PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

Number of scholarship offered	7
Department	DIPARTIMENTO DI MECCANICA

Description of the Research Area

Research on advanced materials and smart structures is playing a crucial role in all the branches of mechanical and production engineering. The design and development of innovative materials is relevant to enhance specific functional properties customized on engineering applications. Both the innovative and existing materials require new processes to enhance material performance, to integrate new features and/or reduce the effect on the environment (i.e., eco-friendly production).

New (numerical and experimental) multiscale models have to be investigated in order to characterize the mechanical behaviour of materials under different service conditions and degradation patterns. Moving from the material to the component and then to the mechanical systems, smartness and metamaterials can further help reaching customized functional performance. Development of smart materials, smart components and integrated measurement and control systems can lead to significant benefits (e.g. structural health monitoring, vibration attenuation, energy harvesting, quality control).

Eventually, advanced modelling and experimental investigation of the interaction between the structure and the environment (e.g., bridge aeroelasticity, tall buildings and roof aerodynamics, cable dynamics) can aid designing a new generation of large structures where dynamic control is included at the design level.

There are 7 available scholarships in this area:
- 1 generic
- 3 thematic (to be specifically selected during application procedure)
- 3 interdoctoral (to be specifically selected during application procedure)

The generic scholarship refers to the following field:

- Advanced Modelling and Testing of Materials for Machine Design

3 thematic scholarships, on the following topics:
- Actively controlled system to test bridge decks in wind tunnel
- Metamaterials for cloaking and acoustic stealth
- Innovative materials and advanced processes

***One thematic interdoctoral scholarship, jointly supervised by the PhD Programme in Mechanical Engineering and by the PhD Programme in Mathematical Models and Materials in Engineering, is available on the following research topic*:**
Real-time optimal control and monitoring of mechanical structures by PDE constrained optimization and reduced order modeling

One thematic interdoctoral scholarship, jointly supervised by the PhD Programme in Mechanical Engineering and by the PhD Programme in Sructural Seismic and Geotechnical Engineering, is available on the following research topic:
Tailored piezoelectric materials and optimally designed metamaterials for enhanced mechanical energy harvesting

***One thematic interdoctoral scholarship, jointly supervised by the PhD Programme in Mechanical Engineering and by the PhD Programme in Industrial Chemistry and Chemical Engineering, is available on the following research* topic:**
Smart technologies for vertical and precision farming

Applicants should select thematic scholarships following the instructions provided in the call for application/application procedure.

The PhD scholarships available in this area are partially funded with the support of the Italian Ministry of Education, University and Research, through the project Department of Excellence LIS4.0 (Integrated Laboratory for Lightweight e Smart Structures).

Further information on the thesis topics available in this can be found at the following link: https://www.mecc.polimi.it/us/phd/admission/

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

THEMATIC Research Field: ACTIVELY CONTROLLED SYSTEM TO TEST BRIDGE DECKS IN WIND TUNNEL

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0 In case of a change of the welfare rates or of changes of the scholarship minimum amount from the Ministry of University and Reasearch,during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The design of long span bridges is based on their aerodynamic performances that are studied in wind tunnel and simulated through numerical simulations. Wind tunnel tests on deck sectional models are the basis to check the bridge aerodynamic stability and to measure the aerodynamic coefficients required by the numerical simulations. Tests are usually performed using passive test rigs with deck rigid models suspended on spring and motion controlled test rigs with deck rigid models connected to actuators. Aim of the present research is to investigate the possibility to exploit active control logic to simulate the aeroelastic behaviour of a bridge deck by a hardware-in-the-loop (HIL) strategy to emulate the structural response of a bridge exposed to turbulent wind. The objective is to have a test rig where the deck sectional model is connected to actuators that are able to move the model itself as it were suspended on the bridge main cables once it is exposed to the wind. For this purpose, a control logic has to be developed to allow the actuators to provide to the model the forces and the displacement the main cables would transmit in a real-life situation when the deck is exposed to aerodynamic loads.
Methods and techniques that will be developed and used to carry out the research	The PhD candidate will develop the control logic of a new wind tunnel setup recently implemented in the Politecnico

