spend more than 200 times its capital cost in energy throughout the course of its working life, which is an average of thirteen years. Clearly, the lowest total cost cannot be reached unless both capital and operating costs are taken into account. 70% of all electricity used in industry, the most advanced technology is used to achieve the highest feasible efficiency levels. The quantity of useable power produced by an electric motor versus the amount of energy required to operate it determines the efficiency of the motor. The most common way to express motor efficiency is as a percentage.

The following specific features help to attain higher efficiencies:
i. Special grade of thinner laminations with low loss. Even at partial loads, this lowers iron loss.
ii. Copper loss is reduced by thicker conductors and higher copper content due to lower resistance.
iii. Longer core length, reduced and uniform air gap between stator and rotor to reduce stray losses.
iv. Special design of fan and fan cover to reduce wind age Losses.

An energy-efficient motor is an electromechanical device that generates greater mechanical energy with less electrical energy. It is a re-engineering of the normal electric motor, which consumes a lot of energy, has a lot of maintenance costs, and emits a lot of greenhouse gas Environmental protection, reduced maintenance costs, low energy consumption, and great energy efficiency are all potential advantages of energy efficient motors. The poor power factor, high energy consumption, and low efficiency of conventional electric motors are caused by low-grade materials used for windings and lamination. There is a significant likelihood of obtaining sustainable energy and demand reduction, as well as a shorter payback period, with a 3 percent efficiency improvement in energy efficient motor. According to comparative studies conducted by renowned academics, compromises were made on materials throughout the design and manufacturing of ordinary electric motors; as a result, the end product had low efficiency, low power factor, and large losses, making it highly expensive to manufacture. Better design, material and manufacturing approach were responsible for the increased efficiency of the energy efficient motor.

In an era when natural resource conservation and energy conservation are so vital, the Induction motor manufacturers have helped by gradually improving their products. environmentally friendly options are offered, As a result, increasing the efficiency of the induction motor contribute to the clean-up of the environment for all living things, and today when Global warming, i.e. pollution, is on the rise.

Induction motor efficiency is determined by intrinsic losses that can only be addressed by changing the motor design. Fixed losses, which are independent of motor load, and variable losses, which are depending on load, are the two forms of intrinsic losses. Magnetic core losses, as well as friction and windage losses, are fixed losses. Resistance losses in the stator and rotor, as well as stray losses, are all examples of variable losses. As a result, we can improve the efficiency of an induction motor by lowering these losses.

Using high-efficiency motors can help you save money in a variety of ways. Saving energy not only lowers your monthly electric bill, but it also delays or eliminates the need to extend your facility's electrical supply system capacity. Installing efficiency measures on a greater scale helps electrical companies to postpone the construction of costly new generating facilities, resulting in lower costs for all consumers.

The right selection and use of high-efficiency motors is the first step toward saving energy and money. You may rapidly calculate the easy payback that would follow from investing in and operating a premium efficiency motor after gathering readily available information such as motor nameplate data, annual operating hours, and electrical rates.

2. OBJECTIVE OF THE THESIS

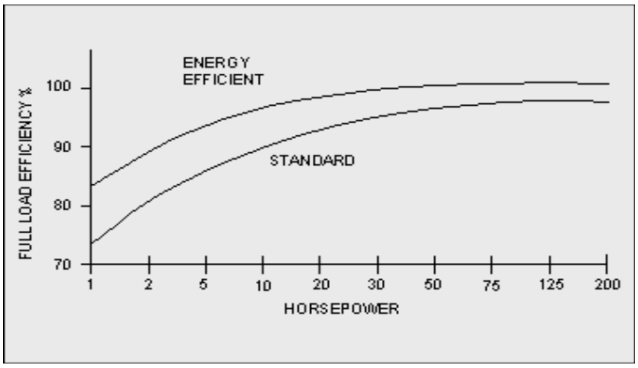
The optimization of induction motor designs in terms of cost and efficiency is the subject of this thesis. The majority of research using optimization techniques to build an induction motor are concerned with minimising the motor cost and describing the optimization methodology used, resulting in a single (or numerous) ideal design (s). A more thorough investigation of the optimization of a three-phase induction motor design was carried out using the Motor-Cad Software in this thesis. This includes the relationship between core lenght parameters, efficiency, and power factor, as well as the effect of electrical steel and other material characteristics and other factors as they arise in an optimal design.

