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Design and fabrication of axial flux ferrite magnet brushless DC motor for electric two-wheelers

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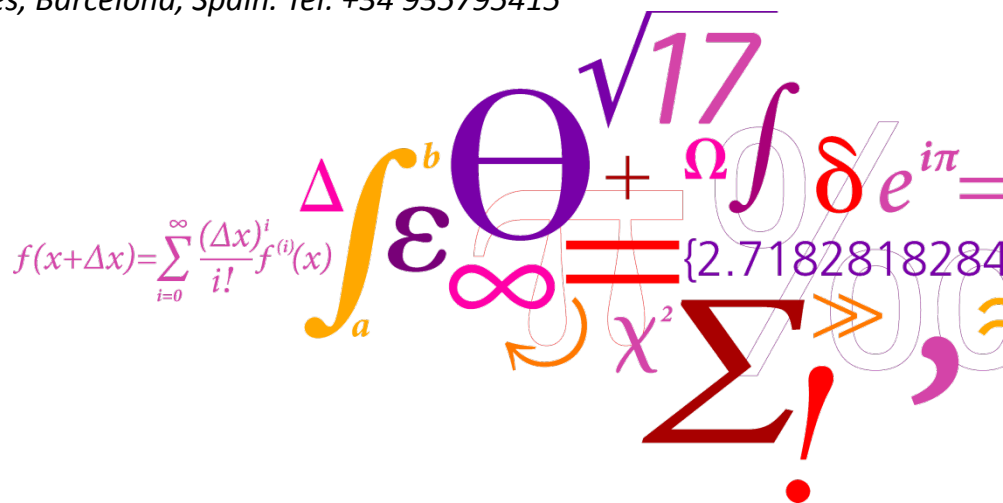
