Generation of asymmetric incommensurable torque signals

L. Kurmann[1], J. L. Duarte[2]
[1]IMTEK, University of Freiburg, Freiburg, Germany
[2]Eindhoven University of Technology, Eindhoven, The Netherlands

Summary

- Using permanent magnets (PMs) as two dimensional spring systems
- By combining trajectories of a rotor with accordingly stator-rotor PM distribution, an asymmetric incommensurable torque signal (AIT-signals) is feasible [1]
- The same AIT-signals were generated with three different approaches for verification purposes (Maxwell Stress Tensor [1], Fourier Series approximation [1] and purely analytical approach (Biot-Savart [2], Lorentz-Force)
- Such AIT-signals have been generated in full agreement with Electromagnetic Theory

Generation of AIT Signals

- A set of stator-rotor PM distribution to maximize an asymmetric torque signal over one revolution. The simplest case with only one stator and one rotor PM is shown in Figure 1
- The asymmetric incommensurable torque signal is created by letting revolve ϕ as well as at least one additional DoF – either z or r (or both, see also Figure 1)

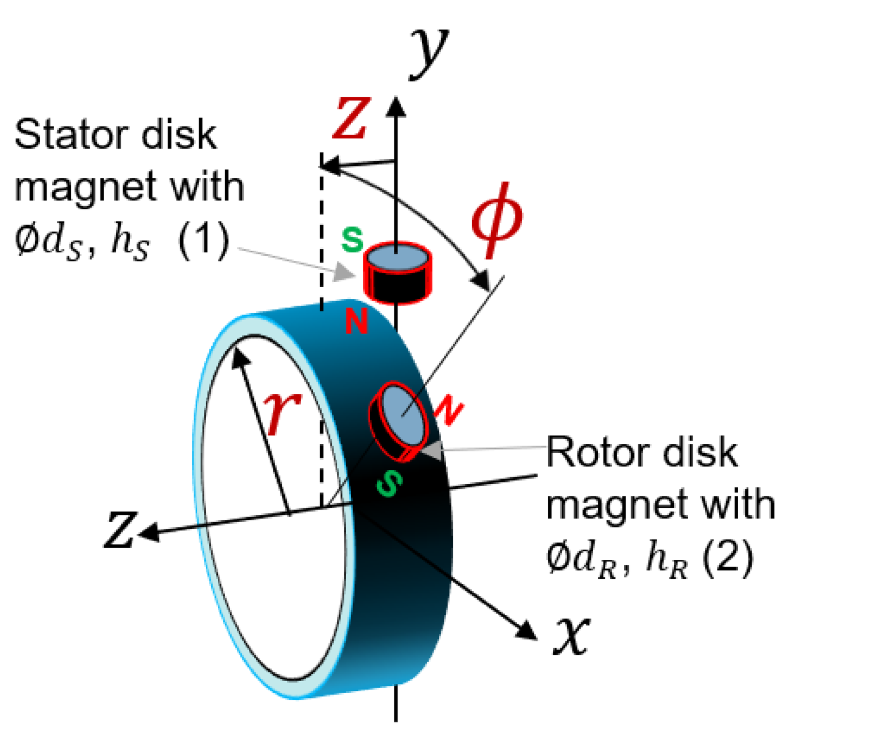
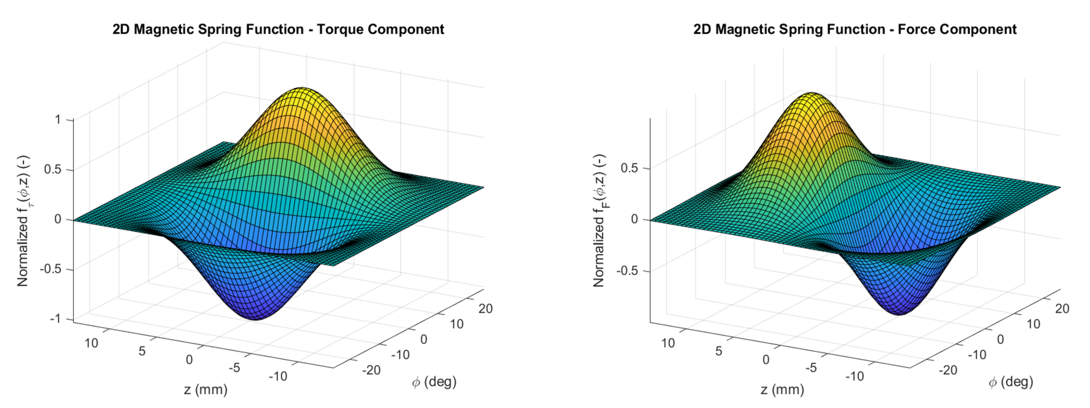
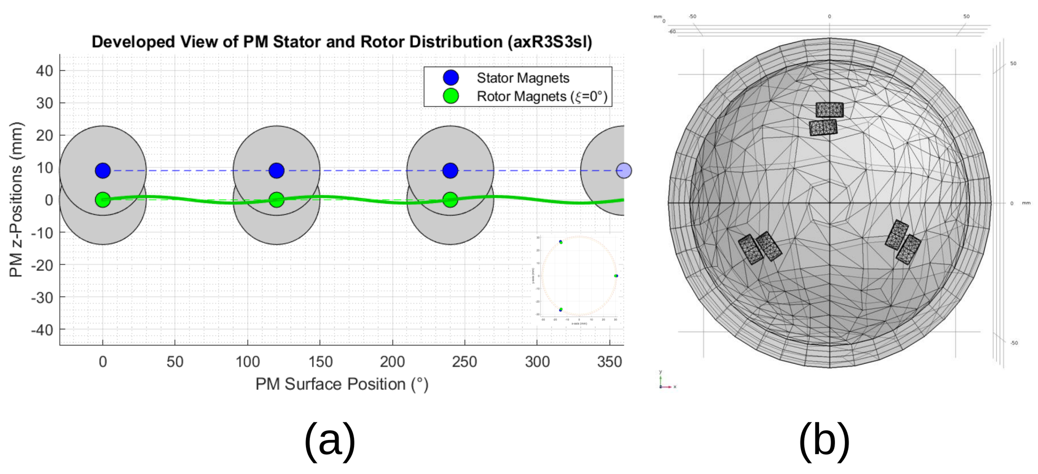


