Position Description

1. General Information

Name of the position	**Virtual vibro-acoustic prototyping using physics-informed neural networks**
Foreseen date of enrolment	January 2025
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • Institut National des Sciences Appliquées de Lyon (INSA-L) • University of Technology Sydney (UTS)
Research Host	Institut National des Sciences Appliquées de Lyon
PhD awarding institutions	Institut National des Sciences Appliquées de Lyon & University of Technology Sydney
Locations	Primary: Lyon, France Secondary: Sydney, Australia
Supervisors	A/Prof. Laurent Maxit (INSA-L) and Dr. Mahmoud Karimi (UTS)
Group of discipline	Mechanical engineering, Physics, Vibrations, Acoustics

2. Research topics (only one of these projects will be funded)

Project 1: Virtual vibro-acoustic prototyping using physics-informed neural networks
In many industrial applications, noise and vibrations performances of the manufactured products need to be controlled in order to fulfil comfort and regulation requirements. Virtual prototype consists of numerical models to predict the vibro-acoustic behaviour of mechanical structures, in order to assess their radiated noise at the early design stages of a project. Classical numerical methods based on discretization approaches, such as the Finite Element Method or the Boundary Element Method present some limitations, in particular to address the mid and high frequency ranges. To overcome this issue, sub-structuring methods such like Craig-Bampton approach (super elements) or receptance/mobility approaches have been developed in order to decompose the global problem into different smaller sub-problems easier to be solved. However, some limitations due to inherent assumptions remain. On another hand, supervised neural networks offer promising results with numerical simulation data in different scientific domains, in particular fluid dynamics. Up to now, the acquired data was not always sufficient to accurately model physical phenomena using a standard neural network due to incomplete data or prohibitive cost of data acquisition. Moreover, in some cases this technique does not respect the underlying physical laws. Recently, the physics-informed neural network (PINN) paradigm has been proposed. The partial differential equations representing the physical laws are directly included in the neural network using automatic differentiation. Some early works have shown the ability of PINN

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for modelling the wave propagations in solid or fluid media. The aim of this PhD is to explore the ability of PINN to model the vibroacoustic behaviour of built-up structures. Models of increasing complexity will be considered. Modelling the flexural motions of beams and thin plates will permit to learn the implementation of PINN and to study the influence of the boundary conditions on the prediction. Then, using the principle of the sub-structuring approaches and parallel computations, investigations will carry out on assembling of different thin structures on one hand, and on the coupling with the acoustic domain in another hand. Finally, an industrial application could be developed to highlight the interests of PINN for virtual prototyping in acoustics.

Supervisors: A/Prof Laurent Maxit (INSA), Dr Mahmoud Karimi (UTS)

Research Fields: Mechanical engineering, Transportation noise, Vibrations, Acoustics, Digital twin, Physics-informed neural networks, Numerical modelling.

Project 2: Control of the noise radiated from stiffened cylindrical shells using acoustic black hole and locally resonant metamaterial

The control of noise radiated from stiffened thin shells like the fuselage of an aircraft or the pressure hull of a submarine is of prime importance for industries. The thin shell is generally stiffened regularly by internal frames in order to resist to static loads keeping the structure as light as possible. However, it is well known that the periodic arrangement of these internal frames induces propagation of Bloch-Floquet waves in the structure which increases the radiation efficiency of the shell. In this thesis, we propose to study two innovative means to reduce the noise radiated by stiffened cylindrical shells: 1. Embedding acoustic black holes (ABHs) in the internal frames: An ABH is a passive and lightweight device for the control of noise and vibrations. It basically consists of a retarding wave guideline that slows down impinging waves and concentrates them at the ABH centre, where energy gets dissipated by means of viscoelastic materials. 2. Attaching locally resonant metamaterials (LRMs) to the internal frames: LRM involve periodically or randomly arranged resonators which are designed to manipulate waves in targeted frequency ranges, which are called band gaps. The two concepts can then be mixed to optimize the radiated noise reduction in the whole frequency range of interest. To date most researches on ABH and LRM have focused on the control of the vibration and sound radiation from academic structures like beams, plates and cylinders. This work will study the efficiency of these devices in the presence of a thin vibrating structure exhibiting Bloch-Floquet waves which are induced by the periodic arrangement of the stiffeners. In the first step, analytical and numerical models will be developed to analyse the physical phenomena involved when the stiffened shell is coupled to these devices. In the second step, parametric analyses will be performed to find the optimal parameters and design to reduce the radiated noise for realistic configurations. Finally, the most promising designs will be investigated experimentally in the lab.