The ability of a community to create goods and services determines its level of income. However, the efficient use of energy is critical to the production of goods and services. Thermal, mechanical, and electrical energy can all be used. Electrical energy, measured in kWh, accounts for more than 30% of all used energy and is increasing. In electric motors, the majority of electrical energy is turned into mechanical energy. The induction motor is without a doubt the most often used electric motor, yet it consumes a lot of energy. Induction motors account for roughly 70% of all industrial loads on a given utility. Heating, ventilation, and air conditioning (HVAC) are the most common applications for induction motor drives.

In the industrial and agricultural sectors, electric motors are critical. These motors were used in both low- and high-speed constant-speed drives. On the basis of comparisons with various standards, this PROJECT discusses the various aspects impacting motor efficiency and methods for increasing it. There's also talk about a little improvement in efficiency.

In the industrial and agricultural sectors, electric motors are critical. These motors were used in both low- and high-speed constant-speed drives. The two concepts of energy efficiency and conservation are intertwined. With the rise in energy consumption, as well as the uncertainty surrounding oil supply and the fluctuating price of traditional fuels, energy efficiency and conservation has become a critical component of both industrial and rural growth.
Induction motors used for irrigation in rural areas and for industrial purposes in urban areas consume a significant quantity of electrical energy. Agriculture and industry are fast booming in countries like India, and electrical energy demand is rising as well. According to a study, a 5% increase in induction motor overall efficiency would save enough energy to equal the energy produced by a new power plant with a few hundred megawatts of capacity.

Design enhancements are incorporated expressly to maximize operational efficiency above standard design motors in energy-efficient motors. The goal of design enhancements is to reduce intrinsic motor losses. The use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, a smaller air gap between the stator and rotor, copper instead of aluminum bars in the rotor, superior bearings, and a smaller fan, among other things, are among the improvements. Energy-efficient motors, which are currently available in India, have efficiencies of 3 to 4 percentage points higher than normal motors.



Typical efficiencies of Standard and Energy Efficient Motors

Typical energy efficient motors are 1.5 percent to 8% more efficient than standard motors, with efficiency gains as high as 12 percent in the 1 HP range. There is a wide variation in how the qualitative terms "High Efficiency" or "Energy Efficient" 3-phase induction motors are utilised among various manufacturers.

The power factor of AC induction motors is an important metric for determining their efficiency. The magnitude of the active current drops as the load on the motor decreases. However, because the magnetising current is proportional to supply voltage, there is no corresponding fall in the motor power factor when the applied load is reduced. Low power factor in electric systems is mostly affected by induction motors, particularly those operating below their rated capacity. Power factors less than one characterise motors, as well as other inductive loads. As a result, the total current draw required to deliver the same actual power is higher than the amount by a load with a higher PF. Because resistance losses in wiring upstream of the motor are proportional to the square of the PF, operating with a PF less than one has a significant effect.

Losses can be reduced to improve motor efficiency. Motor energy losses are classified into several categories, each of which is influenced by the motor's design and construction. Intrinsic losses dictate a motor's efficiency, which can only be lowered by modifications in motor design. Fixed losses, which are independent of motor load, and variable losses, which are depending on load, are the two forms of intrinsic losses. Magnetic core losses, as well as friction and windage losses, are fixed losses. Eddy current and hysteresis losses in the stator make up magnetic core losses (also known as iron losses). They differ depending on the core material and geometry, as well as the input voltage. The size of the air gap between the rotor and the stator is one design factor. Large air gaps maximise efficiency at the expense of power factor, whereas small air gaps compromise efficiency marginally while enhancing power factor greatly.