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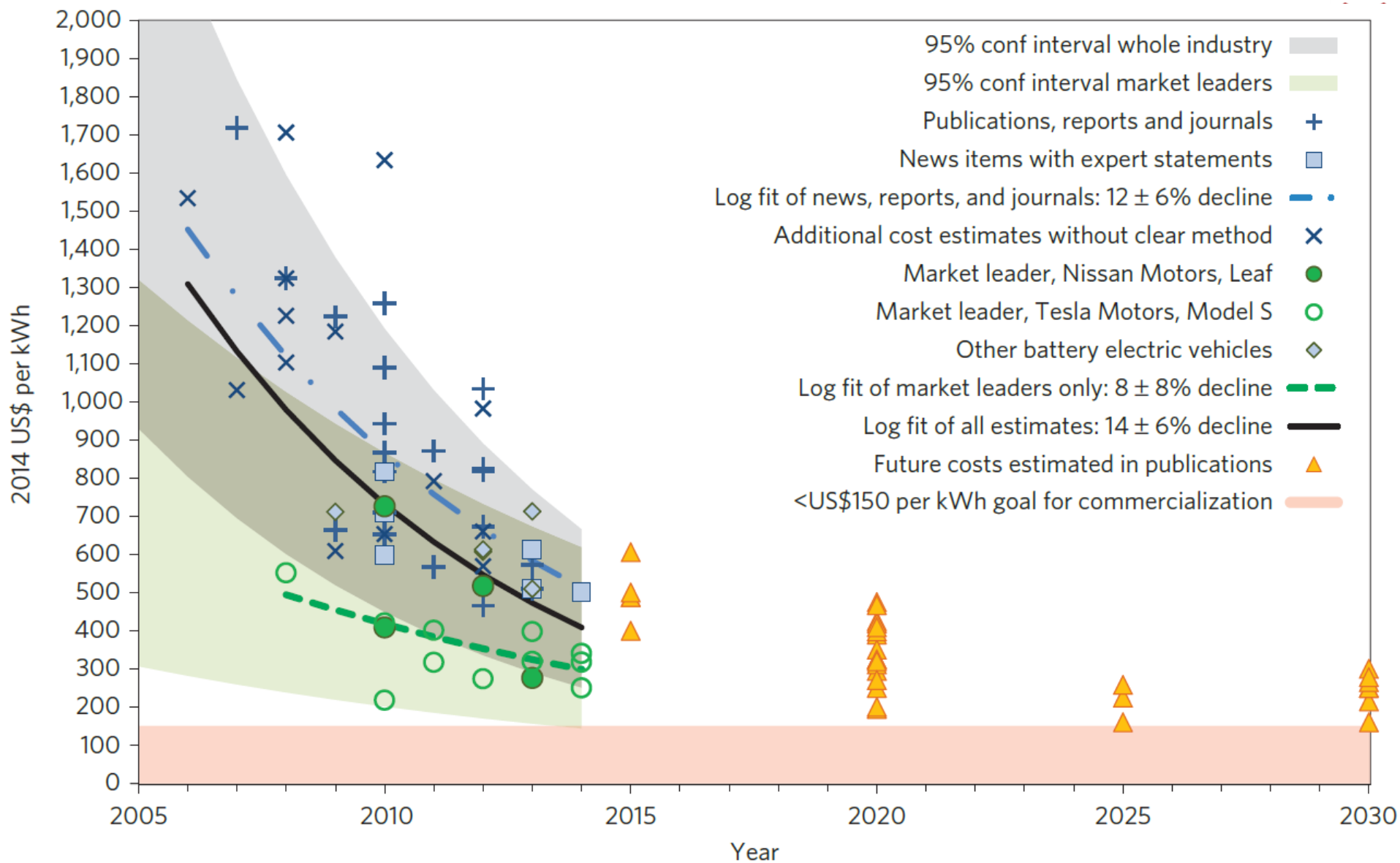
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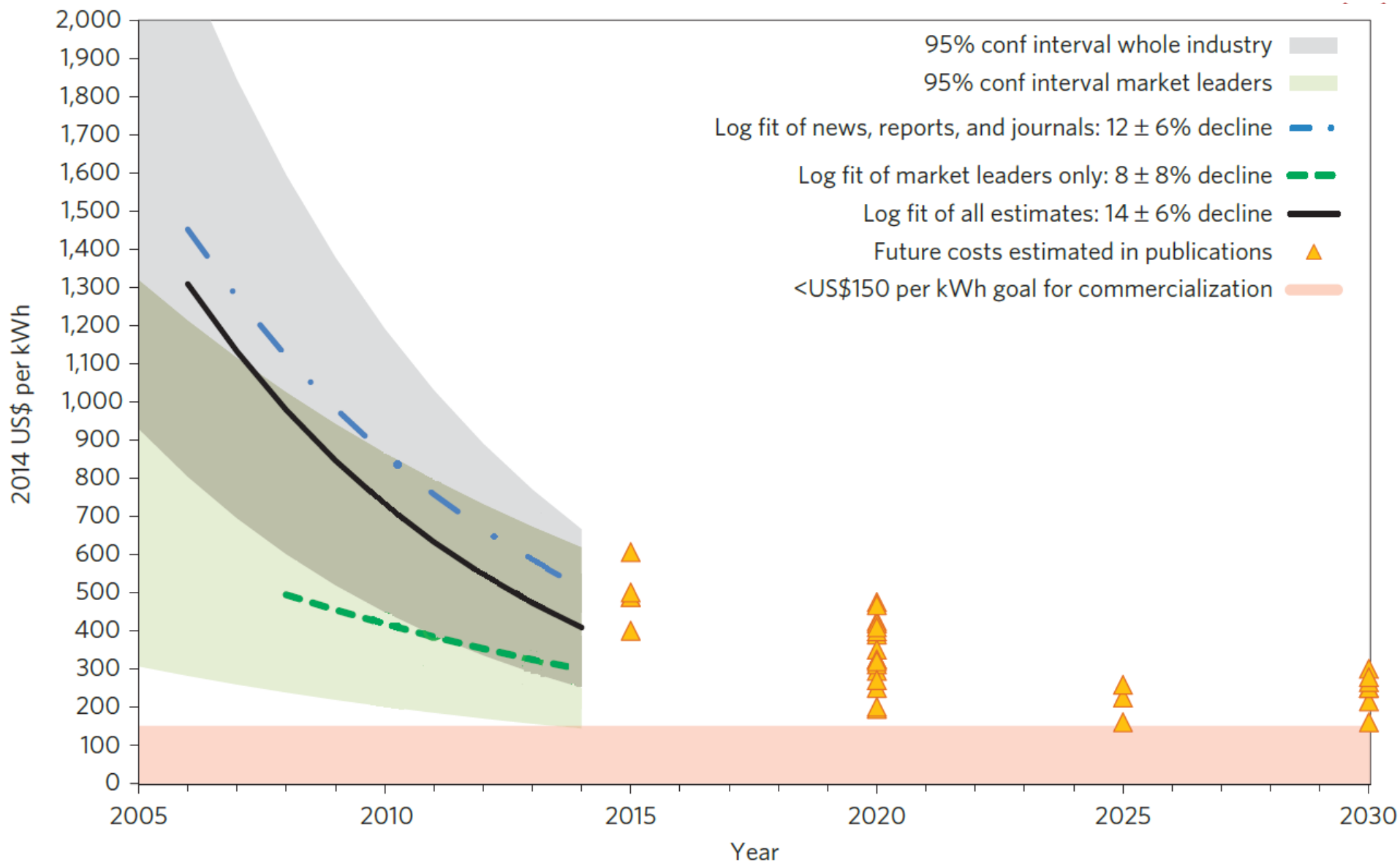


