Development of a SI traceable 3-axis small forces generator in vacuum based on active electrodiamagnetic springs and unknown input observers for uncertain systems

Keywords: small forces measurement and generation, mechatronics, instrumentation, control theory
Partners: FEMTO-ST Institute[1] in Besançon and ICB[2] in Dijon, France
Location: Besançon (trips to the ICB in Dijon are planned)
Supervision: Emmanuel Piat (FEMTO-ST Institute), Eric Lesniewska (ICB) and Joël Abadie (FEMTO-ST Institute)
Duration: 3 years starting between October and December 2020
Salary: 105 k€ / 36 months
To apply: Send your CV, cover letter and reference letters to Emmanuel Piat (emmanuel.piat@ens2m.fr), Eric Lesniewska (lesniew@u-bourgogne.fr) and Joël Abadie (joel.abadie@femto-st.fr) **before the 7 June 2020**

General context

The generation and the measurement of small forces (below the µN) are required in a large variety of applications such as Atomic Force Microscopy (AFM), assessment of the mechanical properties of micro- and nano-structures and surfaces, mechanical characterization of bio-components at a micro- or nano-scale, etc. These applications are currently suffering from the fact that the uncertainty of the measured forces is generally not known. Moreover, due to the lack of defined force standards below 500 mN, the measured forces cannot be linked to the International System of Units (SI). Therefore, the reliability of the small forces measurements and the calibration of the associated sensors are questionable.

Problematic

A force is a physical quantity that cannot be directly measured. In order to get a measurement, the force is always converted into a measurable effect (e.g. displacement, deformation …) using a dynamical system called transducer. Therefore, the force can be interpreted as an unknown input that acts on the dynamics of a system, i.e. the transducer, and whose output, i.e. the effect of the force, is measured with some unknown errors (e.g. noise, bias, drift …). The use of Unknown Input Observers (UIO) for uncertain systems will address the force measurement problem. Indeed, the UIO will produce a reliable estimation of the force despite the dynamics of the system that is not perfectly

[1] http://www.femto-st.fr/en/

[2] https://icb.u-bourgogne.fr/en/

known and subject to time-varying disturbances related to the environment conditions (e.g. heat, humidity …). Using these UIO into force sensors based on macroscopic deadweight mass of several milligrams, i.e. linked to mass standards, may guarantee the traceability of the force measurement and the link to the International System of Units (SI).

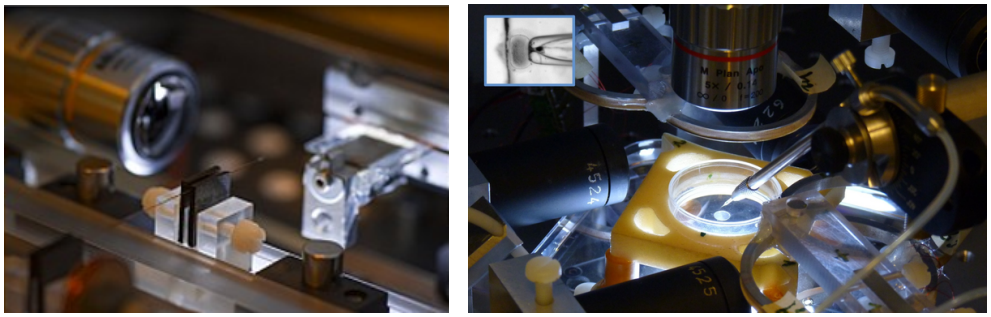

Fig. 1 – Examples of nano-force sensors developed at the FEMTO-ST Institute, world leader in the design of micro- and nano-force sensors using passive autostabilized magnetic springs combined with macroscopic deadweight mass of several milligrams.

Objectives

A work is currently in progress on the design of a mechatronic system for the generation of small forces along the vertical direction only. The objective of the current Ph.D. proposal is to address the more complex case of the generation of small forces that have horizontal components, i.e. expressed along the three directions of space. To this end, a new mechatronic system will have to be designed. In order to get rid of some disturbance forces due to the air, the new system will be placed in a vacuum chamber. Then, the only disturbance forces affecting the system should be the seismic vibrations of the chamber that will have to be measured and compensated for.

The work will be organized around four main points:

- Design of a 3-axis accelerometer that will measure the disturbance forces due to the seismic vibrations of the chamber
- Design of the 3-axis small forces generator
- Use the control theory to address the observation problem of uncertain MIMO (Multiple Input – Multiple Output) systems and develop some new control tools if required
- Use of mathematical tools on interval numbers to spread and calculate uncertainties

Requested skills

Candidates with well-founded knowledge in mechatronics, instrumentation and control theory with a high interest in experimentation are encouraged to apply. A strong interest in control engineering is mandatory. Knowledge related to the micro- and nano-world would be great but optional. The proposed Ph.D. is for motivated, curious, inventive, dynamic candidates having a strong scientific background and a sense of communication in a collaborative and multidisciplinary environment. The candidate will be expected to participate in popularization of science events such as mechatronic challenges, so proficiency in French is mandatory.

The Ph.D. position is part of the TRAVELER research project supported by the Bourgogne – Franche-Comté region and the National Research Agency (contract ANR-17-EURE-0002). It is a full time

research contract of 3 years with a possibility to have complementary part time teaching appointments.

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