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Reducing Usage of Permanent Magnet Material in Magnetic Couplings Using Finite Element Analysis

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Reducing Usage of Permanent Magnet Material in Magnetic Couplings Using Finite Element Analysis

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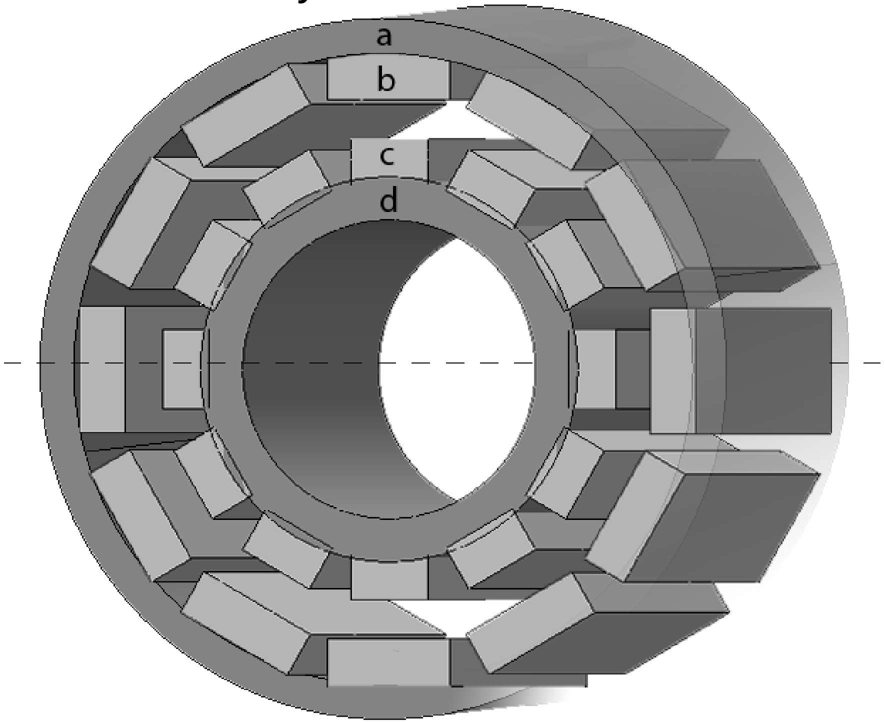
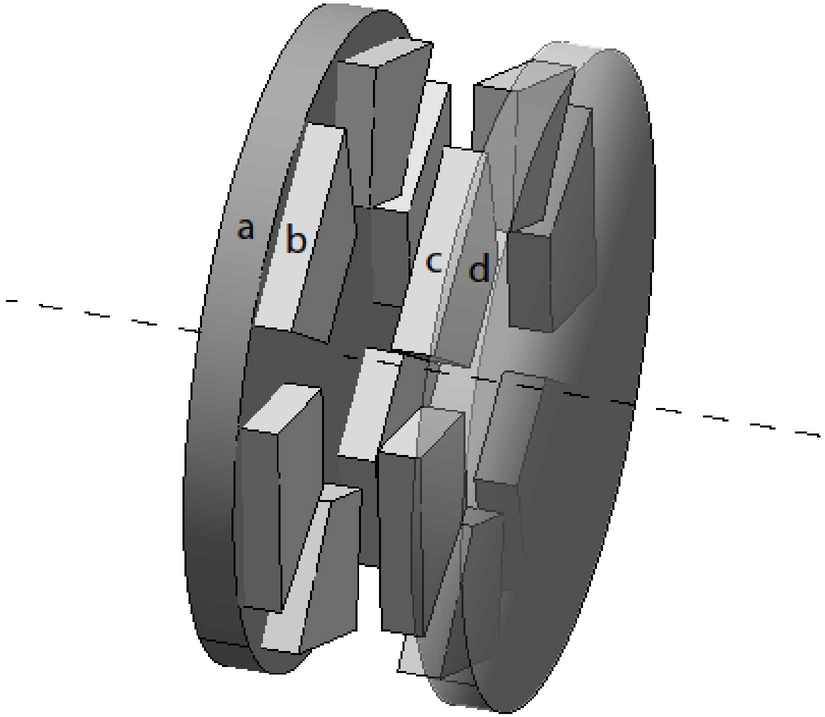
Motivation – Why Permanent Magnet Couplings?

- Contact-less torque transfer
  - Ideal in low maintenance systems
- Sacrificial coupling (overload protection)

