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FINAL *Report*

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Abstract:

This project's aim is to build and test a 6 pole, 1500 rpm, 1 hp, 3 phase synchronous machine with a reasonable cost and good efficiency. The report outlines the complete development process of a synchronous machine model using ANSYS software, conducted in four phases. Each phase considered size, cost, and efficiency trade-offs. It covers the modeling methodology, assumptions, and analysis, detailing the gradual design, construction, and optimization of a 3-phase synchronous machine model aimed at achieving specific torque and efficiency goals.

Introduction:

First, the introduction describes how Ansys Software's ANSYS Electronics Desktop is used. This software is really good for making models of electrical machines and analyzing them. In this project, they used ANSYS Maxwell 2D for the electromagnetic fields to make a synchronous machine model that can do 4.75 N.m of torque. This software helps a lot to see how the machine will work in different situations and how the design choices will affect things like cost and how well it works. Then, it explains about electric machines. These machines are what changes electric energy into moving things and the other way around. They have two big parts – a stator that stays still and makes a magnetic field, and a rotor that moves to make power. The way the stator's magnetic field and the rotor's electromagnetic part work together is what makes the rotor move and create power. It's really important to choose the right shapes and materials for these parts. This will make sure the machine works well, with good torque and not wasting too much energy, and doesn't cost too much. They have to plan the electric and magnetic parts of the machine really carefully to get all this right.

Design:

The designed motor has specific characteristics for the cost, \$4.40/kg for copper, \$1.50/kg for steel, \$240/kg for NdFeB (N35). Moreover, those constants are used in some calculations: Copper resistivity (1.72e-8 ohm-m), Copper density (8900 kg/m³), Steel density (7800 kg/m³), and NdFeB density (7400 kg/m³). Figure 1 displays the electric machine constructed for this project. It features 18 slots, each measuring 10 degrees in width and 15 mm in depth. The machine's outer diameter is 100 mm. Being a 6-pole machine, it incorporates 6 magnets on the rotor, each covering a 40° arc and having a thickness of 4 mm. The motor's length was set at 100 mm. Furthermore, the copper's one turn had a cross-sectional area that constituted 35% of the total slot area.

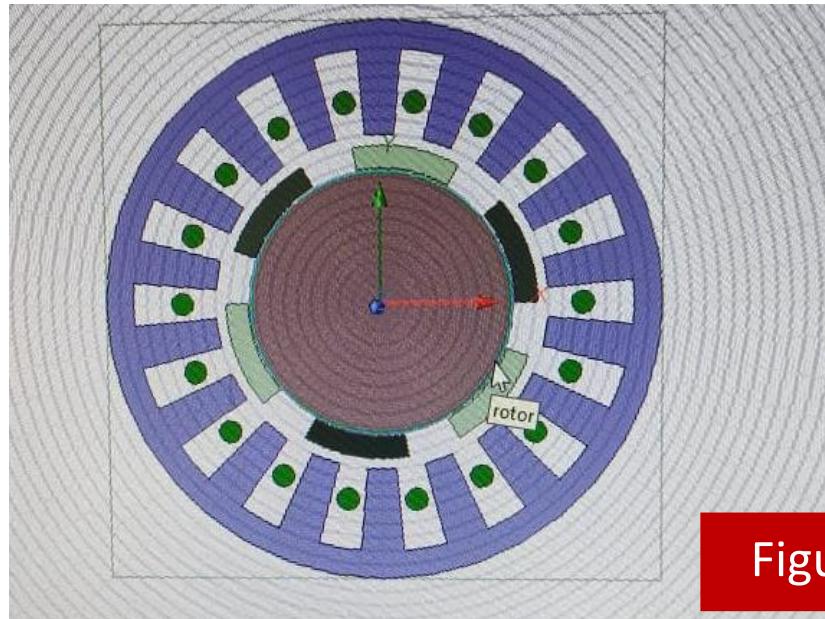


Figure 1

Methods:

Modeling and Desgining the motor in ANSYS, cost calculation for each material and the total cost, copper volume calculation, power losses, and Efficiency calculations were the all the methods that have been done.

For the copper volume calculation in Figure 2 the used equations are:

3 Phases: Volume = 3 x volume of one phase

$d = [\text{inner stator radius} + \text{slot depth}/2]$, End turn length = $3\pi d$

Cross sectional area of the winding in one slot= $[\text{total slot volume}/\text{motor}] \times [\text{slot fill factor}]/\text{slot number}$

Volume per one phase= cross sectional area * End turn length+slot length]

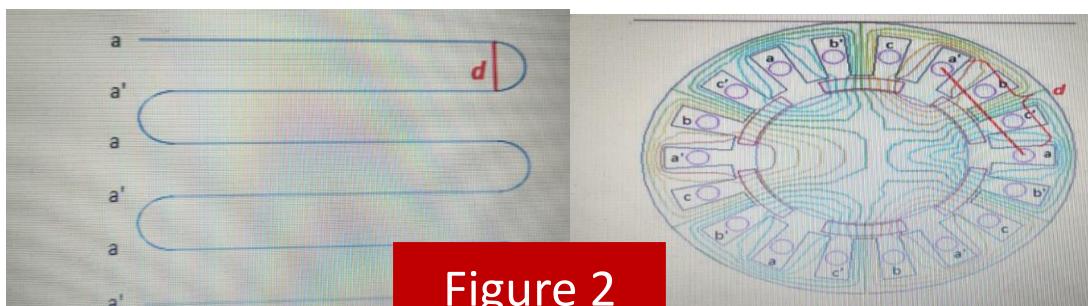


Figure 2



For cost calculations:

The pricing for each material involved in the design of the synchronous machine was determined through several steps. Initially, the volume of each material component was ascertained using the volume calculator feature in the ANSYS Electronics software suite. Subsequently, these volume measurements were translated into masses by applying the known densities of the materials. The final stage involved calculating the total costs by multiplying the determined material masses by their respective per-kilogram prices.

