Public summary of PhD-thesis of Coen Custers
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Towards nanometer performance in moving-magnet positioning devices

Integrated circuits are the basis of microprocessors used in many modern-day devices, such as computers, smart-phones and data storage solutions. The equipment that produces these integrated circuits contain planar motors, to position the circuits at nanometer accuracy under a lens. Researcher Coen Custers looked into parasitic effects in the electromagnetic and mechanical domain that potentially degrade the performance of high-precision planar motors.

A planar motor is a device of which the movable part can be stably levitated and propelled in all directions of space by means of magnetic fields, without the use of any bearings. Currently, in integrated circuits production equipment, the planar motors for the long-stroke motion have moving coils and permanent magnets on the stationary part. In the motor studied during the research, the moving part consists of permanent magnets that create a static magnetic field. As a result, no cables towards the moving part are required and the weight of the mover is strongly reduced. Additionally, this configuration provides possibilities for a system where multiple movers can move around freely, without tangling of cables. On the stationary part, a set of electromagnets or coils, produces the controllable magnetic field for stable levitation and propulsion. The motor needs to perform at very high accuracy and high acceleration levels, to be able to perform positioning tasks in the electronic circuit manufacturing process. Therefore, any effects that could possibly impair the performance should be considered.

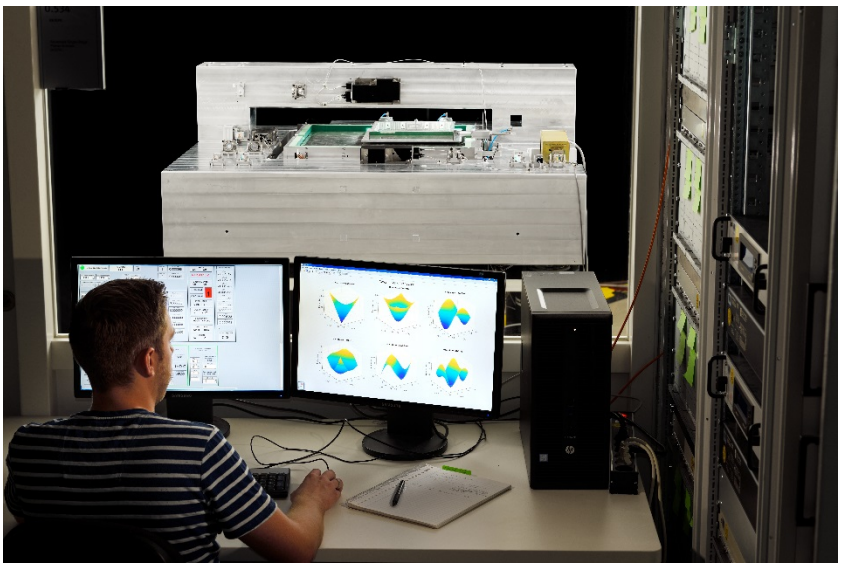
One of the parasitic effects that was investigated, is the so called eddy current effect. Eddy currents are induced in conducting materials when they are exposed to time-varying electromagnetic field. As a result of the eddy currents, a force can be developed which is, generally, undesired. In the researched planar motor, eddy currents are induced in the permanent magnets and cooling plates placed on top of the coils.
To analyze the force that is created by eddy currents in the conducting parts of a moving-magnet planar motor, Custers developed a semi-analytic model to describe the behavior of electromagnetic fields and eddy currents in 3D using a harmonic based formulation. Consequently, he can calculate the resulting parasitic force in space and time. A significant advantage over existing modeling techniques is the fact that the model can incorporate segmentation of conducting parts, without dividing the modeling domain into many small sections, which is necessary in finite element models.

A second parasitic effect that was researched is the flexible behavior that the moving body of the planar motor exhibits. Due to this flexibility, the mover will deform when it is exposed to force, as any mechanical construction will at a certain level. Because the planar motor is intended to perform positioning tasks at nanometer accuracy, the deformation should be controlled. To measure the deformation of the magnetically levitated mover, Custers designed a laser based measurement system able to measure the displacement of the mover on 25 locations simultaneously. He then applied a different method of controlling the currents in the coils, and demonstrated that the deformation of the moving body can be reduced, using the novel measurement system.

This research is an important step towards high-precision moving-magnet planar motors. In the years ahead the research will be continued to compensate the investigated parasitic effects in the design,

calibration processes and control of the machine, which will lead to an improved performance of the motor.

Title of PhD-thesis: Overactuated Magnetically Levitated Systems. Flexible modes and eddy current phenomena in high-precision bearingless planar motors. Supervisor: Elena Lomonova, TU/e. Other main parties involved: NWO, ASML, Prodrive Technologies, Philips, Tecnotion, TNO and SKF



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