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Magnetically Geared Lead Screw

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Introduction

Linear actuation is often achieved through a hydraulic, pneumatic, or mechanical mechanism. These, however, suffer from:

- Large, bulky and loud air compressor
- Likely to leak
- Low efficiency
- Regular maintenance
- Reliability issue
- Noise

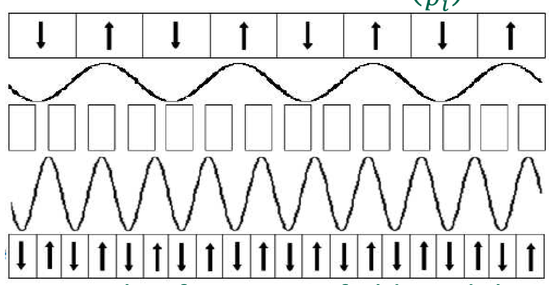
Problem Statement

- Low force per kg of magnets in long stroke length
- Costly to build

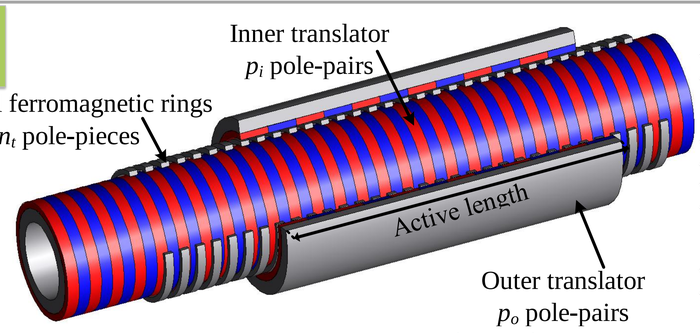
$$n_t = p_o + p_i \quad (1)$$

$$v_t n_t = v_o p_o + v_i p_i \quad (2)$$

$$\text{If } v_o = 0 \Rightarrow v_i = v_t\left(\frac{n_t}{p_i}\right) \quad (3)$$

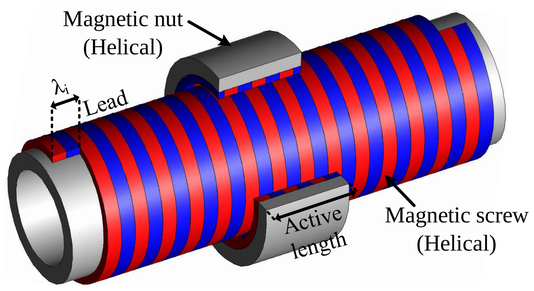


An example of magnetic field modulation



- Based on the magnetic field modulation
- 3 concentric parts
- Linear motion speed change
- No physical contact

Linear Magnetic Gear (LMG)



- Analogous to mechanical nut and screw
- Rotary motion to linear motion
- No physical contact

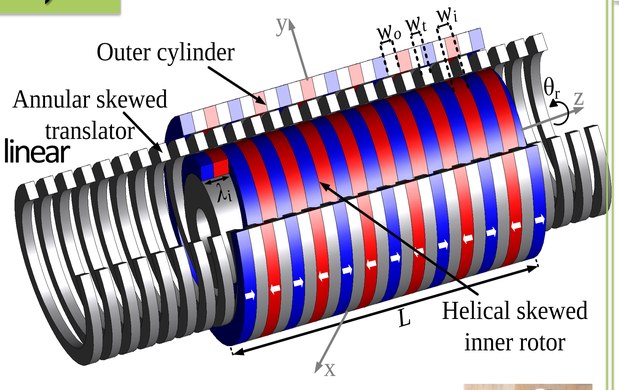
$$v_i = k_i \omega_i \quad (4)$$

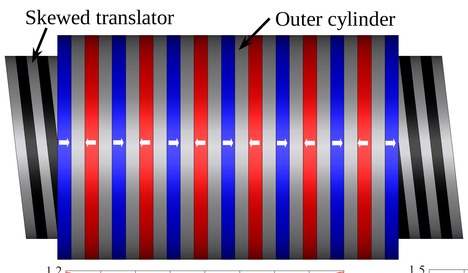
$$k_i = \frac{\lambda_i}{2\pi} \quad (5)$$

Magnetic Lead Screw (MLS)

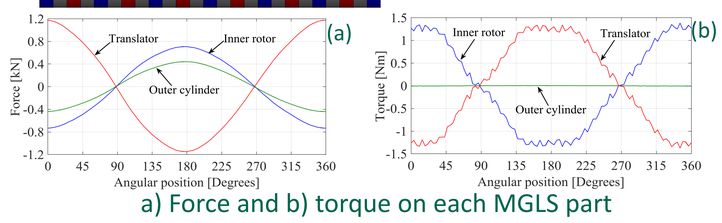
Proposed Magnetically Geared Lead Screw (MGLS)

- Ferromagnetic long stroke translator
- 3 concentric parts
- High speed rotary motion to low speed linear motion
- High force per kg of magnet materials
- Inherently overload protected





