Flow measurement Application : spot wave device for surf

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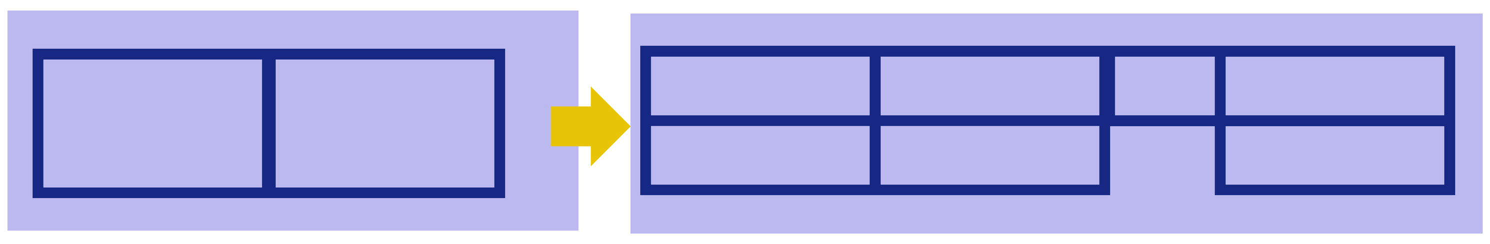
Introduction

In recent years, the sport of surfing has attracted a phenomenal number of adherents, but its practice requires specific weather conditions on the coasts. However, new solutions allowing surfing all year round, whatever the conditions, are appearing thanks to the creation of wave pools. The waves are generated thanks to a discharge plate which executes a pivoting movement. The plate is driven by a motor with a frequency converter via a connecting rod-crank system.
The waves generated by these mechanical movements are easily modulated, their periods and heights can be managed but they do not break. They are non-destructive except that to surf the waves must be destructive, they break creating foam. The goal of my research is therefore to move from a non-destructive generated wave to a destructive wave where we could modulate the properties of the wave to be able to surf, namely the speed of the water and the height of the wave. To do this my idea is to add an obstacle on the ground in order to disrupt the wave and make it break. The aim of my research will therefore be to understand the influence of this obstacle and how to calibrate it.

Methodology

The aim of this research is to understand the influence of obstacles on wave propagation generated by mechanical movements.
To carry out these simulations, the use of OpenFOAM software was very useful. In fact, it specializes in calculations related to fluid mechanics.
We recover an already existing wave generation simulation: WAvemakerFlap. The objective is to add an obstacle to the simulation. Here are the steps:

1. Change the number of definition rectangles from 2 to 5. To do this, you must modify the Mesh file and add rectangles in the vertices.

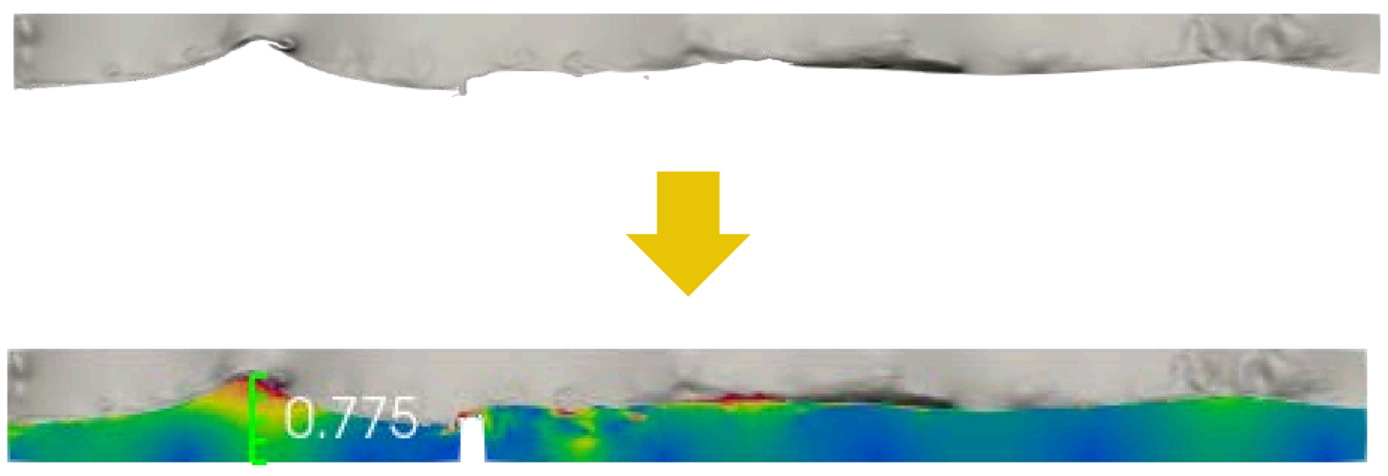


Schema of the Mesh from Wavemakerflap *Schema of our new Mesh*

2. Adding the obstacle is done by not placing a rectangle in the lower part of the Mesh. So that the alpha.water liquid does not spread in this area.