Cylindrical PMC

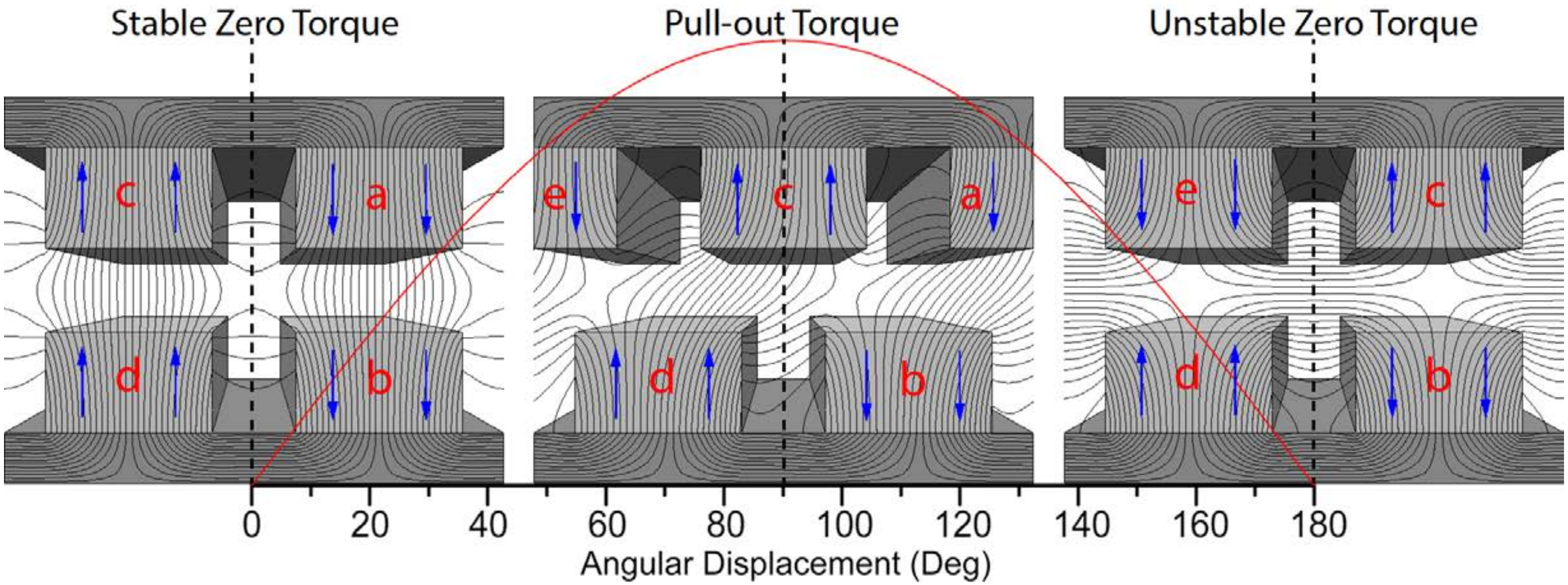


Disk-type PMC



Static Torque In a PMC?

Static torque as a function of angular displacement in a flat PMC representation.



Design objective:

Maximum torque per kilogram magnet

$$TPKM = \frac{T_{po}}{V_{mag} \cdot \rho_{mag}}$$

Pull-out Torque

Magnet Volume

Mass density

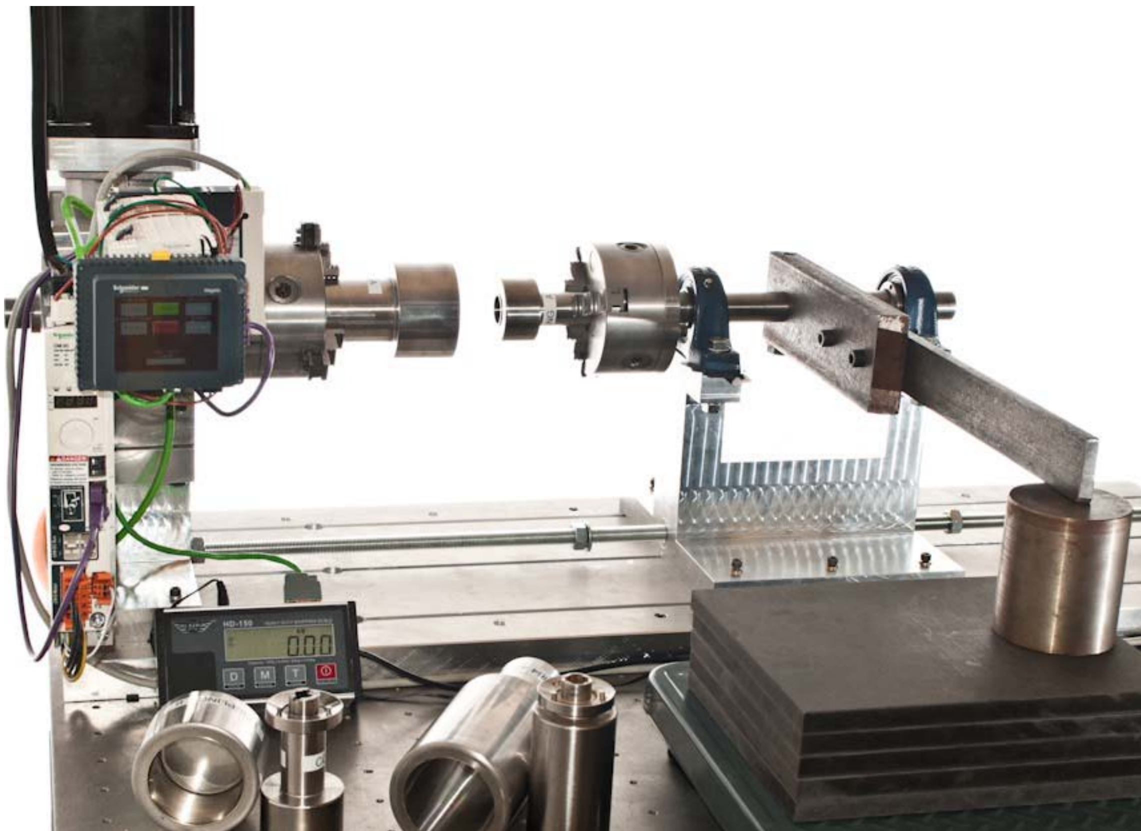
Designed Test-Rig For Static Torque Measurements