Background - Importance of improved ferrite magnets to the growth of electric vehicle

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations
- At present, performance/price factor compared to IC engine vehicles are holding back the growth of EVs



[1] B. Nykvist and M. Nilsson, "Rapidly falling costs of battery packs for electric vehicles," Nat. Clim. Chang., vol. 5, no. 4, pp. 329–332, Mar. 2015.



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Background - Importance of improved ferrite magnets to the growth of electric vehicle

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations
- At present, performance/price factor compared to IC engine vehicle are holding back the growth of EV
- The cost of batteries used in electric vehicles (EVs) has been falling fast and is almost certainly well below the estimates made by many analysts in the past decade¹.
- A low cost powertrain could lead to affordable, efficient and performing EVs in market earlier than expected!
- Introduction of improved energy density ferrite magnet based PM motors is a possible solution to low-cost powertrain

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Outline

- Background
- Specification of electric motor powertrain for two-wheeler
- Challenges in substituting rare earth magnet with ferrite in electrical machines
- Design details of ferrite magnet motor
- Mechanical assembly of motor
- Fabrication of the motor
- Conclusion

Specification of electric motor powertrain for two-wheeler



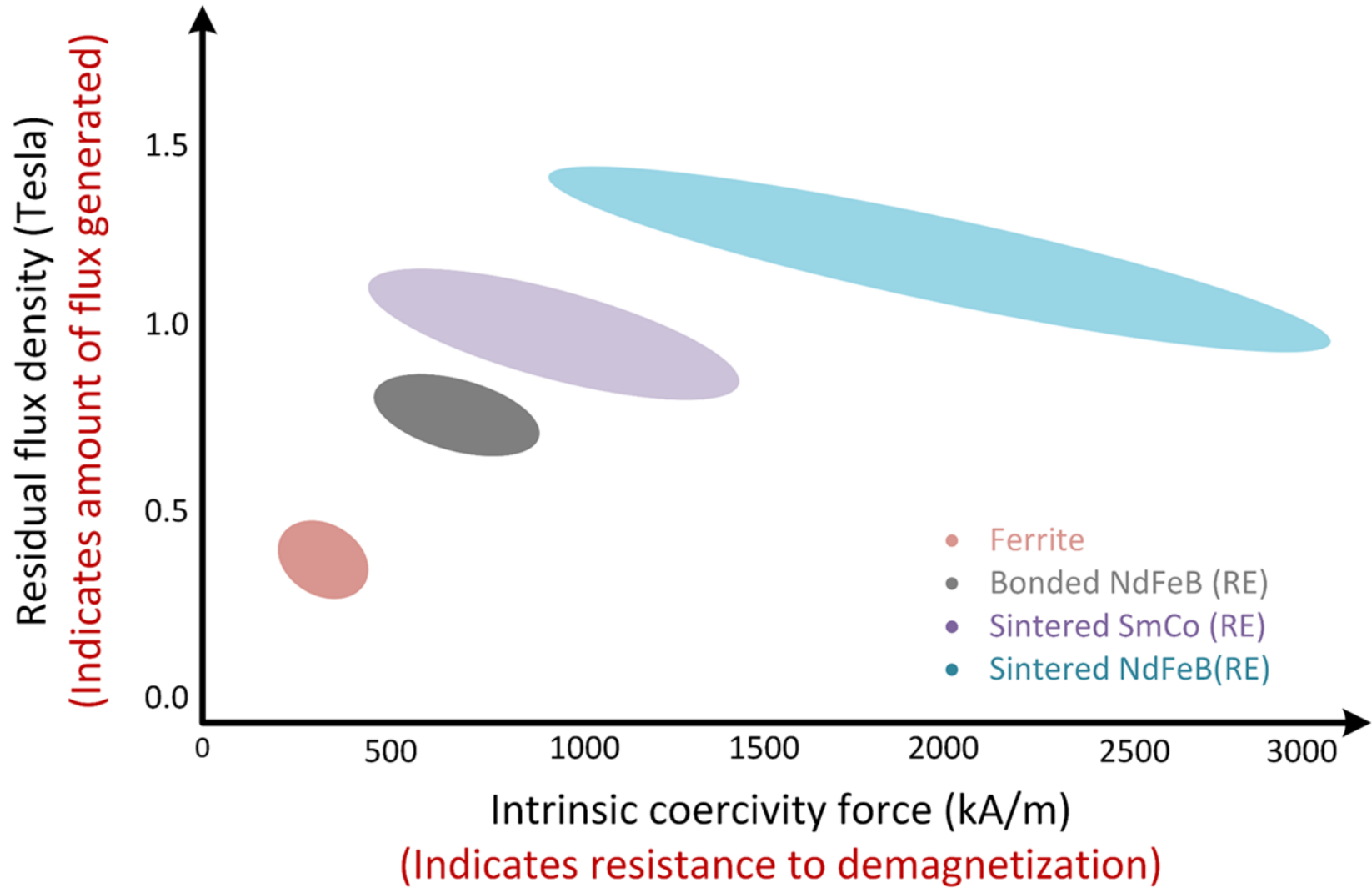
Emmo electric scooter

[Existing motor: Sintered rare earth permanent magnet motor]

Specification of vehicle drive

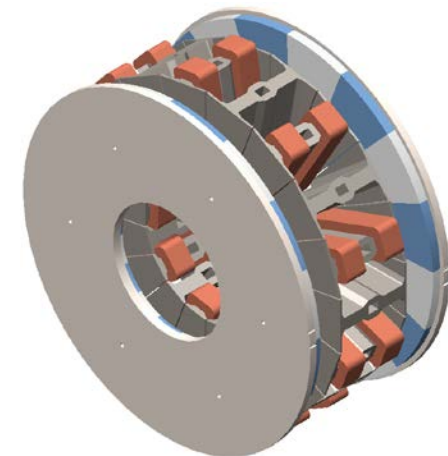
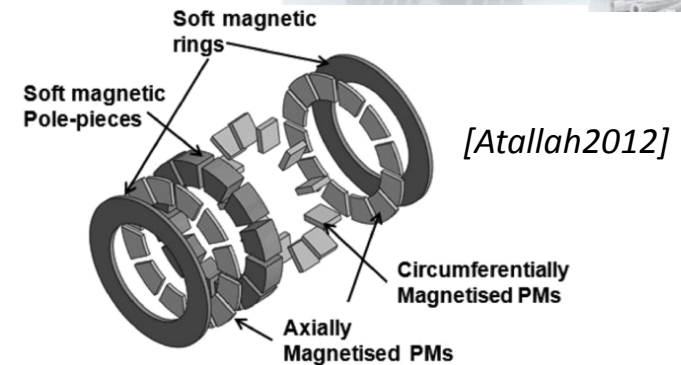
S.N	Name	Unit	Value
1	Maximum vehicle mass including load	kg	130
2	Maximum (Rated) vehicle speed	kmph	30
3	Time to reach rated speed of vehicle	s	15
4	Rated speed of motor	rpm	330
5	Rated power of motor	W	700
6	Rated torque	Nm	20
7	Rated voltage	V	48

Challenges in substituting rare earth magnet with ferrite in electrical machines



Challenges in substituting rare earth magnet with ferrite in electrical machines

- What others are doing
 - Motor without any magnets
 - Switched reluctance motors
 - Synchronous reluctance motors
 - Motor with magnets
 - New topologies to that allows putting more magnet in an efficient way such as axial flux machines, dual rotor machines
- Nanopyme motor topology and configuration offers
 - Low cost position sensing and simple controller
 - Easy to wound and easy to repair modular concentrated winding
 - Direct drive with no gears offers lesser components and improved reliability



