



# PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 40th cycle

**THEMATIC Research Field: NONLINEAR HYBRID EXPERIMENTAL-NUMERICAL REDUCED ORDER MODELS FOR CALIBRATION AND AND REAL-TIME MONITORING OF MEMS DEVICES**

<b>Monthly net income of PhDscholarship (max 36 months)</b>
<b>€ 1500.0</b>
In case of a change of the welfare rates during the three-year period, the amount could be modified.

<b>Context of the research activity</b>	
<p><b>Motivation and objectives of the research in this field</b></p>	<p>MEMS (Micro Electro-Mechanical Systems) industry has played a significant role in technological advancements across various domains over the past few decades. In fact, these devices, including microphones, PMUT, accelerometers, and gyroscopes, have become integral components of smartphones, computers, and vehicles. The demand for such devices continues to grow, driving the need for higher performance and smaller sizes. However, as the size of MEMS devices decreases, their dynamic response and performance are affected. The motion becomes relatively larger compared to the device's characteristic dimensions. Consequently, the assumption of small deformations no longer holds, leading to the occurrence of nonlinear dynamic phenomena. Additionally, fringing field effects of electrostatic actuation and fluid-structure interaction become significant factors. This research aims to develop experimental methods to characterize the response of MEMS devices and utilize the resulting data to create hybrid experimental-numerical models with predictive capabilities. These models will be instrumental for the calibration and real-time monitoring of MEMS devices.</p>
<p><b>Methods and techniques that will be developed and used to carry out the research</b></p>	<p>The candidate will have to get familiar with multi-physics nonlinear dynamics, including classical softening/hardening behavior and more complex</p>



	<p>phenomena such as sub/super-harmonics, parametric resonances, internal resonances, and isolated and quasi-periodic responses, both from an analytical and a numerical point of view. Subsequently, the candidate will carry out experimental tests on MEMS devices (e.g. gyroscope prototypes) provided by STMicroelectronics. Advanced experimental techniques, among which the Control Based Continuation strategy (CBC), will be implemented. This strategy involves using a phase controller (e.g., Phase Locked Loop, PLL) to track the system's resonance. Additionally, the candidate will explore recent regression strategies based on ringdown experiments to develop a data-driven Reduced Order Model (ROM). Finally, the candidate will integrate the advanced experimental techniques and the data-driven ROM to leverage the ROM for increased robustness and noise rejection (similar to a Kalman filter approach), while the ROM will be continually updated using the data provided by advanced experimental techniques. This procedure has potential applications in calibrating mass-produced MEMS devices and providing custom-tailored ROMs for each device. These ROMs can be hosted onboard the device, enabling various functionalities such as filtering, performance degradation monitoring, and fault detection.</p>
<p><b>Educational objectives</b></p>	<p>The PhD candidate is expected to develop a solid competence in MEMS technology, MEMS-oriented experimental procedures, dedicated laboratory equipment, and experiment automation in LabVIEW. Moreover, the candidate will acquire a strong knowledge of nonlinear dynamics and related phenomena.</p>
<p><b>Job opportunities</b></p>	<p>Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared Master of Science holders in the same field.</p> <p>List of Universities, Companies, Agencies and/or National or International Institutions that are cooperating in the research include: STMicroelectronics; Delft Institute of Technology; ETH Zurich.</p>



<b>Composition of the research group</b>	1 Full Professors 0 Associated Professors 1 Assistant Professors 2 PhD Students
<b>Name of the research directors</b>	Proff. Francesco Braghin, Jacopo Marconi

<b>Contacts</b>
Email: francesco.braghin@polimi.it; jacopo.marconi@polimi.it For questions about scholarship/support: phd-dmec@polimi.it

<b>Additional support - Financial aid per PhD student per year (gross amount)</b>	
<b>Housing - Foreign Students</b>	--
<b>Housing - Out-of-town residents (more than 80Km out of Milano)</b>	--

<b>Scholarship Increase for a period abroad</b>	
<b>Amount monthly</b>	750.0 €
<b>By number of months</b>	6

<b>Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information</b>
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of € 5.707,13. Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 700 euro/month- net amount). Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.</p>