Power losses:

The determination of copper loss involved multiple steps, beginning with the calculation of copper resistance per phase, which was computed as follows:

$$R = \text{resistivity} * L/A$$

Copper losses:

the copper loss is calculated by using the power formula $P = 3 I^2 \text{rms} * R$

and the core loss is getting by the graph of medium frequency specific total loss vs peak magnet polarism.

Efficiency Calculations = $P_{out}/P_{in} * 100\% = P_{out}/(P_{out} + P_{copper} + P_{core})$

Results and Discussion:

The spreadsheet (Figure 3) displayed was employed to simplify the calculations in designing and optimizing the synchronous machine. As explained in the calculations section, this spreadsheet integrated various formulas for assessing costs, losses, and efficiency, drawing on dimensions, material choices, operational conditions, and torque data from ANSYS finite element analysis. By altering model variables like geometry, flux density, and current loading, and observing their effects on cost and efficiency, the spreadsheet facilitated more informed decisions for balancing cost and performance. This iterative approach complemented ANSYS simulations, aiding in refining the design to meet specifications more efficiently from both cost and performance perspectives. This involved experimenting with the machine's physical aspects, electromagnetic loadings, and losses calculated through finite element modeling.

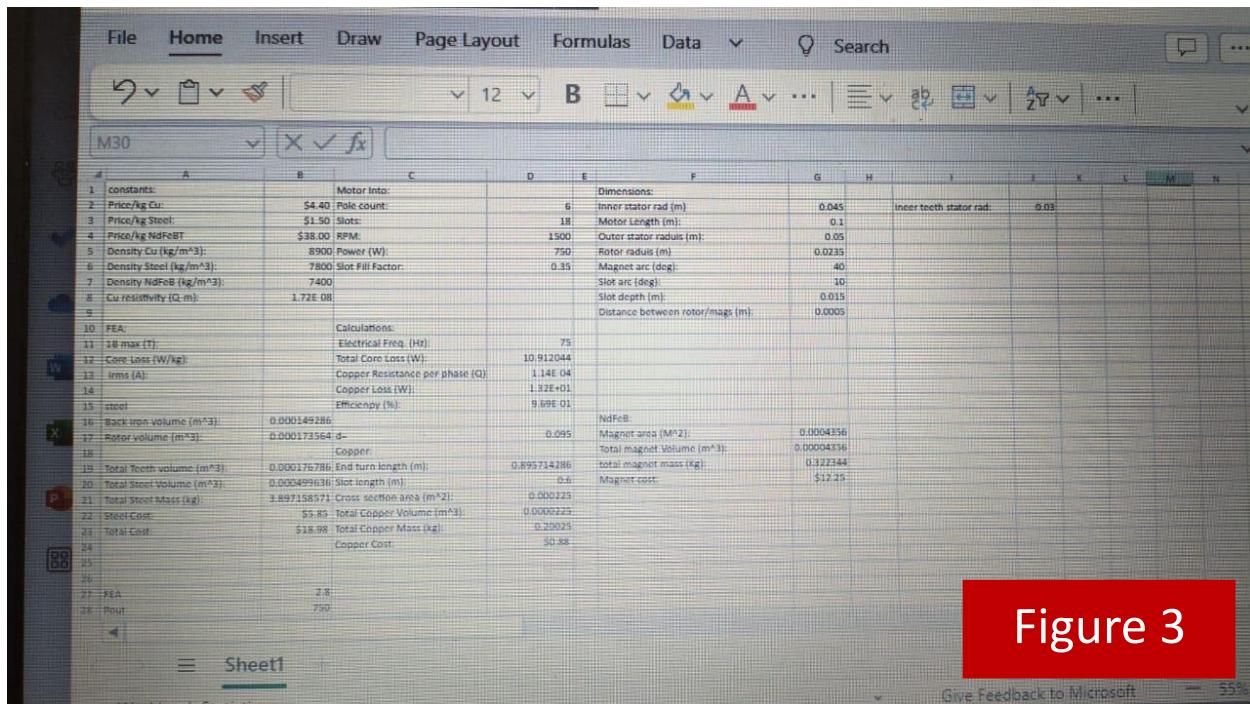


Figure 3

Benefits and conclusion:

The project on designing, simulating, and analyzing a 1 hp, 1500 rpm 3-phase synchronous machine using ANSYS Electronics tools yielded valuable insights and practical skills in electric machine operation. Focused on balancing cost and efficiency, it involved best practices in computer-aided engineering, addressing electromagnetics, losses, and thermal behavior. The ability to prototype and optimize through simulations saved time and costs compared to physical testing. The project's outcomes, including a deeper understanding of engineering trade-offs and the interplay between machine's physical attributes and performance, provide key learnings for future electric machine design and analysis, emphasizing functional and economic viability.