3. ASSESSING EXISTING MOTOR INVENTORY

An inventory of existing motors can serve as a basis for a plan to increase efficiency. Sizes, kind, duty cycle, and loading are all crucial details to keep track of. It's important to keep track of the motor's history, including prior rewinds (if any). Monitoring motors with a significant proportion of running hours assists in picking the optimal size.

Large motors with high duty cycles should be evaluated for energy-saving alternatives. If the run time supports the adjustment, significantly oversized motors would also be a potential contender. A dynamometer or equivalent techniques should be used to test previously repaired motors with long run times for efficiency. For cost considerations, such testing would be confined to very big motors. Sound business cases can be produced using this information to compete for capital upgrade financing.

Having a motor inventory can help you to determine whether to buy a new motor or repair one that has failed. Considering their age, older tiny motors are usually not worth fixing.

Additional advantages come with energy-efficient motors. They usually have greater service factors, longer insulation and bearing lives, reduced waste-heat production, and less vibration due to improved manufacturing procedures and superior materials, all of which promote reliability. There is a significant difference exists between standard and energy-efficient motors. Energy-efficient motors can do more work per unit of electricity consumed because to advances in design, materials, and manufacturing procedures.

	Nominal efficiency range		Average nominal efficiency
hp	Min.	Max.	
1	82.5	85.5	83.5
2	82.5	86.0	84.3
3	82.5	89.5	87.0
5	85.5	89.5	87.9
7.5	87.5	91.7	90.0
10	89.5	91.7	90.6
15	90.2	93.0	91.6
20	90.2	93.6	92.1
25	91.0	94.1	92.6
30	91.7	94.1	93.1
40	93.6	94.5	93.9
50	93.6	94.5	94.1
60	93.6	95.4	94.4
75	94.1	95.4	94.8
100	94.1	96.2	95.1
125	94.1	95.4	95.1
150	94.5	96.2	95.3
200	95.0	96.2	95.5

[a] Based on available published data.

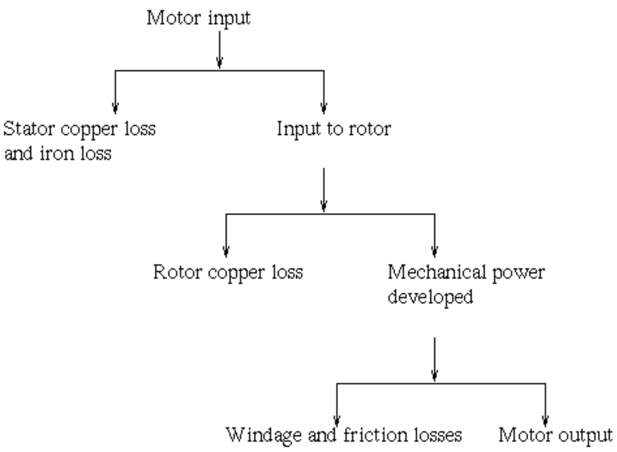
Full-Load Nominal Efficiencies of Three-Phase Four-Pole Energy-Efficient Open Motors

Energy Efficient Motors are ideal for industries that require a lot of electricity and where the motors must run at a steady load for lengthy periods of time.

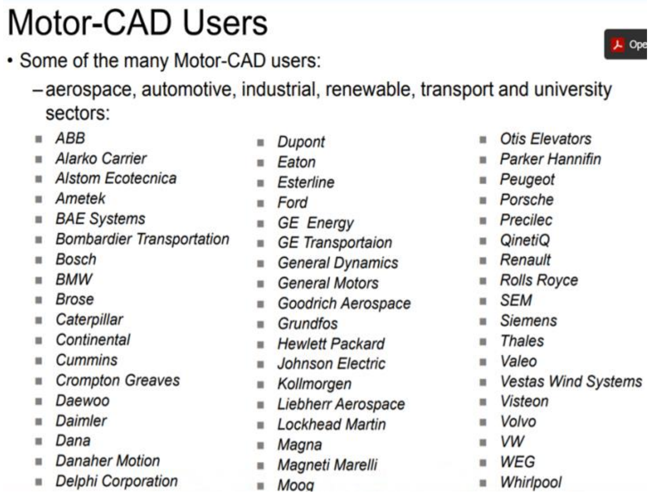
Continuously driven equipment includes Ring Frames, Fans, Blowers, Mixers, Pumps, Compressors, and many more. Industries where these motors are ideal include textile, paper, rubber, petrochemicals, cement, power generation, and many others.

