Rare Earth Free e-Drives Featuring Low Cost Manufacturing

ReFreeDrive

Collaborative Project
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Abbreviations

KPI: Key Performance Indicator

PM: Permanent Magnet

PMa-SYNREL: Permanent-Magnet assisted Synchronous Reluctance Motor

SYNREL: Synchronous Reluctance

WP: Work Package

EXECUTIVE SUMMARY

This report relates to the work carried out in Work Package 4 (WP4) on the design of two Permanent-Magnet assisted Synchronous Reluctance Motor (PMa SynRel) motors, 200 and 75 kW. The main objective of WP4 is the design of the active parts of these two machines in accordance with target Key Performance Indicators (KPI) defined in Figure ES.1, and complementary requirements defined by the end user (JLR and PRI) within WP2.

The main results for PMa SynRel motors are reported in tasks :

4.1.1: Preliminary analysis of SynRel motor technology,

4.1.2: Selection of materials for SynRel motor applications,

4.2.2: Electro-magnetic design of PM SynRel motors

and 4.3.2: Mechanical design of PM SynRel motors

These tasks were achieved without deviation from the DoA. In order to manufacture those motors within WP6, executive drawings were made and sent to MAVEL with respect to defined deadlines. This task finishes the PMa SynRel motor design.

In section 1 are described the main structural choices of the motors to be prototyped. Section 2 and 3 give an overview of the 200 and the 75kW motors in comparison with KPI (Figure ES.1).

Figure ES.1: KPIs for PMa SynRel Motors

CL-KPI	SyncRel PM assist (IFPEN)			
	Spec	Achievement	Spec	Achievement
	75kW	75kW	200kW	200kW
Specific Peak Power (kW/kg)	>3.1	4,4	>4.3	4,9
Peak Power Density (kW/ liter)	>5.0	16,2	> 8.0	22,6
Specific Peak Torque (Nm / kg)	>5.0	7,7	>8.2	9,5
Peak Torque Density (Nm/liter)	>9.0	28	>15.4	46,5
Motor Dimensions Length* (mm)	<185	75	< 310	200
Motor Dimensions Diameter* (mm)	<250	220	<250	220
Active parts weight (kg)	<24	18,7	<47	45,5
Maximum speed (krpm)	15 - 20	12	15 - 20	17,5
Peak efficiency (%)	>96	95	>96	96

KPIs consider following active parts only: Stator and rotor lamination, permanent magnets, copper wires and slot insulation.

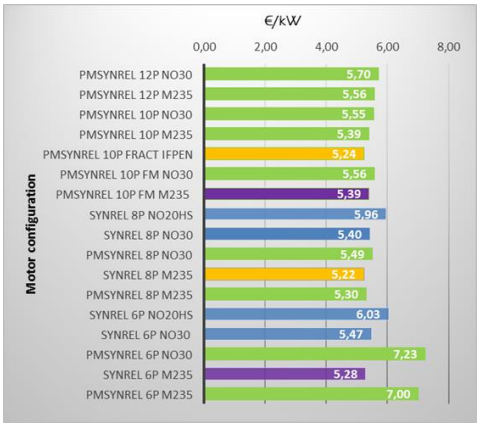

Figure ES.2: Cost to Power ratio at the max efficiency condition

In order to achieve target performances, a multiphysics design approach has been used combining electromagnetic optimization with mechanical and thermal validation. The initial design was selected by techno-economic study based on €/kW criteria (Figure ES.2).

The main challenge was to design a high torque density motor without the use of rare earth magnets (Figure ES.3). For this particular project, rare earth free ferrite magnets have been used. The main idea behind using ferrite magnets was to explore new low cost solutions for high performance electric motors in order to help eliminating the dependency on rare earth magnets.

Compared to Neodymium magnets, ferrite magnets are 60 % less powerful in terms of magnetization. In order to fill this gap, higher armature current densities must be used, increasing considerably the copper losses and the working temperature of the windings. Therefore, the proposed designs have also an integrated cooling solution. The second aspect which is particularly important for ferrite magnets is its low demagnetization resistance.

In order to further decrease the costs, the 75 kW motor have the same design as the 200 kW machine. Only the active length and the winding will be different. Figure ES.4 depicts the 75kW motor performances up to 12 krpm. This speed limitation is due to the gearbox while the motor is able to reach 17krpm.

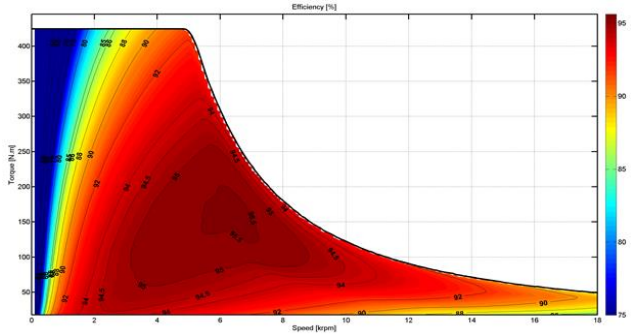

Figure ES.3: 200 kW PMa SynRel Motor – Efficiency map

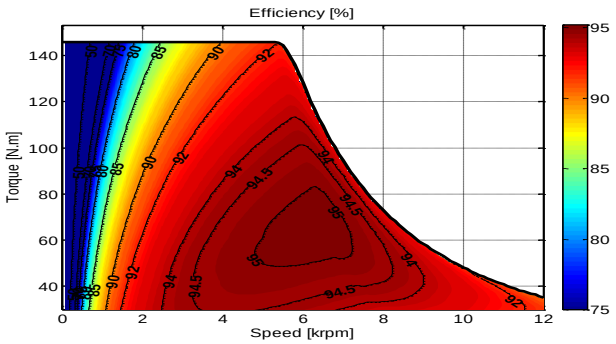

Figure ES.4: 75 kW PMa SynRel Motor – Efficiency map

The impact of the tasks described in D4.5 are:

- Dedicated methodology for designing high current density PMa SynRel motors based on low cost ferrites
- Know-how on the rotor design withstanding the demagnetization issues of ferrites under high current density
- Ferrites market information (suppliers, cost, etc)
- Electrical steel material information through experimental testing