Keynote Address 1

20 years ISMB: Then, Now, Future

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Then

In 1988, there were only very few Institutes working on magnetic bearings. Then as now, the communities of magnetic bearings on the one hand and magnetic levitation on the other hand are quite distinct, with little interaction. On the magnetic bearing side, there was essentially the Higuchi Lab at The University of Tokyo, the Schweitzer Lab at ETHZ, the Allaire Lab at UVA and the Matsumura Lab at Kanazawa University. To my knowledge, no other University or research Institute was at that time involved in any significant AMB activity. Professor Schweitzer had brought the idea of active magnetic bearings and «mechatronics» along with him from München, where a first PhD thesis on AMB had been done (by Heinz Ulbrich), when he came to ETHZ in 1979.

The essential prior art available then was a technical report on a sattelite flywheel (Teldix corporation), the very few publications by S2M corporation and of course some well known scientific publications such as Earnshaw’s famous paper «On the nature of molecular forces» (1842) or Braunbeck (1934), which included rotor levitation and MAGLEV vehicles. The industrial activity at that time on magnetic bearings was carried out by S2M corporation in Vernon, France. A significant portion of their activity at that time concerned vibration control of rotating machinery in submarines in order to reduce acoustic noise, all this work has of course not been published, just as the work on the gyroscopes of the posseidon missiles (US).

For the university research starting around 1980, it was obvious that essentially a PID controller would be enough to attain contact-free levitation, but it seemed natural at that time, when state feedback was the hot topic in control theory, that a MIMO (fully coupled multi-input multi-output) configuration was desirable for a rotor system.

The experimental work started at ETHZ in 1979. An analog controller card was then developped, one card per bearing. True MIMO was realized by backplane wiring (wire wrap), any bearing (small or large) needed a cabinet including power amplifiers, sensor electronics, control and power supply. The first rotor system operated well, but, depending on the tightening on some components on the rotor, the system would whistle loudly at ca 400 Hz, although still levitating stably. This was an impressing lesson as to how small changes in energy dissipation on the rotor can have big effects. An interesting first application of such a system was a rotating crucible for epitaxial growth of III-V semiconductors, a device built for the Max Planck Institute of Solid State Physics in Stuttgart. Contact-free magnetic bearings were prefered for that application in order to avoid contamination of the semiconductor.

Later on we succeeded in operating one of the first digitally controlled AMBs. At this time, Hitachi became interested in AMBs for large turbocompressors. It became conceivable to operate such a machine without the comlex oil hydraulics necessary for conventional bearings. Moreover, such essential parameters as stiffness and damping could be chosen by a controller and easily adapted in real time, which opened up new applications and a new view on rotor dynamics. It was expected that this would allow more freedom in rotor design.

Designers had to cope with a far lower bearing stiffness of AMBs as compared to conventional bearings. On the other hand, the possibility for vibration free operation emerged as the rotor is allowed to move around its principal axix of inertia. A notch filter at synchronous speed, elaborated by several research groups along various design principles, but with essentially similar results, allows to cancel harmonic disturbances due to unbalance.

Many practical problems had to be solved and sometimes proved very difficult, but the development of ever more sophisticated control with ever more diminishing hardware (cost- and volume-wise) was underway. Therefore, when the first ISMB gathered in June 1988 at ETHZ on the initiative of professor Schweitzer, a rich program could be offered where the main presenters were S2M, the four University Institutes mentioned above and several other groups with interesting new applications. It was the first opportunity for most participants to meet and exchange informations, all having worked already for several years on similar problems. It was therefore an extremely fruitful experience and information exchange for all the participants and these contacts implying the groups in Japan, the US, Switzerland, France, Germany, Italy and, already then, China, have lasted up to the present.

At professor Higuchi's intitiative, the 2nd meeting was then held 1990 in Tokyo and the third, chaired by professor Paul Allaire, was held 1992 at University of Virginia.