Table 1. Description of various losses in electrical motors

Fixed Losses	Typical Losses %	Factors Affecting These Losses
Core Losses	15-25	Type and Quantity of Magnetic Material
Friction & Windage Losses	5-15	Selection and Design of Fans and Bearings
Variable Losses		
Stator I^2R_S Losses	25-40	Stator Conductor Size
Rotor I^2R_R Losses	15-25	Rotor Conductor Size
Stray Load Losses	10-20	Manufacturing and Design Methods



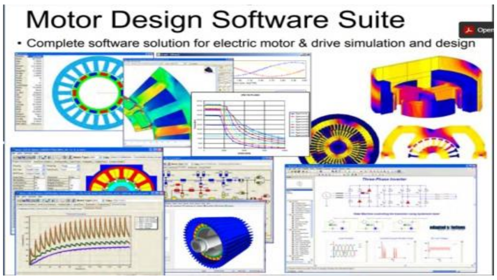
Motor-CAD

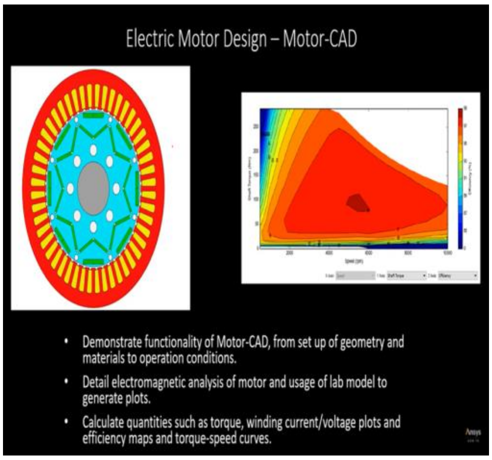


For the thermal study of electric motors, there is a one-of-a-kind analytical software package. The analytical-based algorithms in SPEED & Motor-CAD provide rapid computation speeds and real-time 'what-if' analysis. ANSYS Motor-CAD is an electric machine design tool that lets for rapid multiphysics simulation across the whole torque-speed working range. Design experts can use this tool to assess motor topologies and concepts across the whole working range, resulting in designs that are optimal for performance, efficiency, and size. The four integrated modules in Motor-CAD software, electromagnetics, thermal, virtual testing laboratory, and mechanical, allow users to do multiphysics calculations quickly and iteratively, allowing them to go from concept to final design in less time.

Aim: To design an optimized 3 phase induction so as to increase its efficiency by varying various design parameters .

To optimize the induction motor design we are using ANSYS – Motor Cad software which is a software tool and design tool for fast multiphysics simulation across the full torque-speed operating range. This tool enables design engineers to evaluate motor topologies and concepts across the full operating range, in order to produce designs that are optimized for performance, efficiency and size.