Supervisors: A/Prof Laurent Maxit (INSA), Dr Mahmoud Karimi (UTS)

Research Fields: Mechanical engineering, Vibrations, Acoustics, Transportation noise, Underwater noise, Metamaterial, Acoustic Black Hole (ABH), Locally Resonant Metamaterial (LRM), Noise control solution, Numerical and analytical modelling, Experimental analysis.

Project 3: Acoustic Metamaterials for Flow-Induced Noise Mitigation

A fluid flowing over the surface of a structure produces a turbulent boundary layer (TBL). The pressure field beneath a TBL excites the structure and causes the structure to vibrate, which generates a sound wave that radiates noise away from the structure. This effect is observed in many engineering applications, including over the surfaces of aircrafts, trains and marine vessels. For naval applications, these surfaces have generally a viscoelastic coating applied to them in order to control noise from adjacent machinery, as well as lowering noise from incident sound waves. The acoustic characteristics of these viscoelastic coatings do therefore play an important role in the overall performance of these

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structures. The examination of noise radiation from the outer surface of a marine vessel is challenging because of the complexity of the structures. For example, most shell structures need to be strengthened using ribs and this changes the vibration characteristics of the structure, as well as any viscoelastic material coating the structure. Moreover, the viscoelastic materials are often laminated to enable the absorption of incoming sound waves, as well as reducing machinery noise from the vessel. This project will investigate the radiation of sound from viscoelastic coatings excited by a TBL to improve our understanding of the interaction between turbulent boundary layers and acoustically coated structures through the development of new advanced theoretical models that provide a deep understanding of the underlying physical mechanisms associated with the vibroacoustic behaviour of coated structures induced by a TBL.
Supervisors: A/Prof Laurent Maxit (INSA), Dr Mahmoud Karimi (UTS)
Research Fields: Mechanical engineering, Naval engineering, Vibrations, Acoustics, Metamaterial, Turbulent flow noise, Noise control solution, Underwater acoustics, Numerical and analytical modelling, Experimental analysis

3. Employment Benefits and Conditions

INSA Lyon offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months) with 2 months of probation period and 35 working hours per week.

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary of 28,800 EUR. Of this amount, the estimated net salary to be perceived by the Researcher is 1,928 EUR per month. However, the definite amount to be received by the Researcher is subject to national tax legislation.

Benefits include

- Becoming a Marie Skłodowska-Curie fellow and be invited to join the Marie Curie Alumni Association.
- The candidate will have access to the numerical and experimental facilities of the two laboratories involved in the project:
  - Laboratory of Vibration and Acoustics of INSA Lyon;
  - UTS Tech Lab which is a multidisciplinary research facility with a variety of laboratories and research teams working across engineering and the computer sciences.
- Tuition fees exemption at both PhD awarding institutions.
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events.
- 10,000 EUR allowance to cover flights and living expenses for 12 months in Australia (which may be taken in several blocks over the period of the employment term as best suits the needs of the researcher).
- 25 days paid holiday leave.
- 12 days maternity leave.
- 28 days paternity leave.

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4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

INSA Lyon

Applicants must hold a national Master's degree or another qualification conferring the status of Master (5 years of higher education).

More information: https://www.insa-lyon.fr/en/formation-doctorale

University of Technology Sydney (UTS)

Applicants must have completed a UTS recognised master's by research or bachelor honours degree with first class or second class / division 1 honours, or an equivalent or higher qualification, or submitted other evidence of general and professional qualifications that demonstrates potential to pursue graduate research studies.

The English proficiency requirement for international students or local applicants with international qualifications is: Academic IELTS: 7.0 overall with a writing score of 7.0; or TOEFL: internet based: 94-101 overall with a writing score of 27; or AE6: Pass; or PTE: 65-72 overall with a writing score of 65; or C1A/C2P: 185-190 overall with a writing score of 185.

More information: https://www.uts.edu.au/research-and-teaching/graduate-research/future-research-students/application-essentials

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