Hardware

- Servo-motor (24 Nm)
- Gearbox (1:10)
- Servo-drive + PLC
- Scale with RS232
- Self centring chucks

Automated

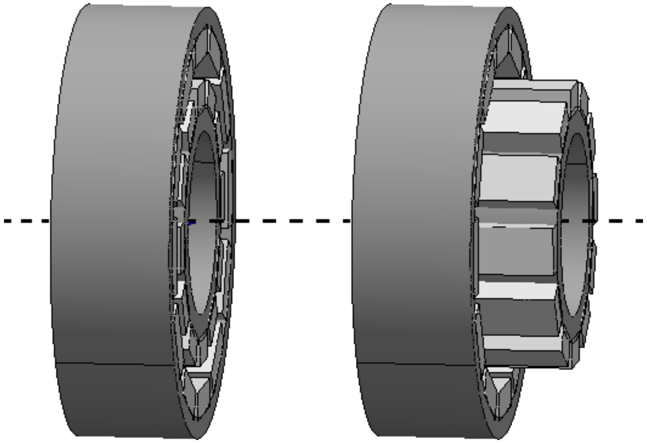
- Touch panel input for control
- Locate zero torque position
- Measurements are stored on USB pen-drive



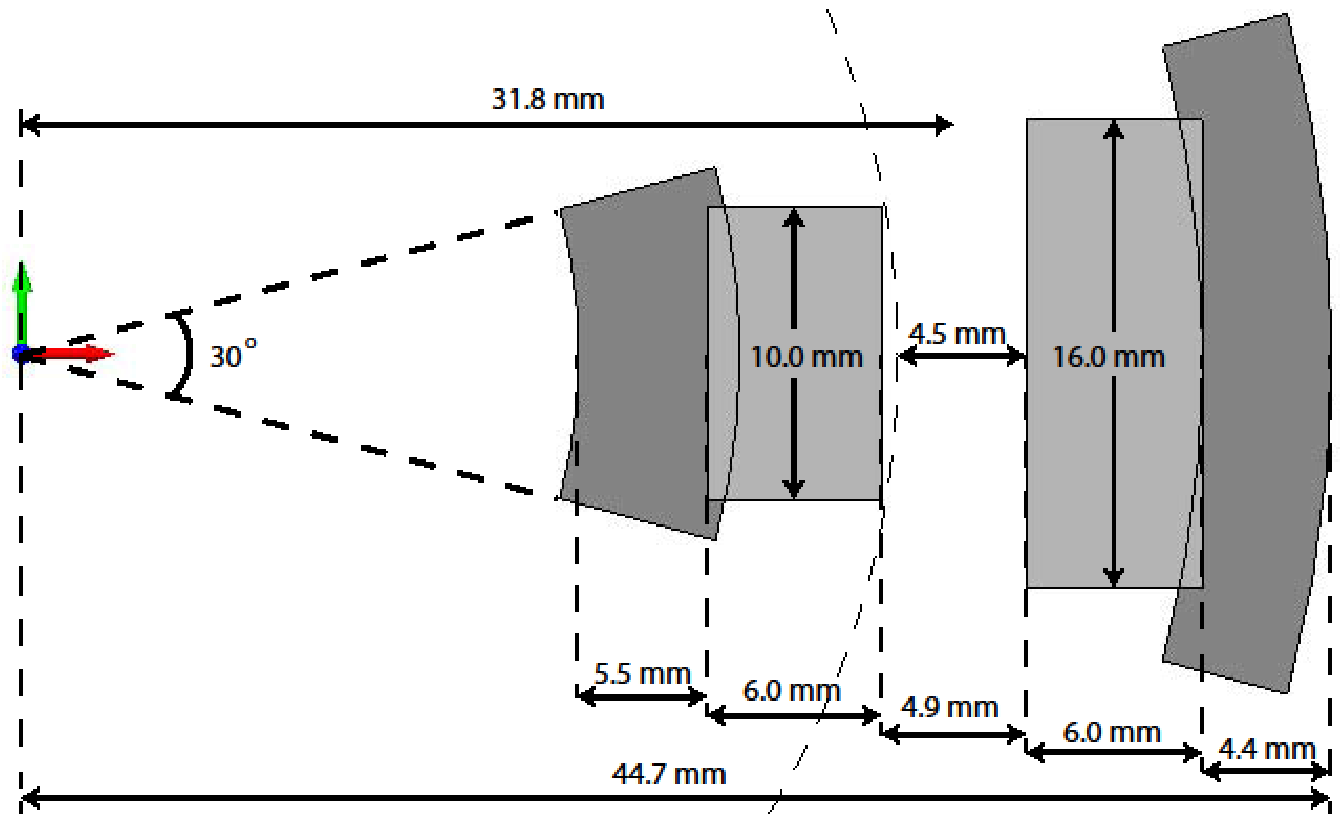
High Accuracy Alignment System

PMC Specification For a 1-row PMC

Type	Cylindrical	Poles	12
B_r	1.21 T	H_c	-891 $\frac{kA}{m}$
Mean Air-gap radius	31.8 mm	Magnets	Nd-Fe-B
Active axial length	25.0 mm	Pull-out torque	14.3 Nm

