PhD thesis

on

Data-Driven Modeling, Control Optimization, and Predictive Maintenance for High-Speed Turbomachinery with Active Magnetic Bearings

We have a vacancy for a PhD student (3 years) in a joint research project between SKF Magnetic Mechatronics "S2M" (Saint-Marcel), the LIAS laboratory (Université de Poitiers) and the Ampère laboratory UMR CNRS 5005 (Ecole Centrale de Lyon).

Keywords : system identification, mechatronics, optimal experiment design, robust control, predictive maintenance, magnetic bearings, rotor dynamics

Project description

S2M Magnetic Bearings leverage more than 40 years of leadership in active magnetic bearing (AMB) technology. With more than 130,000 SKF Magnetic Bearings and high-speed electric motor references in operation across many industries, SKF is the world market leader in the development, manufacture and sale of active magnetic bearings and magnetic bearing control technologies. S2M is located at St Marcel next to Vernon in Normandy.

Active Magnetic Bearing (AMB) [1,2] is a contactless force generator used to levitate rotors and shafts and is used to enable rotation while avoiding friction and thus wear. This type of actuator is frequently used in applications where high rotation speed has to be achieved (e.g., turbomachinery, centrifugal compressors, micro-milling). The rotating device is maintained in a fixed position in the air gap via an advanced control system based on active vibration control technology. A turbomachinery operated with an AMB position control system is known for its high reliability. However, like in any technical systems, faults/failures can also occur in AMB actuated turbomachinery and the performance level may decrease over time.

For this purpose, in this project, we aim at developing data-based learning solutions that, by following the evolution of key parameters of the system, will not only enable the re-design of the position control system (increasing therefore the reliability of these expensive devices), but also allow convenient scheduling of corrective maintenance in order to prevent unexpected equipment failures. This novel technology will not only reduce losses due to machine failures, but also will reduce service cost by providing maintenance only when required (*i.e.*, predictive instead of preventive maintenance). Anticipating failures and

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material degradation is indeed of great industrial and economical interest for S2M and the end-users of high-speed machines on magnetic bearings.

The development of the above-mentioned data-based technology will be enabled by the numerous sensors available in advanced AMB position control systems and the possibility to obtain informative data by exciting the system using specific and dedicated profiles [2]. However, such a development will entail numerous scientific challenges:

- ***Dynamical model learning for control re-design and predictive maintenance***. Since the turbomachinery dynamics evolve with time, the obtained performance level is thus only guaranteed as long as the system dynamics remain close to the model used at the commissioning phase. Data-based model learning techniques must therefore enable an accurate tracking of the system dynamics to detect when control re-design is necessary and/or to predict the moment of the next maintenance round.
- ***Data collection***. If the identified model must be used for control re-design or to predict the moment of the next maintenance round, the data used to identify that model must be sufficiently informative to obtain a sufficiently accurate description of the system dynamics to achieve these objectives. Generating such informative data using an excitation signal is here particularly challenging since the rotating device may not deviate too much from its central position. Optimal experiment design solutions aiming at generating informative data using non-intrusive excitation signals [3,4] will be considered for this purpose.
- ***Validation***: all along this project, tests will be performed on actual turbomachinery at SKF Magnetic Mechatronics, Saint Marcel, France, in order to validate the new solutions with real data.

Supervision team

This PhD project will be supervised both by academic and industrial partners.

The control team at SKF (led by A. Farhat) will supervise the project from the industrial point-of-view.

From the academic one, the project will be supervised by G. Mercère (Professor at the University of Poitiers) and X. Bombois (CNRS Research Director at Ampère Laboratory). Their expertise covers the different control engineering aspects present in this research project (data-based modeling and its interplay with robust control, optimal experiment design, black box and gray box model learning, LTV, LPV model and LFR data-based modeling, statistical analysis). The PhD student will be registered either at the Graduate School of Poitiers University or at the Graduate School EEA at the University of Lyon.

Appointment

This challenging job is based on a fixed-term appointment for a period of three years during which the PhD candidate will be able to gain both academic and industrial experience.

Candidate requirements

Applicants should have a MSc degree in engineering from a good-quality engineering school. They should possess a strong background and interest in mathematics and, ideally, in system identification and advanced control. They should have excellent analytical and problem solving skills and, preferably, well-developed programming skills. Applicants should have a good knowledge of Matlab. The candidate should have excellent oral and written communication skills in English.

Application procedure

If you are interested by this challenging project, please contact X. Bombois (xavier.bombois@ec-lyon.fr) and G. Mercère (guillaume.mercere@univ-poitiers.fr) by email with subject "PhD thesis SKF/LIAS/Ampère", attaching an academic CV, a cover letter, a pdf of your diplomas and transcript of course work and grades, a recommendation letter from your MSc thesis' supervisor, a certificate of proficiency in English, as well as any other document which can enrich the application.

References

[1] Bleuler, H.; Cole, M.; Keogh, P.; Larsonneur, R.; Malsen, R.; Nordmann, R.; Okada, Y.; Schweitzer, G. & Traxler, *Magnetic bearings: theory, design, and application to rotating machinery*. Springer, 2009

[2] Blom, R. *Model-based process monitoring and control of micro-milling using active magnetic bearings*, PhD thesis, TU Delft, 2011. https://repository.tudelft.nl/record/uuid:da6ca476-2692-4497-84de-7967eeb3b62c

[3] Bombois, X.; Scorletti, G.; Gevers, M.; Van den Hof, P. & Hildebrand, R. *Least costly identification experiment for control*. Automatica, 2006, 42, 1651-1662. https://hal.science/hal-00413370v1/document

[4] Bombois, X.; Scorletti, G.; Mercère G. *Verifying robust output amplitude constraints for multisine excitation in system identification*. Submitted to International Journal of Control, 2023. https://hal.science/hal-04675923v2/document

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