TRANSCOM 2025: 16th International Scientific Conference on Sustainable, Modern and Safe Transport

Design of stator-magnet transverse-flux linear oscillatory machine for reciprocating drives in transport

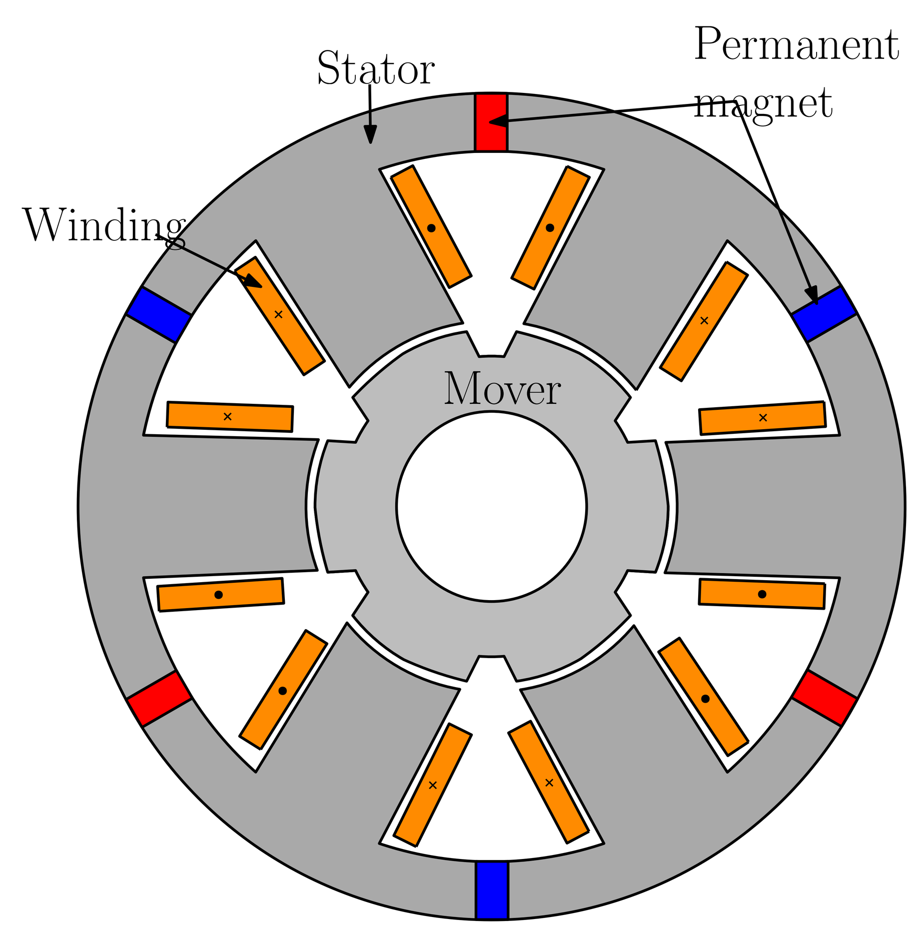
Matúš Horník[1], Pavol Rafajdus[1], Hao Chen[2], Andrej Blaško[1]

1 Department of Power System and Electric Drives, University of Zilina, Univerzitna 8215/1, Zilina 01026, Slovakia

2 School of Electrical Engineering, China University of Mining and Technology, No1,Daxue Road,Xuzhou,Jiangsu,221116,P.R.China

INTRODUCTION

Electric vehicles (EVs) offer a promising solution to mitigate climate change and environmental pollution. Among the key components of EVs are compressors, which are essential for air conditioning (AC) systems and battery thermal management, in EVs an separate electric motor is needed for their operation. Batteries in EVs needs to be constantly cooled, for the reason the compressor is constantly functioning and higher efficiency is desired. This paper explores the design and optimization of a stator-magnet transverse-flux linear oscillatory machine (SMTLOM) for compressor applications in EVs. SMTLOM also provides option for reducing rare-earth materials in the PMs.