3. Then once the simulations are operational, the analysis and visualization is done on the Paraview software. Where data can be processed in an intuitive and visuale way.

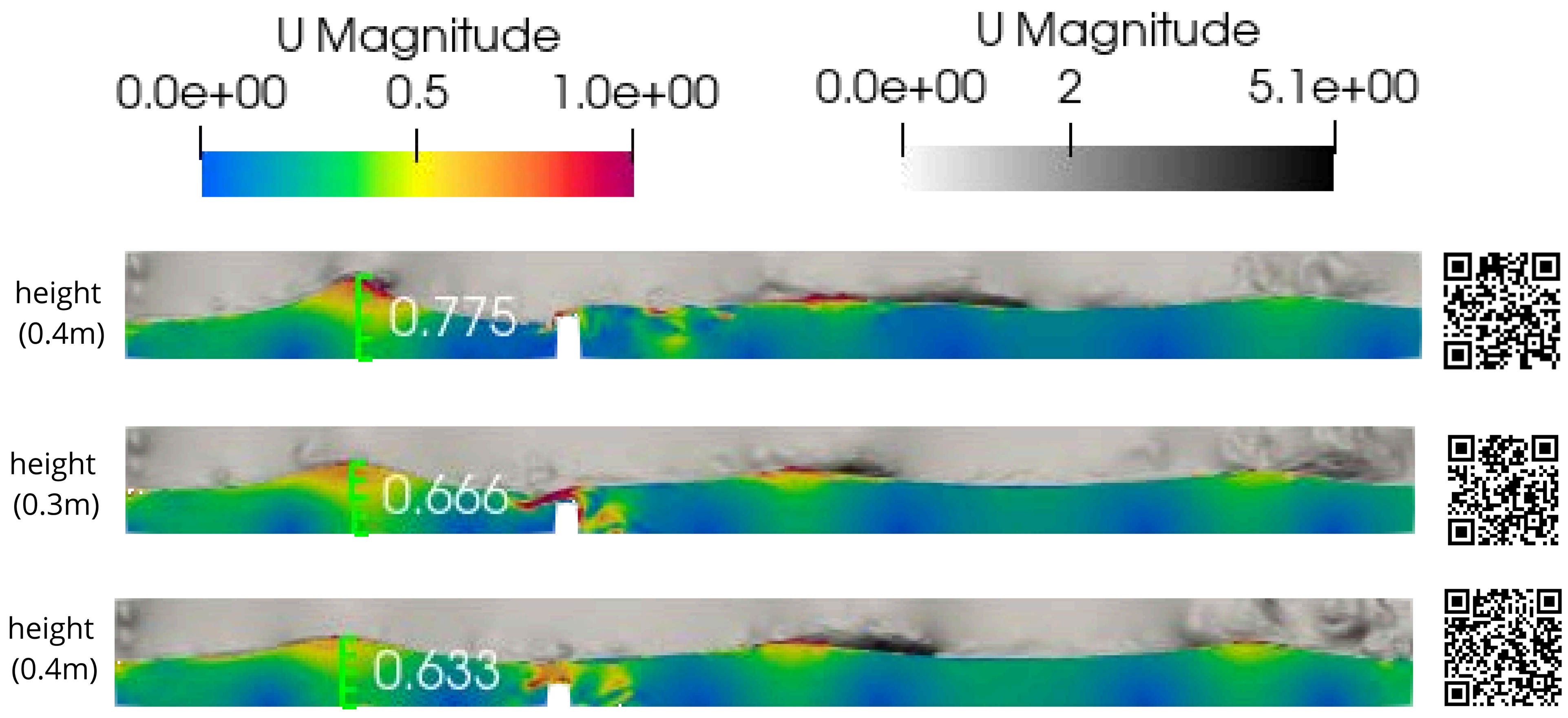
4. Colorization and separation of air and water. This for better visualization of flows