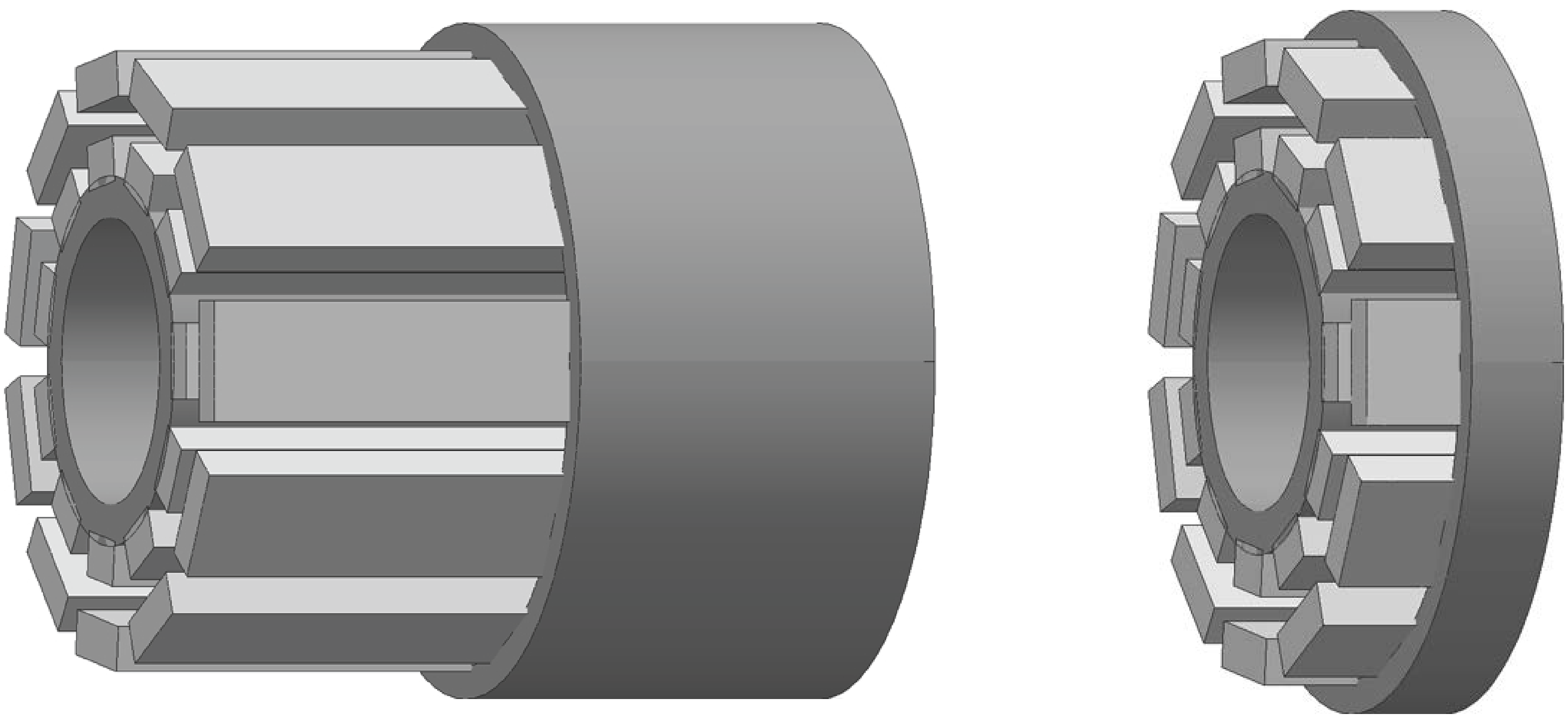


Dimensions of PMC



1-row PMC And 4-row PMC

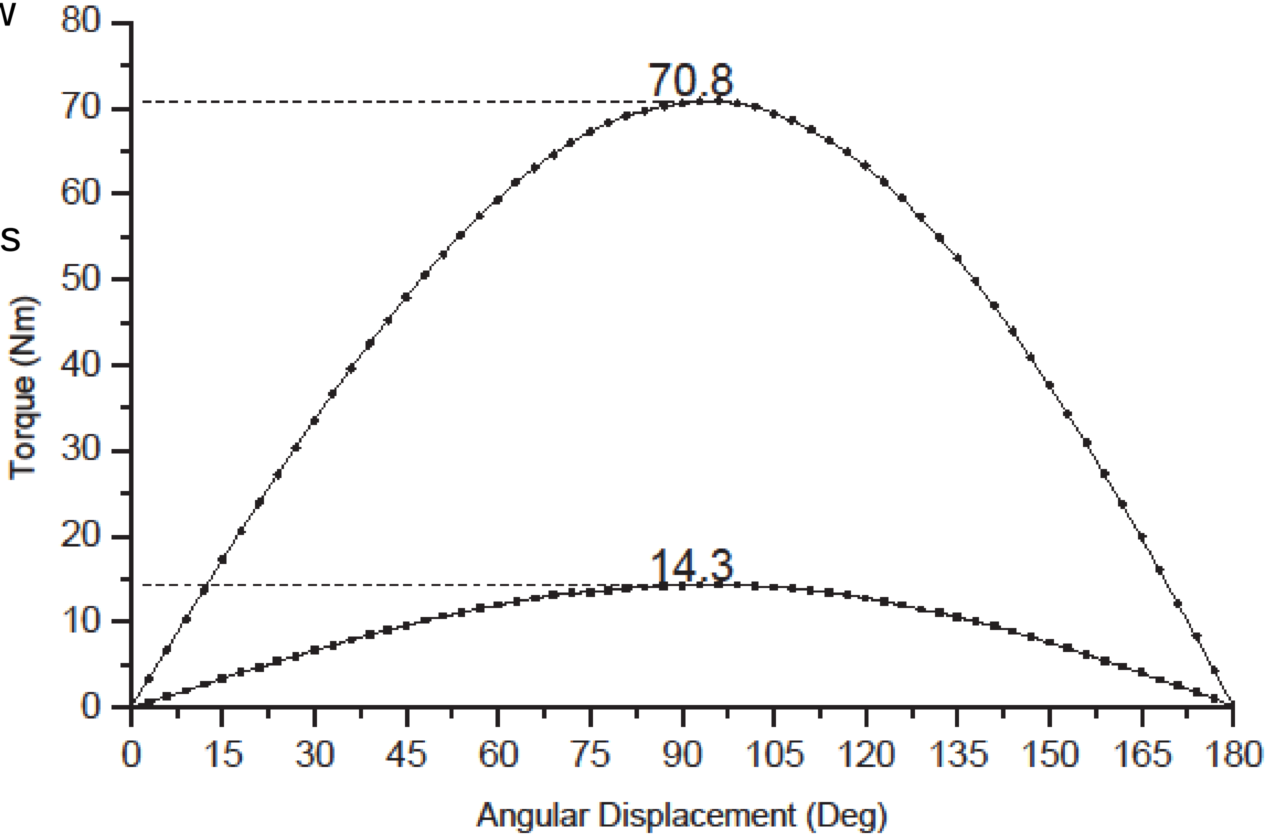
The 4-row has an active axial length of 100 mm compared