Ph.D. thesis proposal

Title : **Numerical modelling of the environmental impact of tidal turbines noise**

Laboratory : **Roberval Laboratory, University of Technology of Compiègne, France**

Applicant : **CSC-student**

1) Study context

At the various international conferences on the impact of climate change, it was always recommended to reduce the use of fossil energy and double the part of renewable energies to reach 30% of the energy produced in the world.

In this context, France has begun to develop these energies, in order to diversify and reach the threshold of 30% more quickly. Among these, the tidal turbine, defined as the electricity produced by the kinetic energy of the marine and fluvial currents. Indeed, France is bordered by three maritime facades offering one of the world's potential for the most important marine currents at several sites. Because the extraction of marine energy is a great global challenge, the various governments in France strongly encourage scientists to explore this vast area of research. The installation of turbines farms for extracting marine energy requires a pre feasibility study. Among the problems studied, we cite for example the impact of the turbines on the erosion of soil support; the variation of the sediment dynamics near the tidal turbines; the collisions sedimentary particles on the turbine blades and the noise on biodiversity, fauna and flora.

The study of the noise impact on the marine (or fluvial) environment has been massively studied for noise sources coming from the propellers of commercial vessels (Wang *et al.*, 2016). This impact has been studied both numerically and experimentally (Kuperman *et al.*, 2004; Kozaczka *et al.*, 2001; Arveson & Vendittis, 2000; Grelowska, 2013; Listewnik, 2014) . To our knowledge the sources of tidal stream noise is little studied or invested by few researchers around the world (Frid *et al.*, 2011; Haikonen, 2014; Gill, 2005; Lloyd, 2013).

The acoustic effect of the tidal stream farm in operation is studied by superimposing their frequency and frequency of underwater environments. Therefore, the extent of impact will strongly depend on the type of tidal turbine deployed. Indeed, the sounds produced by the blades of the device can produce hearing disorders or even serious injury to fish and marine mammals passing very close to the latter.

The subject proposed for this thesis is to study, via the development of appropriate numerical simulation tools, the environmental impact of noise generated by tidal turbines deployed in the marine or fluvial environment. The supervision of the work of this thesis will be provided by Dr. Emmanuel Perrey-Debain on the acoustic part and by Dr. Hassan Smaoui on the marine and fluvial hydrodynamic part.

2) Details of the proposal

A subject of growing importance is the acoustic impact of RME (Renewable Marine Energy) in the environment. To allow installation of these systems, the authorities request environmental studies, including impacts of underwater noise on the marine fauna. However, this information is currently often not available or inaccurate due to the lack of data or understanding of the different physical mechanisms that are taking place; this includes the sound generation mechanism and the long-range propagation of underwater acoustic waves. Thus, predictive methods for estimating the underwater-radiated operational noise of any of these RME installations are necessary.

The first objective of this thesis is to evaluate by numerical means the noise radiated in water by a tidal turbine in operation in marine or fluvial environment. The noise of hydrodynamic origin of a tidal turbine is due to the non-stationarity of the flow accompanying the movement of the blades. Following classical acoustic analogy for low Mach numbers flows, equivalent sources of sound are dipolar in nature, constituted by the fluctuations of the forces exerted on the blades. The approach proposed in the thesis is therefore to implement analytical models for the description of the sources from a numerical simulation of the flows. This could be based on an averaged approach (code U-RANS for Unsteady Reynolds-Averaged Navier-Stokes) or on a more refined CFD simulation like LES (Large Eddy Simulation) in the spirit of (Lloyd *et al.*, 2013). In order to evaluate the acoustic radiation from the blades, the Ffowcs Williams and Hawkings (FWH) acoustic analogy using only the term relating to fluid loading should be developed and applied for the radiation in free-field. The next step is develop a simple model based on rotating dipoles, which should yield similar far-field acoustic radiation.

The second objective is to develop underwater acoustic propagation models in marine or/and fluvial environment, which include the presence of reflecting and scattering boundaries, i.e. water surface and bottom, the acoustic impedance of the seabed and sound speed gradients in the water, see (Lloyd *et al.*, 2011) and (Kozaczka *et al.*, 2017).