	di Milano wind tunnel composed by 6 electric actuators allowing for the position control of a deck sectional model in the high speed test section of the experimental facility. An initial dynamic characterization of the system and of all its components will be performed. This information will be used in a HIL control logic to experimentally simulate the aeroelastic response the deck model would have if it were suspended through hangers to the bridge main cables reproducing the correct parameters of stiffness and damping. To this aim, the instantaneous aerodynamic force measured on the model has to be introduced in a simulation of the system aerodynamic response running simultaneously to the experiment to provide to the actuators the value of the corresponding force and position to be applied to the model.
Educational objectives	The PhD candidate will be working in one of the most challenging research fields of wind engineering and design of long span bridges. The PhD candidate will become an expert in advanced modelling belonging to different fields of engineering. The candidate is supposed to provide original contributions to the development and verification of numerical and experimental tools for simulating bridge aeroelastic response. The relationships established with international experts in this field will enable the candidate to develop the capability to cooperate within an international high level research team.
Job opportunities	Future job opportunities are primarily in the wind engineering field, including engineering companies, engineering and project management companies, operators and infrastructure managers. In a more general way, the competence acquired will indisputably be of interest for R&D departments of companies dealing with issues related to road/railway infrastructure design. Besides this, job opportunities will be with national and international academic and non-academic institutions and organizations, engaged in innovation, research and technical development. Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to

	Master of Science holders in the same field.
Composition of the research group	5 Full Professors 5 Associated Professors 0 Assistant Professors 2 PhD Students
Name of the research directors	Prof. Daniele Rocchi, Prof. Tommaso Argentini

Contacts
Phone: +39 02 2399 8458 Email: daniele.rocchi@polimi.it Email: phd-dmec@polimi.it

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

Scholarship Increase for a period abroad	
Amount monthly	662.5 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
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 5401,42 euro. Accommodation in Politecnico's Residences (http://www.residenze.polimi.it) is available for PhD candidates; special rates will be applied to selected out-of-town candidates (detailed info in the call for application). 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. 550 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.

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

THEMATIC Research Field: INNOVATIVE MATERIALS AND ADVANCED PROCESSES

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0 In case of a change of the welfare rates or of changes of the scholarship minimum amount from the Ministry of University and Reasearch,during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The demand arising from technological innovations driven by the uptake of new manufacturing processes and improved product performance, is strongly motivating the development of innovative structural and functional materials with advanced and new properties.Future materials need to be designed/optimized according to their specific processing route (e.g. materials for additive manufacturing), need to possess specific thermal and physical properties to fulfill special functions (e.g. phase change materials for thermal storage) could preferably show variation of their properties within the volume of a single components (e.g. multi-materials, gradient 3D lattices, metal-ceramic composites). Even more, they could act as smart materials adding a further dimension to materials science, being able to react to external stimuli by providing a change in their behaviour or properties. In addition, metalworking processes also require extensive innovation to allow the control of both traditional and new materials according to reliable, cost-effective and sustainable criteria.Several research projects are available within this frame. Details about the specific topics will be supplied on request.
Methods and techniques that will be developed and used to carry out the research	The Material research group has expertise on microstructural and mechanical characterization of advanced metallic alloys. The methods to be used will

	involve Thermodynamic modelling of alloy microstructure, tools for experimental analyses on phase and microstructure analyses (optical and electron microscopy, EBSD, XRD, DSC) and mechanical characterization among others by tensile testing, fracture toughness, fatigue testing, creep. For more details about infrastructures, see: https://www.mecc.polimi.it/us/research/departmental-laboratories/
Educational objectives	At the end of the PhD cycle the candidate will be able to define, design and carry out original research programs by working in a team or leading a research group in the field of smart materials. Opportunities will be offered for spending visiting periods hosted by project partners for scientific cooperation.
Job opportunities	Job opportunities are foreseen at national and international academic institutions, high-tech companies and SMEs involved in innovation and technical development sharing research with the Materials groups at PoliMi. Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.
Composition of the research group	4 Full Professors 6 Associated Professors 2 Assistant Professors 10 PhD Students
Name of the research directors	Prof. Maurizio Vedani

Contacts
Phone: 02 2399 8230 Email: maurizio.vedani@polimi.it phd-dmec@polimi.it

Additional support - Financial aid per PhD student per year (gross amount)

Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	662.5 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
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 5401,42 euro. Accommodation in Politecnico's Residences (http://www.residenze.polimi.it) is available for PhD candidates; special rates will be applied to selected out-of-town candidates (detailed info in the call for application). 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. 550 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.

POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

THEMATIC Research Field: METAMATERIALS FOR CLOAKING AND ACOUSTIC STEALTH

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0 In case of a change of the welfare rates or of changes of the scholarship minimum amount from the Ministry of University and Reasearch,during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Acoustic cloaking refers to the possibility of making an obstacle neutral with respect to an incident sound. This is achieved by surrounding such obstacle with a layer of inhomogeneous and anisotropic material (called cloak) that guides acoustic waves around it, in such a way that the field outside the cloak remains as similar as possible to that obtained in the absence of the obstacle itself. By bending the acoustic rays in such a way that they never impinge onto the surface of the scatterer and that they come back onto their original trajectories, not only reflections are avoided, but also the shadow past the obstacle is erased. Such technology could have several interesting applications. The inhomogeneity and anisotropy required in the material properties required for cloaking make it impossible to realize it with conventional materials. For this reason, microstructured composites (also known as metamaterials) need to be engineered in such a way that their homogenized dynamic properties match the required ones in the frequency range of interest. Nowadays, experimental evidence of cloaking has been produced both in air and water in a bi-dimensional setting, i.e., when the obstacle is a circular or elliptical cylinder, and the incident wave propagates in the plane perpendicular to the axis of the obstacle. When dealing with a three-dimensional problem, the microstructure to be designed must be effective for every

	possible direction of propagation, and should thus present a 3D topology, that can be obtained only via 3D printing techniques. The first goal of the research activity, is thus to design, optimize, and experimentally test a 3D cloak. Moreover, when the relative motion between the fluid and the obstacle cannot be neglected (high Mach numbers) the standard design techniques of cloaking based on coordinate transformation fail because of the loss of invariance of the wave equation when the convective term is considered. However, it has been theoretically shown that a coordinate transformation in the space-time continuum can be used to design cloaks that work up to Mach 0.2. A second objective of the research activity is thus to improve the practicability of cloaks in presence of moving fluids.
Methods and techniques that will be developed and used to carry out the research	First, a method to systematically address the design of cloaks for simple three-dimensional geometries like spheres, or cylinders closed by hemispherical caps will be developed by using the tools of Transformation Acoustics. The dependence of acoustic performance on the design parameters (geometry of the obstacle, thickness of the cloak, overall mass constraints) will be evaluated too. More complicated geometries will be targeted instead with PDE-constrained optimization. Then, the 3D microstructure that implements the required material distribution must be designed. In this stage, algorithms for structural optimization will be developed to adjust the topology of the unit cells such that the long-wavelength equivalent material properties match those previously computed. Selective laser melting 3D printing will be used to fabricate the cloak, that will be then experimentally tested underwater to compute the reduction in target strength. Finally, new coordinate transformations will be investigated to address acoustic cloaking in presence of high Mach numbers.
Educational objectives	The challenges that the successful student will have to face are theoretical, numerical, and experimental. Among these, one can list: • development of suitable analytical models to compute the material properties required for cloaking;

	• implementation of coupled acoustic/structural numerical simulations to validate the effectiveness of the cloak when acoustic radiation is sent towards it; • deployment of structural optimization algorithms combined with numerical homogenization of microstructures to obtain the final geometry of the unit cell that make the cloak; • design of the experimental setup to validate the cloak in underwater acoustics;
Job opportunities	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. The research is carried out in cooperation with several leading universities worldwide such as Imperial College London, ETH, and Harvard.
Composition of the research group	1 Full Professors 1 Associated Professors 1 Assistant Professors 2 PhD Students
Name of the research directors	Prof. Francesco Braghin

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

Scholarship Increase for a period abroad	
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