to 25 mm of the 1-row PMC



Experimental Results of Static Torque

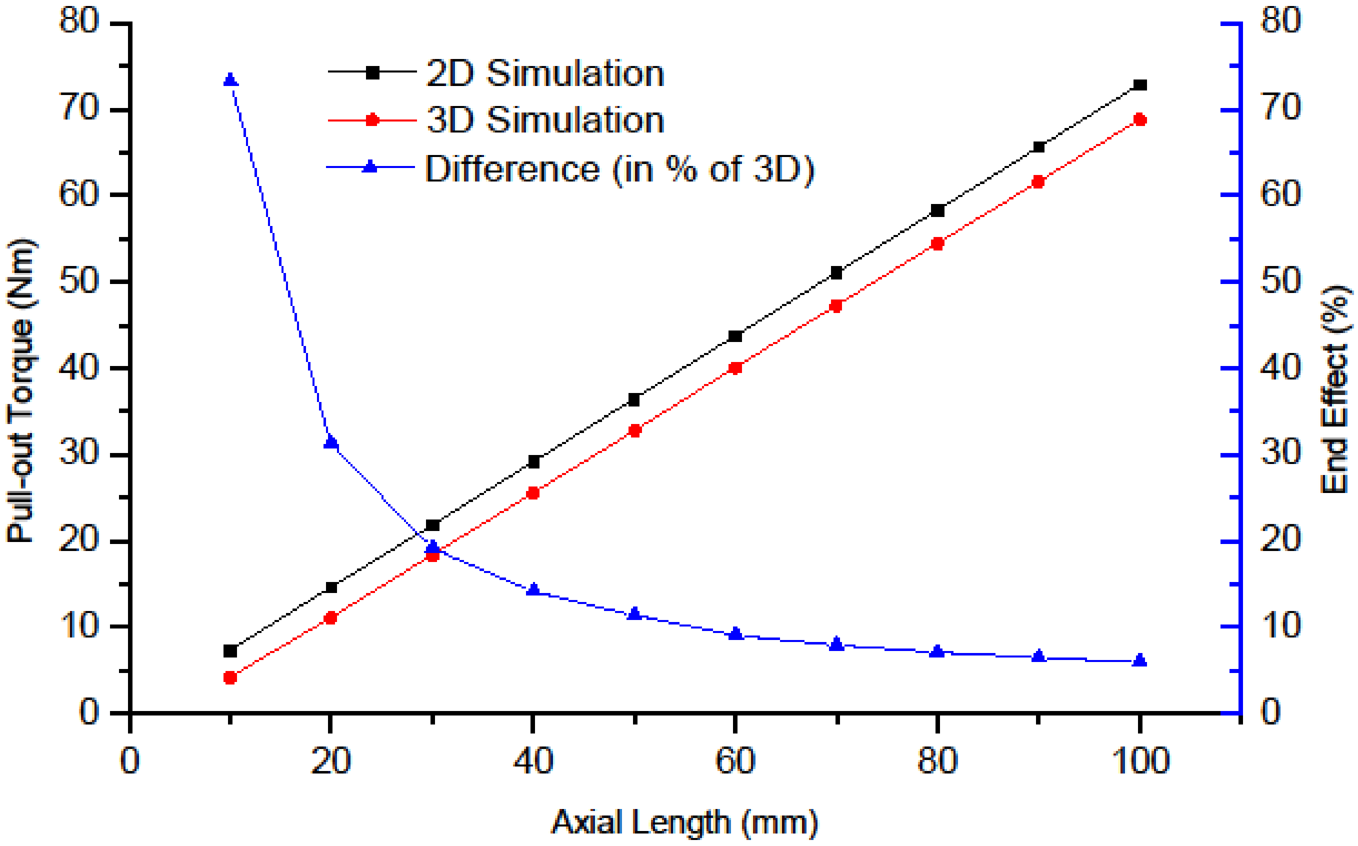
Pull-out torque of 4-row PMC is almost 5 times that of the 1-row PMC.

