Optimization of Five Ultra-High Vacuum Voice Coil Actuator Topologies

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ABSTRACT
In this paper, a coupled electro-thermal optimization of five ultra-high vacuum compatible voice coil actuators (VCAs) is performed. Based on the resulting force range and steady state coil temperature, a prototype VCA is manufactured. Its performance is measured on a test setup.

1 INTRODUCTION
High-precision positioning is often achieved by voice coil actuators (VCAs). However, in an ultra-high vacuum (UHV) environment, commercially available VCAs do not suffice due to the creation of outgassing product by the coils [1], which reduces the achievable degree of vacuum. The production of coil outgassing product can be contained by encapsulating the bobbin in a tube and by the selection of alternative bobbin materials. Within a limited actuator volume, this results in a reduction of the permanent magnet (PM) and coil volume. Moreover, the absence of convective cooling reduces the heat transport to only the thermal conduction through the coil bobbin. As a result, the force range decreases and the thermal behavior is deteriorated. The required force range recovery and thermal behavior improvement can result from the optimization of different VCA topologies.

In this paper, five ultra-high vacuum compatible voice coil actuators (UHV VCAs) are optimized for operation in a vacuum environment and compared. The optimization is performed by means of a coupled electro-thermal approach using the finite element (FE) software environment Cedrat FLUX²D in order to improve both the thermal behavior and the force range.

2 OPTIMIZATION AND MEASUREMENTS
As a result of the bobbin encapsulation and material replacement, the thermal behavior of a vacuum compatible bobbin is deteriorated with respect to ambient VCAs. The thermal behavior of the vacuum compatible bobbin is measured using an infra-red camera in Fig. 1a, and compared to the results from FE analysis in Fig. 1b, both of which have been performed under ambient conditions at rated power level.

The observed temperature gradient over the bobbin surface is reduced in a coupled electro-thermal optimization, in which the force range is improved as well. Five VCA topologies are considered for which topology variations include the removal of an airgap, the improvement of the thermal path, and the increase of the flux density in the airgap and the coils. These result from modifications to the geometries of the PMs, the coils, and the iron parts. The resulting topologies are compared on their force over stroke linearity and steady state coil temperature, at rated power levels. In four of the five actuator topologies the stroke is limited by an undesired detent force which is absent in the manufactured vacuum compatible prototype VCA [2]. On the test setup in Fig. 2, its linearity of the force with respect to the stroke is measured at multiple current levels.

3 CONCLUSIONS
In this paper, five ultra-high vacuum compatible voice coil actuators (VCAs) have been electromagnetically and thermally optimized in the Cedrat FLUX²D finite element (FE) software environment and compared. A prototype vacuum compatible VCA has been manufactured and its performance has been obtained on a test setup, the results of which will be compared with FE simulations.

REFERENCES