Nanopyme motor topology

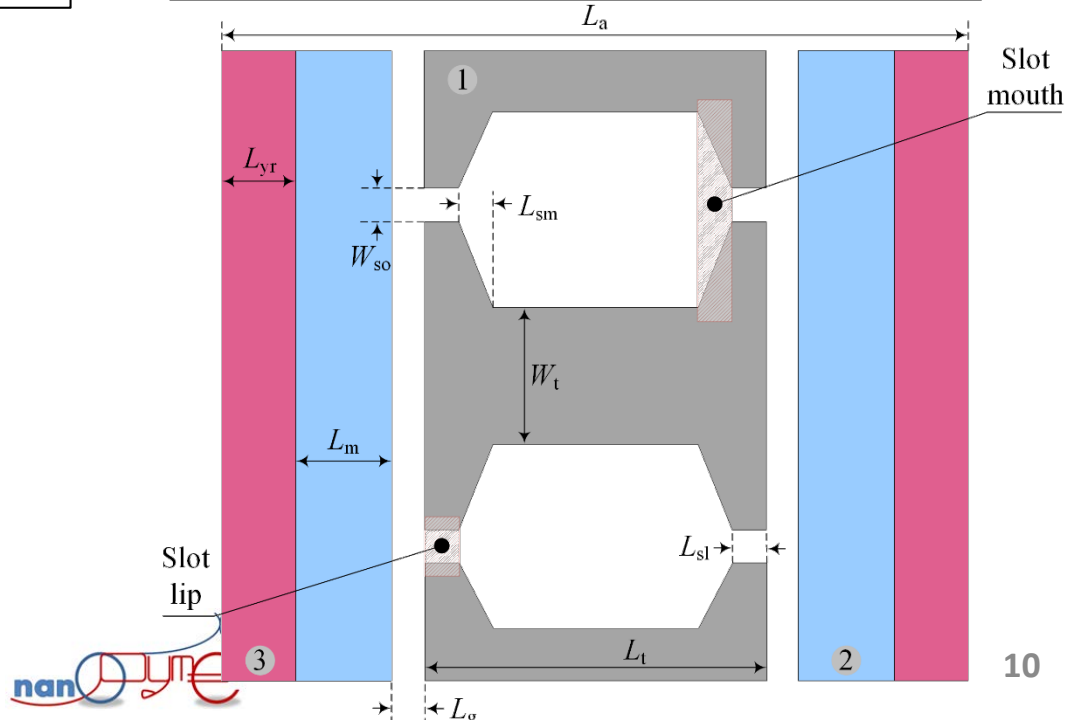
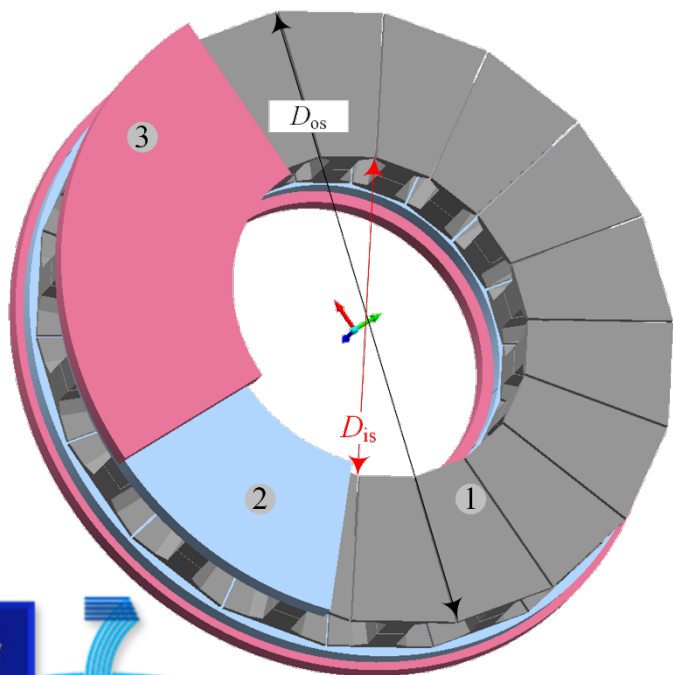
Design details

Design constraints

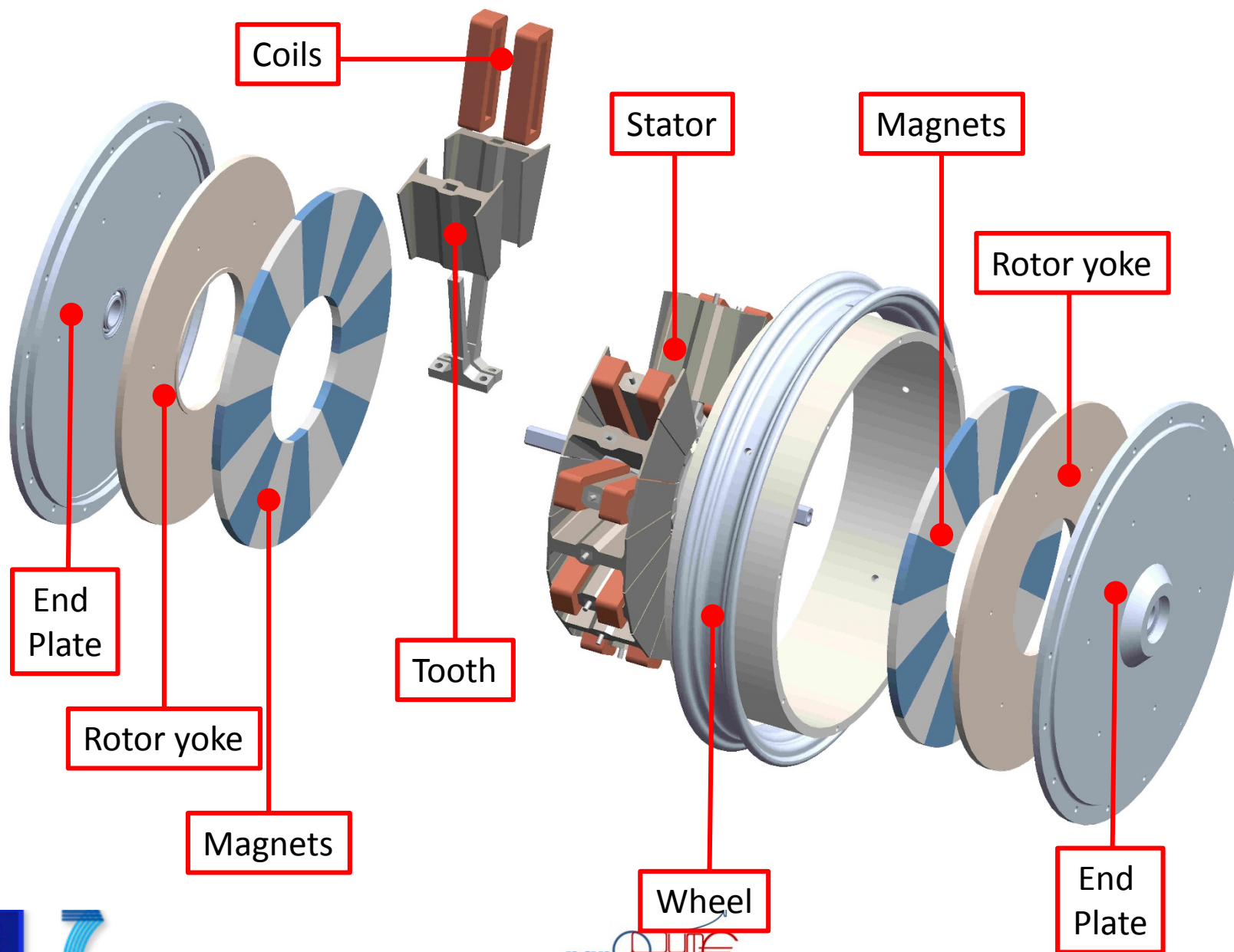
Number of stator slots	18
Number of rotor poles	16
Length of airgap	0.4 mm
Outer diameter of stator	260 mm
Gross slot fill factor	50%
Width of slot opening	1 mm
Depth of slot lip	2 mm
Depth of slot mouth	2 mm
Current density of coil	4.5 A mm^{-2}
Ratio of pole arc to pole pitch	1