The main characteristics of ISMB in my view is the twofold task of strengthening the link between academic research and industrial applications of AMBs and of international exchange between Europe, Asia and America. It is therefore appropriate that ISMB is scheduled every two years. On the local level there are annual meetings to keep track of the progress and to disseminate academic findings towards industrial projects, while at the same time academia is inspired by new demands from industry. 1988 was also the year of the foundation of MECOS Traxler AG in Winterthur, devoted from the beginning to control of AMBs with Digital Signal Processors (DSP). This choice, not obvious at the time, has subsequently been proven correct.

Now

While the growth of magnetic bearing applications has maybe not been as fast as some would have hoped in 1988, the next 10 years nevertheless saw a steady increase in all aspects: Performance, cost efficiency, number of installed systems, number of applications, research topics. Cumulated over time, this growth is quite significant. The one disappointing application field has been machine tools, where no real breakthrough could be achieved. The combination of low inherent stiffness and strong noise injection over a wide frequency band still lets AMB machine tools appear as a dauting challenge. On the other hand, AMBs have strongly established themselves in vacuum technology, by far the application domain with the highest number of sold AMBs and the largest number of competing producers. Thus, turbo-molecular pumps make an important contribution to the semiconductor industry and to the CERN to name just two prominent examples. Other markets, more specialized, emerged, such as e.g. compressors for CO2 lasers. And many applications in small numbers, but for larger machines, have been successfully realized.

Biomedical applications such as heart pumps are promising, but development has been slow due to the extremely slow certification procedures in this difficult domain. These trends have been confirmed in the last 10 years. One specific trend had been underestimated, but it lead to truly spectacular developments: It is the miniaturization of electronics and also electromechanical components. This has permitted a full integration of the electromechanical part into the system, the separate electronics cabinet is now obsolete for most applications (except of course for very large bearings). These integration efforts have in turn permitted a drastic drop in overall costs and this has fueled further increase in the number of applications.

Future

What could we expect for the future?

In my view, the integration potential, although not yet at a saturation, will slow down as compared to the past few years. Future growth will therefore rather be driven by the application side and comparatively less so by technology improvements. One example of such emerging applications could be the already mentioned blood pumps or artificial hearts. A more spectacular breakthrough could be excpected in the domain of textile machines, where success has not yet come up to now. This will need a further cost reduction and this is why « passive » bearings might regain somewhat in interest, as extremely low cost of contact free levitation is a key condition in the textile machinery sector. New tends indicate that passive bearings with High Temperature Super Conductors have quietly, but rather quickly, passed from the status of lab curiosities to serious industrial layouts. This has been highlighted by a keynote (Kummeth, Siemens) at the 10th ISMB in Martigny. Such a bearing is appropriate in a situation e.g. with very high security demands. But other scenarii for viable HT Super Conducting systems are also conceivable. Diamagnetic levitation or passive electrodynamic bearings might finally find an application, maybe for flywheels for energy storage or at least for momentum wheels in sattelites.

Self-sensing (Sensorless) bearings have been and still are an interesting field of reserach, but practical application seems elusive in this case, at least up to now.

New players will come up with new ideas and new applications. I think specifically of China and Korea. China is making impressive progress with AMB equipment for nuclear power plants (circulation pumps), again highlighted at ISMB10 two years ago in a keynote speech. Such developments certainly contribute significantly to further growth in AMB research and application. We are therefore particularly looking forward to the next ISMB in 2010 in China.

All these developments will not avoid the key question of the customer: Why do I really need a contact-free bearing? Only if a definite positive, well founded answer to this question can be given a magnetic bearing will be applied.

The specific technical conditions of magnetic rotor bearings and of MAGLEV vehicles are so fundamentally different that I believe the two communities will continue to be separate, although superficially there seem to be strong similarities. The main reason is the long track in the case of MAGLEV vehicles which implies most severe cost restrictions on this component. Another reason is the completely different power supply situation.

So, Magnetic Bearings, not just AMBs, will certainly continue to be of great interest for a growing community of application engineers and researchers. I believe that the number of applications will continue to grow steadily, but at a relatively moderate growth rate, as over the last 20 years. On the other hand, the variety of solutions, the technical richness and the sheer excitement of creative, original new ideas for contact-free rotor levitation will certainly continue to surprise and delight us, as in the past 20 years.