Adaptive clamping system for coordinate measuring technology

Graduate

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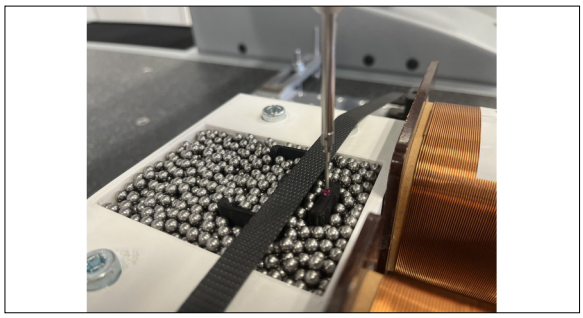
Introduction: Modern metrology requires fixtures that secure complex geometries quickly, repeatably, and without damaging the workpiece. This thesis develops an innovative, shape-adaptive fixturing system as a functional prototype for use on a 3D coordinate measuring machine (CMM). Target values were defined as 0.5 µm relative motion and 2 µm elastic deformation during measurement. The methodology comprised a review of the state of the art and patents, the application of TRIZ, a requirements specification, a morphological matrix, and a structured concept evaluation. Concepts with magnetizable spheres were prioritized due to low energy demand, high modularity, and fast switching capability.

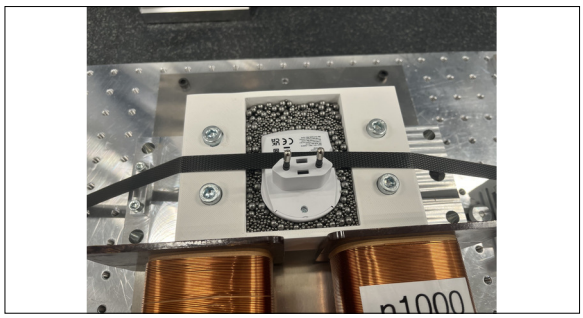
Approach: A feasibility study with a switchable magnet of approximately 600 N and steel spheres of 10 mm diameter confirmed the working principle. Building on this, the prototype was changed from a planar electromagnet plate to a transformer-like design. The specific magnet arrangement was determined in practical experiments and assessed with COMSOL simulations. The goal was a field guidance that exploits the forces within the sphere bed so that the workpieces achieve the required fixation and stability. The magnet is switchable (on/off), enabling a transition between a compliant and a locked state. The design remains compact and suitable for the measurement environment. An additional strap can be used for extra fixation if required.
For validation, the prototype was tested metrologically. The deflection of different test objects in various probing directions was analysed on a Leitz Reference 7 5 5 equipped with an HP-S-X1H probe head. Repeat measurements and MATLAB-based analysis considered different conditions, including comparison between the magnet switched on and operation under residual magnetization, as well as different configurations of the test objects and the spheres in the bed.

Result: The results show stable and highly repeatable clamping. The Z-direction proved most sensitive and led to concrete optimization proposals, including an adjustable basin geometry and linearly adjustable positions of the reel and strap. The work demonstrates the technical feasibility of the prototype, contributes to adaptive fixturing in precision metrology, and outlines next steps for further optimization and for the development of additional prototypes.

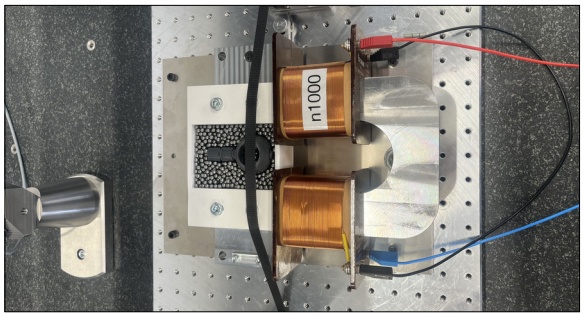
Repeat measurement in Z-direction
Own presentment



Fixation of a power adapter
Own presentment



Developed prototype (Fixation of a ball valve)
Own presentment



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Subject Area
Mechanical Engineering