TECHNISCHE UNIVERSITÄT
ILMENAU

50. Internationales
Wissenschaftliches Kolloquium

September, 19-23, 2005

# Maschinenbau von Makro bis Nano /

# Mechanical Engineering from Macro to Nano

## Proceedings

Fakultät für Maschinenbau /
Faculty of Mechanical Engineering

**Impressum**


| | |
|---|---|
| Herausgeber: | Der Rektor der Technischen Universität Ilmenau<br>Univ.-Prof. Dr. rer. nat. habil. Peter Scharff |
| Redaktion: | Referat Marketing und Studentische Angelegenheiten<br>Andrea Schneider<br><br>Fakultät für Maschinenbau<br>Univ.-Prof. Dr.-Ing. habil. Peter Kurtz,<br>Univ.-Prof. Dipl.-Ing. Dr. med. (habil.) Hartmut Witte,<br>Univ.-Prof. Dr.-Ing. habil. Gerhard Linß,<br>Dr.-Ing. Beate Schlütter, Dipl.-Biol. Danja Voges,<br>Dipl.-Ing. Jörg Mämpel, Dipl.-Ing. Susanne Töpfer,<br>Dipl.-Ing. Silke Stauche |
| Redaktionsschluss:<br>(CD-Rom-Ausgabe) | 31. August 2005 |
| Technische Realisierung:<br>(CD-Rom-Ausgabe) | Institut für Medientechnik an der TU Ilmenau<br>Dipl.-Ing. Christian Weigel<br>Dipl.-Ing. Helge Drumm<br>Dipl.-Ing. Marco Albrecht |
| Technische Realisierung:<br>(Online-Ausgabe) | Universitätsbibliothek Ilmenau<br>ilmedia<br>Postfach 10 05 65<br>98684 Ilmenau |
| Verlag: | isle<br>Verlag ISLE, Betriebsstätte des ISLE e.V.<br>Werner-von-Siemens-Str. 16<br>98693 Ilmenau |





| | | |
|---|---|---|
| ISBN (Druckausgabe): | 3-932633-98-9 | (978-3-932633-98-0) |
| ISBN (CD-Rom-Ausgabe): | 3-932633-99-7 | (978-3-932633-99-7) |

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=15745

50. Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
19.-23. September 2005

V. Kireev / R. Volkert / E. Kallenbach / N. Gorbatenko

# Investigations on Actuators for a High-Precision Long-Stroke Magnetic Levitated Stage

Tendency to the new, more powerful and precise positioning systems keep on moving. Modern ultra-precision technique requires the positioning uncertainty below the 10 nm range with strokes of more than 200 mm in the *xy*-plane. This requires a deeper understanding of limits settled by different physical principles of the sensors and actuators used in such systems.

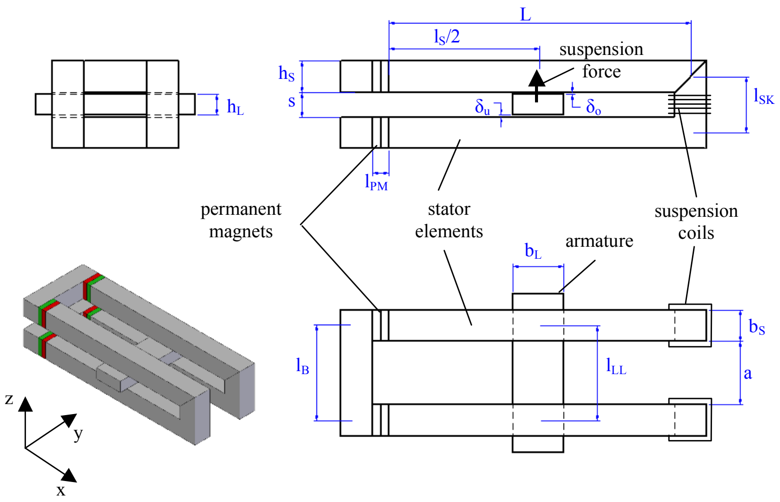


**Fig. 1: Actuator structure with geometry parameters**

Using of capacitive or laser-interferometer-based measuring systems makes it logically to place the whole positioning system or at least its moving parts and the position sensors in a vacuum chamber to reduce the environment's influence on the feedback position signal. Therefore, some principles of actuation, especially based on the electromagnetic field forces, turn to be preferably for such critical applications.

The parameters of these actuators have to be extensively investigated to avoid parasitic effects that could take place when the actuators and the measuring systems are integrated in the magnetic levitated stage. The components' geometry and placement can play an important role to minimize the undesirable effects of sometimes inevitable interactions and to achieve the required position uncertainty and the moving range.