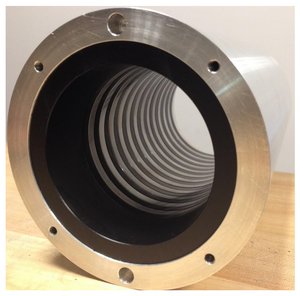
$$\omega_i = v_t\left(\frac{n_t}{p_i k_i}\right) \quad (6)$$



a) Force and b) torque on each MGLS part

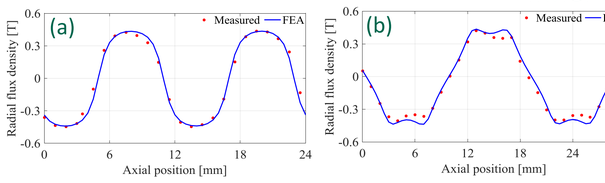
Prototype 1

Inner rotor

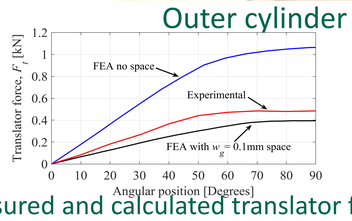


Outer cylinder

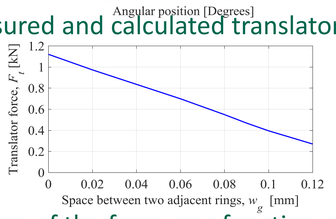
Translator



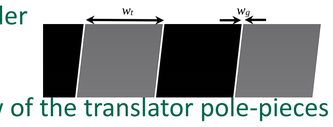
Radial flux density along z-axis at radial distance of 0.85mm from the surface of the a) inner rotor and b) outer cylinder



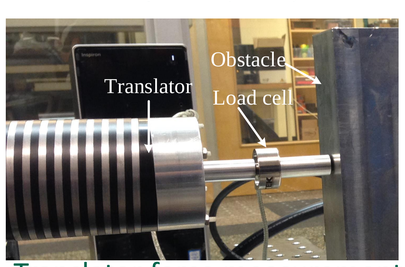
Measured and calculated translator force



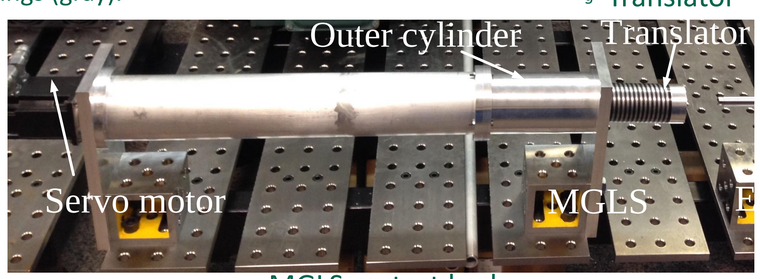
Variation of the force as a function of w_g



Close up view of the translator pole-pieces and w_g space between plastic (black) and steel rings (gray).



Translator force measurement

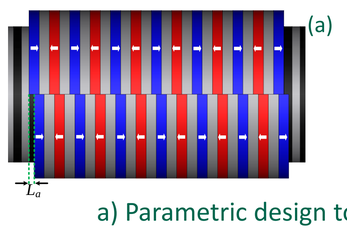


MGLS on test bed

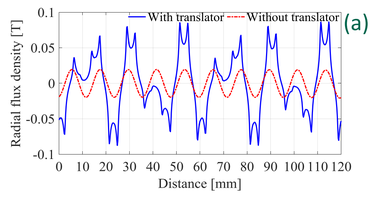
Prototype 1 Issues

- Skewed translator rings are relatively hard and expensive to manufacture
- Small tolerance inaccuracies in the rings results in significant force reduction

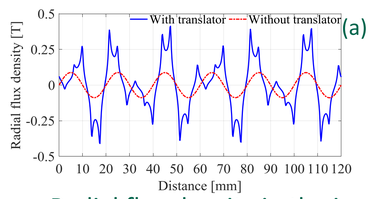
Prototype 2



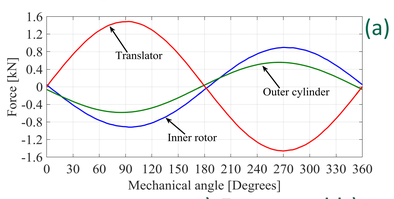
a) Parametric design to investigate the effect of the axial shift, L_a, between the top and bottom set of half rings (b) Maximum translator force versus, (c) proposed new MGLS



Radial flux density in the outer airgap due to inner rotor magnets. b) Harmonic content with translator present

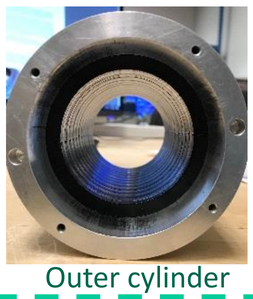


Radial flux density in the inner airgap due to outer cylinder magnets. b) Harmonic content with translator presents



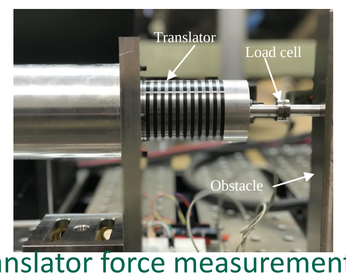
a) Force and b) torque on each MGLS part

Translator



Outer cylinder

- Translator rings are not skewed
- Cost of fabrication is lower



Translator force measurement