This is due to the influence of end-effects



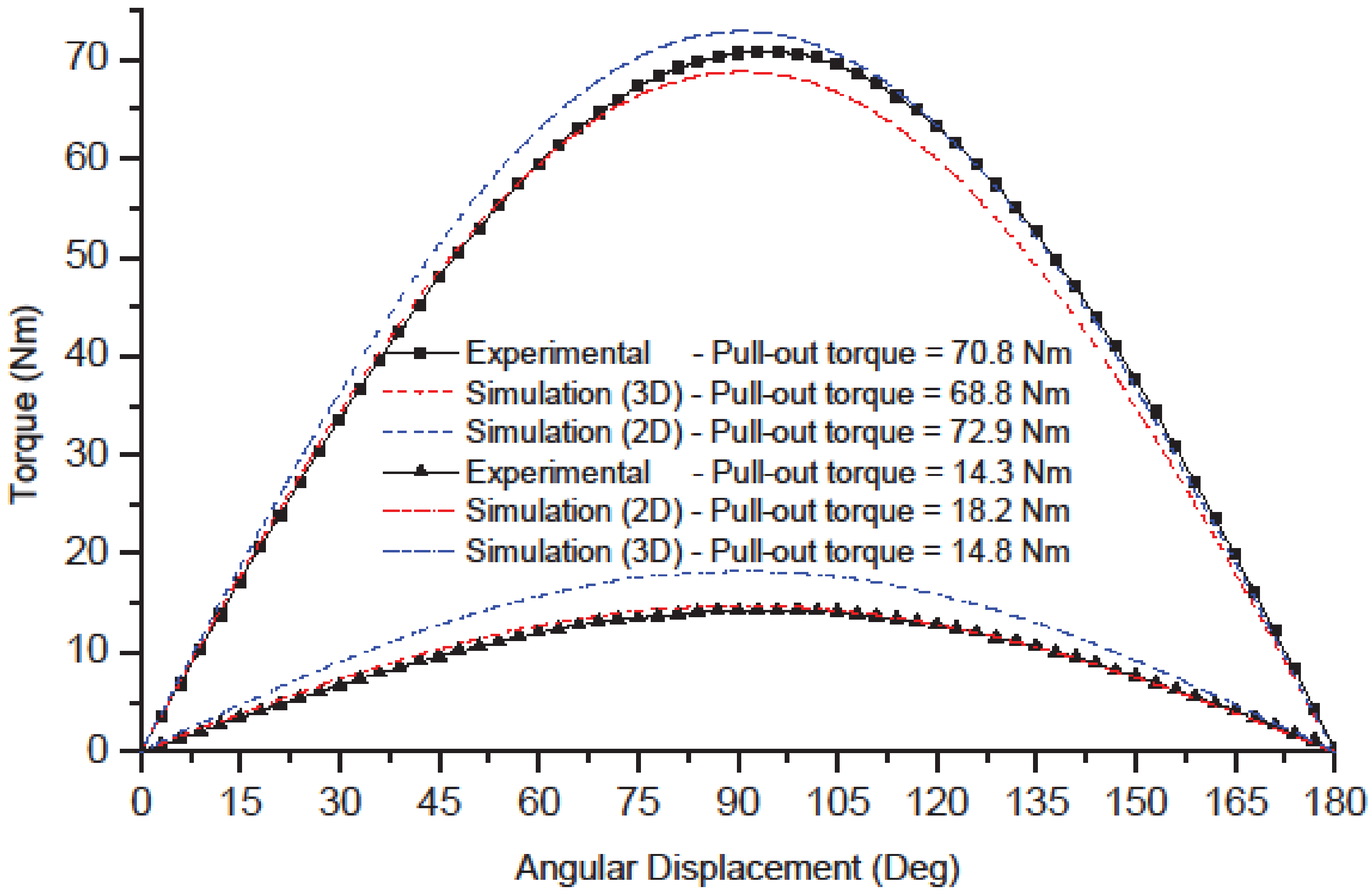
End-Effects, Explored By FEA

- End effects are significant if the PMC is short



Comparing Experimental and Simulation

