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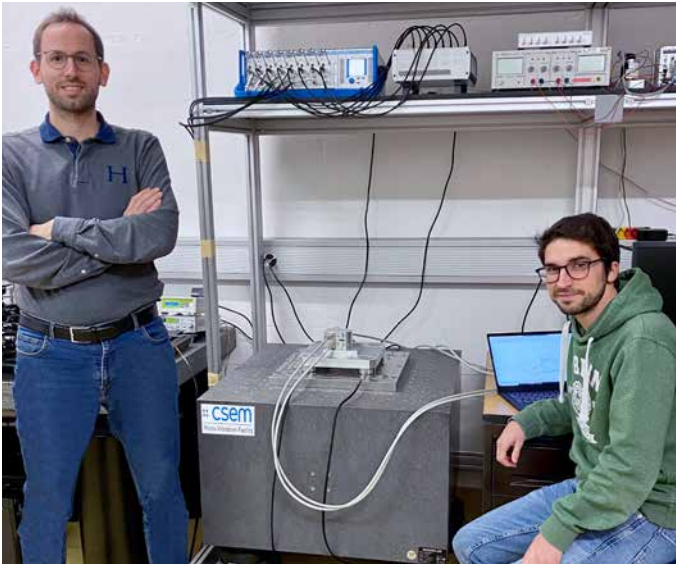
measure. analyze. innovate.



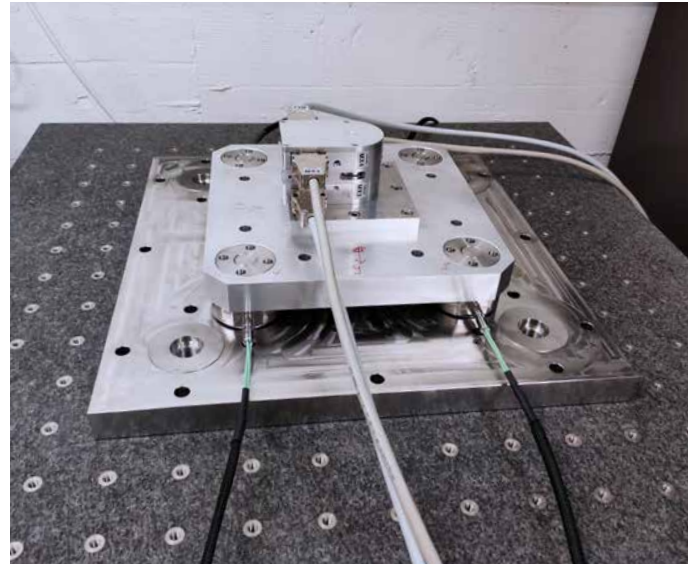
Ultimate smoothness

Kistler supports development of innovative space technology test equipment at CSEM

⋮ csem



Leopoldo Rossini (left) and Guzmán Borque Gallego, the two scientists from CSEM in Neuchâtel, with the multi-component dynamometer and a complete measuring chain from Kistler for space technology testing



At the CSEM facility in Neuchâtel, a magnetic bearing reaction wheel is tested on a highly sensitive, custom multi-component dynamometer from Kistler that includes four piezoelectric force sensors.

As part of their research on magnetic bearings for satellite attitude control, two engineers at CSEM are using a dynamometer from Kistler to capture the micro-vibrations of a novel type of magnetic bearing reaction wheel. Based on precise micro-vibration measurements, they were able to characterize the effectiveness of a control algorithm that actively suppresses synchronous vibrations over the full speed range – allowing higher rotational speeds thanks to reduced disturbances and power consumption.

In 2019, the CSEM (Centre Suisse d'Electronique et de Micro-technique) headquartered in Neuchâtel celebrated 35 years of technological innovation and knowledge transfer. Headquartered in Neuchâtel, this scientific network originally had close ties with the watchmaking industry: over the years, it has evolved into a versatile and truly European research and technology hub – and above all, a valuable partner for universities and industry partners in Switzerland and beyond. CSEM, a nonprofit organization, now employs more than 500 researchers and engineers who focus on a vast range of application areas: renewable energies, biomedical technology, microsystems, industrial automation, quantum and laser technologies as well as scientific instrumentation – including the development of new technologies for space applications such as additive manufacturing, compliant mechanisms, and magnetically levitated actuators.

Advances in the development of innovative space technologies

In the field of space technology, CSEM has been a partner of the European Space Agency (ESA) for many years. One focus of their joint research – which is also part of ESA's mid-term strategy – is the elimination of vibration emissions originating from components aboard satellites. As well as limiting the precision of attitude control for satellites, these micro-vibrations lead to higher energy consumption and (in case of imaging missions) cause deterioration of image quality.

There are different ways to counter unwanted vibrations either at the source or the payload. As part of its exploration of different approaches, CSEM currently has several projects focusing on numerical models, active-passive mitigation, and algorithm-based notching. In one of these projects, CSEM and its partners are working with an innovative technology based on magnetic levitation. Leopoldo Rossini, who heads the micro-vibration facility at CSEM, reports: "With support from Kistler measurement technology, we examined a reaction wheel prototype with a magnetic bearing. This technology from Celeroton, a Swiss company, offers many advantages such as no friction, a virtually infinite lifetime, the possibility of actively suppressing unwanted vibrations by control, and the opportunity to achieve higher performance at higher speeds."

"We're pleased to have new Kistler technology here, because our partners at ESA and in Germany also use it for qualification purposes. This equipment is very robust and did not break down even when stressed beyond the given constraints."