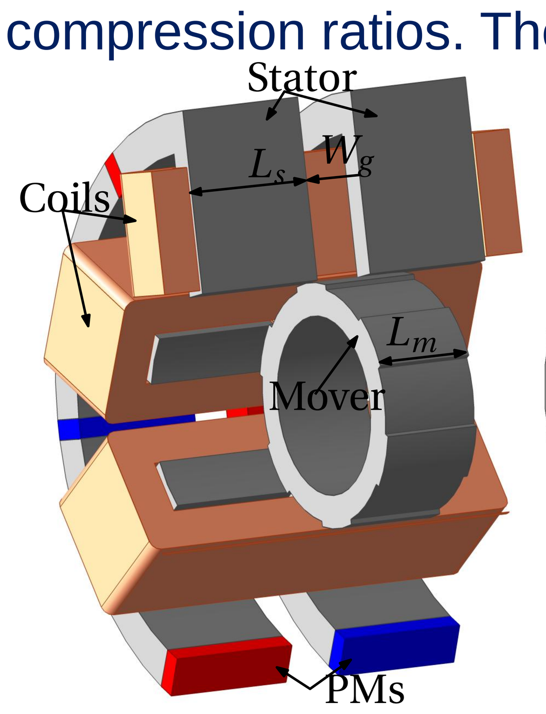


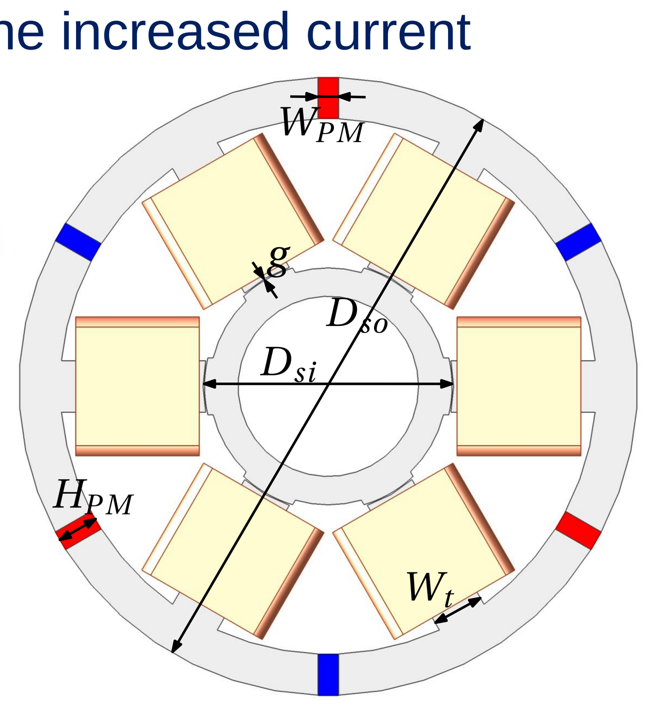
DESIGN MATERIALS

Rare-earth PM of grade NdFeB 45SH, are embedded in the stator yoke, this design provides two key advantages: simplified installation and replacement of PM, as well as enhanced protection against vibrations caused by the mover. Additionally, embedding the PM changes the flux path configuration from a series to a parallel structure. Therefore, using significantly less PM. For iron core steel of grade M270-50A was used.

Requirements

For SMTLOM to be used as a compressor, some specifications are needed, such as dimensions, force, current, etc. In a linear compressor, the force or current required depends on compression and decompression. Rapid transitions between compression and decompression, require bursts of higher current to quickly accelerate and decelerate the mover, for this purposes mechanical springs are used to lower needed current. As the required power changes, as well as current, a two mode current system is proposed. In low-current or efficiency mode, the compressor operates with minimal energy input, sustaining oscillation at its natural resonance frequency. This mode stabilizes system pressure and reduces mechanical and thermal stress, extending component lifespans. High-current or power mode is activated when greater force is required to handle higher loads. This includes compressing liquids, overcoming increased backpressure, or achieving high compression ratios. The increased current amplifies the magnetomotive force in the armature winding, resulting in higher thrust and enabling the mover to achieve the necessary compression.



