Development and Optimization of a Highly Compact, Dynamic Linear Drive

Degree programme: Master of Science in Engineering | Specialisation: Industrial Technologies
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Today's high-tech medical appliances require outstanding accuracy, reliability and speed. Reduced process times not only yield in increased throughput and therefore better financial returns for the operator, but also in reduced recovery times for the patient. Often, machine performance depends on single components or assemblies, acting as bottlenecks. This thesis is focused on optimizing the dynamic capabilities of a linear axis to improve overall machine performance.

Project Outline

In collaboration with an industrial partner, Bern University of Applied Sciences is developing an ultra compact and highly dynamic linear drive system to replace an already existing and applied solution. Besides a very compact form factor, maximum thrust force density and best possible efficiency, the final design must also allow extraordinary positioning accuracy.

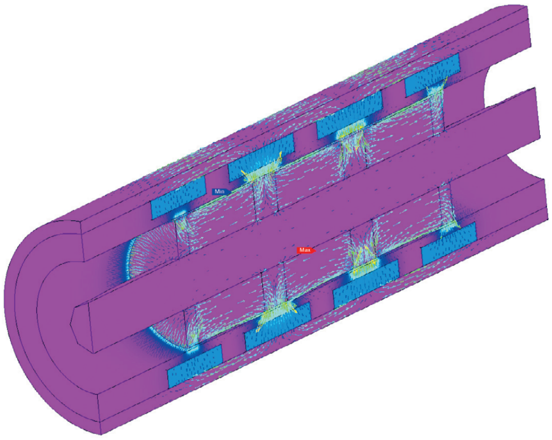
Methodology

In a first step, an extensive literature study is compiled and different designs are evaluated using 3D Finite Element Analysis in JMAG Designer. During this step, several design parameters such as static thrust, acceleration and linearity are evaluated and the different designs are compared to one another. Also, an initial idea to use a «Halbach Array» for improved thrust, whilst not increasing the actual mass of the moving parts, is evaluated. In addition to applying a Halbach Array, different materials for the design are studied as well.
Once a suitable design is chosen, the geometry and dimensions of the linear drive are further optimized, allowing best possible performance for a given form factor. Also, a more in depth theoretical background in applied Electromagnetics is derived, allowing to develop mathematical models of the actuator and improving general understanding for further optimizations.
Once geometry and materials are determined, the coils and, more specifically, the wire used for the design must be chosen appropriately. Therefore, a high fidelity reduced circuit model of the actuator as well as a suitable control structure for evaluation purposes are developed. Once this model is assumed to be sufficiently detailed, a suitable wire can be selected using parametric analysis. In a final step, an actual physical prototype is built.

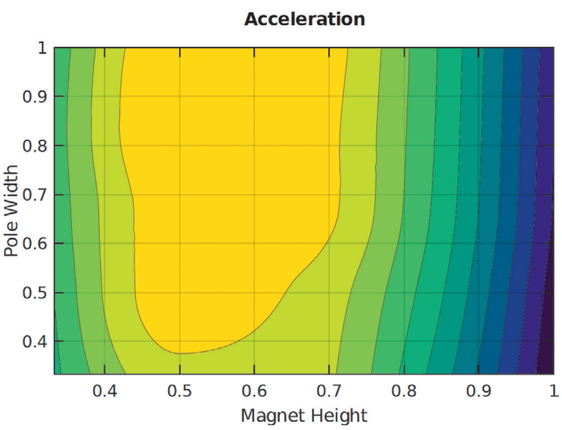
Results

By using state of the art techniques to evaluate different designs and optimize a promising approach, a single phase linear actuator was developed, theoretically meeting and even exceeding the requirements given by our industrial partner. Also, several expensive and complicated solutions have been shown not to be as effective in this particular case.
During the course of this thesis several problems had to be mastered. By proving a, strictly speaking, simple design to perform just as well or even better than more elaborate ones, greatly facilitates the production process and tools required to build the final actuator.

Joel Wenger



Magnetic Flux and Joule Loss Density in a Reference Actuator



Result of a Parametric Study on a PMTL Actuator using FEA