**The Lattice Boltzmann Method to Simulate Fluid Flow Around Tidal Devices.**

The UK government wants to increase the consumption of renewable energies to move towards a more sustainable future. From this plenty of research has been achieved into the use, effectiveness and optimisation surrounding renewable devices, particularly surrounding the uses of wind and solar energy. Within the fields of computational fluid dynamics and fluid flow specifically, a plethora of research has been conducted surrounding wind turbines including optimal locations, design and the turbulence created by them, Wang, S. et al (2010).

Tidal devices lack this research, however current projects being undertaken by Simec Atlantis and the Swansea Bay Tidal Lagoon are providing more research on this reliable power source. The proposed thesis will conduct research into the ongoing effects, challenges and limitations of tidal devices.

A key goal of this thesis will be to understand the complexities that exist within the fluid flow created by these devices as they generate energy. This generation could be from a paddle swaying through the ebb and flow of waves, via rotary blades or by overtopping. A particularly interesting area to study is the chaotic diffusion created by these flows also known as turbulence. This instability is a consequence of the mixing process within the flow and is usually characterised as a swirling vortex.

The flow surrounding these devices would be defined as turbulent flow and will require the solution of the turbulent Navier-Stokes equations (NS). The central aim of this PhD will be to develop a novel numerical method which can be easily adapted to model different scenarios for various renewable devices. This will be implemented in software to simulate and better study turbulent flow around tidal devices therefore allowing, in future work, optimisation of the design, distance, and location of such devices. This is particularly important for the tidal lagoon method as it is still within theory and testing stages. If funding is achieved, the first tidal lagoon device will be created in Swansea, which could pave the way for further research, development and industrialisation within the field.

Complex flow such as that of a mixing of two fluids requires significant computational resources and numerical development to get a good level of accuracy. Tidal devices display these complex flows in abundance whether it be through the interaction of both fluid and air to create waves to overtop a barrier or through the cyclic vortices created after a spinning air foil. These phenomena where multiple fluids are interacting require the simulation of multiphase flows to study them. For this study the interaction of both air and water will be considered and will be treated as incompressible, immiscible fluids.

Despite there being a multitude of numerical methods that can model multiphase flows – for example the one fluid approach, volume-of-fluid method, level-set method and front-tracking method – they are typically inefficient when modelling large scale structures as they require intense computational effort. The Lattice-Boltzmann method, or LBM for short, uses simple algebraic calculations and basic mechanical properties to simulate a fluid. Instead of solving for macroscopic variables such as density, velocity and temperature as found within the NS the method solves a distribution function in discrete velocity space and then solves the macroscopic properties using the distribution as per Liou, TM et al. (2017). This approach drastically reduces the computational time needed to simulate the flow as it is easily paralleled, meaning that simulations using this method can be run far more quickly than with other methods. The LBM has shown promising results in the understanding and modelling of complex multiphase flows and the turbulent features within them, however further development is needed.

The Lattice-Boltzmann method is a flexible and extensible computational framework which allows for highly efficient and accurate models of complex flows to be achieved. As such it is this model which will be used as the basis for development of a new multiphase flow model. Zhou (2004, 2007, 2008 & 2014) has already developed and extensively validated the various LB methods for different flows with or without turbulence. This provides a solid foundation for further development of a more powerful LBM to solve the complex multiphase flow equations.

The overall objective therefore is to create a model LBM to help further understand the nature surrounding turbulence around renewable devices and multiphase flows. To achieve this objective the new NS equations must be established; this will ultimately be what the model will be solving and relating back to in order to confirm the accuracy of the model. Suitable, relatable tests will be used to compare the established novel LBM and confirm its accuracy before proceeding with the prototype. Only once all benchmark tests are validated will the renewable device be placed into the flow. From there more results can be obtained by creating barriers and moving boundaries and, once confirming the 2D case, this will be extended to the third dimension to see whether the results and model still hold up. Once this has been completed some fine tuning of the program and model will be undertaken using sensitivity and parameter studies.

The program will be established using FORTRAN as the back-end for faster computation of the model whilst a more modern language will be used for the front-end/user interface. A Matlab program will also be used to compare similar simulations.

**References**

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