3) PhD research plan

1st year. (i) Identification of the relevant scientific literature, theories and concepts.

(ii) Practice the incompressible flow simulations involving moving mesh on a commercial software (Fleunt from ANSYS Corp or Star-CCM+ from CD-adapco).

(iii) Identify the pressure fluctuations on the blades and apply FWH analogy to simulate acoustic radiation in free field.

2nd year. (i) Development of a simple model based on rotating dipoles. Comparison with the FWH analogy.

(ii) Extension of the rotating dipole model (originally developed for free-field propagation) to simulate the propagation of acoustic waves in ideal waveguides, i.e. by replacing the shallow sea with a flat acoustic system and assuming that the boundary surfaces of the half spaces limiting the water layer are parallel to each other and by assuming a rigid bottom and a pressure release condition at the sea-air interface.

3rd year. (i) Development of underwater acoustic propagation models in more realistic marine or/and fluvial environment, which include the presence of reflecting and scattering boundaries, i.e. water surface and bottom, the acoustic impedance of the seabed and sound speed gradients in the water.

(ii) Dissemination of results in national/international conferences. Writing papers for publication in recognized scientific journals.

(iii) Writing the doctoral dissertation.

4) References

Arveson P.T. and D. T. Vendittis (2000): Radiated noise characteristics of modern cargo ship, *J. Acoust. Soc. Am.*, Vol 107(1), pp 118–129.

Frid C., E. Andonegi, J. Depestele , A. Judd, D. Rihan, S.I. Rogers and E. Kenchington (2011): The environmental interactions of tidal and wave energy generation devices. *Environmental Impact Assessment Review*, Vol 32(1), pp 133-139.

Gill, A.B. (2005): Offshore renewable energy: ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology*, Vol 42(4), pp 605-615.

Grelowska G., E. Kozaczka, S. Kozaczka and W. Szymczak, (2013): Underwater Noise Generated by a Small Ship in the Shallow Sea. *Archives of Acoustics*, Vol38(3) 351-356

Haikonen,K. (2014): Underwater radiated noise from Point Absorbing Wave Energy Converters: Noise Characteristics and Possible Environmental Effects. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology* 1200. Uppsala: Acta Universitatis Upsaliensis, 62 pages.

Kozaczka E. and G. Grelowska (2011): Shipping low frequency noise and its propagation in shallow water, *Acta Physica Polonica A*, Vol 119(6A), pp 1009–1012.

Listewnik, K. (2014): Disturbances in noise propagation, generated by a moving ship in shallow water. *Hydroacoustics Journal*, Vol 17, pp 127-134.

Lloyd, T.P. (2013): Large eddy simulations of inflow turbulence noise: application to tidal turbines. *PhD thesis*, in the Faculty of Engineering and the Environment. University of Southampton, 209 pages.

Wang L., S. Robinson and P. Theobald (2016): calculation of ship source level in shallow water by propagation model. *Proceeding of INTER-NOISE 2016*, pp 7083-7089.

Lloyd T.P., S.R. Turnock, V.F. Humphrey (2013): Computation of inflow turbulence noise of a tidal turbine, 10th European Wave and Tidal Energy Conference, at Aalborg.

Lloyd T.P., S.R. Turnock, V.F. Humphrey (2011): Modelling techniques for underwater noise generated by tidal turbines in shallow waters, Proceedings of the 30th International Conference on Ocean, Offshore and Arctic Engineering.

Kozaczka E., Grelowska G. (2017): Theoretical model of acoustic wave propagation in shallow water. *Polish Maritime Research* 2 (94) 2017 Vol. 24; pp. 48-55.

5) Profile of the applicant

The applicant should hold an M2 in Fluid Mechanics or Applied Mathematics and skilled in the following area:

- Numerical modelling;
- CFD software (as ANSYS-FLUENT, STAR CCM+, etc.);
- Environmental flows;
- Code programming (Fortran90, C, C++).

6) Contacts

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