Figure 1: Concept view of rotary-translatory nonlinear PM spring system, with a rotary (ϕ), an axial (z) and a radial (r) DoF.



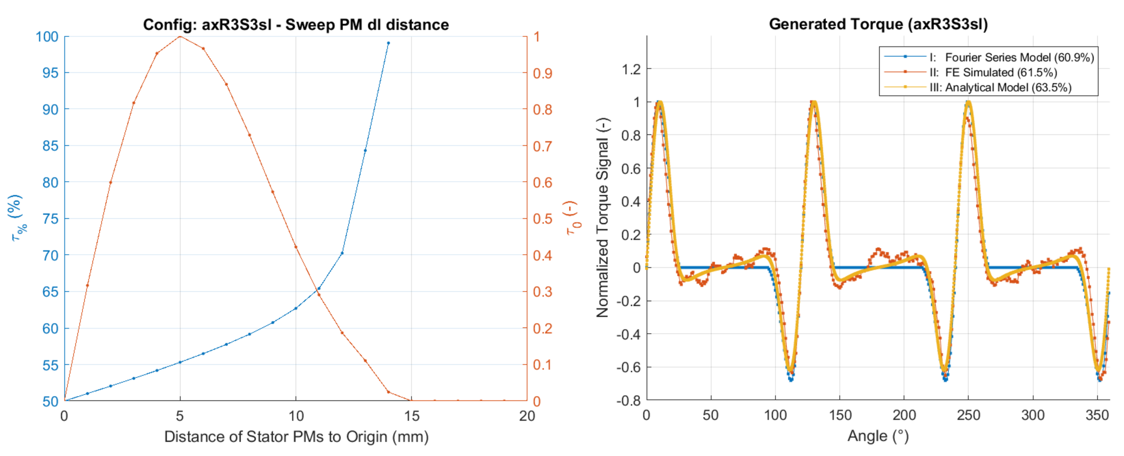
(a) (b)