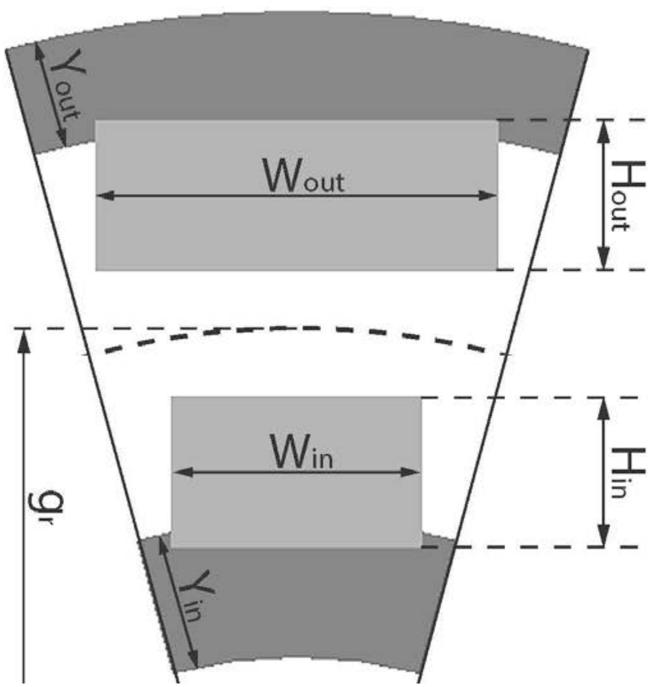
- Simulations are based on 3D FEA

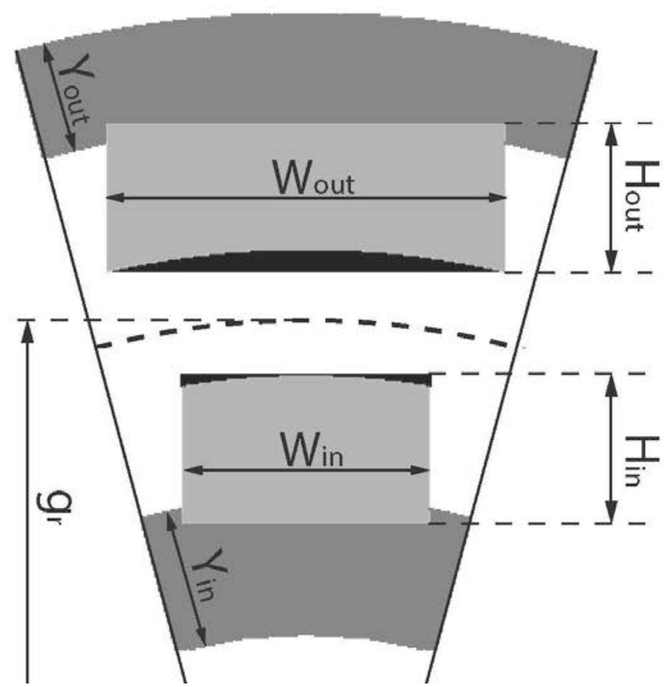


Introducing Two PM Shapes

Rectangular PMs
(original)

Concave / Convex PMs
(new)