Optimised designs

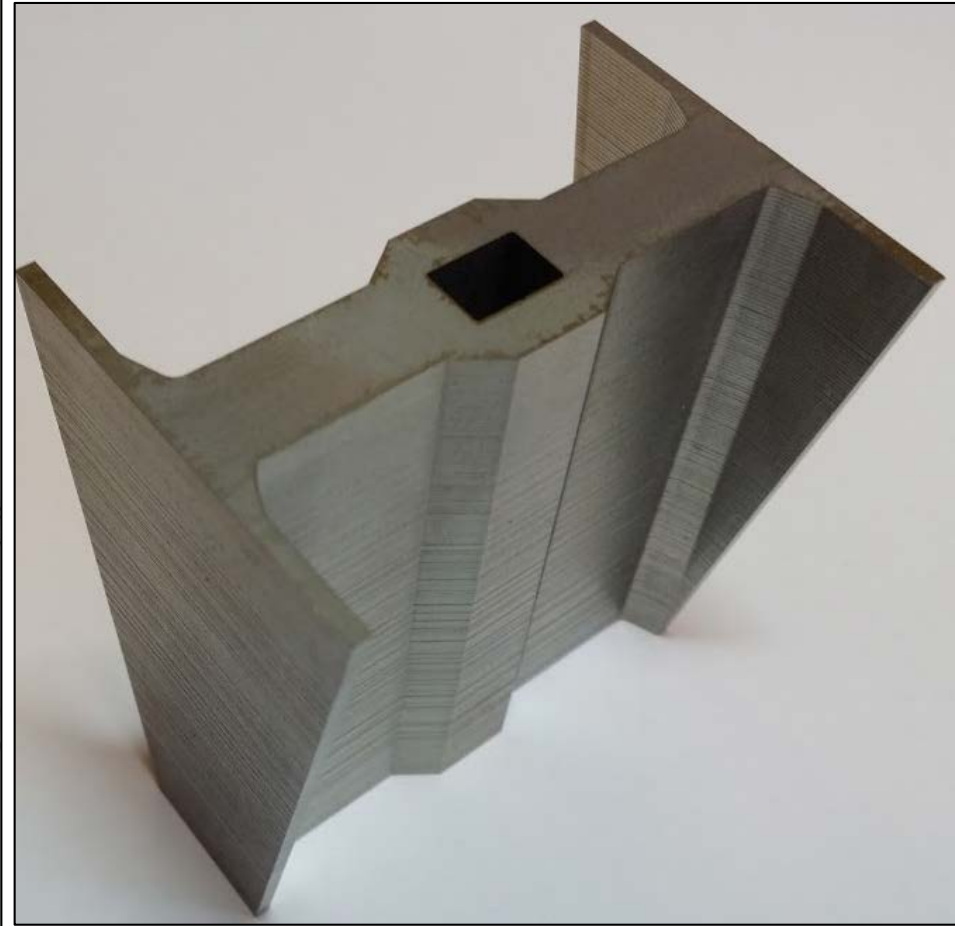
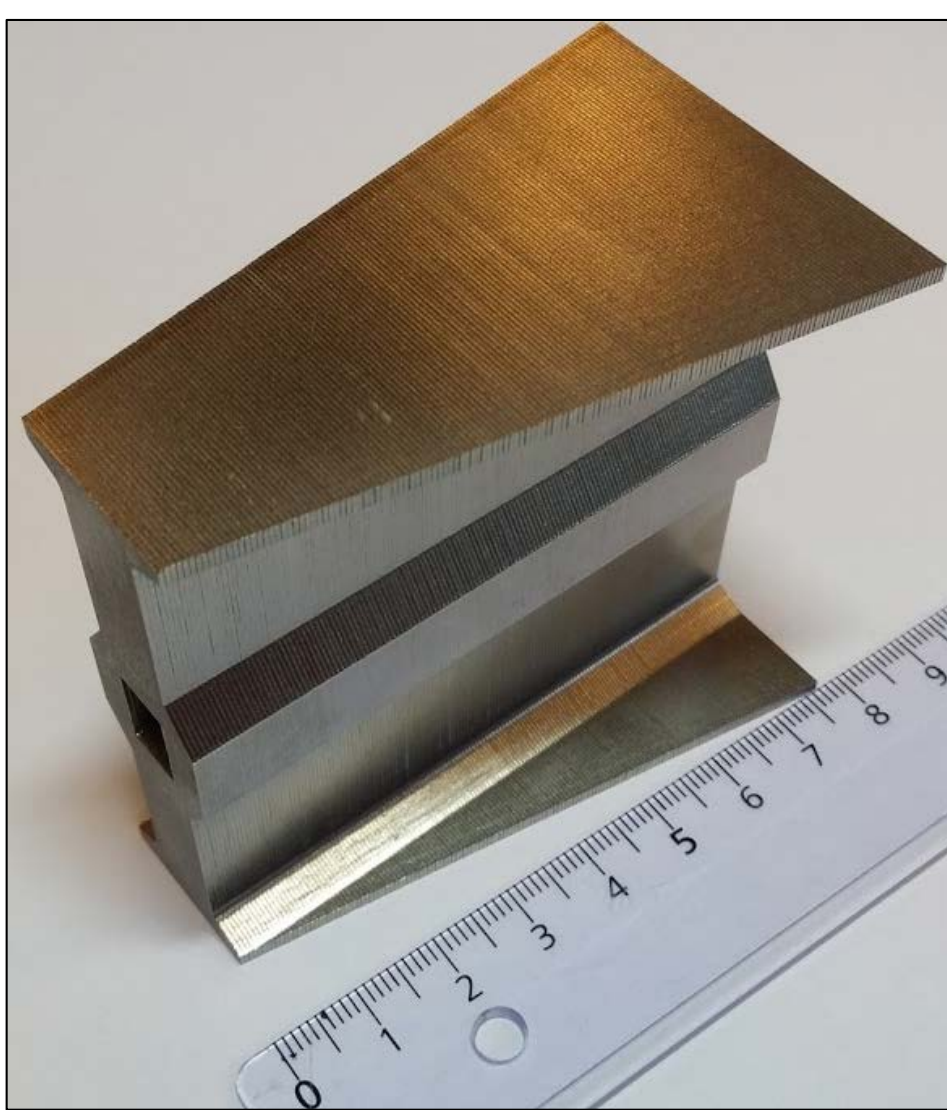
Design	63	88	124	143	158	270
L_m (mm)	7.5	9.5	8	7	7	7.5
h (%)	0	10	5	0	5	10
λ_d (%)	50	52.5	50	47.5	45	47.5
L_{yr} (mm)	7	7	7	8	8	8
W_t (mm)	11.3	11.9	11.3	10.8	10.2	10.8
N_c	24	24	24	28	22	22
D_{ct} (mm)	2.8	2.8	2.8	2.6	2.8	2.9
L_t (mm)	32.4	30.6	32.2	32.6	33.4	32.6
L_a (mm)	62.2	64.4	63	63.4	63.9	64.4
R_{ph} (m Ω)	36	35	36	52	34	32
I_{ph} (A)	28.0	28.4	28.2	23.4	28.5	29.4
P_{cu} (W)	56.8	56.1	57.2	56.3	55.2	55.8



