Magnetic Gear Design and Testing with MagNet

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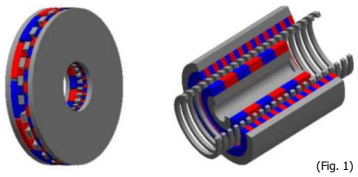
Introduction

In order to capitalise on the large potential of wave and tidal marine energy, a wide variety of devices have been proposed, the majority of which are faced with the same obstacles of low frequency operation and high operation and maintenance (O&M) costs.
Some proposed solutions have been large direct drive machines, mechanically geared systems or introducing intermediate stages such as hydraulics which have different associated issues such as lower efficiency, cost or physical size resulting in high installation costs.
Magnetic gear (MG) systems present an alternative solution which has the potential to have the advantages of the reduced failure rates of direct drive systems with the less expensive higher frequency machines.

Magnetic Gear Overview

Though there are now several MG designs capable of high torque (1) the most promising system is the ferromagnetic pole, magnetic field modulated magnetic gear (FMMG) first proposed by K. Atallah et.al. (2) due to its ease of implementation, high magnetic material utilistaion and variable configuration, such as linear and axially orientated (Fig. 1)



(Fig. 1)

The FMMG works by the insertion of ferromagnetic poles (FMPs) into the airgap between magnetic pole rotors which modulates the magnetic field and results in each rotor "seeing" the same pole number.
The number of FMPs for correct operation is determined by the following equation:

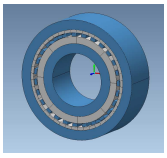
$$n_s = p_l + p_h$$

Where p_l, p_h are the low speed pole number and high speed pole number respectively.
The gear ration is then as follows:

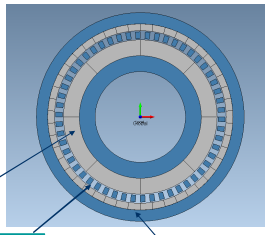
$$G_r = \frac{p_l}{p_h} = \frac{n_s - p_h}{p_h} = \frac{w_h}{w_l}$$

MG Design with MagNet

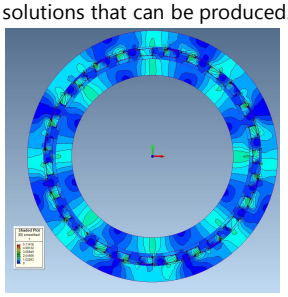
MagNet is a 3D electro-magnetics modelling software from Infolytica.. The software is compatible with the VB scripting language which was used to implement a MG model which can quickly design a system for a wide variety of parameter specification. Figures 2 & 3 show how an MG system is represented in the software and Figures 4 & 5 show an example of the graphical solutions that can be produced.



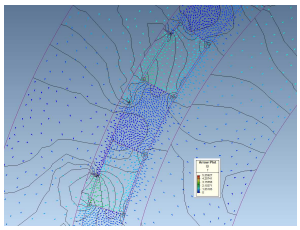
(Fig. 2)



(Fig. 3)



(Fig. 4)

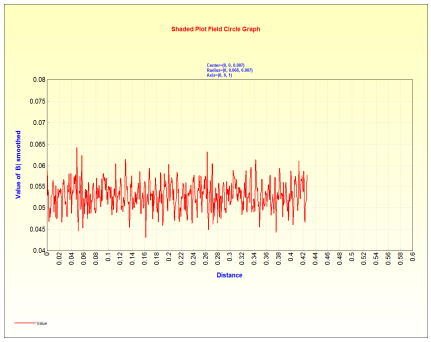


(Fig. 5)

Effect of FMPs on the Magnetic Field

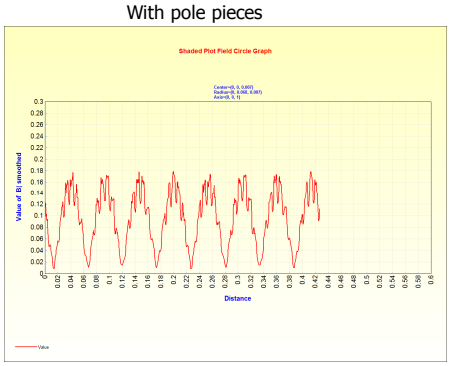
Magnetic field magnitude produced by outer rotor magnets at inner rotor radius for 8:46 MG (Inner rotor magnets considered air)

Without pole pieces



(Fig. 6)

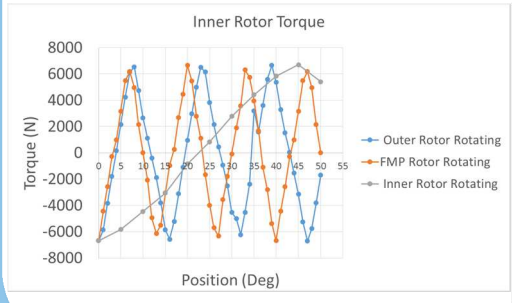
With pole pieces



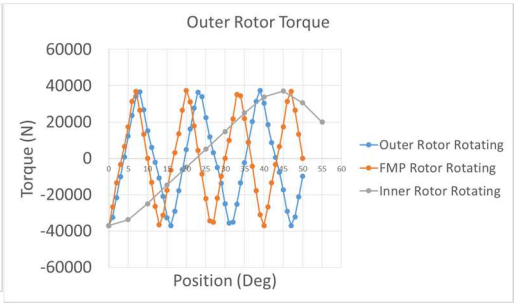
(Fig. 7)

Correct Operation

In order to observe the gearing effect a series of tests were run whereby one rotor was rotated 1 degree with the other two held stationary. The change in torque acting on the inner (Fig.8) and outer (Fig. 9) rotors show the correct operation of a 1:5.75 MG system.



(Fig. 8)



(Fig. 9)

References
(1) S. Tlali, P.M. and Wang, R.-J. and Gerber, "Magnetic gear technologies: A review," Electrical Machines (ICEM), 2014 International Conference on, pp. 544–550, 2014.
(2) K. Atallah and D. Howe, "A novel high-performance magnetic gear," IEEE Transactions on Magnetics, vol. 37, no. 4 I, pp. 2844–2846

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