PhD thesis

on

Data-driven health monitoring and predictive maintenance of high speed turbomachinery operated with active magnetic bearing

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 : dynamical model learning, mechatronics, optimal data design, heath monitoring, 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] 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 speed rotation 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 a fault-tolerant operation of the rotating machinery (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 material degradation is indeed of great industrial and economical interest for S2M and the end-users of high-speed machines on magnetic bearings.

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The development of the above-mentioned data-based health monitoring 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. However, such a development will entail numerous scientific challenges:

- ***Data collection***: a specific attention will be paid to the design and the acquisition of informative data sets for model learning. For this first step, optimal experiment design solutions [2] will be considered. Generating cheap and non-intrusive input signals for online model learning is indeed an essential step for developing a health monitoring system once the magnetic bearing solution has been sold.
- ***Dynamical model learning***: once reliable data sets are available, the problem of model learning for intelligent maintenance solution design will be tackled. 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. In order to develop online smart predictive maintenance solutions, we thus suggest to use operational data to follow, via modern model learning techniques, the evolution of specific key model parameters, and then to use these parameters as entries of dedicated statistical analysis tools (like Support Vector Machine based classifiers [3]) to determine when future maintenance activities should be scheduled.
- ***Validation***: all along this project, test plans will be designed and 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 S. Benbouzid) will supervise the project from the industrial point-of-view.

From the academic one, the project will be supervised by G. Mercère (Associate 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 at the Graduate School of Poitiers University.

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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 "data-driven health monitoring and predictive maintenance of high speed turbomachinery operated with active magnetic bearing", 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

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[3] Suykens, J.; Van Gestel, T.; De Brabanter, J.; De Moor, B. & Vandewalle, J. *Least squares support vector machines*. World Scientific Publications, 2002.

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