Parametric Design Optimization Of A Novel Permanent Magnet Coupling Using Finite Element Analysis

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2014 ECCE
IEEE ENERGY CONVERSION CONGRESS & EXPO
PITTSBURGH, PA, USA | SEPTEMBER 14-18, 2014

Ministry of Science, Innovation and Higher Education

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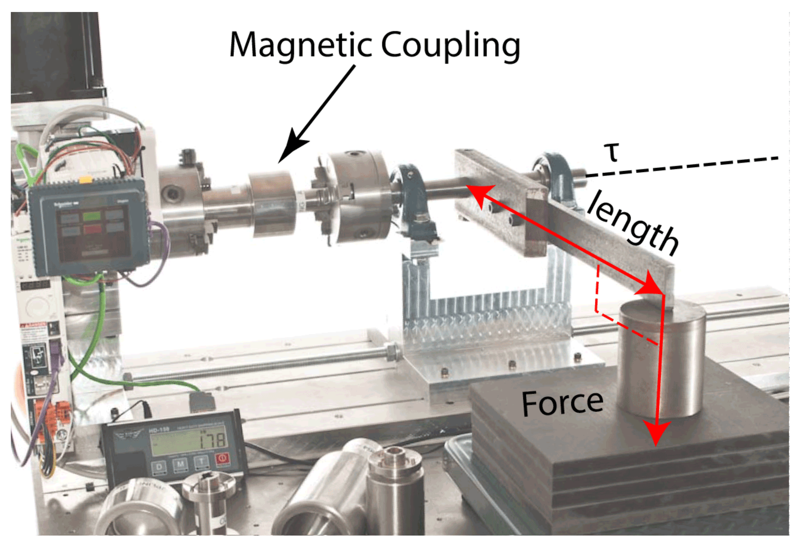
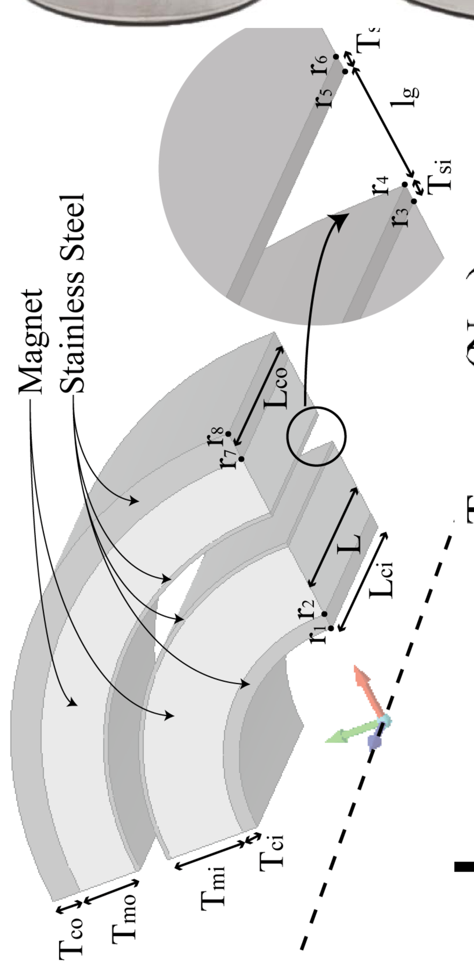
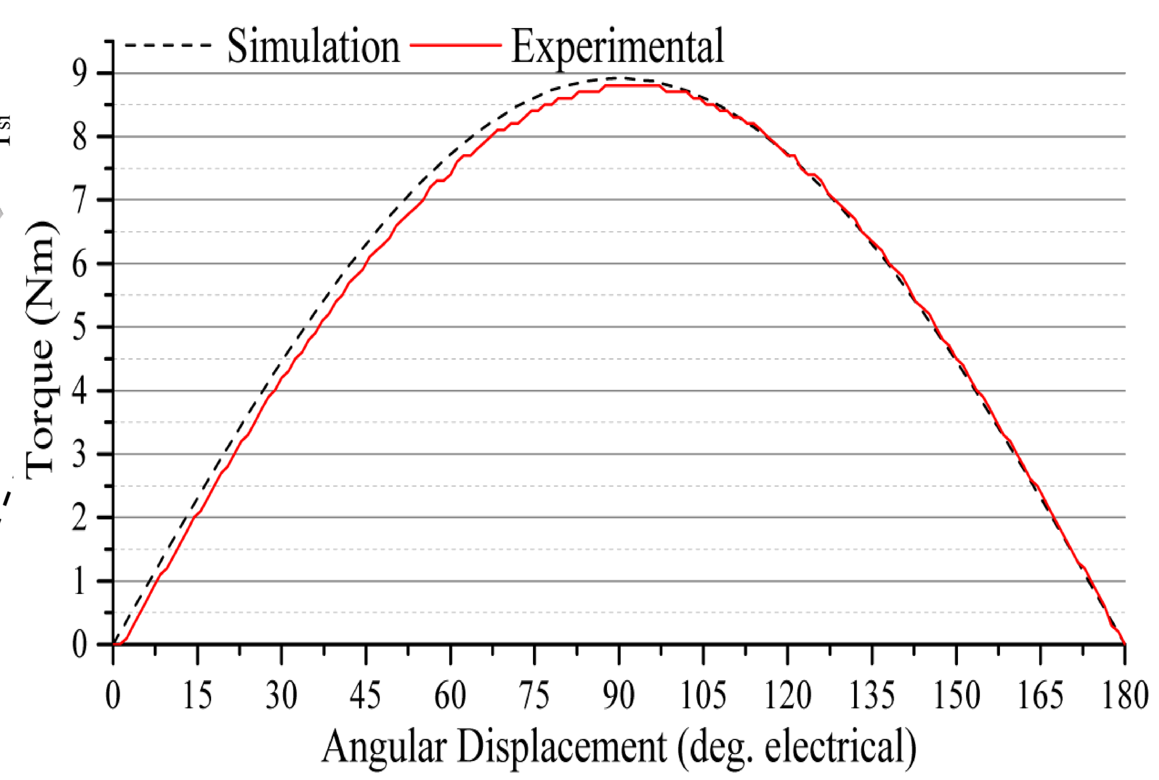