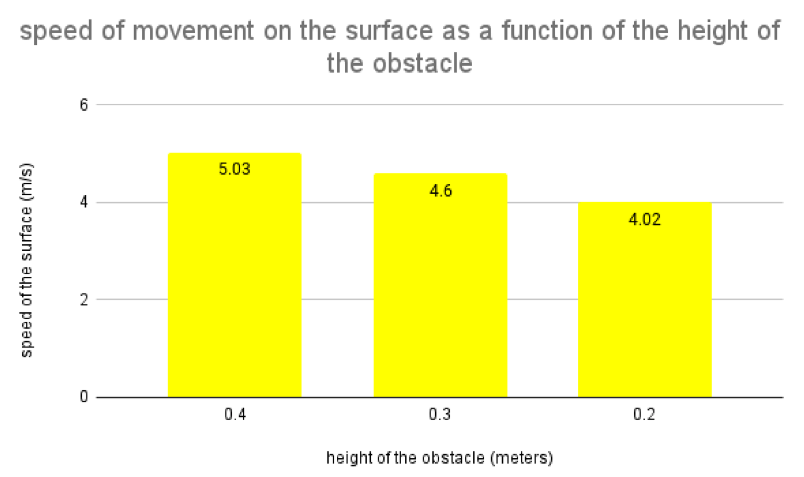
5. adding filters to better track the data

Simulation Results

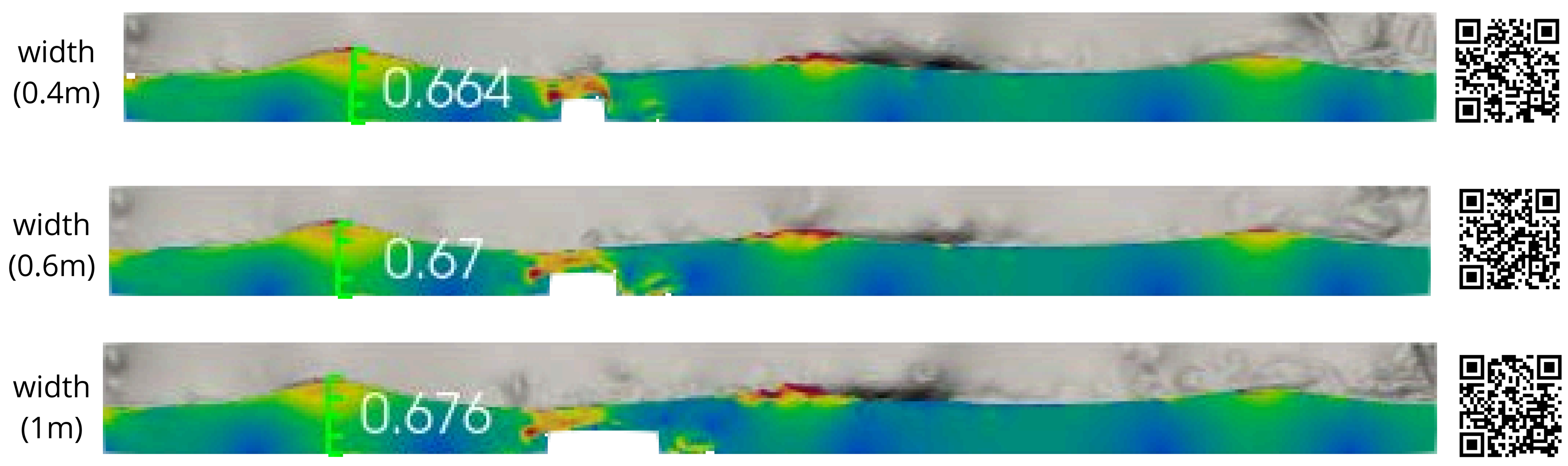
1.Results of simulations where the height of the obstacle varies.



The variation in the height of the obstacle allows us to affirm that the higher the obstacle is, greater is the speed on the surface. It reaches a maximum speed of 5.03 m/s with the highest obstacle. It is also possible to notice that the higher the obstacle is,higher is the wave. It reaches a maximum height of 0.775 m with the highest obstacle (0.4m).
Thanks to the visual comparison of the 3 graphs, the observation of the difference of atmospheric disturbances is possible. Indeed, the speed of movements in the air is much more intense when the height of the obstacle is low, especially in the right area of the propagation channel.



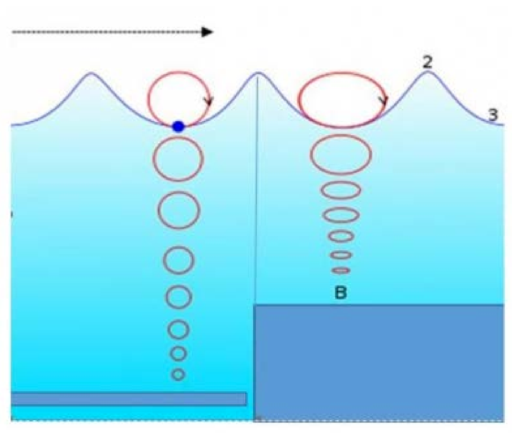
2.Results of simulations where the width of the obstacle varies.