Figure 2: Resulting amplitude signals of torque component (a) and force component (b)



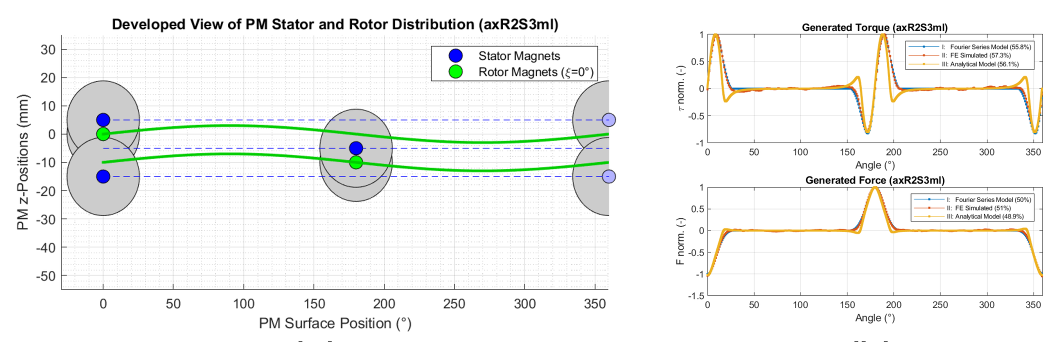
(a) (b)

Figure 3: Setup of stator PMs (blue) and rotor PMs (green) with harmonic rotor PM trajectory (a) and FE model for calculating magnetostatically force and torque signals using Maxwell stresstensor (b)



(a) (b)

Figure 4: Diagram (a) depicts a stator PM distance sweep 0…20mm and resulting torque signals in % (left axis) and normalized (right axis); (b) shows the corresponding created torque signal of all summed up 3 rotor disk PMs applying the 3 different methods.



(a) (b)

Figure 5: Setup of stator PMs (blue) and rotor PMs (green) with harmonic rotor PM trajectory (a) and normalized torque and force components of resulting PM distribution.

Application for Nonresonant KEH

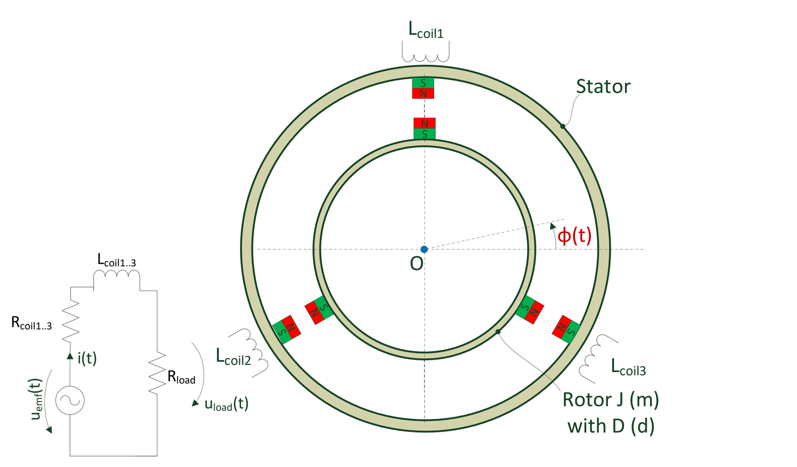
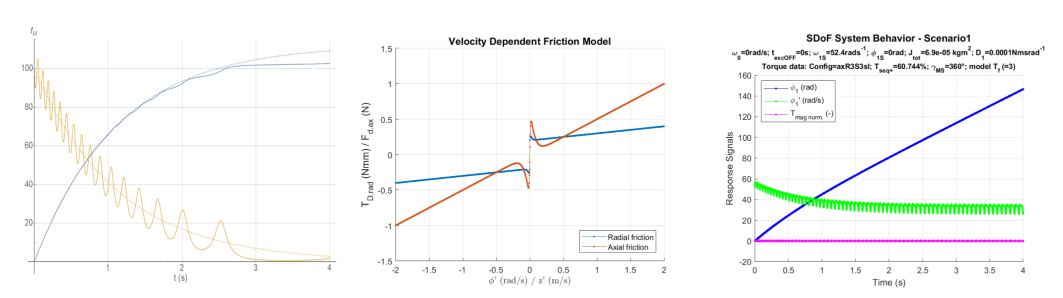