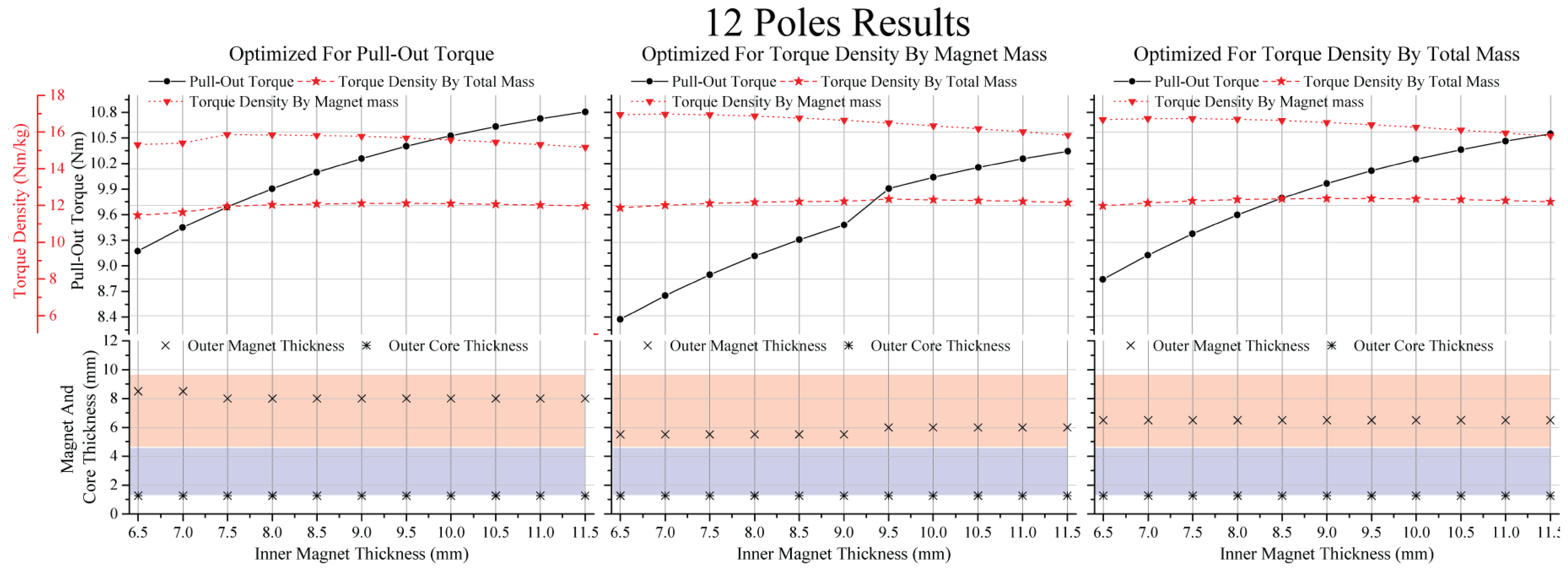
Abstract—A parametric design optimization routine has been applied to a novel magnetic coupling. Coupling designs are modeled in a 3-D finite element environment, and evaluated by three design objectives: pull-out torque, torque density by magnet mass, and torque density by total mass. Magnet and outer core thicknesses are varied discretely, whereas outer dimensions and air-gap length are kept constant.

