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Electric Drivetrain Considering Magnetic Springs for Oscillating Load Applications

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Goal

Benchmarking three different **solutions** to drive directly (i.e. **without gearbox**) the shedding mechanism of the **weaving looms** applications, which have a strongly oscillating load pattern; the **solutions** are:

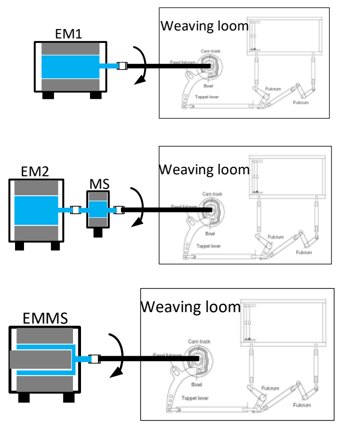
1) conventional PM synchronous motor (**EM1**)
2) conventional PM synchronous motor with assistance of a **separate magnetic spring** (**EM2MS**)
3) PM synchronous motor with assistance of **integrated magnetic spring** (EMMS)

The main performance **indicators** for the benchmarking of this study are the amount of required **materials**, the **consumed power** and the **flexibility**.

Motivation

- Electric motor systems consume a large part of the generated energy which is about **46%** of the generated energy worldwide [ref1]. Reducing energy consumption is crucial. This work focuses on applications with cyclic load pattern.
- Recently, **passive** elements such as **magnetic** and mechanical **springs** have received interest for applications with a cyclic load pattern. The main goal of using these passive elements is to store energy and release it when needed.
- In [ref2], a **comparison** between the **energy** consumption of a permanent magnet motor **with** and **without magnetic spring** for high dynamic industrial applications was reported. It was found that energy consumption and peak torque of the magnetic spring assisted drivetrain are about **6** and **3 times** respectively **lower** than using the conventional servo motor.
- A disadvantage of **the spring** is that its torque profile is fixed by **design** of the spring, which reduces the **flexibility** of the drive system towards other load patterns.

Approach



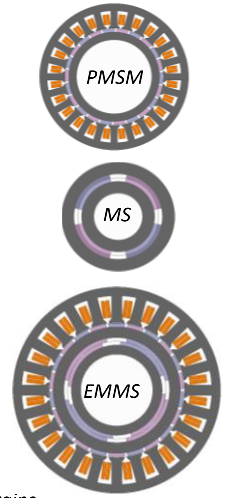


Fig. 1. Schematic of the three drivetrains.

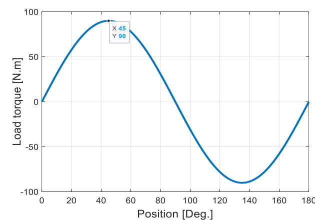
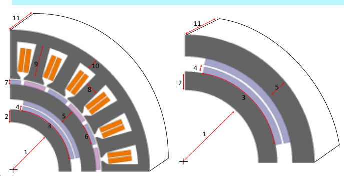


Fig. 2. Load torque versus the rotating position at 600 rpm.

Table I. Design parameters
(1) Shaft radius
(2) Inner stator yoke thickness
(3) PM coverage ratio of the magnetic spring
(4) PM thickness of the magnetic spring
(5) Rotor yoke thickness
(6) PM coverage ratio of the motor
(7) PM thickness of the motor
(8) Teeth width
(9) Teeth height
(10) Stator yoke thickness
(11) Stack length



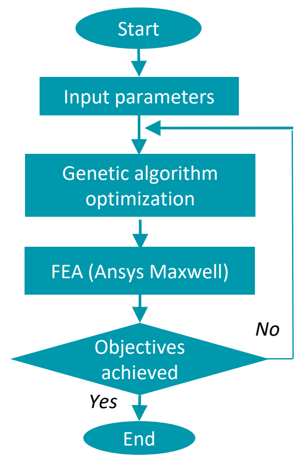


Fig. 3. Optimization flow chart.

Results

Parameter	EM1	EM2+MS	EMMS
Outer diameter [mm]	192	192+116	192
Stack length [mm]	**110**	**65+80**	**75**
Steel mass [Kg]	9.60	5.65+3 =8.65	8.50
Copper mass [Kg]	2.40	1.45	1.60
Magnet mass [Kg]	0.95	0.55+0.75=1.30	1.30
Total mass [Kg]	**12.95**	**11.40**	**11.40**
Motor RMS torque [N.m]	**63**	**33**	**33**
Inertia [Kg.m²]	0.010	0.0062+0.0032 =0.0094	0.011
Total losses [W]	**178**	89+22=**111**	**121**
Flexibility	**High**	**Medium**	**Low**
Cost	**low**	**Medium**	**High**

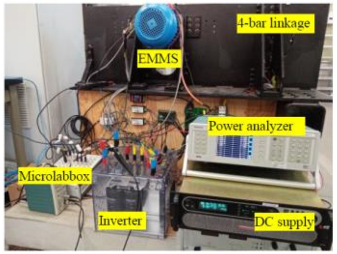


Fig. 4. Experimental setup.

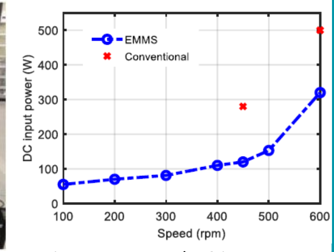


Fig. 5. Measured DC input power

Key take-aways

- The power consumption of the drivetrains that use a **magnetic spring** is **lower** by about **40%** compared to the **conventional electric motor**.
- Introducing a **magnetic spring** in the drivetrain **reduces** the **flexibility** of the system.
- The **cost** of the **magnetic spring** assisted drivetrain is **higher**. However, the higher cost of the drivetrain will be paid back by **lower energy consumption**.

Further reading

- ref1: https://doi.org/10.1109/MIAS.2010.939427
- ref2: https://doi.org/10.3390/act8010018