Mechanical assembly of the motor



Fabrication of motor - stator tooth



Material : M400-50A

Fabrication of motor - stator coils



Fabrication of motor – tooth mounting assembly

Tooth holder



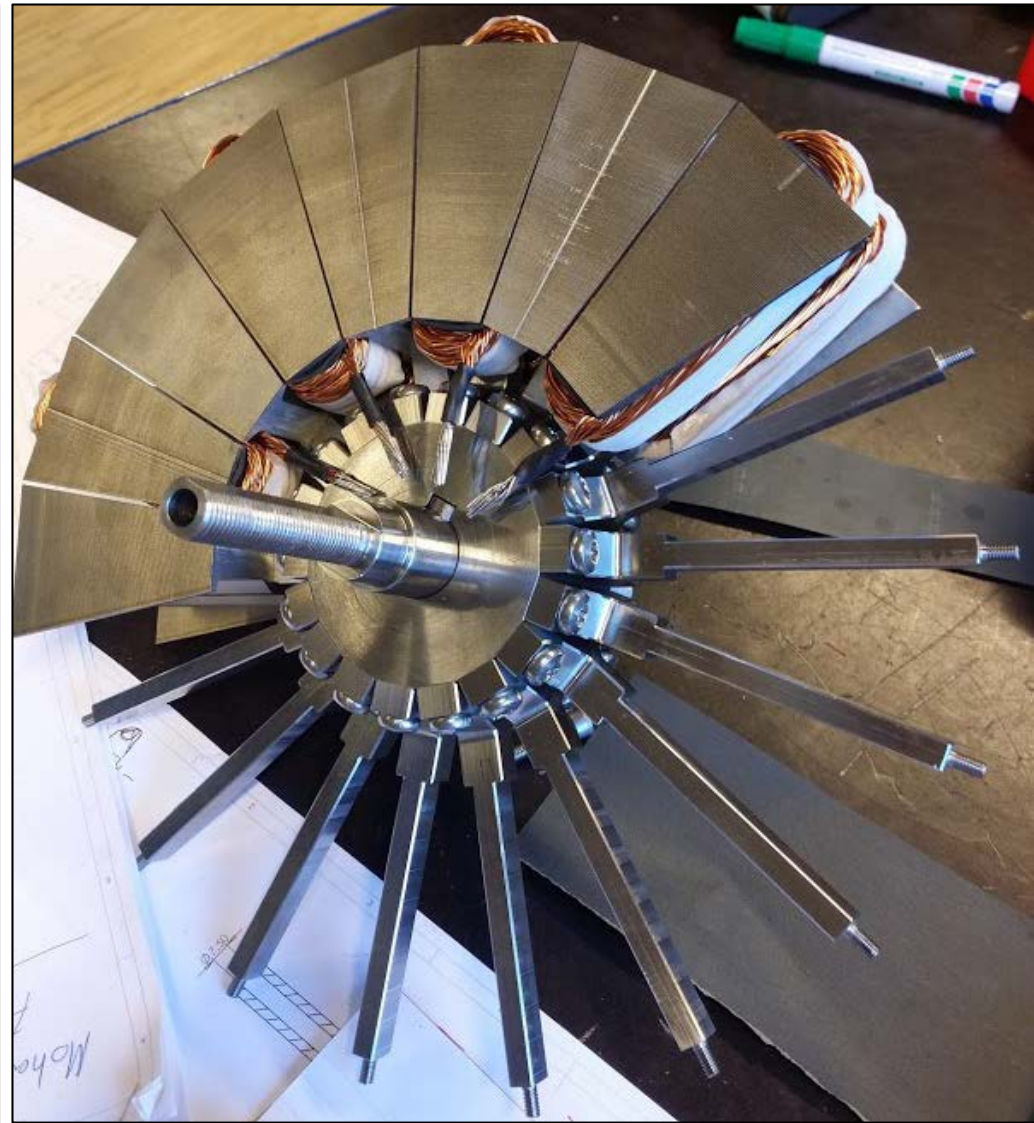
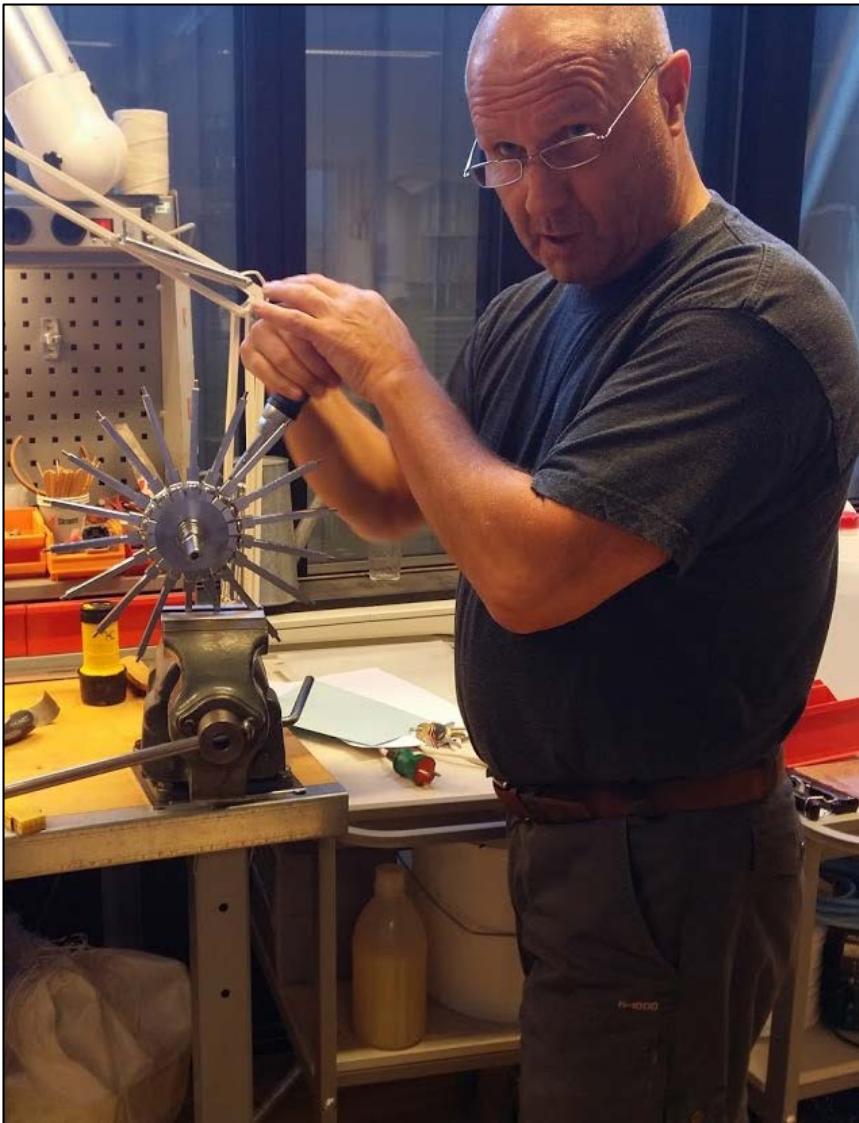
Tooth holder