Figure 6: Nonresonant KEH system with PM distribution from Figure 4



(a) (b) (c)

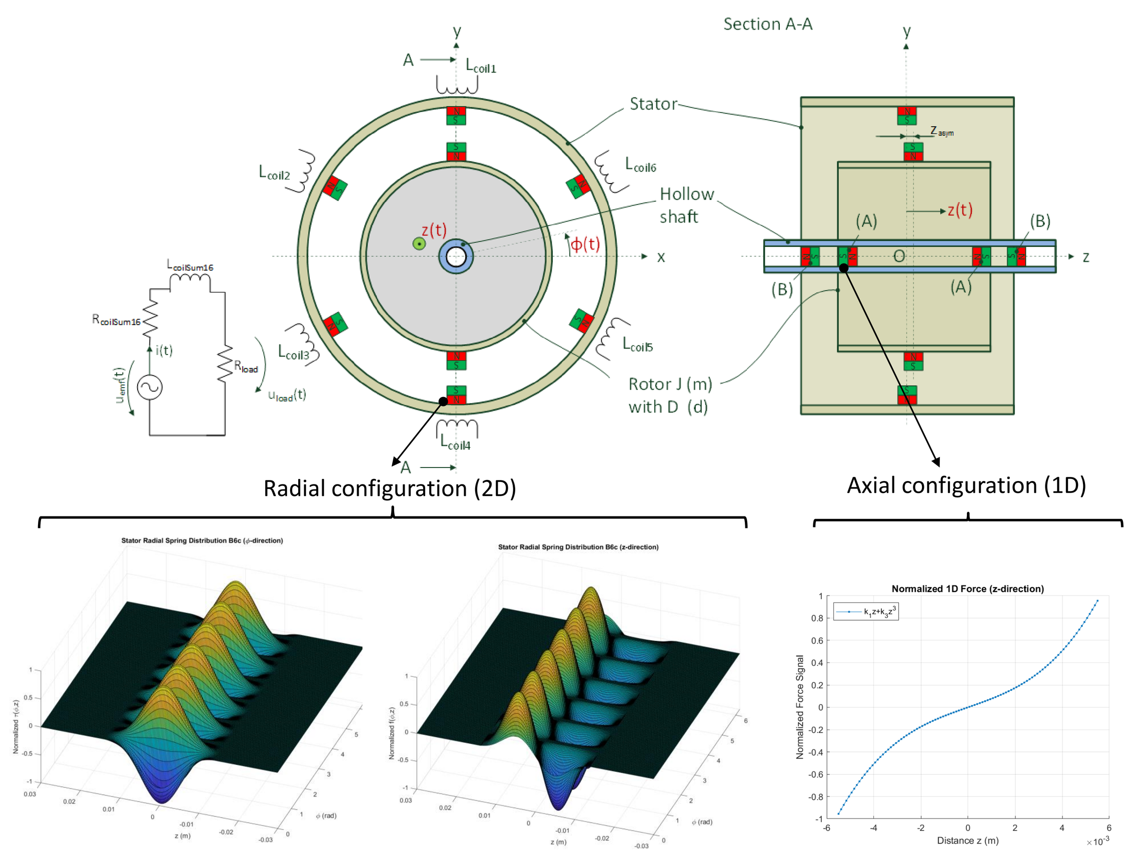
Figure 7: Simulation of rotary DoF with and without harmonic axial constraining force and no stiffness signals applied (a) and taking in account nonlinear friction model (b). Resulting dynamic behavior when applying PM distribution geometry from Figure 4 (c).