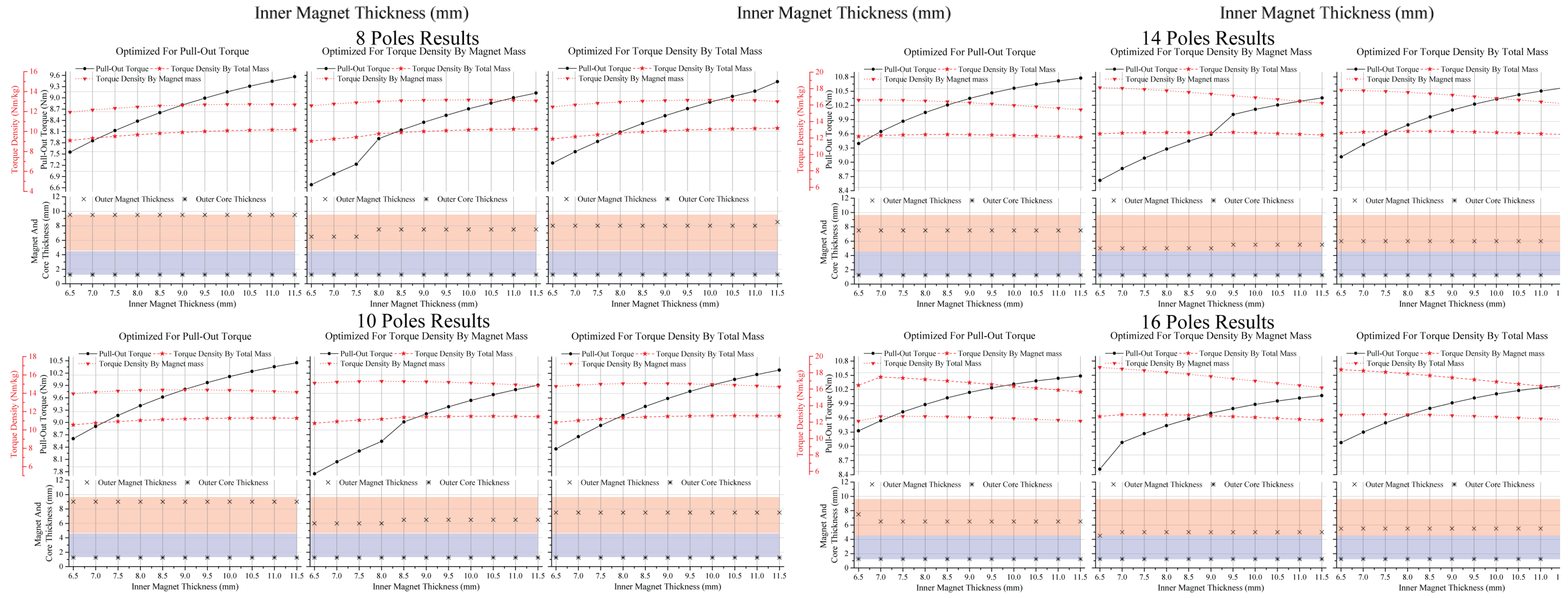


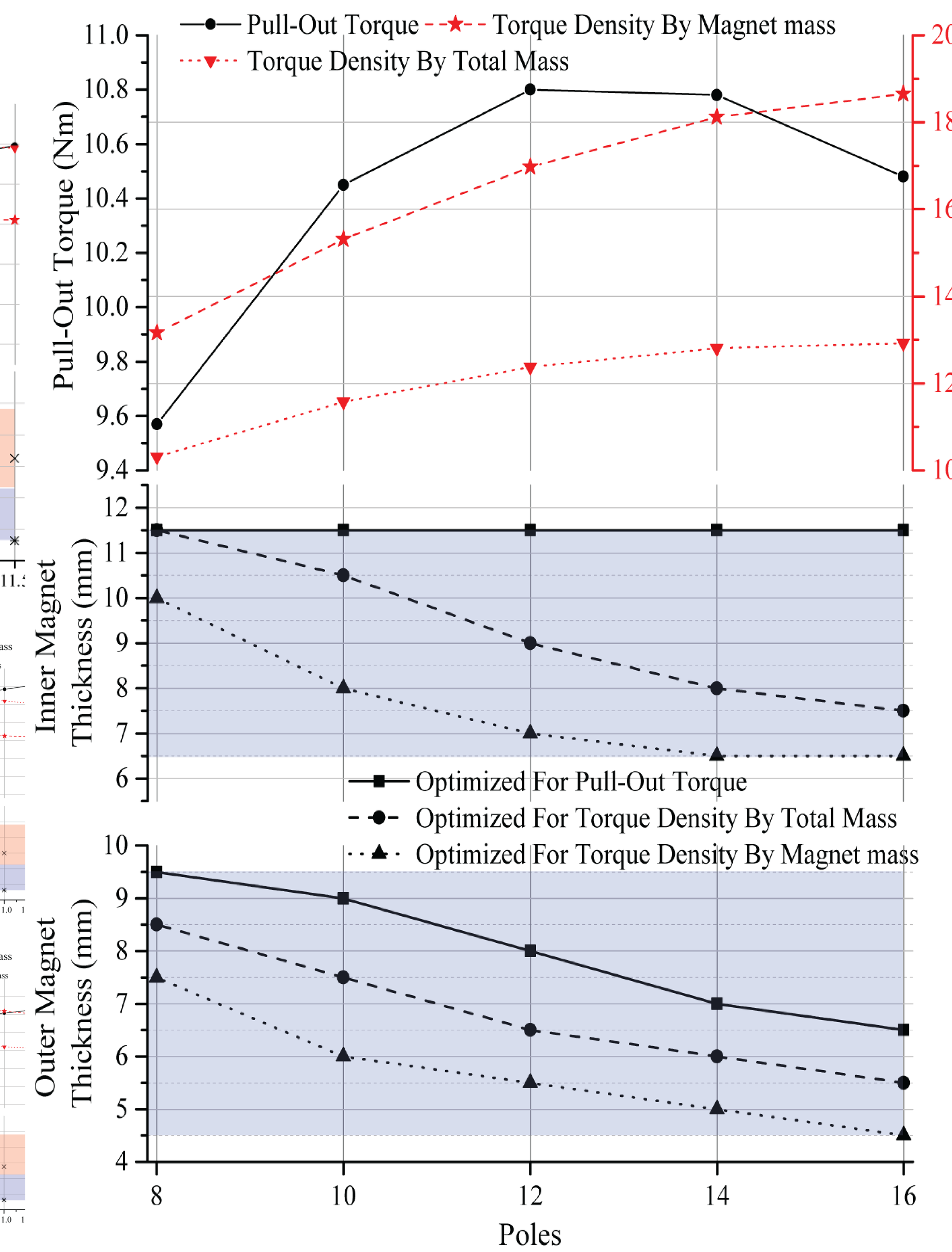




	Start	End	Step	Combinations
T_{mi}	6.50 mm	11.50 mm	0.5 mm	11
T_{mo}	4.50 mm	9.50 mm	0.5 mm	11
T_{co}	1.25 mm	4.45 mm	0.2 mm	17
Poles	8	16	2	5
Total				10,285







