Position Description

1. General Information

Name of the position	**Reinforcement learning for real gas turbulence modelling**
Foreseen date of enrolment	1 October 2023
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • École Centrale de Lyon (EC Lyon) • Queensland University of Technology (QUT)
Research Host	École Centrale de Lyon
PhD awarding institutions	École Centrale de Lyon & Queensland University of Technology
Locations	Primary: Lyon, France Secondary: Brisbane, Australia
Supervisors	Prof. Christophe CORRE & Ass. Prof. Alexis GIAUQUE (EC Lyon) Prof. Emilie SAURET (QUT)
Group of discipline	Compressible Flows, Computational Fluid Dynamics, Turbulence Modelling, Machine Learning

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

Project 1: *Q-based reinforcement learning for turbulence modelling in dense gas flows*
The proposed PhD thesis is focused on the development of novel turbulence closures for the Reynolds-Averaged Navier-Stokes (RANS) equations applied to the description of dense gas flows in geometries of industrial interest (ORC turbines). The complex thermodynamic description of dense gases motivates the use of machine learning techniques to derive relevant models. The first stage of the work will adapt to RANS modelling a supervised learning methodology previously developed and applied by the research team for Large Eddy Simulation. This development will take advantage of reference High-Fidelity LES results produced with the solver AVBP developed at CERFACS. All RANS simulations needed to build models relevant for dense gas flows will be performed using the open-source SU2 solver. In a second stage, an even more innovative approach will be tackled through the exploration of non-supervised learning. While most (if not all) methods currently proposed to improve turbulence modelling in Fluid Dynamics are intrinsically supervised (they require a form of high-fidelity results to be tuned), alternative methods exist which do not require supervision, among which Reinforcement Learning (RL). RL relies on an agent which dynamically interacts with its environment (here the turbulent solver) making use of rewards gathered through its evolution and possibly following a policy in order to eventually produce an accurate representation of local turbulence statistics. RL has led to impressive progress for

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applications such as self-driving cars or chess but still needs to be properly transposed to the CFD domain, where its lack of supervision is especially attractive since bypassing the need high-fidelity data. This first project is focused on Q-based RL where the agent learns to predict a future value from a known state and acts consequently. The models developed will be assessed on various configurations including one of interest for ENOGIA, a French ORC turbine manufacturer, partner of the project.

Supervisors:

Prof. Christophe CORRE (EC Lyon, LFMA), Ass. Prof. Alexis GIAUQUE (EC Lyon, LMFA)
Prof. Emilie SAURET (QUT, Faculty of Engineering)

Research Fields: Turbulence Modelling, Real Gases, Machine Learning, Turbomachinery Flows

Project 2: *Policy-based reinforcement learning for turbulence modelling in dense gas flows*

The proposed PhD thesis is focused on the development of novel turbulence closures for the Reynolds-Averaged Navier-Stokes (RANS) equations applied to the description of dense gas flows in geometries of industrial interest (ORC turbines). The complex thermodynamic description of dense gases motivates the use of machine learning techniques to derive relevant models. The first stage of the work will adapt to RANS modelling a supervised learning methodology previously developed and applied by the research team for Large Eddy Simulation. This development will take advantage of reference High-Fidelity LES results produced with the solver AVBP developed at CERFACS. All RANS simulations needed to build models relevant for dense gas flows will be performed using the open-source SU2 solver. In a second stage, an even more innovative approach will be tackled through the exploration of non-supervised learning. While most (if not all) methods currently proposed to improve turbulence modelling in Fluid Dynamics are intrinsically supervised (they require a form of high-fidelity results to be tuned), alternative methods exist which do not require supervision, among which Reinforcement Learning (RL). RL relies on an agent which dynamically interacts with its environment (here the turbulent solver) making use of rewards gathered through its evolution and possibly following a policy in order to eventually produce an accurate representation of local turbulence statistics. RL has led to impressive progress for applications such as self-driving cars or chess but still needs to be properly transposed to the CFD domain, where its lack of supervision is especially attractive since bypassing the need high-fidelity data. This second project is focused on policy-based RL where the agent learns from a policy which is not directly correlated with the value of Q. The models developed will be assessed on various configurations including one of interest for ENOGIA, a French ORC turbine manufacturer, partner of the project.