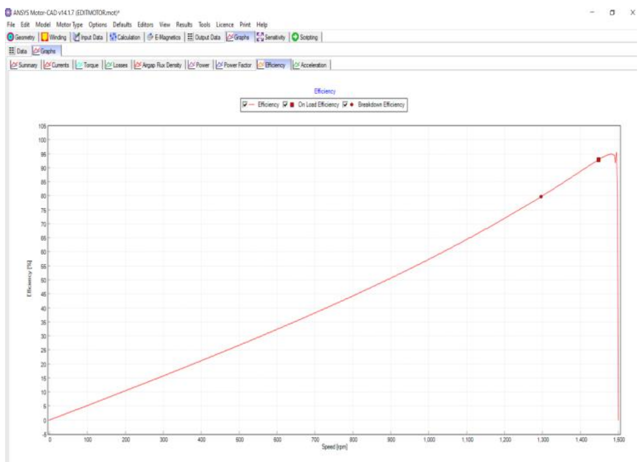


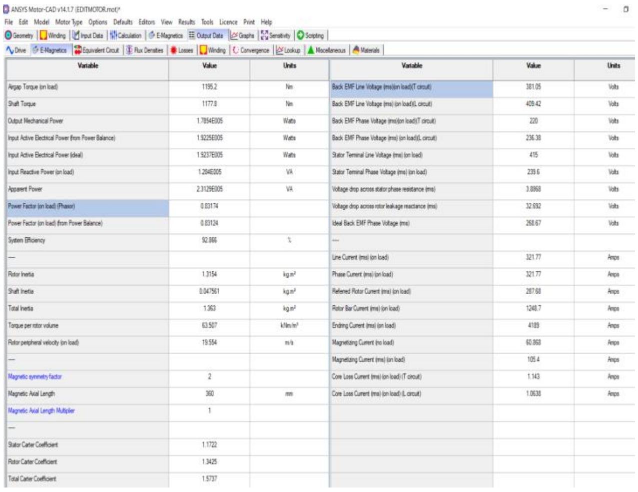
Hence by varying various parameters in the Motor Cad software we tabulate the following above table and got efficiencies for various air gap and for different core length parameters.

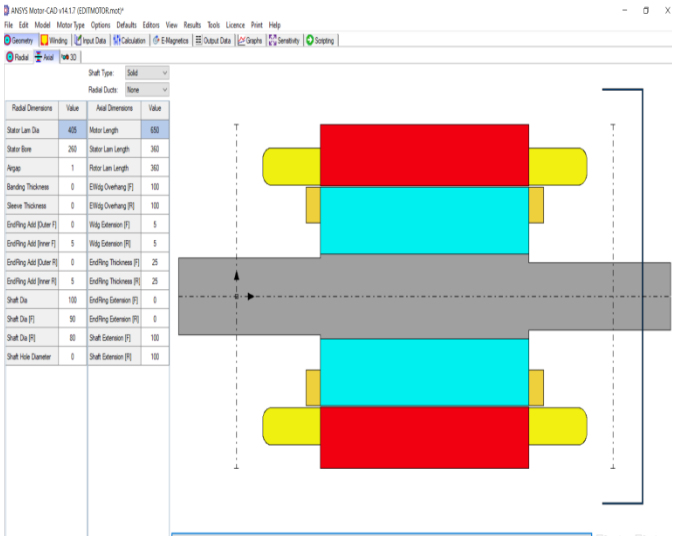
Air Gap (mm)	Core Length (mm)	Currents Drawn (A)	Airgap Flux Density	Stator tooth Flux Density	Rotor tooth Flux Density	Stator Back iron Flux Density	Rotor Back iron Flux Density	Losses (KW)	Power Factor	Efficiency (%)
0.6	360	286.1	0.5041	1.383	1.654	1.733	1.124	12.41	0.9115	93.38
	380	286.84	0.4762	1.306	1.562	1.637	1.062	12.84	0.9112	93.16
	400	294.14	0.4498	1.234	1.476	1.546	1.003	13.77	0.9067	92.81
0.7	360	312.67	0.4998	1.37	1.64	1.71	1.117	14.13	0.8931	92.96
	380	297.15	0.4748	1.302	1.56	1.63	1.061	13.43	0.9004	93.01
	400	283.4	0.4519	1.239	1.485	1.553	1.01	12.82	0.9050	93.04
0.8	360	305.28	0.4974	1.363	1.636	1.709	1.113	13.02	0.8599	93.1
	380	302.02	0.4724	1.295	1.554	1.623	1.058	13.47	0.8792	92.94
	400	293.72	0.4498	1.233	1.48	1.545	1.007	13.38	0.8899	92.87
0.9	360	318.12	0.4948	1.355	1.63	1.699	1.11	13.65	0.84139	92.90
	380	315.92	0.4683	1.283	1.543	1.608	1.05	14.05	0.8496	92.71
	400	306.74	0.4456	1.221	1.468	1.53	0.999	13.93	0.8598	92.65
1	360	314.07	0.4954	1.356	1.634	1.701	1.113	13.16	0.8314	92.99
	380	313	0.4682	1.282	1.544	1.607	1.052	13.57	0.8361	92.78
	400	317.9	0.4434	1.214	1.463	1.522	0.9967	14.52	0.8437	92.46
1.2	360	317.71	0.4962	1.358	1.641	1.702	1.12	13.27	0.8253	92.96
	380	315.1	0.4699	1.286	1.554	1.612	1.06	13.68	0.8371	92.78
	400	316.81	0.4437	1.214	1.468	1.522	1.001	14.09	0.8282	92.52

