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Motor Integrated Permanent Magnet Gear for Traction

A Motor Integrated Permanent Magnet Gear (MIPMG) consist of a magnetic gear with modulating steel segments and an integrated permanent magnet machine. A very high torque density and efficiency can be achieved with a MIPMG, approx. 100 Nm/L and up to 90-95% respectively, which makes the MIPMG a great choice for a traction motor in an electric vehicle. In the AAUDI a MIPMG is connected directly to each rear wheel through driveshaft's and thereby avoiding losses from mechanical differential and gearbox.

Principle of Magnetic Gears



Version One of the MIPMG

A stall torque of 520 Nm was measured with the first demonstrator build. When the size of the MIPMG v.1 is compared with the Leroy Somer PM machine which have an identical maximum torque, the torque density becomes obvious (Fig.3). The MIPMG v.1 had problems with massive losses at higher speeds which was improved in version 2.

Version Two of the MIPMG

The MIPMG v.2 was designed specific to fit the size and wanted performance of the AAUDI. The calculated losses based on FEMM simulation was reduced with more than a factor 8 compared to the MIPMG v.1 (Fig.4). At this point efficiency of the MIPMG v.2 has been measured to 93.5% at certain load points.



Fig. 5: Exploded view of the MIPMG v.2.





Fig. 3: Size comparison of a Leroy Somer PM machine and the MIPMG v.1.



Fig. 4: Calculated losses of the MIPMG v.1 and v.2.





Description	MIPMG v.1	MIPMG v.2
Nominal motor speed [rpm]	5,791 (62 km/h)	9,146 (129 km/h)
Maximum motor speed [rpm]	14,000 (196 km/h)	10,595 (150 km/h)
Maximum output torque [Nm]	480	600
Maximum output power [kW]	~33	~64
Maximum stall torque @ 20[°C] [Nm] (2D FEA)/(Measured)	642/520	923/-
Torque density from active volume @ 20[°C] [Nm/l] (2D FEA)/ (Measured)	113/92	107.4/-
RMS phase current density @max torque & 50[°C] [A/mm ²]	6.7	10.7
Copper loss @ maximum torque and 50[°C] [W]	~340 (480 Nm)	~620 (600 Nm)
Volume of active parts [L]	5.66	8,6
Stack length of gear [mm]	100	195
Stack length of stator and motor magnets [mm]	60	115
Radius of the outer yoke [mm]	134.25	120
Gear ratio	1:8.83	1:9
Number of motor- and high speed gear poles	12	8

Number of poles on the outer cylinder

Copper fill factor

Number of turns per teeth

Winding cross section area [mm²]

Mass of copper [kg]

Mass of steel [kg]

Mass of magnets [kg]

Table. 1: Specifications for the two versions of the MIPMG.

Fig. 7: Section view of the MIPMG v.2.



Fig. 8: The measured efficiency is compared with the Tesla Roadster.



Fig. 9: The MIPMG v.2's are being mounted in the AAUDI.



64

0.4

12

10

2.0

28.9

15.4





ET PROJEKT UNDER





106

0.4

14

10

3.3

20

6.9



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