Supervisors:

Prof. Christophe CORRE (EC Lyon, LFMA), Ass. Prof. Alexis GIAUQUE (EC Lyon, LMFA)
Prof. Emilie SAURET (QUT, Faculty of Engineering)

Research Fields: Turbulence Modelling, Real Gases, Machine Learning, Turbomachinery Flows

Project 3: *Soft Actor-Critic reinforcement learning for turbulence modelling in dense gas flows*

The proposed PhD thesis is focused on the development of novel turbulence closures for the Reynolds-Averaged Navier-Stokes (RANS) equations applied to the description of dense gas flows in geometries of industrial interest (ORC turbines). The complex thermodynamic description of dense gases motivates the use of machine learning techniques to derive relevant models. The first stage of the work will adapt to RANS modelling a supervised learning methodology previously developed and applied by the research team for Large Eddy Simulation. This development will take advantage of reference High-Fidelity LES results produced with the solver AVBP developed at CERFACS. All RANS simulations needed

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to build models relevant for dense gas flows will be performed using the open-source SU2 solver. In a second stage, an even more innovative approach will be tackled through the exploration of non-supervised learning. While most (if not all) methods currently proposed to improve turbulence modelling in Fluid Dynamics are intrinsically supervised (they require a form of high-fidelity results to be tuned), alternative methods exist which do not require supervision, among which Reinforcement Learning (RL). RL relies on an agent which dynamically interacts with its environment (here the turbulent solver) making use of rewards gathered through its evolution and possibly following a policy in order to eventually produce an accurate representation of local turbulence statistics. RL has led to impressive progress for applications such as self-driving cars or chess but still needs to be properly transposed to the CFD domain, where its lack of supervision is especially attractive since bypassing the need high-fidelity data. This third project is focused on Double Agent or Soft Actor-Critic RL which combines two independent predictions of Q and an artificial neural network dedicated to the policy. The models developed will be assessed on various configurations including one of interest for ENOGIA, a French ORC turbine manufacturer, partner of the project.
Supervisors: Prof. Christophe CORRE (EC Lyon, LFMA), Ass. Prof. Alexis GIAUQUE (EC Lyon, LMFA) Prof. Emilie SAURET (QUT, Faculty of Engineering)
Research Fields: Turbulence Modelling, Real Gases, Machine Learning, Turbomachinery Flows

3. Employment Benefits and Conditions

École Centrale de Lyon offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months). The employment contract includes a probation period of one month, which may be renewed once for a period not exceeding the initial duration. The total working hours per week is 35h.

The remuneration, in line with the European Commission's rules for Marie Skłodowska-Curie fellows, will consist of a gross monthly salary of EUR 2,044 in 2023. Of this amount, the estimated net salary to be received by the researcher is EUR 1,640 per month. However, the final amount to be received by the Researcher is subject to national tax legislation (approximately EUR 100 / month). This salary will increase during the thesis and should reach, on average, EUR 2,340 gross (i.e. EUR 1,870 net) per month.

Benefits include

- Access to all the necessary facilities and laboratories at EC Lyon (LMFA) and QUT.
- 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.
- 27 days paid holiday leave.
- Sick leave.
- Parental 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.

EC Lyon

To be admitted in a Doctorate program, Applicants must hold a Master's degree (foreign degrees are examined by the doctoral schools to determine whether they are equivalent to a Master's).

More information: https://www.ec-lyon.fr/en/research/doctorate/admission-enrolment-doctorate

Important: the authorisation of the Defence Security Officer may be required before admission. In case of denial, the enrolment will not be carried out.

Queensland University of Technology

To be eligible for entry into a Doctor of Philosophy (PhD), applicants normally must have:

- an Australian or comparable AQF first class or second class division A bachelor honours degree (AQF Level 8); or
- an Australian or comparable AQF master's degree (by research or coursework) (AQF Level 9); or
- a doctorate (by research or coursework) (AQF Level 10).

Applicants who hold a coursework masters and/or doctorate must:

- have completed a significant research component, normally 25% or more of the credit point value;
- have a minimum grade point average of 5 (on a 7 point scale) in that course; and
- present evidence of research experience and potential for approval.

In addition, QUT requires that all students demonstrate a specified level of English proficiency. QUT accepts English language proficiency scores from the following tests. Tests must be taken no more than 2 years prior to the QUT course commencement.

English Test	Overall	Listening	Reading	Writing	Speaking
PTE Academic/PTE Academic Online	58	50	50	50	50
Cambridge English Score	176	169	169	169	169
IELTS Academic / IELTS Online	6.5	6	6	6	6
TOEFL iBT / Home / Paper	79	16	16	21	18

Short-listed applicants will need to submit an online application at QUT.

For more information and details on how to apply to QUT:

How to apply: https://www.qut.edu.au/research/study-with-us/how-to-apply
Admission Criteria for the Doctor of Philosophy:
https://cms.qut.edu.au/__data/assets/pdf_file/0015/640320/criteria-for-phd-admission.pdf

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