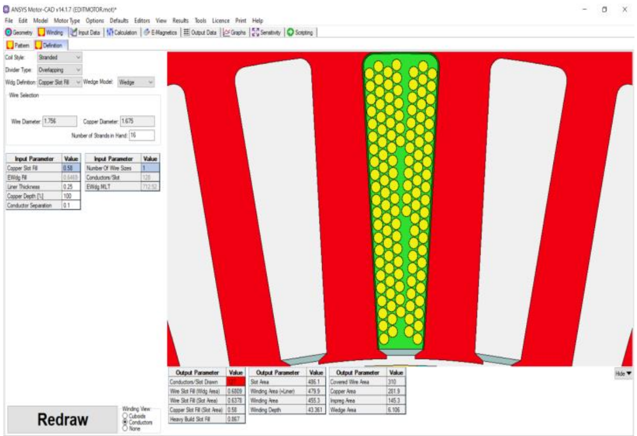
Rotor material	Current Drawn(A)	Power Factor	Losses (KW)	Efficiency (%)
Aluminium (Alloy 195 cast)	324.48	0.83	11.02	94.32
Brass (70% Cu,30%Zn)	306.67	0.82	12.6	93.11
Aluminium (Cast)	308.81	0.83	10.72	94.18

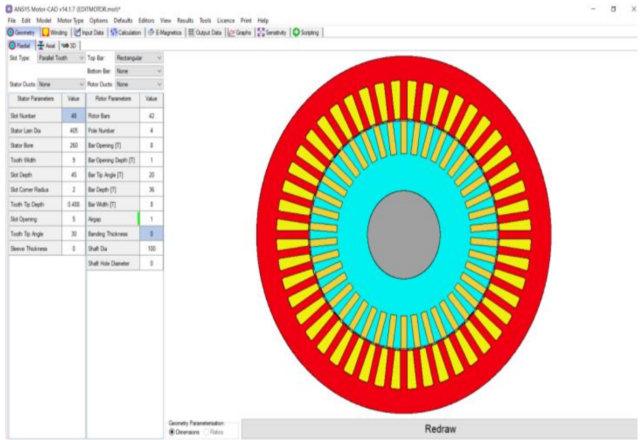
Stator Core material	Currents Drawn(A)	Power Factor	Losses (KW)	Efficiency (%)
M19 24 Gauge Steel	312.73	0.86	13.57	92.98
M19 26 Gauge Steel	312.93	0.86	13.73	92.90
M19 29 Gauge Steel	312.79	0.86	13.62	92.95
M43	312.68	0.86	13.58	92.97

