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 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

	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 to 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

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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	
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 euro 5401.42.

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. 662 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.