industrial development center

Titel: Design of an electric motor (PMSM) & manufacturing lab

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Date: 06/09/2021

Produceras inom ramen för det Vinnova finansierade projektet
Nästa Generations drivlineproduktion – UDI steg 3, Implementera

VINNOVA
Sveriges innovationsmyndighet

Projektpartner:
AFRY, Automotive Components Floby AB, AB Dahréntråd, Högskolan i Skövde, Koenigsegg Automotive AB, Leax Group AB, Lunds tekniska högskola, Precomp Solutions AB, RISE IVF AB, Science Park Skövde AB, Surahammars Bruks AB, Tekniska Högskolan i Jönköping, Volvo Lastvagnar, Volvo Penta, Volvo Personvagnar, Xylem Water Solutions Manufacturing AB

Electrification and electromobility make it possible to reach the sustainability goals of the climate. But it requires the industry to change rapidly from the manufacturing of combustion engines to electrical drive lines. This swift change requires new competence, which can be provided by the University of Skövde.

One of the required competencies that are requested is knowledge about the electrical driveline, and specifically manufacturing of electrical motors. There are courses today that include labs where the students disassemble and assemble a small electrical motor. This project is about designing a new lab including most steps in the manufacturing and testing of an electric motor. A new motor suitable for the lab is designed and its performance is evaluated.

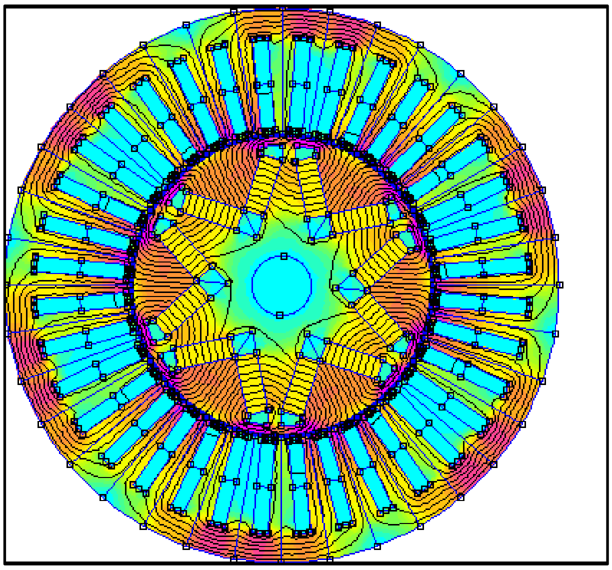
The project presents deals with the design, analysis, assembly and tests of a permanent magnet synchronous motor (PMSM). An analytical model was carried out to find an approximation model of the machine, then a Finite Element Simulation was carried out using FEMM software to validate the design.

Once the final design was selected, a motor prototype was built and an assembly instruction manual was designed, different tests and measurements manual was designed to verify the prototype.

This project carries two design directions, the motor design & the lab design. A list with several steps was carried out to design the motor, such as motor type selection, rotor topology selection, material selection, electrical model design, analytical model design, numerical model (FEM analysis) and, finally, motor prototype assembly.

Regarding the lab design, a list of steps is defined: design the measurements and tests manual to be realized on the designed motor, select the necessary instruments and equipment used in the tests, design a lab manual (assembly instructions), selection and purchase of instruments and equipment, build the designed lab and, finally, run and evaluate the lab.

The design process started with the selection of the motor type, a permanent magnet synchronous motor (PMSM) was selected and a V-shape for its rotor topology. The material of the motor was defined as well, where the rare earth magnet (NdFeBN45M) was selected since it shows the highest values of coercivity and remanence. Which helps in reducing the machine size.



The analytical model was carried out by applying mathematical equations to find an approximation of the motor parameters, it starts with setting the specifications of the machine and with some pre-design decisions and assumptions which the designer must make to simplify the design process and to assure good performance.

The designed motor doesn't have any performance specifications but it has to be of a suitable size to the assembly by hand therefore the design started by setting the desired dimensions of the machine, then some methods

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and techniques were applied to elevate the efficiency of the machine in a way that the designed machine has high efficiency but also small size.

Hairpin winding was selected for the stator winding, in hairpin winding a high fill factor can be achieved, and the greater is the filling factor the lower are the copper losses and therefore a higher efficiency is achieved.

The finite element analysis was carried out by the FEMM software, a 2D section was modelled and the results were obtained directly from FEMM and some results were obtained by using Lua script codes.

The manufacturing process was defined as well, such as cutting, stacking and winding process, the cutting process of the lamination sheets was obtained by the cutting laser and the stacking by welding.

A PMSM of 36 slots and 6 poles was modelled in the analytical method it gave a 4.2kW with 21 N.m of rotating torque, 0.5 mm was selected for the air gap but due to manufacturing limits it was increased to 1 mm, the V-shape rotor parameters were calculated but then they were optimized in function of the rotating torque by SyR-e software.

The stator hairpin winding parameters were defined: 18 turns with 4 conductors per slot.
Similar values were obtained in the numerical method, the numerical method allows to obtain graphics and data of the motor parameters (Torque, Current, EMF, Losses, Inductances and Cogging torque). Once the machine losses were defined the efficiency was calculated and it's of 98,88%.

The high obtained efficiency is due to the low obtained copper losses, By using Hairpin winding the copper losses were decreased to a very low value which increased the efficiency. While the iron losses don't show a high value either.

The assembly instruction manual was designed and defined for each assembly phase:

- Cutting lamination sheets process by a laser cutter.
- Stator & rotor cores stacking process by welding.
- Insulation & Hairpin winding process.
- Final Assembly.

Once the prototype is built, a test manual was designed to verify the results obtained from FEMM simulation, the machine parameters were measured during the tests are:

- Rotating torque
- EMF.
- Machine Losses.
- Efficiency.

From a machine designer's perspective, the motor's performance must be monitored and studied from all its aspects, therefore, a thermal study must be performed to be able to choose a cooling method suitable for the designed machine, the design can be optimized by a genetic algorithm, harmonics and noises analysis should be performed, the previous analysis were not performed but assigned as future work.