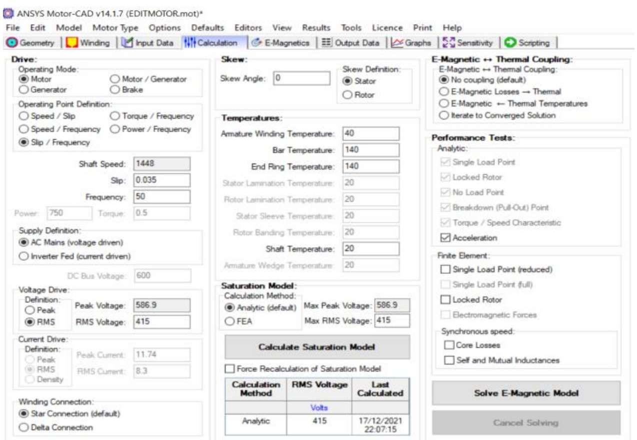


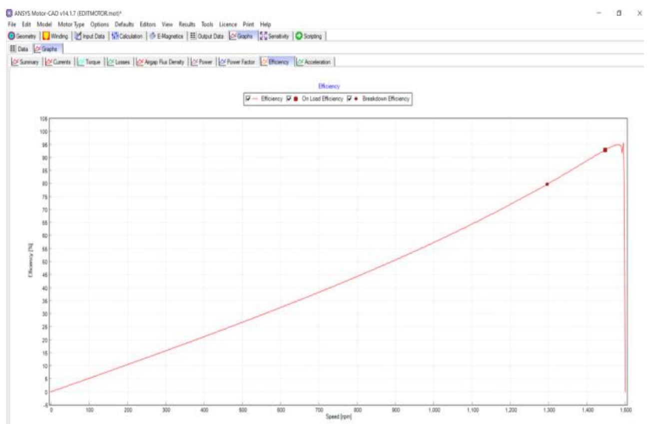


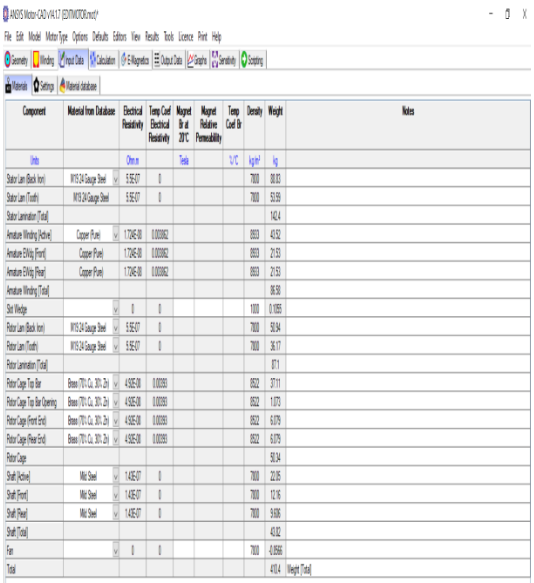


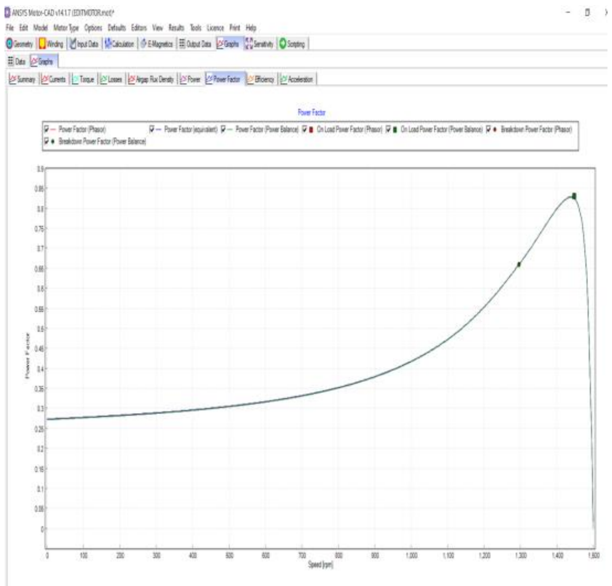


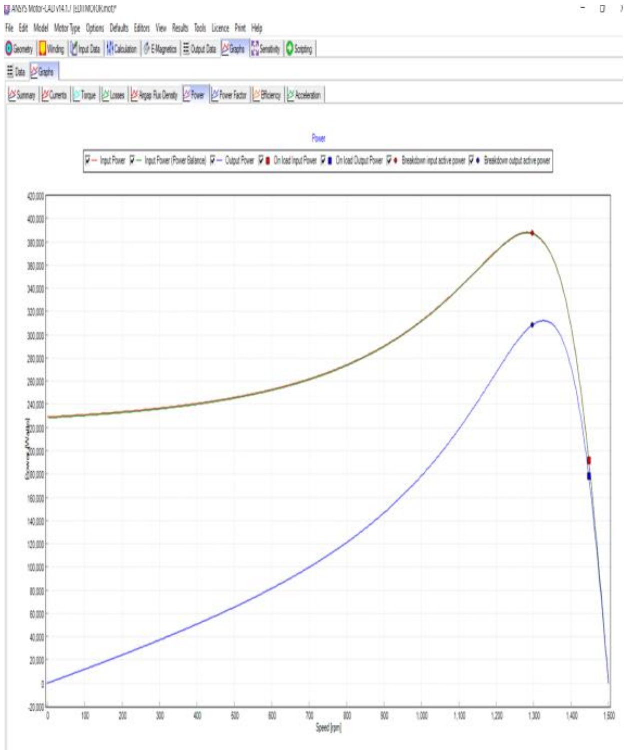












4. CONCLUSION

We are able to optimize the efficiency of the standard motor from 90% to an efficiency of approx 93% , hence we are able to achieve an increase of 3 % increase in efficiency by varying various design parameters Like air gap lengh and core length parameters and material used for stator and rotor laminations .

5. REFERENCES

[1] Attaianese, V. Nardi, A. Perfetto. and G. Tomasso. "Vectorial torque control: A novel approach to torque and flux control of induction motor Drives". IEEE Trans. On Industry Applications, vol. 35, n 6, pp. [7]J. Ka Kang, S. K. SUI. "Torque ripple minimization strategy for direct torque of induction motor". Proc. IEEE Industry Applications Society Annual Meeting, IAS'98, St. Louis, USA, Oct., 1998.

[2] G.S. Kim, I. J. Ha, M. S. KO., "Control of induction motors for both high dynamic performance and high power efficiency". IEEE Trans. Ind. Electron., Vol. 39, No 4, August 1992.