To illustrate the decision process by design of a magnetic levitated stage, an actuator modification of [1] implementing the magnetic bearing of a planar positioning system is introduced (Fig. 1). Some topologies for placing of three or four these actuators in the whole system are discussed, with its advantages and drawbacks.

Some experimental results from an actuator test rig are represented (Fig. 2, Fig. 3). Variable force hysteresis values shown at Fig. 3 are of interest. The width of the hysteresis loop depends on the x-position of the movable element and consequently on the volume of magnetic material to be demagnetized.

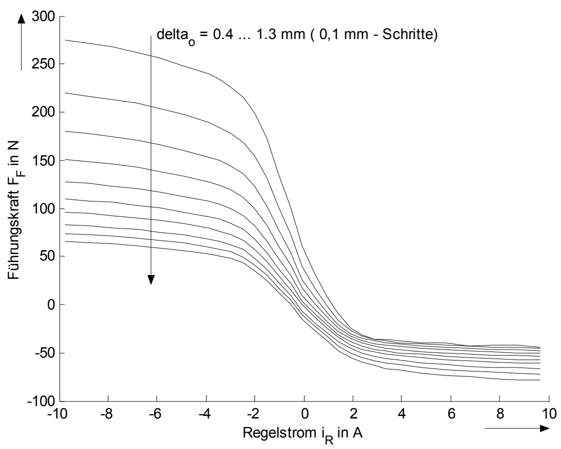


**Fig. 2: Actuator force $F_F$ for different airgaps**

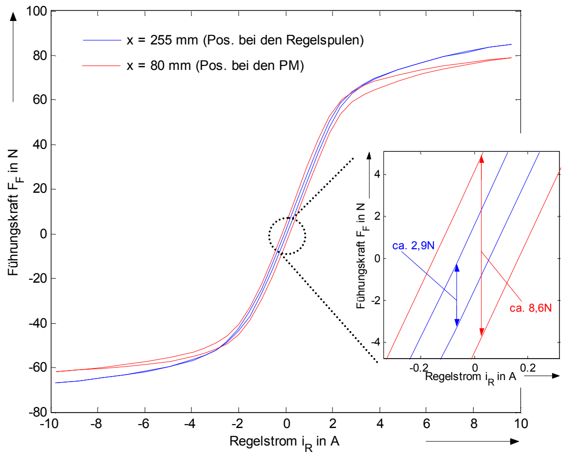


**Fig. 3: Actuator force hysteresis**

The actuator can be used for micro- and nano-positioning stages as a bearing element with relative large strokes in the *xy*-plane. The maximal suspension force of such an actuator is of 60…270 N and depends on the initial air gap $\delta_0$ (Fig. 2).

The vertical position of the movable element in a single actuator has been successfully stabilized with a simple PID-controller with a sampling frequency of 10 kHz. For better dynamic in a whole system with 3 or 4 such actuators a robust state-space controller must be implemented. The noise behavior and position stability can be improved through extreme low-noise position sensors and taking into account the actuator-specific force hysteresis. Some aspects about the force hysteresis compensation of an electromagnetic actuator with a Jiles-Atherton model can be found in the same proceedings' volume [2].

For propulsion of the movable element in the *x*-direction the stator elements must be wound with propulsion coils (not shown at Fig. 1). The propulsion forces due to these coils are relatively low (8…10 N). Therefore, for higher drive forces an additional drive or another drive principle has to be used.

### References


[1] Overschie, P.M.; Jabben, L.; van Eijk, J.; Molenaar, A.: Design of a 6-DoF Contactless Motion Stage with Stationary Magnets and Coils, in *Proceedings of the 6th International Symposium on Magnetic Suspension Technology*, Politechnico di Torino, Italy, pp.157–162, October 2001.

[2] Volkert, R.; Ströhla, T.; Weißenborn, E.; Bertram, T.: Entwurf und Erprobung neuartiger Reglerstrukturen für einen magnetisch geführten Mehrkoordinatenantrieb unter Echtzeitbedingungen. 50. Internationales Wissenschaftliches Kolloquium, Tagungsband, Ilmenau, 2005.



**Authors:**

Dipl.-Ing. V. Kireev
Prof. Dr.-Ing. habil. N. Gorbatenko
South-Russia State Technical University
Prosveshenija 132, 346428 Novotcherkassk, Russia
Tel.: +007 86352 55449
Fax: +007 86352 42056
E-mail: v.kireev@gmx.de

Dipl.-Ing. R. Volkert
Prof. Dr.-Ing. habil. E. Kallenbach
Technische Universität Ilmenau, FG Mechatronik
PF 10 05 65, D-98684 Ilmenau
Tel.: +49 3677 69 24 85
Fax: +49 3677 69 18 01
E-mail: eberhard.kallenbach@tu-ilmenau.de