Leopoldo Rossini, heads the micro-vibration facility at CSEM

Advanced satellite components with low vibrations

The CSEM engineers use a measuring chain from Kistler to examine the vibrations of the reaction wheel prototype. The custom dynamometer comprises four 3-component force sensors sandwich-mounted between two steel plates – a design that achieves maximum mechanical stiffness (see the image). This measuring instrument is mounted on a granite block suspended over four pneumatic isolators so that environmental influences are eliminated as far as possible. Because the micro-vibrations occur in the millinewton range, a highly sensitive measuring chain with very low noise is required. As well as the reaction wheel, various actuators such as a stepper motor and a cryo-cooler can be placed on the instrumentation table to perform the desired measurements.

In the case of the magnetically levitated reaction wheel prototype, the speed range from $-20,000$ to $20,000$ rpm was covered: this allowed full characterization of the effectiveness of a multiple-harmonic force rejection algorithm capable of suppressing the main vibrations generated during operation. "The lack of physical contact due to magnetic levitation opens up some very interesting opportunities," according to Guzmán Borque Gallego, an R&D Engineer at CSEM. "It leaves us almost free to position the rotor in such a way that the vibrations are minimized – for instance, by letting the rotor rotate about its main axis of inertia to suppress any vibration related to the rotor unbalance, which reduces these emissions to near zero."

Accurate real-time measurements enable closed-loop control

"The equipment from Kistler is ideal, and it provided us with results of very high quality," Borque Gallego notes. "We're measuring rather small forces in the millinewton range – but even in microneutons, we can still see differences. This allows comfortable judgement of all the measurements, leading to high-quality data in the process." Data acquisition is handled by a rapid prototyping system at 20 kHz and thanks to the accurate measurements, the effect of the control algorithm can be clearly identified (see the diagrams). Rossini adds: "We received positive feedback about the high quality of the measurements from partners and customers who have extensive experience with this kind of data. None of this would have been possible without support from Kistler: Application Specialist Reinhard Bosshard assisted us in many ways, for example by helping us to choose the right equipment to complete the optimal measuring chain."

Although the researchers initially intended to use the modern LabAmp 5167A with a digital output, they finally opted for the 5080A charge amplifier from Kistler, which allows even more accurate measurements thanks to its very low-noise input stage. "We're pleased to have new Kistler technology here, because our partners at ESA and in Germany also use it for qualification purposes," Rossini adds. "This equipment is very robust and did not break down even when stressed beyond the given constraints. Now that it has proven its abilities, we will definitely use it for



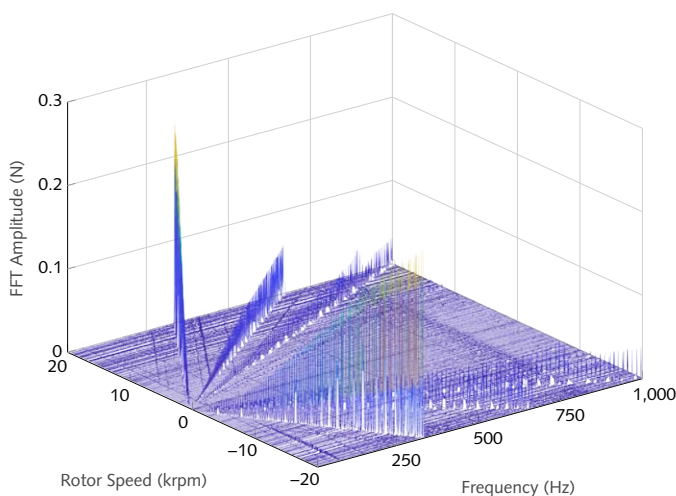
The 5080A multichannel laboratory charge amplifier from Kistler delivers high signal quality over a wide measuring range, making it ideal for complex dynamometer applications.

future projects in the field of vibration characterization – where we already operate accelerometers from Kistler."

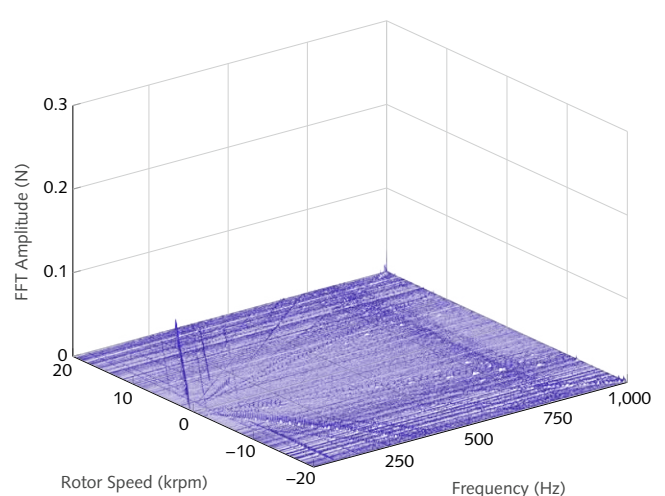
Best possible preparation for the long journey into space

How is the magnetic bearing reaction wheel technology developed by CSEM, Celeroton AG, and their partner in Germany likely to evolve? And will it soon be launched into space? "The advantages of magnetic bearing reaction wheels are obvious: they can generate far lower vibrations and rotate faster than conventional wheels – which means improved performance as well as reduced size and weight. And thanks to the absence of friction, there is no wear and the wheel's lifetime is virtually unlimited," Borque Gallego emphasizes. "This is a fascinating project, and we hope to move ahead to the next steps: practical use, testing, and maybe even validation together with our partners."

(a) Waterfall Plot of Exported Vibrations w/o Active Vibration Control (Fx)



(b) Waterfall Plot of Exported Vibrations w/ Active Vibration Control (Fx)



The waterfall plots of the micro-vibrations measured at CSEM show the peak amplitudes of forces as a function of rotor speed and frequency – measured with a dynamometer from Kistler – with and without active control of micro-vibrations.



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