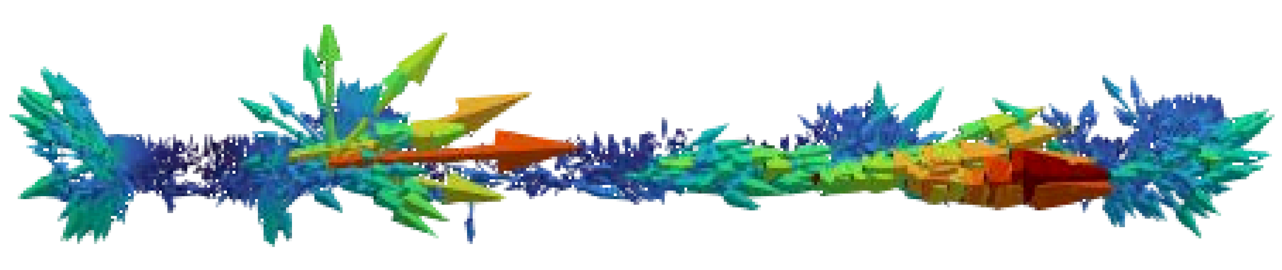
It seem that the variation of the width of the obstacle doesn't have an impact on the height of the wave or on the speed mouvement on the surface, which is always ≃ 4.55 m/s. However it's possible to notice an increasement of the mouvement an perturbation in the center of the channel.

3.Analyse of the direction of the movements and the energy transfer

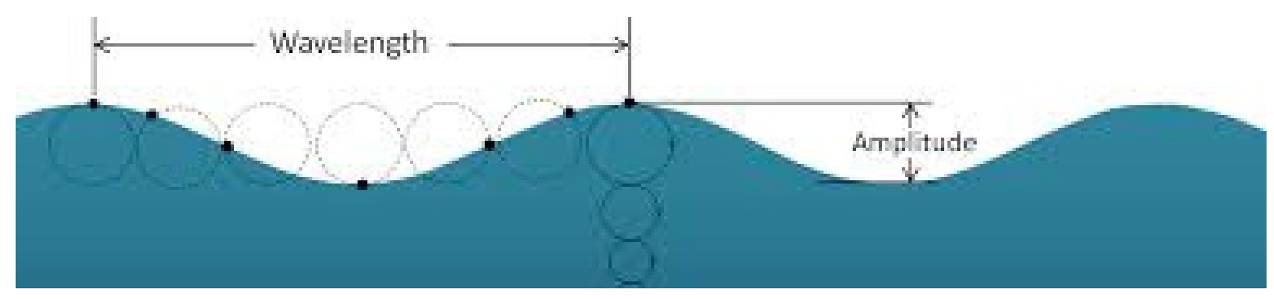
Using the theory of shallow water, when Hwater ≤0.5*λ (λ=wave length), and the Saint-Venant equations we obtain the speed equation : $c=\sqrt{(g \times Hwave)}$. The presence of an obstacle therefore modifies the value of the speed to $c=\sqrt{(g \times Hwave1)}$, as $Hwave \neq Hwave1$. This will therefore also modify the kinetic energy, $Ec = 0.5 \times m \times c^2$, and the form of its movement. The elliptic movement will therefore find itself more crushed.



Trajectory of particules from [2]



surface movement from my Openfoam simulation



The parameters of a wave from [1]

This modified depth is also responsible of the change in the camber of the wave, $\gamma=(Hwave)/(water\ deep)$. When this camber becomes too high the wave breaks. The kinetic energy then becomes dissipative energy called swell energy, the water particles are projected forward to obtain a surface parallel to the ground. Its formula, in the thory og shallow water, is: $Eswell = 0,5 \times Hwater^2 \times T$ (where T is the wave period). The energy is therefore dissipated in the air and absorbed in the water mass.

Conclusion

Considering all the data obtained in the different simulations, we can see that the width of the obstacle has no influence on the wave. The interesting parameter of the obstacle is its height. The greater this height, not exceeding the water level, the more the movement of the particles will be modified. The normally circular movement becomes elliptical and can in extreme cases reach a simple back and forth movement. This change in depth, due to the obstacle, will also influence the curvature of the wave and create a breaking of the latter, via the dissipative energy of the swell.
The logical continuation of these simulations would be to add the influence of the wind by then having a dynamic air flow of a chosen speed and direction. The most interesting case would be an air flow opposite to the direction of propagation of the wave, which would simulate a so-called off-shore wind. It is generally considered good for surfing because it digs into the waves.
Thanks to the influence of this parameter, we could create a completely artificial surf spot where we would control the wave generation characteristics, its breaking and its camber.

Acknowledgements

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References

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