Rare Earth Free e-Drives Featuring Low Cost Manufacturing

ReFreeDrive

Collaborative Project
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V3.0	25.03.2020	Final version
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Abbreviations

EWG: Ethylene-Water-Glycol

KPI: Key Performance Indicator

JLR: Jaguar Land Rover

NGO: Non-Grain Oriented

RFD: ReFreeDrive

SynRel: Synchronous Reluctance

UAQ: University of L'Aquila

WP: Work Package

EXECUTIVE SUMMARY

This document presents the steps of the medium power (75 kW) Pure Synchronous Reluctance Motor (SynRel) manufacturing; this motor has been designed by University of L'Aquila (UAQ) within the Work Package 4 (WP4).

For this activity, the single actions have been defined for the manufacturing of the prototypes. Sub-contractors have also been identified who have dealt with some processing and motor assembling.

The Key Performance Indicators (KPIs) are listed in Table 1 with the ReFreeDrive (RFD) goals.

Table 1: KPIs for 75 kW Pure SynRel Motor

Parameter	Unit	75 kW		
		Reference Renault Fluence	RFD Goals	Achiev.
Specific Peak Power	kW/kg	1.94	> 2.52	4.04
Peak Power Density	kW/lit	8.75	> 8.75	13.1
Peak efficiency	%	95	≥ 97	95
Active parts weight	kg	36	< 30	23.4

KPIs consider the active parts only: stator and rotor lamination, copper wires and slot insulation.

The motor performances satisfy the KPIs given in the Table 1 except the peak efficiency (slightly lower than the RFD goal). It is important to remark that this type of motor is disadvantaged compared to Induction and Permanent Magnet motors because the rotor has no windings and magnets and this penalizes its performance.

The actions related to the construction of the medium power Pure SynRel Motor are shown in Figure 1.

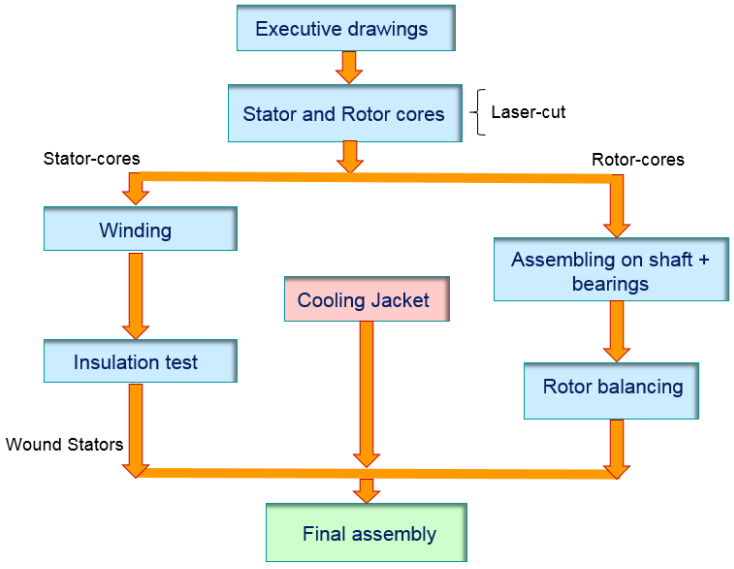

Figure 1: Actions for the 75 kW Pure SynRel motor manufacturing

The main goals of deliverable D6.3 consist in:

- Stator and rotor cores manufacturing by laser-cut
- Stator winding manufacturing with round wire
- Manufacturing of cooling jacket
- Final assembly

The D6.3 deliverable fulfilled these objectives. The deviation in time is explained by the underestimated time to manufacture some mechanical key component such as “ribbed shaft” which had to be produced by an experienced supplier.

The impact of the WP6 task 6.3 is the availability of medium power e-motor for testing and vehicle demonstration.

Figure 2 shows the wound stator and the rotor core of the 75 kW Pure SynRel motor.

Figure 2: 75 kW Pure SynRel motor: wound stator and rotor core

1 MANUFACTURING OF THE PURE SYNREL MOTOR FOR 75 KW

The medium power Pure SynRel Motor (6-pole, 54-slots, 220 mm outer diameter, and 95 mm stack length) has been designed by University of L'Aquila in the Work Package 4 (WP4).

1.1 Stator and rotor cores

Starting from the University of L'Aquila executive drawings, the stator and rotor cores have been realized by laser-cut by the sub-contractor LCD (Switzerland): Figure 3 shows the process.

The electrical steel is the Non-Grain Oriented (NGO) fully-processed isovac M235-35 A (0.35 mm thickness) with backlack (for the cores assembly).