	Best Design		T_{mi} [mm]	T_{mo} [mm]	T_{co} [mm]	τ_{po} [Nm]	D_{tot} [$Nm \cdot kg^{-1}$]	D_{mag} [$Nm \cdot kg^{-1}$]
8 Poles	τ_{po} [Nm]	= 9.57	11.5	9.5	1.25		10.20 (↓ 1.07%)	12.70 (↓ 3.50%)
	D_{tot} [$Nm \cdot kg^{-1}$]	= 10.31	11.5	8.5	1.25	9.42 (↓ 1.57%)		12.98 (↓ 1.37%)
	D_{mag} [$Nm \cdot kg^{-1}$]	= 13.16	10.0	7.5	1.25	8.70 (↓ 9.09%)	10.16 (↓ 1.45%)	
10 Poles	τ_{po} [Nm]	= 10.45	11.5	9.0	1.25		11.29 (↓ 2.50%)	14.14 (↓ 7.64%)
	D_{tot} [$Nm \cdot kg^{-1}$]	= 11.58	10.5	7.5	1.25	10.05 (↓ 3.83%)		14.92 (↓ 2.55%)
	D_{mag} [$Nm \cdot kg^{-1}$]	= 15.31	8.0	6.0	1.25	8.54 (↓ 18.28%)	11.18 (↓ 3.45%)	
12 Poles	τ_{po} [Nm]	= 10.80	11.5	8.0	1.25		11.98 (↓ 3.23%)	15.17 (↓ 10.61%)
	D_{tot} [$Nm \cdot kg^{-1}$]	= 12.38	9.0	6.5	1.25	9.97 (↓ 7.69%)		16.52 (↓ 2.65%)
	D_{mag} [$Nm \cdot kg^{-1}$]	= 16.97	7.0	5.5	1.25	8.65 (↓ 19.91%)	12.01 (↓ 2.99%)	
14 Poles	τ_{po} [Nm]	= 10.78	11.5	7.5	1.25		12.11 (↓ 5.46%)	15.44 (↓ 14.79%)
	D_{tot} [$Nm \cdot kg^{-1}$]	= 12.81	8.0	6.0	1.25	9.79 (↓ 9.18%)		17.55 (↓ 3.15%)
	D_{mag} [$Nm \cdot kg^{-1}$]	= 18.12	6.5	5.0	1.25	8.61 (↓ 20.13%)	12.51 (↓ 2.34%)	
16 Poles	τ_{po} [Nm]	= 10.48	11.5	6.5	1.25		12.13 (↓ 6.19%)	15.68 (↓ 15.92%)
	D_{tot} [$Nm \cdot kg^{-1}$]	= 12.93	7.5	5.5	1.25	9.49 (↓ 9.45%)		18.08 (↓ 3.06%)
	D_{mag} [$Nm \cdot kg^{-1}$]	= 18.65	6.5	4.5	1.25	8.52 (↓ 18.70%)	12.68 (↓ 1.93%)	

Design Constraints—Outer radius, r_8 = 44.7 mm, active axial length, L = 25 mm, air-gap length, l_g = 3.45 mm, steel sleeves, $T_{so} = T_{si}$ = 0.5 mm, and inner core, T_{ci} = 1.8 mm.

Conclusion—The 3-D finite element based parametric optimization routine was applied to the permanent magnet coupling executed for three different design objectives; pull-out torque (τ_{po}), torque density by total mass (D_{tot}), and torque density by magnet mass (D_{mag}). The compromises between the three have been presented and discussed.