High-precision motion system design by topology optimization considering additive manufacturing

A. Delissen[1], M. Oligschläger[2], E. Boots[2], D. Laro[2], F. van Keulen[1], M. Langelaar[1]

[1]Delft University of Technology, Delft, the Netherlands

[2]MI-Partners, Eindhoven, the Netherlands

a.a.t.m.delissen@tudelft.nl

Abstract

Dynamic behaviour is essential in the design process of high-precision motion stages. Manual design of a stage is a time-consuming process, involving many iterations between engineers responsible for mechanics, dynamics, and control. Using additive manufacturing, previously unproducible geometries can now be fabricated. To leverage the enormous design freedom that this provides, computational design approaches are required. This contribution presents a topology optimization approach to generate designs with optimized eigenfrequencies, and with dynamic performance beyond that of traditional designs.

The computational effort required for topology optimization of eigenfrequencies at the design resolution required for industry-relevant applications remains a major challenge. Next to that, producability by additive manufacturing and integration of post-processing steps like machining and assembly of actuators are crucial. For instance, in post-processing support material can be removed, which is required for the printing process, but which can be detrimental to the dynamic performance of the stage. In our approach, all these aspects are included in a single optimization problem, which removes the need for manual modifications of the optimized result.

The effectiveness of the proposed method is demonstrated in the form of a case study, consisting of a physical demonstrator of a magnetically levitated stage, which fulfils the requirements of a vacuum compatible semiconductor inspection system. The optimized design is directly ready-to-print, where post-processing and full assembly steps are included in the optimization. In comparison to traditional motion stages, its eigenfrequencies are superior, which is also experimentally validated. By demonstrating all the required steps from the conception of the design using topology optimization until its experimental validation, we show that the complexity that additive manufacturing offers can be effectively exploited and considerable benefits for high-end industrial applications are achievable.

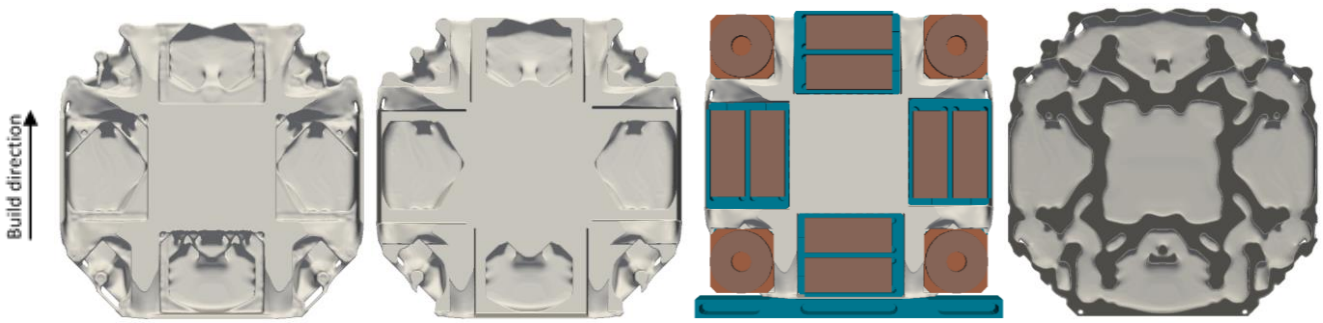

Figure 1: Overview of the final design, for different manufacturing steps of the stage