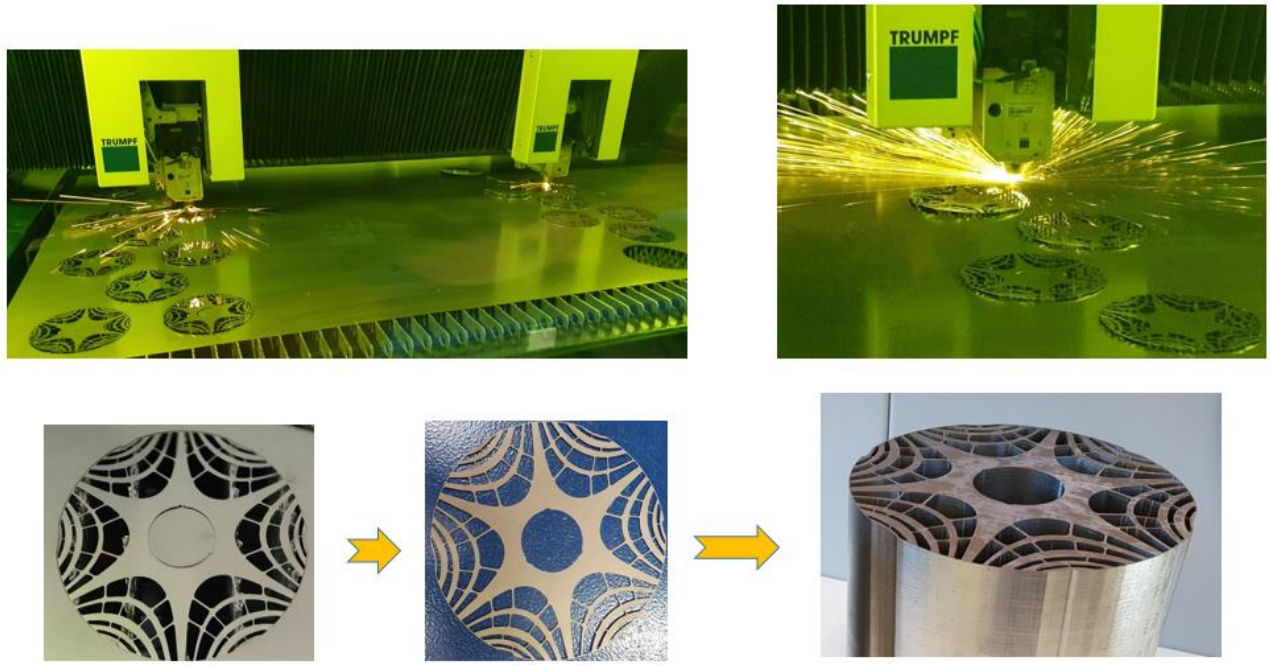

Figure 3: Laser cut for the rotor cores of Pure SynRel motor (Courtesy by LCD)

Figure 4 shows the stator and rotor cores for the Pure SynRel Motor.

It is important to remark that all the prototypes (rotor, stator, materials for characterization) have been made with the material taken from the **same coil**.

RINA-CSM have used some samples for testing and magnetic characterization.

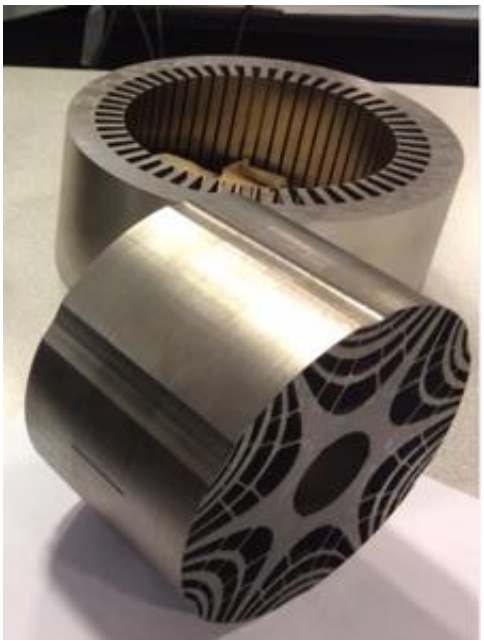

Figure 4: 75 kW Pure SynRel motor: stator and rotor cores

The rotor cores realized by LCD have been shipped to R13 Technology and then to MAVEL for the assembly on shaft and balancing.

The selected bearings (2 for the Gearbox side and 1 for the Connection side) by GMN Italia are (Figure 5):

- KH 6007 2RZ C TA P4+ DUL T284;
- KH 6006 2RZ C TA P4+ UL T284.

The chosen resolver (Figure 5) is: SINGLSYN TAMAGAWA TS 2225N2084E102 - by Garnet.

Figure 5 shows also the shaft.

Figure 5: Bearings, resolver and ribbed shaft

1.2 Stator winding

The stator winding for the 75 kW Pure SynRel Motor has been manufactured by the sub-contractor Vignini Elettromeccanica (Italy). The stator cores realized by LCD have been shipped to R13 Technology and then to Vignini Elettromeccanica for the winding insertion according to the UAQ design.

This activity has been divided in the followings steps:

1) Slot liner insertion into the stator slots;
2) Stator winding with round wire;
3) Insulation testing;
4) Insertion of the thermal sensors;
5) Stator resin coating.

The Figures 6, 7 and 8 show the manufacturing processes of the stator winding (without potting).

For the slot insulation, the 0.35 mm thick Nomex paper 180°C has been used.

The average phase resistance at room temperature is 17.2 mOhm.