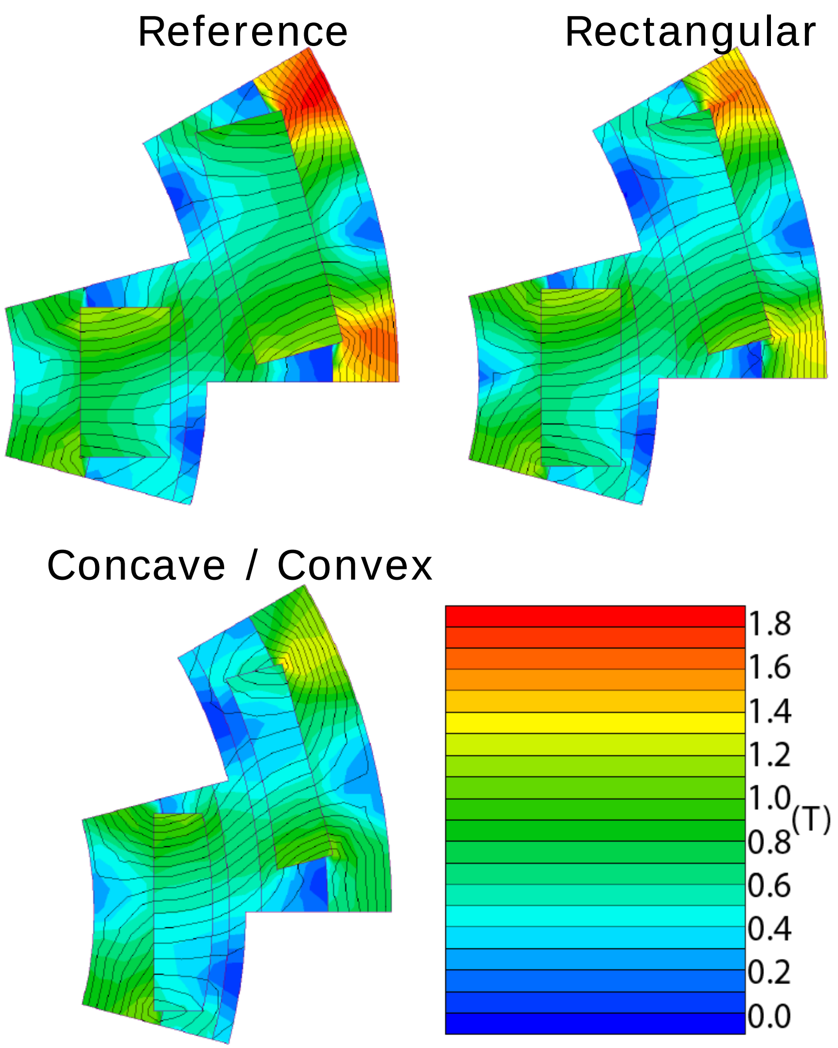
Automated Design Simulation

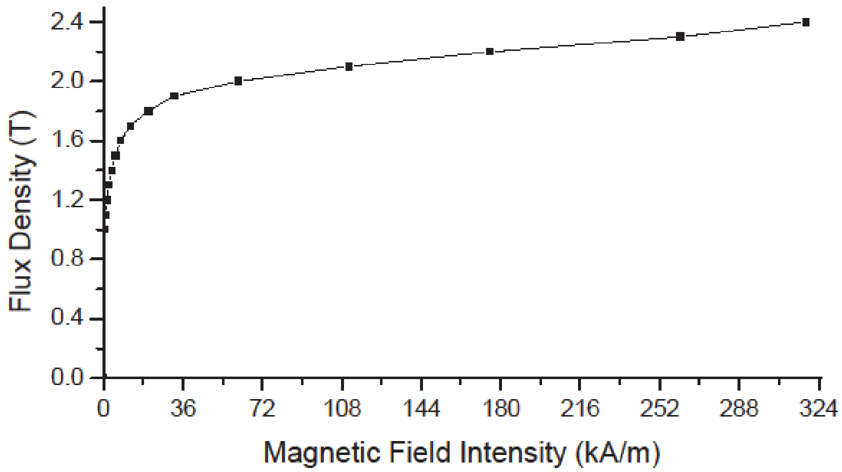
Controlling model parameters in Infolytica MagNet Through Matlab script

Variable	*Minimum*	*Maximum*	*Increment*	*Best Design*
		Rectangular Magnets		
H_{in}	5.0 mm	6.2 mm	0.2 mm	5.4 mm
H_{out}	4.0 mm	5.4 mm	0.2 mm	4.4 mm
W_{in}	10.0 mm	13.5 mm	0.5 mm	12.0 mm
W_{out}	15.5 mm	18.0 mm	0.5 mm	16.0 mm
Pull-out Torque				14.8 Nm
TPKM				48.6 Nm/kg
TPKM Increase				15.6%
		Concave/Convex Magnets		
H_{in}	3.2 mm	5.8 mm	0.2 mm	4.0 mm
H_{out}	3.2 mm	5.8 mm	0.2 mm	4.0 mm
W_{in}	10.0 mm	14.0 mm	0.5 mm	13.5 mm
W_{out}	12.0 mm	17.0 mm	0.5 mm	13.5 mm
Pull-out Torque				14.8 Nm
TPKM				66.2 Nm/kg
TPKM Increase				57.6%
		Reference PMC		
	H_{in}	H_{out}	W_{in}	W_{out}
	6.0 mm	6.0 mm	10.0 mm	16.0 mm
Pull-out Torque				14.8 Nm
TPKM				42.0 Nm/kg

Further Steps

- The core-back of the both rectangular and concave / convex (best) designs could be optimised to further increase the torque per kg magnet.





Conclusion

- 3D FEA simulations were found to accurately calculate the static torque:
  - 2D is inaccurate since end-effects are not included
  - This is less pronounced in longer couplings

- Design of PMC with two different PM shapes were presented:
  - Rectangular and concave / convex
  - TPKM increase of rectangular: 15.6%
  - TPKM increase of concave / convex: 57.6%

- Further investigation could lead to even better results:
  - Core-back thickness could be decreased
  - Prototyping of the couplings

- Thank you

References and further reading

- S. Hogberg, B. B. Jensen, F. B. Bendixen, “Design and Demonstration of a Test-Rig for Static Performance-Studies of Permanent Magnet Couplings,” *IEEE Transactions on Magnetics*, Vol. , No. , pp. , 2013. http://dx.doi.org/10.1109/TMAG.2013.2274645 (early access)

- S. Högberg, B. B. Jensen, F. B. Bendixen, ”Improving Torque per Kilogram Magnet of Permanent Magnet Couplings using Finite Element Analysis,” *IEEE International Electric Machines and Drives Conference* (IEMDC2013), Chicago, Illinois, USA, May 2013. http://dx.doi.org/10.1109/IEMDC.2013.6556229

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Acknowledgements

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Ministry of Science, Innovation and Higher Education

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