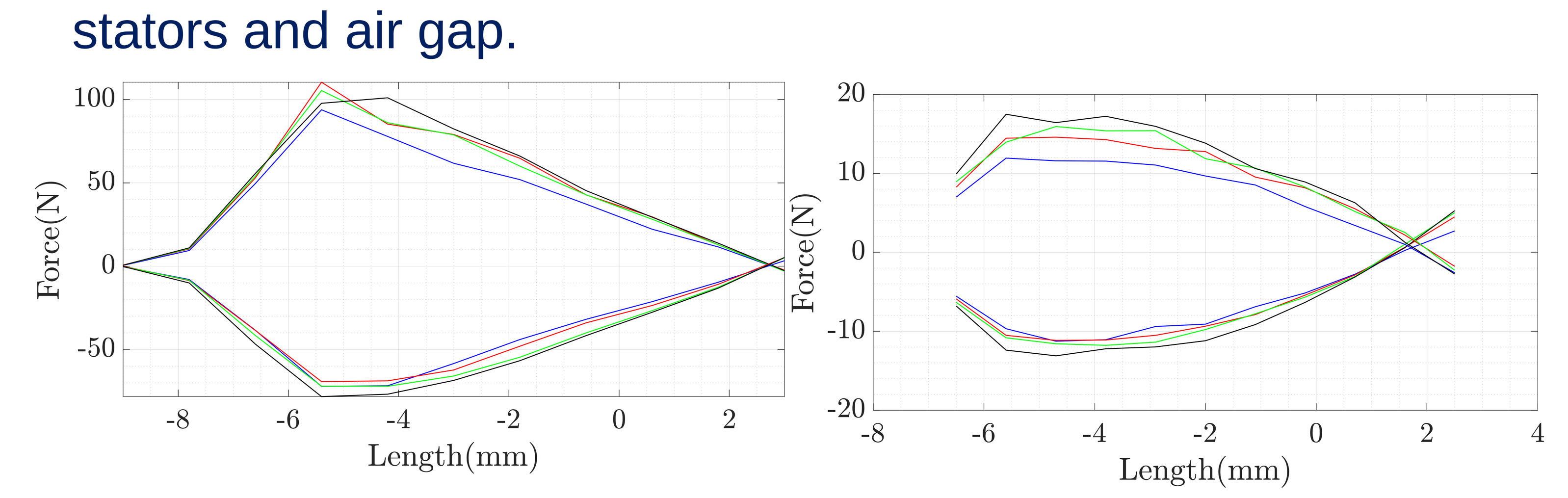


Summary of SMTLOM Parameters

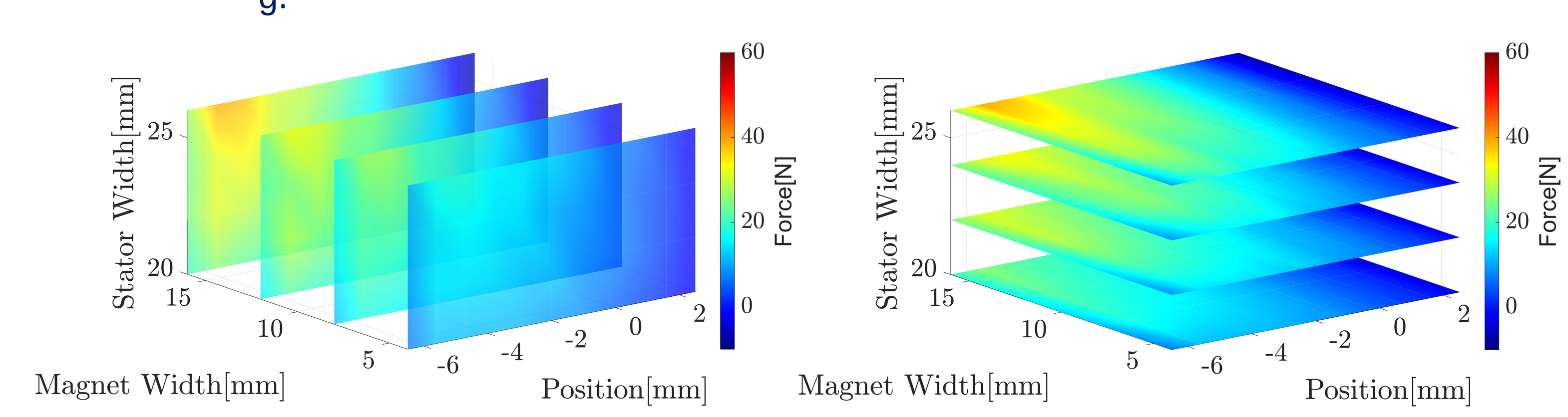
Parameter	Unit	Value
Voltage RMS	[V]	145
Current RMS	[A]	0.3 & 1.7
Frequency	[Hz]	75
Total width	[mm]	60
Stator diameter	[mm]	120
Efficiency mode force	[N]	~25
Power mode force	[N]	~55
Maximum voltage peak	[V]	205
Maximum current peak	[A]	2.5
Mover diameter	[mm]	46
Coercivity of PM	[A/m]	-1053200
Remanent flux density of PM	[T]	1.35