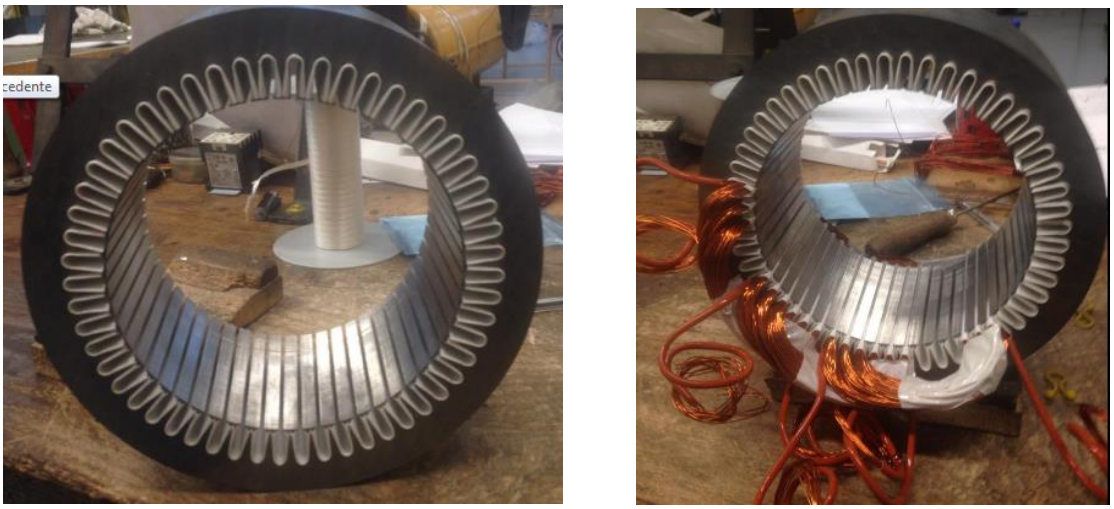

Figure 6: Manufacturing processes of the 75 kW stator winding

Figure 7: Final wound stator

Figure 8: Wound stator and rotor core

1.3 Cooling Jacket

The cooling jacket for the Pure SynRel Motor has been designed by MAVEL and manufactured by the sub-contractor HK KG Model Co LTD (China). The liquid system cooling is all in series: inverter and stator jacket. The cooling fluid is a mixture Ethylene-Water-Glycol (EWG).

The new length of housing is 325 mm: this new stack length has been confirmed by Jaguar Land Rover (JLR). The housing is the same of the 200 kW Pure SynRel motor.

Figure 9 shows a detail of the stator jacket and shields that have been assembled with the drive housing.

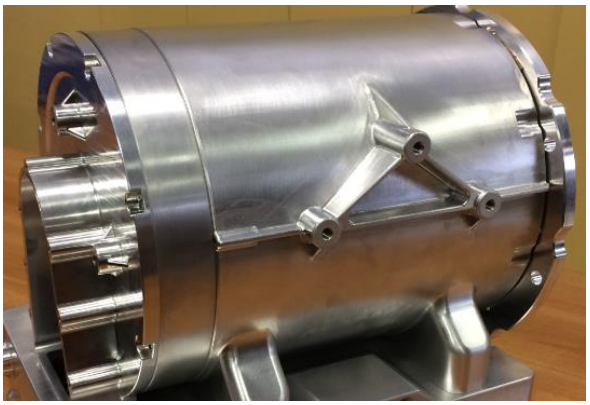

Figure 9: Cooling jacket

1.4 Final assembly

The wound stator, rotor core, bearings, shaft, resolver and the cooling jacket were shipped to MAVEL for the full motor assembly of the 75 kW Pure SynRel motor.

The final motor assembly process consists of the following steps:

- Wound stator insertion in the internal cooling case (Figure 10).
- Insertion of the stator with the cooling case inside the external case and assembly of the connection flange.
- Insertion of rotor stacks on shaft (Figure 11).
- Assembly of the rotor on the gearbox flange with its bearings and insertion of the rotating part of the encoder on the end of the rotor shaft.
- Final motor assembly (Figure 12).

Figure 10: Wound stator insertion in the cooling jacket

Figure 11: Insertion of rotor stacks on shaft

Figure 12: Final motor assembly

The weights of the active materials and shaft are listed in the following Table 2. The total motor weight is 23.4 kg.

Table 2: 75 kW Pure SynRel Motor: weight of the active materials and shaft

Component	Unit	Weight
Stator core + winding	kg	14.6
Rotor core	kg	5.8
Shaft	kg	3.0
Total weight	kg	23.4

2. CONCLUSION

The main goals of deliverable D6.3 consisted in:

- Stator and rotor cores manufacturing by laser-cut
- Stator winding manufacturing with round wire
- Manufacturing of cooling jacket
- Final assembly

The objectives were fulfilled and the deviation in time was in major part due to a slight delay in the construction of a mechanical part and particularly the “ribbed shaft”.

All the motor components (wound stator, rotor core, bearings, shaft, resolver and the cooling jacket) were shipped to MAVEL for the full motor assembly of the 75 kW Pure SynRel motor.