- Start energy with $\omega_S = \phi'$ is used to start revolving a rotor with inertia J
- Friction component τ_D depending on position ϕ and velocity ϕ' - using a nonlinear friction model.
- Stiffness component τ_Σ a carefully chosen arrangement of rotor-stator PM distribution forming a 1D or 2D spring system (Figure 2)
- The simplified case, a nonresonant KEH system, can be modelled as a mathematical physical model with a SDoF DE of the form:

$$J\phi'' + \tau_D(\phi', \phi) + \tau_\Sigma(\phi) = 0$$

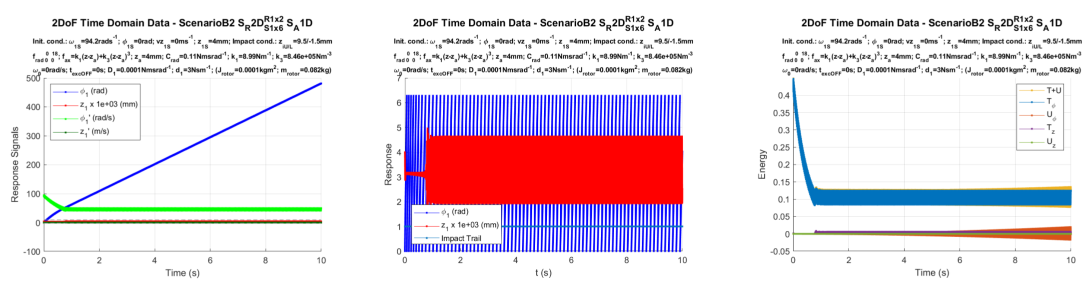
- Instead of rotary and axial distribution, also rotary and radial distribution can be chosen, patent application ongoing

Application for Resonant KEH



(a) (b)

Figure 8: Resonant KEH system (top) with 2D stiffness amplitude diagrams for radial movement, normalized τ- and f-functions (a), and 1D stiffness diagram for axial movement (b)



(a) (b) (c)

Figure 9: Dynamic behaviour of resonant KEH (a) with parametric oscillation of 2nd DoF visible in (b); continuous increase of potential energy shown in (c)

- In resonant KEH systems, at least a 2DoF system is necessary to describe the mathematical physical model
- Such a DE system form two mutually coupled Mathieu DE, leading to complex resonance behaviour

Conclusion

This study demonstrated in theory that (1) asymmetric incommensurable torque signals are feasible (2) using non-conservative rotor PM-field trajectories and (3) that magnetic fields can do work if a 2D/3D charge-ring/cylinder (with geometrical extension) is considered. These claims are in full agreement with the classical Electromagnetic Theory. The fundaments for the forecasted energy source, which is necessary to deliver this netto work, remain a research question, and further open-source experiments are indispensable to verify the presented theoretical claims.

References

[1] L. Kurmann and Y. Jia, "Oscillators with Nonpolar Magnetic Repulsion System and its Use in Rotary Nonresonant and Resonant Kinetic Energy Harvesters," IOSR Journal of Applied Physics, vol. 10, no. 4, pp. 57–76, 2018.

[2] S. Babic and C. Akyel, "Magnetic Force Between Inclined Circular Filaments Placed in Any Desired Position," IEEE Trans. Magn., vol. 48, no. 1, pp. 69–80, 2012.

Contact

Email: lukas.kurmann@gmail.com

The 18th International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications (PowerMEMS 2018), December 4-7, 2018, Daytona Beach, Florida, USA