[3] P. Famouri, J.J. Cathey,"Loss minimization control of an induction motor drive". IEEE Trans. Ind. Applicat. Vol. 27, No. I, pp.32-37, Jan./Feb. 1991.

[4] I J.M. Moreno , M. Cipola, J. Peracaula. "Tnduction motor drives energy optimization in steady and transient states : a new approach".EPE ' 97, Trondheim, Vol. 3, pp. 705-710.

[5] S. Nadel, M. Shepard, S. Greenberg, G. Katz, and A. T. de Almeida, Energy-Efficient Motor Systems, American Council for an EnergyEfficient Economy, Washington, DC, 1992, pp. 164–165.

[6] R. J. Lawrie, “Premium-efficiency motors: Soon they’ll be law,” Elect. Construction Maintenance, vol. 95, no. 7, pp. 32–38, July 1996. [3] D. W. Novotny and T. A. Lipo, Vector Control and Dynamics of AC Drives. Oxford, U.K.: Clarendon, 1996

[7] K. S. Rasmussen and P. Thøgersen, “Model based energy optimizer for vector controlled induction motor drives,” in Proc. EPE’97, Trondheim, Norway, Sept. 1997, pp. 3.711–3.716.

[8] I. Kioskeridis and N. Margaris, “Loss minimization in scalar-controlled induction motor drives with search controllers,” IEEE Trans. Power Electron., vol. 11, pp. 213–220, Mar. 1996.

[9] A. Kusko and D. Galler, “Control means for minimization of losses in AC and DC motor drives,” IEEE Trans. Ind. Applicat., vol. IA-19, pp. 561–570, July/Aug. 1983.