RESULTS

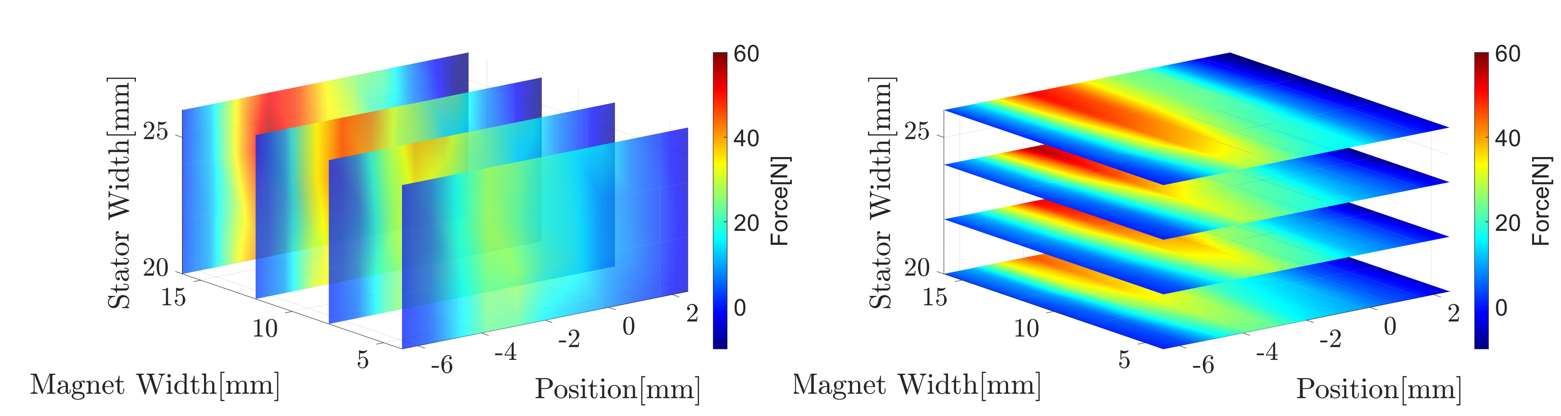
The SMTLOM consist a two stator design and usage of a 3D flux. Therefore a 3D simulation of a whole model was conducted. The optimization objective is to obtain a SMTLOM design with a generated thrust for each mode as given in requirements. The optimization of the SMTLOM is performed by means of a parameter sweep over the key parameters. Some key parameters of the SMTLOM are mover width, stator width, air gap between stators and air gap.



As a result of the optimization showed in figures above, desired force in power mode was achieved. However, the efficiency mode force is still lacking. To find the limits of the SMTLOM around given requirements, last research was concluded. In it the limits were exceeded, to find out if it is possible to use SMTLOM for reciprocating drive if the limits are raised. So the L_s, W_{PM} and W_g were changed. Results are show below. First for 8mm W_g, then for 12mm W_g.



With the W_g = 8mm, showed above, the produced force of the SMTLOM barely reaches the required force. This occurs with maximum width of the magnet and the stator, which is not a desired situation.



When the W_g is 12mm, the SMTLOM achieves the desired force in different models. Even when the magnet is 10mm the force is achievable. That is why it is more suitable for our application then

CONCLUSION

The transverse flux linear oscillatory machine was modelled and simulated, with a specific focus on their applicability in compressor applications. Proposed machine is a stator-magnet moving-iron transverse flux linear oscillatory machine, which is promising in its small dimension, high power output and reduction of permanent magnets used.
This machine was modelled based on specific requirements, and the results of the model were presented, demonstrating its potential for compressor applications. Further exploration is essential to determine the most efficient and cost-effective solution for compressor applications, ensuring optimal performance and minimal reliance on rare-earth materials.

ACKNOWLEDGEMENTS

We would like to thank BSH Drives and Pumps s.r.o. for their support during the preparation of this thesis. Their assistance with identification of technical requirements, feedback and the practical aspects of manufacturing greatly contributed to the successful completion of this work. This research was funded by the Slovak Cultural and Educational Grant Agency KEGA 044ŽU-4/2025.