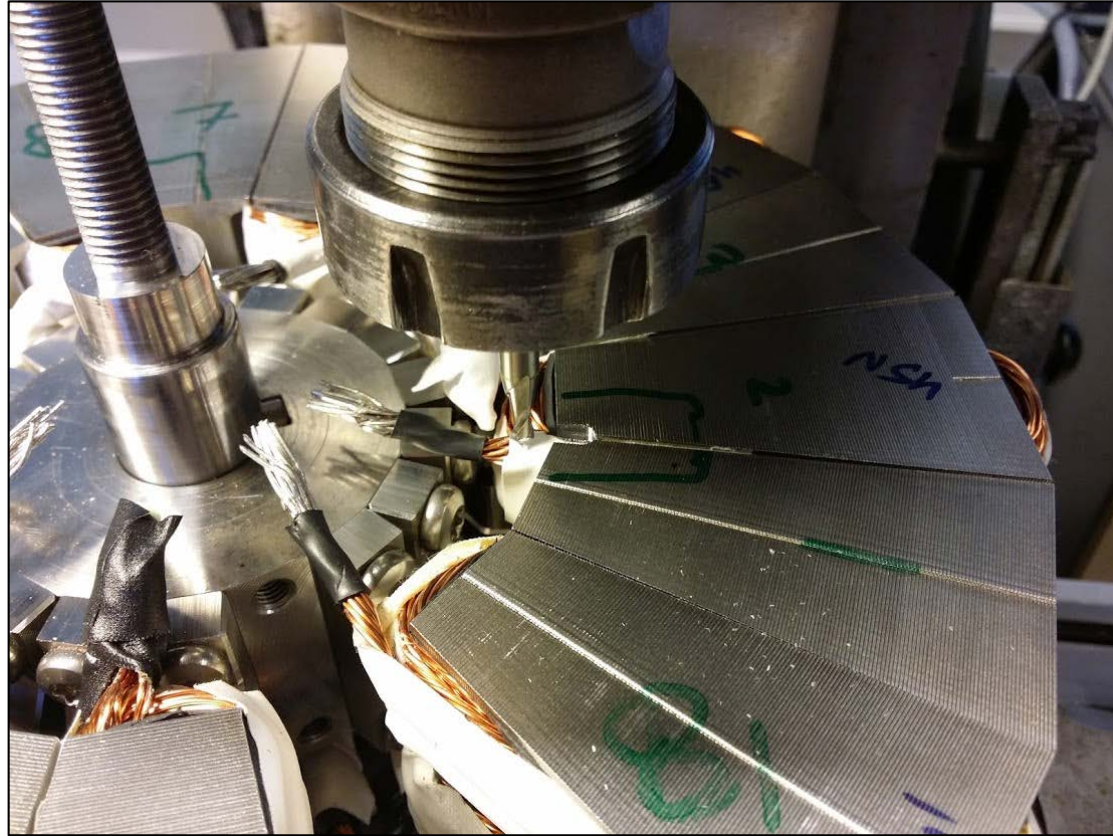
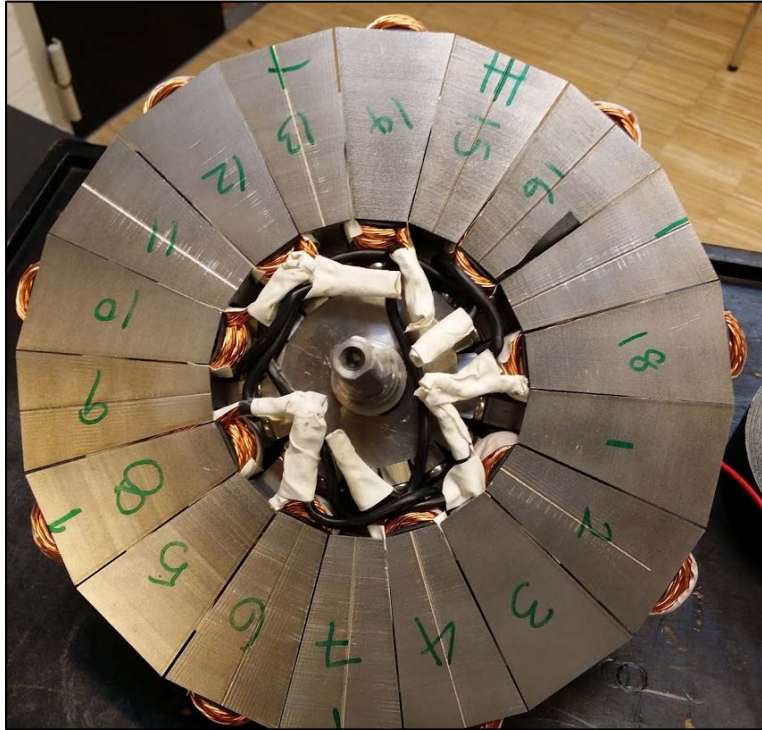
Shaft



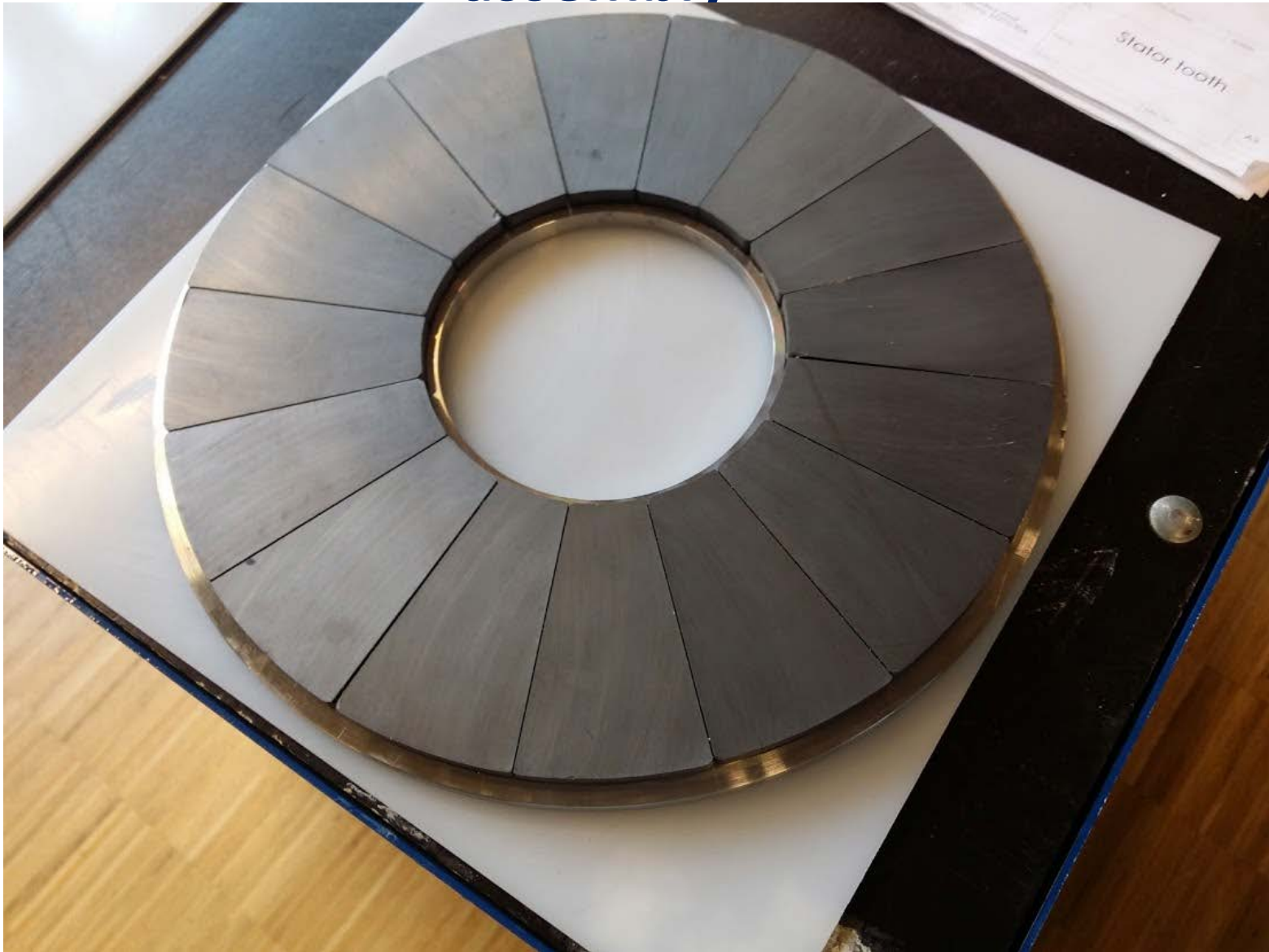
Fabrication of motor – tooth mounting assembly



Fabrication of motor – Completed stator and rotor position sensor mounting



Fabrication of motor – Rotor yoke and magnet assembly



Completed motor on vehicle



Conclusion

- Introduction of improved energy density ferrite magnet based PM motors could improve the adoption rate of electric vehicles by offering low-cost powertrain
- DTU along with Nanopyme partners has fabricated and successfully completed first trial assembly of axial flux ferrite magnet motor for electric two-wheeler application
- In coming weeks DTU will fine-tune the motor assembly and integrate the motor to wheels of vehicle
- The on-board vehicle test of powertrain according to ISO 13064 standard is scheduled for October 2015. This will be followed by test bench evaluation of motor

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Consortium



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www.nanopyme-project.eu